# Wireless Radiation and Electromagnetic Field Studies Published since 2024 (Volume 3)

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**The impact of electromagnetic radiation on human health: a narrative review of in vitro and in vivo evidence**

Bahrani F, Henz D, Spitz J, Muller K, Dobaradaran S. The impact of electromagnetic radiation on human health: a narrative review of in vitro and in vivo evidence. J Environ Health Sci Eng. 2026 Sep 21;24(2):39. doi: 10.1007/s40201-026-01006-x.

Abstract

Purpose: The pervasive use of electromagnetic radiation (EMR) emitting devices has raised public health concerns; however, a comprehensive synthesis of in vitro and in vivo evidence is lacking. This narrative review aims to critically evaluate the health impacts of EMR exposure, identify knowledge gaps, and provide a foundation for future research.

Methods: A literature search of Science Direct, Google Scholar, and Web of Science (2000-2026) identified 17,240 records. After duplicate removal and title/abstract screening, 640 articles underwent full-text assessment. Following exclusion of 525 articles (lack of sham/control, solely thermal effects, inaccessibility, non-mammalian models), 115 studies were included. The relevant literature was reviewed and narratively synthesized.

Results: EMR exposure consistently induces oxidative stress, DNA damage, and apoptosis, with the nervous and reproductive systems being most vulnerable. Neurobehavioral impairments (anxiety, memory deficits, hippocampal damage) and reproductive toxicity (reduced sperm quality, testicular injury, hormonal dysregulation) were frequently reported. Outcomes are highly dependent on exposure parameters frequency, power density, duration, and modulation. Carcinogenicity evidence remains mixed: some animal studies report increased tumor incidence, while others show no effects.

Conclusion: EMR exposure, particularly at mobile communication frequencies, can induce biological effects primarily through oxidative stress, inflammation, and apoptosis. Future research should prioritize

long-term prospective human studies and real-world multi-frequency exposure scenarios.

Conclusion

This review consolidates evidence from in vitro and in vivo studies demonstrating that EMR exposure consistently induces oxidative stress and DNA damage across multiple tissues, with the nervous and reproductive systems being the most vulnerable targets. The severity and nature of these effects are highly dependent on exposure parameters, including frequency, power density, duration, and modulation pattern, with higher frequencies and prolonged exposure generally associated with more pronounced adverse outcomes. At the mechanistic level, oxidative stress emerges as a central mediator, triggering inflammatory cascades, apoptosis, and disruption of the blood brain barrier and testicular architecture. While the majority of studies confirm neurobehavioral impairments, reproductive dysfunction, and systemic inflammation, a subset of investigations, particularly those involving intermittent or low-dose exposure revealed adaptive responses or lack of overt toxicity, underscoring the importance of exposure protocols in risk assessment. Evidence regarding carcinogenicity remains mixed: some animal studies report increased tumor incidence, while others show no effects, and specific EMF parameters even exhibit therapeutic potential against cancer cells. These contradictions highlight critical knowledge gaps, particularly the scarcity of long-term human data and the lack of standardized exposure protocols. Future research must focus on delineating the thresholds and mechanisms that distinguish harmful effects from beneficial clinical interventions. Accordingly, future research should prioritize well-designed prospective human studies, explore multi-frequency real-world exposure scenarios, and investigate the molecular mechanisms underlying both harmful and protective effects.

https://link.springer.com/article/10.1007/s40201-026-01006-x

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**The Impact of Radiofrequency Exposure on Reproductive Health in Mice and Rats: A Systematic Review**

Tabanfar S, Fouladi Dehaghi B, Sobhani S. The Impact of Radiofrequency Exposure on Reproductive Health in Mice and Rats: A Systematic Review. J Occup Health Epidemiol 2026; 15 (1) :78-88.

Abstract

Background: In recent decades, growing concerns have emerged considering the decline in human fertility rates. Exposure to radiofrequency (RF) fields has been proposed as a potential risk factor. This systematic review examines in vivo studies exploring the association between RF radiation exposure and reproductive health in mice and rats.

Materials and Methods: Based on PRISMA protocol a comprehensive search was undertaken in ISI Web of Science, MEDLINE–PubMed, and Scopus to August 2024. After applying inclusion/exclusion criteria, 36 (26 in male, 6 in female, 4 in both) out of 1470 identified articles were selected for analysis.

Results: The majority of studies reported adverse reproductive effects, especially in male mice and rats, including reduced sperm quality, histopathological testicular damage, oxidative stress, and hormonal disturbances. Key mechanisms included oxidative stress, apoptosis, and mitochondrial dysfunction.

Studies in female mice and rats were limited but indicated potential risks for pregnancy outcomes (e.g., diminished infant size, fetal abnormalities). Nevertheless, 8 studies found no significant effects.

Conclusion: Current evidence suggests that RF-EMF may adversely affect the male reproductive system, while findings concerning its influence on female reproductive health remain inconsistent and require further investigation. Substantial methodological heterogeneity in exposure parameters—including frequency, duration, distance, SAR, and exposure type (whole-body vs. localized), animal models used, and specific characteristics of RF sources—impaired direct comparability across studies. Future studies should apply standardized exposure paradigms, advanced molecular techniques, and long-term assessments to elucidate the reproductive risks of RF radiation and their relevance to human health to enable more robust risk assessments.

Open access: http://johe.rums.ac.ir/article-1-1062-en.html

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**Mobile Phone Call Duration and Cardiovascular Outcomes: Prospective and Genetic Evidence on a Potential Depression-Related Pathway**

Yin Y, Luo Y, Liu T, Zhang Q. Mobile Phone Call Duration and Cardiovascular Outcomes: Prospective and Genetic Evidence on a Potential Depression-Related Pathway. Bioengineering (Basel). 2026 Sep 5;13(9):1035. doi: 10.3390/bioengineering13091035.

Abstract

Background: Mobile phone use has been associated with cardiovascular disease (CVD), but the role of major depressive disorder (MDD) in this relationship remains uncertain.

Methods: We examined self-reported weekly mobile phone call duration and incident heart failure (HF), coronary artery disease (CAD), stroke, and myocardial infarction (MI) in four UK Biobank at-risk cohorts (N = 320,343-328,170) using Cox regression. Baseline MDD was evaluated as a stratification and effect-modification variable. We also conducted two-sample MR and an exploratory two-step MR analysis of the pathway from call duration through MDD to CVD. Genome-wide significant instruments ($p<5\times10^{-8}$) defined the primary MR analysis; $p<10^{-6}$ was examined as a sensitivity threshold.

Results: In fully adjusted Cox models, call duration greater than 6 h/week was associated with CAD (HR 1.18, 95% CI 1.10-1.27) and stroke (HR 1.17, 95% CI 1.05-1.29) but not HF or MI. MDD-by-call-duration interactions were not significant (all interaction $p\geq0.115$). Primary IVW MR estimates supported associations of genetically predicted call duration with MDD (OR 1.56, 95% CI 1.04-2.33) and CAD (OR 1.69, 95% CI 1.13-2.55), whereas estimates for HF, stroke, and MI were imprecise. None of the four primary two-step indirect effects excluded the null, and none remained significant after false-discovery-rate correction at the sensitivity threshold.

Conclusions: Longer weekly mobile phone call duration was prospectively associated with CAD and stroke in UK Biobank. The MR findings provide exploratory, but not conclusive, support for an MDD-related pathway.

Open access: https://www.mdpi.com/2306-5354/13/9/1035

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**Occupational exposure to radiofrequency electromagnetic fields and risk of follicular lymphoma: Family case-control study**

R. Mate, G. Benke, S.P. Loughran, M.J. Abramson, C.M. Vajdic, M.C. Turner, M. Turuban, E. Cardis, M.T. Van Leeuwen, M. Odutola, M. Hertzberg, F. Bruinsma, J.F. Seymour, H.M. Prince, F. Roncolato, S. Opat, S. Milliken, E. Verner, R. Lindeman, K. Karipidis. Occupational exposure to radiofrequency electromagnetic fields and risk of follicular lymphoma: Family case-control study. Cancer Epidemiology, Volume 105, 2026. doi: 10.1016/j.canep.2026.103233.

Abstract

Introduction Concerns persist regarding possible associations of exposure to radiofrequency electromagnetic fields (RF-EMF) and cancer risk. Few studies have examined the association between occupational exposure to RF-EMF and the risk of follicular lymphoma (FL). Existing research has typically assessed FL in combination with other lymphomas and has suboptimal exposure assessment. We investigated the possible association between occupational RF-EMF exposure and FL in a family-based case-control study using improved exposure metrics.

Methods The study population consisted of 727 FL cases and 484 family controls. Exposure to RF-EMF was estimated using self-reported lifetime occupational histories and exposure intensity rating from the INTEROCC job-exposure matrix (JEM) (separately for electric and magnetic fields) and the CANJEM. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated from logistic regression models.

Results We observed no consistent associations between RF-EMF exposure and FL. For the highest compared to the lowest quartile of lifetime exposure, results using the INTEROCC JEM showed an OR of 0.98 (95%CI: 0.68–1.40) for electric fields and OR of 1.02 (95%CI: 0.72–1.46) for magnetic fields. RF-EMF exposure defined using the CANJEM showed an OR of 0.94 (95%CI: 0.68–1.31). There were also no consistent associations when applying latency periods or time windows.

Conclusion Our findings do not support any consistent association between occupational RF-EMF exposure and risk of developing FL.

https://www.sciencedirect.com/science/article/pii/S1877782126002493

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**Exposure to pulse modulated radiofrequency electromagnetic fields does not affect Sternberg working memory performance**

Verrender A, Dalecki A, Loughran SP, Duff A, Shore JL, Croft RJ. Exposure to pulse modulated radiofrequency electromagnetic fields does not affect Sternberg working memory performance. Int J Radiat Biol. 2026 Sep 22:1-8. doi: 10.1080/09553002.2026.2733658.

Abstract

Purpose: To replicate a previously reported finding that radiofrequency electromagnetic field (RF-EMF) exposure improves performance on the Sternberg working memory task, as indicated by decreased reaction time, and to test whether this effect, if verified, can also be induced by exposure to an infrared electromagnetic field (IR-EMF).

Materials and methods: Forty-eight healthy adults participated in a randomized, counterbalanced provocation study. Working memory performance was assessed using a modified Sternberg working memory task, which was calibrated to individual performance levels in a preliminary testing session. An sXh920 planar exposure system was used to generate a 920 MHz GSM-like signal, providing two double-blind conditions (peak-spatial SAR average over 10 g) of 0 W/kg (Sham) and 2 W/kg (RF-EMF). A standard, 'off the shelf' 250 W infrared globe provided an IR-EMF exposure with an equivalent heating profile over the skin as that due to the RF-EMF exposure (circa 0.3 °C).

Results: RF-EMF exposure did not reduce reaction time in the Sternberg working memory task. Exploratory tests also revealed there was no effect of IR-EMF on reaction time, and no other performance measures (response bias and response discrimination) were affected by either RF-EMF or IR-EMF exposure.

Conclusions: The current study found no evidence that acute exposure to RF-EMF decreases reaction time on a Sternberg working memory task. The failure to replicate our previously reported effect of RF-EMF exposure on reaction time indicates that our initial finding was not an effect of RF-EMF exposure and was likely due to chance.

Open access: https://www.tandfonline.com/doi/full/10.1080/09553002.2026.2733658

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**Real-World Assessment of RF-EMF Exposure From 3G, 4G, and 5G Mobile Networks Across Different Urbanization Levels**

A. -K. Lee *et al*. Real-World Assessment of RF-EMF Exposure From 3G, 4G, and 5G Mobile Networks Across Different Urbanization Levels. *IEEE Access*, vol. 14, pp. 134636-134653, 2026, doi: 10.1109/ACCESS.2026.3728447.

Abstract

As 5G mobile networks become increasingly widespread, realistic assessment of radio-frequency electromagnetic field (RF-EMF) exposure in modern mobile-network environments is becoming increasingly important. This study characterized real-world downlink (DL) and uplink (UL) RF-EMF exposure across different urbanization levels in South Korea using commercial 3G, 4G, and 5G mobile networks. DL electric-field strengths and UL transmit powers were simultaneously measured in urban and rural environments using frequency-selective field measurements and mobile-network logging systems. The measured exposure levels were used to calculate brain specific absorption rate (SAR) using anatomically realistic child and adult numerical models. The results showed that, under the measurement and dosimetric conditions considered in this study, brain SAR associated with DL exposure from base-station infrastructure was comparable to or exceeded that associated with UL exposure in most tested scenarios. Urban–rural differences in whole-brain-averaged SAR reached 6.2 dB for the child

model and 5.7 dB for the adult model, whereas age-related differences were substantially smaller. These findings indicate that environmental and network-infrastructure factors are major determinants of RF-EMF exposure variability in dense modern mobile-network environments. By integrating real-world measurements with anatomically realistic dosimetry, this study provides a practical framework for RF-EMF exposure assessment and characterization in evolving mobile communication networks.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11672739&isnumber=11323511

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**Citizen science-based mapping of radiofrequency electromagnetic field exposure in Europe : A proof-of-concept validation study**

Baruah A, Sandoval-Diez N, Belácková L, Roga L, Jalilian H, Fröhlich J, Thielens A, Röösli M, Huss A. Citizen science-based mapping of radiofrequency electromagnetic field exposure in Europe : A proof-of-concept validation study. Environ Res. 2026 Oct 8:125886. doi: 10.1016/j.envres.2026.125886.

Abstract

Characterising population-level radiofrequency electromagnetic field (RF-EMF) exposure from mobile telecommunications networks at fine spatial resolution has been limited by the cost and scale of conventional measurement methods. The ETAIN 5G Scientist app, developed within the ETAIN (Exposure To electromAgnetic fIelds and plaNetary health) project uses citizen science smartphone data to produce calibrated RF-EMF exposure maps for 4G/5G networks at 25 x 25 $m^2$ spatial resolution across Europe. As of 2026, the app had collected over 19 million measurements globally. We conducted a proof-of-concept validation of these exposure maps in two European cities with contrasting urban and network characteristics: Utrecht (Netherlands) and Basel (Switzerland). Walking measurement campaigns used the ETAIN app installed on smartphones and the ExpoM-RF4 reference exposimeter carried simultaneously in a backpack. App-derived exposure estimates were compared with spatiotemporally matched reference measurements at the grid-cell level. Validation was performed separately for 4G Long-Term Evolution (LTE) and combined 4G LTE and 5G New Radio (NR) environmental exposure estimates. 4G LTE exposure estimates correlated strongly with measured exposure in both Utrecht ($r_s$ = 0.87, 95% CI: 0.80-0.91, N = 127) and Basel ($r_s$ = 0.71, 95% CI: 0.63-0.78, N = 214; both $p < 0.001$). The combined 4G LTE and 5G NR exposure estimates correlated strongly in Utrecht ($r_s$ = 0.88, 95% CI: 0.81-0.92; 19.7% of grid cells with 5G NR detection) but showed moderate correlation in Basel ($r_s$ = 0.41, 95% CI: 0.29-0.53; 45.3% of grid cells with 5G NR detection). Sensitivity analyses showed map reliability stabilised at five or more observations per grid cell and improved when data from two network operators were combined. These results demonstrate that the ETAIN 5G Scientist application can produce validated, spatially continuous RF-EMF exposure maps at scale. The approach is well suited for characterising exposure trends as mobile networks continue to evolve.

Highlights

- Citizen science smartphone application produces validated RF-EMF exposure maps at 25 m resolution.
- App-derived 4G LTE exposure estimates correlated well with reference measurements (rs = 0.71-0.87).
- Map reliability stabilises at approximately three to five observations per cell.
- Two network operators were sufficient for stable exposure estimates.

Open access: https://www.sciencedirect.com/science/article/pii/S0013935126022188?via%3Dihub

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**Estimating Environmental RF-EMF Exposure From Mobile Networks Using Signal Indicators Collected With the ETAIN 5G Scientist App**

Sandoval-Diez N, Belácková L, Jalilian H, Veludo AF, Roga L, Deltour I, Henderson S, Loughran S, Thielens A, Zahner M, Fröhlich J, Huss A, Röösli M. Estimating Environmental RF-EMF Exposure From Mobile Networks Using Signal Indicators Collected With the ETAIN 5G Scientist App. Bioelectromagnetics. 2026 Oct;47(7):e70071. doi: 10.1002/bem.70071.

Abstract

Smartphones track indicators of a reference signal to maintain network connectivity. These can serve as proxies for a subset of environmental radiofrequency electromagnetic field (RF-EMF) exposure from mobile networks. In this multi-country study, we developed conversion functions linking signal indicators collected with the ETAIN 5G-Scientist app to measured RF-EMF exposure. Parallel measurements were conducted across six European countries and Australia using frequency-selective exposimeters and the app. Associations of signal strength and quality indicators with exposure were analysed using log-linear regression models: (1) serving-cell level, relating exposure in the serving frequency band to indicators of the connected cell (Europe n = 2960; Australia n = 747); and (2) location level, relating indicators aggregated across network providers to environmental exposure from 4G-LTE and 5G-NR networks (Europe n = 61; Australia n = 48). At the serving-cell level, 4G-LTE signal strength was positively associated with exposure, while signal quality was inversely associated. For 5G-NR, only signal strength was associated with exposure, with weaker and less consistent relationships than for 4G-LTE. At location level, aggregation across providers reduced model error, suggesting residual variability operates at short temporal and spatial scales. These findings support using smartphone signal indicators to estimate components of environmental RF-EMF exposure, although further validation is needed, particularly for 5G-NR.

Conclusions

Signal indicators collected with the ETAIN 5G Scientist app provide a promising basis for characterising average environmental RF-EMF exposure from mobile networks at the population level. LTE signal indicators were found to be more informative proxies for environmental exposure, whereas NR signal indicators currently appear to be less reliable. While smartphones are not measurement instruments and cannot replace dedicated devices for compliance assessment, they may offer a scalable, low-cost approach to RF-EMF exposure assessment that is well aligned with the needs of epidemiological research and risk communication. However, future studies should assess the validity of this approach in independent settings and populations.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70071

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**Cell Phone Tower Radiations And Associated Health Hazards In Hilla City, Babylon, Iraq**

Hussain ZA, Baiee HA, Abduirasol ZA. Advances in Applied Biological Research. Cell Phone Tower

Radiations And Associated Health Hazards In Hilla City, Babylon, Iraq. 3(1):57-63.
doi: 10.48165/aabr.2026.3.1.06

Abstract

Background: The obvious increase in mobile phone base stations in Iraq after the year 2003 has raised worries about potential nonspecific health symptoms affected by electromagnetic radiation produced. Studies on this issue in Iraq were scarce. Objective of the study: To identify the possible nonspecific health problems among adult inhabitants who lived for five years or more at a distance of up to 300 meters from mobile phone base stations and towers compared to those who lived far away from cell phone towers (500 meters and more).

Methods: A cross sectional descriptive study was conducted in Hilla city, Babylon province, during the period from November 2017 through February 2018. A non-probability (purposive sample) was selected from populations living in AL-Hilla urban regions for more than five years close to four randomly selected base station towers and those who lived in areas more than 500 meters from the same cell towers. A convenience sample constituted 278 adults aged 18 years and above of both sexes who were investigated after obtaining their verbal consent and who had completed a pretested questionnaire that focused on the subjective symptoms they suffered from via in-depth face-to-face interviews.

Results: The findings of the current study revealed a statistically significant increase in ill-health effects (prevalence of nonspecific symptoms) <0.05 among those living in the locality <300 meters from mobile telephone base stations compared to those who lived far away from the mobile phone stations >500 meters. The strongest associations (<0.01) were fatigue, headache, sleeping disorders, difficulty in concentration, and dizziness. The male-to-female ratio in this study was 1.5:1. The social problems related to this health issue included that only one in five of the participants mentioned that they were informed before setting the stations near their houses, and 75% of inhabitants near the stations reported conflicts with the owner of the building where the cell phone tower was placed.

Conclusion: The study found significant health-related nonspecific symptoms (headache, fatigue, and sleep disturbance) among adults living close to mobile telephone base stations compared to those who lived far away. It is sensible that mobile telephone base stations be located at least 500 meters from the houses of inhabitants.

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https://www.acspublisher.com/journals/index.php/aabr/article/download/24477/20960/44644

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**Spatial and Temporal Characterization of RF-EMF Exposure from Mobile Base Stations in Urban Tirana: A Multi-Band Field Measurement Study**

Kuqi D, Myzeqari B, Zeneli E, Kuqali M, Askushaj D, Plaku M. Spatial and Temporal Characterization of RF-EMF Exposure from Mobile Base Stations in Urban Tirana: A Multi-Band Field Measurement Study. Applied Sciences. 2026; 16(17):8676. doi: 10.3390/app16178676

Abstract

This study presents a spatial and temporal characterization of radiofrequency electromagnetic field (RF-EMF) exposure across six frequency bands (LTE 800, 900 MHz mobile band, LTE 1800, 2100 MHz mobile band, LTE 2600, and 5G NR 3600 MHz) at two central urban squares in Tirana, Albania: Karl Topia (KT, N = 86) and Mustafa Kemal Atatürk (MKA, N = 85). Each of 171 georeferenced points was surveyed in one 360 s daytime session (80 weekdays; 91 weekends; April–May 2026) using a NARDA SRM-3006 selective analyzer. A reproducible Python/GIS workflow combined band-wise root-sum-square aggregation, LOOCV-guided inverse-distance weighting, percentile hotspot sensitivity, temporal comparison, and multi-frequency compliance assessment. LTE 800 had the highest mean exposure (1.37–1.55 V/m). Pooled unadjusted weekday values exceeded weekend values in all bands; after adjustment for site and diurnal window with campaign-day-clustered standard errors, evidence remained for the 900 MHz, 2100 MHz, LTE 2600, and 5G NR 3600 bands, while spatial confounding could not be eliminated. The 5G NR 3600 Emax/Eact ratio was 6.8×, consistent with burst-like transmission but insufficient alone to confirm TDD behavior. All values were below ICNIRP 2020 reference levels ($Q_{Th}$ = 0.0269). The results constitute site-specific initial reference data for the two surveyed squares rather than a national baseline; the workflow is transferable to comparable multi-band monitoring campaigns.

Open access: https://www.mdpi.com/2076-3417/16/17/8676

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**RF-EMF brain dose from mobile phones and the role of reception quality - a simulation study using the ETAIN 5G Scientist App**

Beláčková L, Jalilian H, Sandoval Diez N, den Boer B, Herssens H, Roga L, Zahner M, Fröhlich J, Thielens A, Röösli M, Huss A. RF-EMF brain dose from mobile phones and the role of reception quality - a simulation study using the ETAIN 5G Scientist App. Environ Res. 2026 Sep 24:125736. doi: 10.1016/j.envres.2026.125736.

Abstract

Telecommunication technology continues to evolve, with recent transition from 4G to 5G networks. This can change radio-frequency electromagnetic field (RF-EMF) exposure from mobile devices. To accurately assess personal exposure, mobile device use in various environments with different network qualities should be considered when investigating exposure levels. Using the "ETAIN 5G-Scientist" app, we collected the signal strength quality indicators for both, 4G-LTE and 5G-NR: Reference Signal Received Power and Synchronization Signal Reference Signal Received Power (RSRP and ss-RSRP), for the main providers in the Netherlands (2024-2025). We used calibration functions to estimate far-field exposure from collected RSRP and ss-RSRP. We calculated the corresponding brain dose, based on previously developed specific absorption rate and simulated RF-EMF brain dose for a range of typical activities with mobile phones. We observed signal strength indicators ranging from -140 to -56 dBm RSRP (4G-LTE, N=150789) and -125 to -61 dBm ss-RSRP (5G-NR, N=2192). For the same type of mobile phone use, this, resulted in different estimated daily brain dose (mJ $kg^{-1}$ $day^{-1}$) levels. During the suboptimal network quality (RSRP: -120 dBm) the daily brain dose was higher (5 min call, 150 mJ $kg^{-1}$ $day^{-1}$; 5 min watching video, 26 mJ $kg^{-1}$ $day^{-1}$) compared to optimal network quality (RSRP: -60 dBm)(5 minute call, 4 mJ $kg^{-1}$ $day^{-1}$; 5 min watching video, 5 mJ $kg^{-1}$ $day^{-1}$). Our model based estimate show that even a few minutes of calling under suboptimal signal quality conditions resulted in higher brain dose than 24h environmental exposures. Personal RF-EMF exposure from mobile phones is strongly determined by the technology and

the associated signal quality, this should be factored in when doing exposure studies or epidemiological research.

Highlights

• RF-EMF exposure from mobile phone is related to the signal quality of the phone
• Exposure is higher when the phone is connected to 4G-LTE network compared to 5G-NR network
• Suboptimal network signal quality results in higher exposure to the same mobile phone usage compared to when the network quality is strong

Conclusions

Mobile phone base station exposure in addition to, own mobile phone use contributes to personal exposure. Our approach showed 5G-NR technology is more efficient in the sense that it causes much less brain dose for the same usage scenarios as compared to 4G-LTE. Our study showed that depending on transmit power of the mobile phone and used technology (4G-LTE vs 5G-NR), the received brain dose from phone use can vary largely. As transmit power of the mobile phone depends heavily on the signal strength, this information in combination with phone use duration would be expected to improve accuracy of exposure assessment of RF-EMF into epidemiological analyses. In line with previous assessments, it was shown that near field exposure represents the main contribution to overall brain dose in most situations and therefore it is of relevance to accurately assess the exposure. To expand on this work, it is planned to use the ETAIN 5G Scientist app on population level and use the dose calculations to estimate population dose estimates.

https://pubmed.ncbi.nlm.nih.gov/42785508/

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**IEC/IEEE Approved Draft International Standard for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body**

IEC/IEEE Approved Draft International Standard for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body from Wireless Communications Devices, 100 kHz to 10 GHz Part 1—General Requirements for using the Finite Difference Time Domain (FDTD) Method for SAR Calculations," in *IEC/IEEE P62704-1/D3, 2025* , vol., no., pp.1-86, 5 Oct. 2026.

No abstract

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11724654&isnumber=11724653

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**λ-psSAR to Estimate Cellular Phone Radiation Exposures**

Fernández-Rodríguez CE, Bonin G, Bevilaqua CR, Bulla G, De Salles AAA, Heroux P, Philips A, Chamberlin K. λ-psSAR to Estimate Cellular Phone Radiation Exposures. IEEE Access, doi: 10.1109/ACCESS.2026.3737007.

Abstract

This paper introduces an alternative method for estimating local thermal stress from cellular-phone exposures in human heads. The method, λ-psSAR, defines the peak spatial specific absorption rate over a volume whose dimensions vary with the carrier wavelength in tissue. We systematically compare fixed averaging masses from 100 to 0.01 g and wavelength-based volumes for two antennas, four head or compliance models, and eight frequencies from 1 to 10 GHz. Temperature rise is calculated with the Pennes bioheat equation, including thermal conduction, metabolism, and blood perfusion. Across the simulated cases, the conventional 10 g average does not provide a consistently stronger correspondence with temperature rise than smaller fixed or wavelength-dependent averaging volumes. The results therefore support investigating alternative averaging rules for measured or simulated SAR distributions. In particular, smaller and frequency-adaptive volumes preserve more of the spatial localization of deposited energy and may provide a better representation of increasingly concentrated absorption as frequency rises, although measurement uncertainty and experimental validation must be assessed before any regulatory use.

## Conclusions

Across the combinations of anatomy, antenna, frequency, and averaging volume considered here, the conventional 10 g psSAR did not show a consistently stronger correspondence with temperature increase than smaller fixed masses or wavelength-dependent volumes. This indicates that alternative spatial-averaging rules can perform at least as well as the conventional criterion within the present thermal comparison. The physical interpretation is one of spatial resolution: a larger averaging support suppresses steep local gradients and peaks, whereas smaller cubes preserve a more localized representation of deposited energy. The proposed λ-psSAR adds frequency adaptation by reducing the averaging volume as wavelength decreases, which may better follow the increasing spatial concentration of absorption at higher frequencies.

The most relevant next step is measurement-based validation. Conventional and alternative averages should be calculated from the same experimentally acquired SAR maps and compared across frequencies, devices, laboratories, and, where feasible, measured or independently predicted temperature rise. Such studies should determine whether smaller fixed or wavelength-dependent volumes improve thermal correspondence without introducing unacceptable sensitivity to probe spacing, interpolation, positioning, boundary handling, and uncertainty. The present work therefore supports evaluating alternatives to the 1 g and 10 g cubes, but it does not yet justify replacing existing homologation criteria.

The computational burden is concentrated in the electromagnetic and thermal field solutions rather than in the additional spatial averages. Nevertheless, the present conclusions remain limited by the finite model set, normalized single-frequency exposures, approximate tissue wavelength and density used to define the variable masses, and reliance on the Pennes bioheat model. These limitations preclude treating any single wavelength fraction as a universal biological or regulatory averaging scale at this stage.

This work was funded by the Electromagnetic Safety Alliance, Inc. The authors acknowledge the contribution of the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF) to the design of the study.

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**Low-Cost Sensors in 5G RF-EMF Exposure Monitoring: Validity and Challenges**

Rathebe PC, Kholopo M. Low-Cost Sensors in 5G RF-EMF Exposure Monitoring: Validity and Challenges. *Sensors*. 2026; 26(2):533. doi: 10.3390/s26020533

Abstract

The deployment of 5G networks has transformed the landscape of radiofrequency electromagnetic field (RF-EMF) exposure patterns, shifting from high-power macro base stations to dense networks of small, beamforming cells. This review critically assesses the validity, challenges, and research gaps of low-cost RF-EMF sensors used for 5G exposure monitoring. An analysis of over 60 studies covering Sub-6 GHz and emerging mmWave systems shows that well-calibrated sensors can achieve measurement deviations of ±3–6 dB compared to professional instruments like the Narda SRM-3006, with long-term calibration drift less than 0.5 dB per month and RMS reproducibility around 5%. Typical outdoor 5G FR1 exposure levels range from 0.01 to 0.5 $W/m^2$ near small cells, while personal device use can cause transient exposures 10–30 dB higher. Although mmWave (24–100 GHz) and Wi-Fi 7/8 (~60 GHz) are underrepresented due to antenna and component limitations, Sub-6 GHz sensing platforms, including software-defined radio (SDR)-based and triaxial isotropic designs, provide sufficient sensitivity for both citizen and institutional monitoring. Major challenges involve calibration drift, frequency band gaps, data interoperability, and ethical management of participatory networks. Addressing these issues through standardized calibration protocols, machine learning-assisted drift correction, and open data frameworks will allow affordable sensors to complement professional monitoring, improve spatial coverage, and enhance public transparency in 5G RF-EMF exposure governance.

Open access: https://www.mdpi.com/1424-8220/26/2/533

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**Beyond the 5G-COVID moment: the scope of EMF mis- and disinformation on German-language social media**

Eder T, Aue K, Drescher LS, Dressel K, Groh G, Roosen J. Beyond the 5G-COVID moment: the scope of EMF mis- and disinformation on German-language social media. J Radiol Prot. 2026 Sep 11. doi: 10.1088/1361-6498/aea624.

Abstract

Public perception of health risks from electromagnetic fields (EMF) and 5G mobile networks diverges persistently from the scientific evidence base, a gap increasingly shaped by social media. While existing research has examined the acute COVID-5G conspiracy episode on individual platforms, systematic multi-platform analyses of the broader EMF misinformation landscape remain scarce. This study

presents a mixed-methods analysis of EMF and 5G-related misinformation across YouTube, Telegram, and Twitter/X in German-language social media, combining automated classification, sentiment analysis, and topic modelling with structured qualitative content analysis. The three corpora comprise over 430,000 posts from more than 16,000 accounts, covering content published primarily between 2019 and 2024. The analysis reveals that EMF misinformation circulates in a predominantly pseudo-expert communicative register rather than overtly inflammatory language, is structurally embedded within broader conspiracy ecosystems rather than circulating as standalone content, and is sustained by commercial incentive structures alongside ideological motivations. The three platforms serve complementary functional roles within an integrated distribution network. While the pandemic-era peak in activity has subsided, the underlying network infrastructure remains intact. The findings establish an empirical baseline for the German-language EMF misinformation landscape against which future developments, including the impact of generative AI on misinformation production, can be measured.

Open access: https://iopscience.iop.org/article/10.1088/1361-6498/aea624

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**Strain-dependent effects of long-term exposure to 27.5 GHz 5G millimeter waves on male reproductive outcomes in mice**

Palone F, Novelli F, Pasquali E, Leonardi S, De Stefano I, Fratini E, Tanori M, Piscitelli M, Merla C, Pinto R, Ardoino L, Zambotti A, Camera F, Pazzaglia S, Capstick M, Samaras T, Mancuso M. Strain-dependent effects of long-term exposure to 27.5 GHz 5 G millimeter waves on male reproductive outcomes in mice. Reproductive Toxicology, Volume 146, 2026. doi: 10.1016/j.reprotox.2026.109370.

Abstract

Background  The biological impact of prolonged exposure to 5 G millimeter-wave frequencies (FR2) on male reproductive health remains insufficiently characterized despite the global deployment of this technology in the near future. Here, we investigated the effects of chronic 27.5 GHz FR2 exposure on testicular function and sperm quality in three mouse strains with distinct genetic backgrounds (Car-S, CD1, and C57BL/6 J).

Methods  Adult males (8-weeks old at the onset of the study) were exposed for 100 days to low (6.67 W/m²) or high (20 W/m²) power density, or were SHAM-exposed. Reproductive parameters were assessed through testicular histopathology, serum testosterone measurement, and quantitative and qualitative sperm analyses.

Results  Continuous temperature monitoring and dosimetry confirmed that exposure remained strictly non-thermal throughout the experiments. The average ambient temperature recorded during the study was 22.8°C, while the mean whole-body specific absorption rate (SAR) was 0.26 W/kg and 0.77 W/kg under the LPD and HPD exposure conditions, respectively. Car-S mice showed significant reductions in sperm concentration and motility, increased tail abnormalities, and alterations in testicular architecture and testosterone levels, irrespective of prior carcinogen treatment administered for the evaluation of skin carcinogenesis. CD1 mice were largely resistant, displaying preserved sperm parameters with only minor morphological defects, whereas C57BL/6 J mice exhibited intermediate sensitivity, with reduced sperm viability and motility but normal concentration, morphology, and histology.

Conclusions  These findings demonstrate that genetic background strongly influences susceptibility to long-term 27.5 GHz FR2 exposure, highlighting the importance of integrating functional sperm endpoints and population heterogeneity in human health risk assessment.

Highlights

- Long-term 27.5 GHz FR2 exposure affects sperm quality depending on genetic background.
- Sperm motility and tail morphology are the most sensitive indicators of 27.5 GHz FR2 effects.
- The biological effects occur regardless of significant changes in temperature.
- Biological effects were observed without a consistent dose-response relationship.

Open access: https://www.sciencedirect.com/science/article/pii/S0890623826002133

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**Radiofrequency Radiation Alters Redox Homeostasis, ATP Status, and Apoptosis-Associated Responses in Human Ovarian Epithelial Cells**

Ahmad S, Nagar G, Yadav N, Singh S, Shrivastava A, Singh R. Radiofrequency Radiation Alters Redox Homeostasis, ATP Status, and Apoptosis-Associated Responses in Human Ovarian Epithelial Cells. *Cells*. 2026; 15(19):1826. doi: 10.3390/cells15191826

Abstract

With the expansion of wireless communication technologies, radiofrequency radiation (RFR) has become a persistent component of the environmental exposome. The 2450 MHz frequency is a widely used RF band in wireless and microwave technologies, providing an environmentally relevant model for evaluating non-ionising radiation effects. Although non-ionising, RFR may influence cellular homeostasis through non-thermal stress pathways, yet its cellular effects in ovarian-derived models remain insufficiently defined. This study examined whether 2450 MHz RFR was associated with redox, ATP-related, and apoptosis-associated responses in SKOV3 ovarian epithelial cells. Cells were exposed for 30, 60, and 120 min under controlled conditions at a measured electric field intensity of 13.44 V/m. MTT-based viability/metabolic activity at 24 h and 48 h post-exposure, ROS, nitrite, ATP, mitochondrial membrane potential, apoptosis-related gene expression, and Annexin V-FITC/PI staining were assessed. RFR exposure did not significantly reduce MTT-based viability/metabolic activity at 24 h post-exposure; at 48 h, a significant reduction was observed in the 120-min group compared with the control and 30-min groups. Exposed cells showed progressive ROS accumulation, increased nitrite levels, and changes in ATP levels, with an increase at 30 min followed by lower levels at 60 and 120 min relative to 30 min, while the JC-1 red/green ratio showed no significant change. Apoptosis-associated transcriptional changes were marked by increased Bak1, Nip-2, and Caspase-4 and reduced Bcl-xL and Bag3 expression and a non-significant increase in Bad expression. Annexin V-FITC/PI analysis demonstrated an exposure-duration-associated increase in Annexin V-positive populations, with a predominance of Annexin $V^+/PI^+$ cells following 120 min of exposure. Overall, these findings indicate an exposure-associated cellular stress phenotype involving redox, ATP status, and apoptosis-related alterations in SKOV3 cells under defined in vitro conditions.

Open access: https://www.mdpi.com/2073-4409/15/19/1826

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**A Monte Carlo Computational Framework Yielding Optimal RF-Dose Bounding for Rodent Bioassays Conducted in Reverberation Chambers**

A. Faraone *et al*., A Monte Carlo Computational Framework Yielding Optimal RF-Dose Bounding for Rodent Bioassays Conducted in Reverberation Chambers. *IEEE Access*, doi: 10.1109/ACCESS.2026.3741073.

Abstract

Large-scale lifetime rodent bioassays conducted in reverberation chambers (RCs) rely on automated radiofrequency (RF) power control feedback, driven by a sparse set of field probes, to regulate cohort-wide RF energy absorption. As moving rodents load the RC differently from calibration phantoms, the relationship between probe readings and the realized whole-body specific absorption rate (wbSAR) shifts. Compounded by inevitable instrumentation and thermal calibration errors, sparse field sampling may introduce a wider, yet undetected, exposure variance. To quantify and mitigate these effects, a Monte Carlo (MC) dosimetry framework emulating the calibration-to-live experiment chronology, including field-sensing-driven RF-power control, is presented for an RC loaded with 96 male rat models at 900 MHz. Feedback control schemes based on net RF input power and total RF energy density metrics are compared in terms of realized RF dose. Contextualized within historical bioassay parameters, the computational results indicate that compounding sparse field sampling at arbitrary RC locations with said errors induces an unknowable, unrecoverable cage-wise exposure spread, potentially causing dose-group overlaps and overexposures. To identify optimal probe locations and types, an MC-based selection criterion is demonstrated to substantially mitigate dosimetric spread, bounding cohort-wide exposures within known envelopes and providing a reliable dosimetric design framework for future rodent bioassays.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11723136&isnumber=6514899

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**Occupational exposure to extremely low-frequency fields and cardiovascular consequences: a systematic review**

Raeisi E, Maghare Dehkordi S, Yazdanirad S, Mohammadian-Hafshejani A. Occupational exposure to extremely low-frequency fields and cardiovascular consequences: a systematic review. Public Health Rev. 2026 Sep 25;47:1609952. doi: 10.3389/phrs.2026.1609952.

**Abstract**

**Objective:** Exposure to extremely low-frequency (ELF) electromagnetic fields can have harmful effects on human health. The present systematic review study aimed to investigate the relationship between occupational exposure to ELF and cardiovascular outcomes.

**Methods:** Searches were conducted in six electronic bibliographic databases: Scopus, PubMed, Web of Science, Embase, MEDLINE, and Google Scholar. This search included records up to August 19, 2026. The search strategy used two sets of keywords. Following the selection of proper studies, relevant data were

extracted by the reviewers. To assess the risk of bias in the included studies, the Joanna Briggs Institute checklist was used.

**Results:** Seven of fourteen studies (50 percent) showed that there is an association between ELF field exposure and cardiovascular outcomes. However, the available evidence is insufficient to establish causality. Some of the outcomes reported in the studies included acute myocardial infarction, arrhythmia, hematological parameters, coronary heart disease, and hypertension.

**Conclusion:** Exposure to ELF fields may be associated with some cardiovascular outcomes. However, the confirmation of this relationship remains ambiguous, and it requires further investigations in future research.

**Excerpt**

Extremely low-frequency (ELF) electromagnetic fields are a type of electromagnetic field with frequencies from 1 to 300 Hz [1]. Exposure to these waves is common in occupational environments because it can occur during production, transfer, distribution, and use of electricity [2]. Some effects due to exposure to ELF electromagnetic fields include cerebral cancer, bladder cancer, breast cancer, Alzheimer's disease, behavioral and mental problems, sleep and wake rhythm disorder, and changes in perception and memory [3]. Compared with these outcomes, the possible cardiovascular effects of ELF exposure have received less attention and remain less clearly understood [4].

**Conclusions**

An association between occupational exposure to ELF electromagnetic fields and cardiovascular outcomes was reported in seven of the 14 studies included in this review. However, the findings were not consistent across the studies, and the current evidence is not sufficient to confirm a causal relationship. The differences in the results of the studies could be because of differences in exposure frequency, exposure duration, and exposure level to the ELF field. Some studies reported associations with acute myocardial infarction, coronary heart disease, arrhythmia, blood pressure, and other cardiovascular-related changes, whereas others found no significant effects. Therefore, although a possible relationship between occupational ELF exposure and cardiovascular health cannot be ruled out, the strength and clinical importance of this association remain uncertain. The findings of this research may be useful to plan strategies to prevent cardiovascular diseases in different settings. However, more studies are needed to investigate the effect of the ELF electromagnetic field with the mentioned characteristics in various environments to confirm these results. Moreover, some confounding factors, such as personal, occupational risk, and psychosocial factors, may influence this association. The roles of these factors must be considered in future studies. Also, differences in these effects between various people with different factors should be examined in future research.

Open access: https://www.ssph-journal.org/journals/public-health-reviews/articles/10.3389/phrs.2026.1609952/full

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**Justification of sanitary protection zones for 0.4–330 kV overhead power lines based on magnetic field exposure and normalization of its levels**

Rozov VY, Dumanskyi VY, Pelevin DY, Kundius KD. (2026). Justification of sanitary protection zones for 0.4–330 kV overhead power lines based on magnetic field exposure and normalization of its levels. *Electrical Engineering & Electromechanics*, (5), 85–95. doi: 10.20998/2074-272X.2026.5.11

Abstract

Problem. In Ukraine, the current sanitary protection zones (SPZ) and right-of-way (ROW) zones of overhead power lines (OHLs), within which the construction of residential buildings is prohibited, are established by regulatory legal acts solely based on the criterion of electric field (EF) strength, without taking into account magnetic field (MF) flux density. This situation poses a serious threat to the health of the population living near OHLs, since, unlike the EF, the MF has a significantly higher penetrating capacity and, under conditions of long-term exposure, exhibits carcinogenic properties. Furthermore, the features of MF distribution outside the current OHL ROW zones remain insufficiently studied. This creates risks of widespread population exposure exceeding the maximum permissible level of the MF.

Goal. Substantiation of the boundaries of SPZ for designed 0.4–330 kV OHLs based on the regulatory MF flux density level of 0.5 μT, and the development of rational methods for normalizing the MF level of existing OHLs.

Methodology. A comprehensive combination of theoretical and experimental studies of the MF flux density distribution of 0.4–330 kV OHLs outside their current ROW zones, as well as a comparative sanitary and hygienic assessment of the obtained data.

Results. The necessity of expanding the boundaries of ROW (SPZ) zones for 110–330 kV OHLs and utilizing developed «magnetically clean» OHLs to ensure the protection of public health from MFs has been substantiated.

Scientific novelty. It has been theoretically proven and experimentally confirmed that it is the MFflux density, rather than the EF strength, that is the determining factor for establishing safe boundaries of OHL SPZ. The necessity of establishing the SPZ width at 30 m for 110 kV OHLs and 83 m for 330 kV OHLs is substantiated. The synthesis of «magnetically clean» OHLs based on the method of vector MF compensation has been performed. Practical value. Practical recommendations have been developed for normalizing OHL MF flux density by increasing the width of the SPZ (PZ) for 110-330 kV OHLs, and constructing synthesized «magnetically clean» OHLs for their local use in critical areas during the modernization of existing legacy OHLs. References 56, tables 3, figures 11.

Open access: https://eie.khpi.edu.ua/article/view/369825

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**Electromagnetic exposure safety assessment of electromagnetic security gates: a review**

Bai W, Lu M. Electromagnetic exposure safety assessment of electromagnetic security gates: a review. Front Public Health. 2026 Sep 18;14:1935419. doi: 10.3389/fpubh.2026.1935419.

Abstract

In this review, electromagnetic security gates include walk-through metal detectors (WTMDs), electronic article surveillance (EAS) systems, radio-frequency identification (RFID) systems, and millimeter-wave (MMW) security screening systems. These technologies are widely used in public-security screening, theft prevention, access control, and industrial inspection, making electromagnetic-exposure safety a public-health concern. This review traces their technological development, summarizes operating principles and emission characteristics, and examines potential biological effects of electromagnetic-field exposure. It also reviews exposure-assessment methods and applies an adapted evidence-appraisal framework to synthesize experimental, numerical, and epidemiological evidence, evaluate interactions with active medical devices and passive metallic implants, and assess evidence strength and limitations. Particular attention is given to potentially susceptible populations and frequency-specific exposure metrics. Major evidence gaps and future research priorities are identified.

Open access: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2026.1935419/full

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**Power-Frequency Magnetic Field Exposure near Transmission Infrastructure in Taif, Saudi Arabia: Empirical Decay Modeling and Benchmarking Against ICNIRP and EU Precautionary Limits**

Aljuaid AM. Power-Frequency Magnetic Field Exposure near Transmission Infrastructure in Taif, Saudi Arabia: Empirical Decay Modeling and Benchmarking Against ICNIRP and EU Precautionary Limits. Safety 2026, *12*(5), 131. doi: 10.3390/safety12050131.

Abstract

Rapid urbanization in Taif City, Saudi Arabia, has brought high-voltage overhead and underground power lines into close proximity to residential neighborhoods and recreational areas, yet the Kingdom has no dedicated national standard for public exposure to power-frequency magnetic fields. (1) Background: This study quantified extremely low-frequency (ELF, 50 Hz) magnetic field exposure at eight sites in Taif and benchmarked it against international guidelines and comparable field studies. (2) Methods: The magnetic flux density was measured with two independently calibrated meters (MESTEK EMF01, WINTACT WT3121) at controlled distances from each source over multiple days; the data were analyzed by two-sample t-tests, log–log regression of the spatial decay, and hazard quotient benchmarking. (3) Results: The peak flux density reached 42.5 µT at 0 m from an underground cable, and decayed to below 1 µT within 10–50 m of overhead lines; the fitted decay model $B(r) = 3431 \cdot r^{-2.94}$ ($R^2 = 0.826$) was steeper than the ideal single-conductor law, consistent with three-phase cancellation. All values remained below the ICNIRP 100–200 µT reference level, but several exceeded the 3–10 µT precautionary values applied in the EU, and all exceeded, at close range, the ≈0.3–0.4 µT threshold linked to elevated childhood leukemia risk. The results agree with European (Gajšek et al.), Italian regulatory (Filosa and Lopresto), and Mexican (Ciudad Juárez) field data. All near-source readings also exceeded the EUROPAEM 2016 precautionary guidance values for sensitive populations. Repeat sampling at the overhead line site showed a reproducible diurnal load effect, with midday fields ~28% above morning values and a 1.40 ratio between the largest and smallest readings, confirming that spot measurements cannot represent the 24 h exposure. (4) Conclusions: The findings support a precautionary national exposure framework that treats the ICNIRP reference levels as a ceiling against acute effects rather than as a sufficient standard, and incorporates long-term precautionary values

together with targeted engineering mitigation for Taif. Because the reported values are spot rather than 24 h measurements, the exceedances identify sites requiring continuous monitoring rather than confirming regulatory breaches; a 24 h, multi-height, harmonic-resolved campaign is planned as the necessary next step.

Open access: https://www.mdpi.com/2313-576X/12/5/131

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**Quantum Effects in Evolution: Terrestrial Fine-Tuning of Magnetic Parameters**

Adams B, Hassasfar A, Sinayskiy I, Nunn A, Guy G, Petruccione F. Quantum Effects in Evolution: Terrestrial Fine-Tuning of Magnetic Parameters. Comput Struct Biotechnol J. 2026 Jun 4;35(4):0125. doi: 10.34133/csbj.0125.

Abstract

All life on Earth shares an evolution that is coupled to specific environmental conditions, including the geomagnetic field, which would suggest that biological materials have evolved some degree of magnetic sensitivity. Mounting evidence supports the idea that living organisms can detect and respond to weak magnetic fields, and the radical pair mechanism provides a plausible quantum-level basis for magnetic field sensitivity in biological processes. In the context of evolution, however, fundamental questions remain. How does natural selection act on quantum phenomena such as spin dynamics? What evolutionary pressures have tuned or preserved magnetic sensitivity at the quantum level? In this paper, we offer some potential answers, by closer inspection of the spin Hamiltonian central to the radical pair mechanism. We focus on the fact that hyperfine coupling constants are determined by the local protein environment, which is specified by genetic sequence. Variations in these parameters can alter reactive oxygen species (ROS) outcomes, providing a potential pathway by which quantum-level effects influence organism fitness and possible selection. As proof of principle, we employ a simple qualitative model to demonstrate how variations in nuclear spin, hyperfine coupling strength, and anisotropy might alter ROS levels under different magnetic field conditions. Although these ideas remain speculative, they suggest a framework for investigating how magnetic environments may have influenced the evolution of biological function, with implications for health, disease, and adaptation to altered magnetic environments.

Open access: https://spj.science.org/doi/10.34133/csbj.0125

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**Magnetoreception, flexible use of cues and low-information navigation in animals**

Lohmann KJ, Gill JP, Taylor BK, Lohmann CMF. Magnetoreception, flexible use of cues and low-information navigation in animals. J Exp Biol. 2026 Oct 1;229(19):jeb252932. doi: 10.1242/jeb.252932.

Abstract

Magnetoreception - the ability to detect Earth's magnetic field - is widespread among animals. Despite recent progress, fundamental gaps in our knowledge remain. The two main goals of modern magnetoreception research are to: (1) understand how magnetic information is used by animals in navigation; and (2) uncover the biophysical mechanisms that underlie magnetic field detection. The

discovery that animals use magnetic information not only as a directional (compass) cue, but also as a kind of 'map', has revolutionized research in animal navigation. Recent findings suggest that animals use magnetic cues flexibly and idiosyncratically to help guide spatial movements. We propose that a valuable but seldom used approach to studying animal movements is to consider ways in which seemingly complex navigational feats can be accomplished with minimal information, often without the need for classical map-and-compass navigation, a cognitive representation of the environment, or prior knowledge of the terrain. We also used a recently developed model to demonstrate that natural selection can potentially 'tune' magnetic navigation systems to optimize navigation in different parts of the world, and we illustrate the possibility with examples of long-distance migrations by sea turtles, fishes and birds. Emerging evidence further implies that there are multiple magnetoreceptive mechanisms rather than a single, universal way of sensing magnetic fields. We argue that the path forward, for both unraveling animal navigation and elucidating mechanisms of magnetoreception, requires a thoughtful balance between a search for unifying principles and an expectation of major differences among species and populations.

https://pubmed.ncbi.nlm.nih.gov/42860888/

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**A review of potential health risks of radiofrequency electromagnetic field exposure from mobile phones and base stations in children and pregnant women**

Dogra S, Rajput S, Rathi A, Gautam R, Mazumder P, Sinha A, Sahoo RK, Pati S, Mukherjee A, Arora T (2026) A review of potential health risks of radiofrequency electromagnetic field exposure from mobile phones and base stations in children and pregnant women. Front. Public Health 14:1915745. doi: 10.3389/fpubh.2026.1915745.

Abstract

Over the last decade, the rapid expansion of mobile communication technologies has substantially increased population exposure to radiofrequency electromagnetic fields (RF-EMF). This has raised concerns about possible health implications, particularly for vulnerable groups like children and pregnant women. Although international agencies have reported no consistent evidence of harmful effects at established exposure limits, uncertainties remain regarding long-term and developmental effects. This review synthesizes and evaluates epidemiological and experimental evidence published between 2015 and 2025; a period characterized by rapid technological transitions (4G to 5G), advances in exposure assessment techniques, and increasing reliance on wireless devices. Confining the time frame ensures a more relevant and up-to-date assessment of current exposure patterns and emerging biological insights. The review explores the association between RF-EMF exposure and major health outcomes, including reproductive and developmental effects, cancer risk, and neurological changes. It also integrates mechanistic pathways involving oxidative stress, DNA damage, and ROS signalling. Although no definitive causal relationship has been established, the evidence remains inconsistent due to variability in study design, exposure metrics, and outcome definitions. Notably, experimental and high-exposure studies provide biologically plausible mechanisms, particularly through oxidative stress pathways; however, these findings have not been consistently observed in the human population. Children and foetuses may exhibit greater susceptibility because of developmental and physiological factors, yet high-quality longitudinal evidence remains limited. Overall, further standardized,

mechanistic, and long-term studies are needed to strengthen the scientific evidence base and inform public health policy.

Conclusion

The current evidence indicates that the association between RF-EMF exposure and health outcomes in vulnerable groups particularly children and pregnant women remains uncertain and not yet definitively resolved. Although mechanistic and experimental studies suggest potential effects such as disruptions in calcium signaling, oxidative stress and potential effects of cognition, neurodevelopment and reproductive health (such as impacts of fetal development, fertility and endocrine function). A major limitation across the literature is lack of standardized and objective exposure metrics by which epidemiological findings remain inconsistent. Many studies depend on self reported usage rather than objective measurements such as dosimetry or environmental monitoring. Furthermore, the distinction between near field and far field exposures complicate risk evaluation, as metrics like SAR does not adequately reflect cumulative and real life exposure scenarios. Although guidelines from ICNIRP effectively address established thermal effects of RF-EMF exposure, uncertainties remain regarding potential long term, low intensity and non thermal biological effects, particularly during sensitive developmental stages. The rapid development of wireless technologies, with 5G networks expanding across the globe and increasing more dependency on device at younger ages, means that there is urgent need to continuously re-evaluate current safety standards. Future research should focus on well designed studies, standardized exposure assessment especially those started during pregnancy and early life stages and adopt interdisciplinary strategies integrating experimental, epidemiological and computational modelling to better understand mechanisms and dose–response relationships. Further in future epidemiologic studies, more emphasis should be placed on the use of objective exposure assessment, standardised dosimetry, repeated exposure measurements, and rigorous control of potential confounding factors to improve causal inference. A prudent approach may therefore be considered in the form of precautionary measures such as minimizing unnecessary exposure, public awareness and promoting safe device practices. Ultimately, only rigorous, advanced research and reassessment will address existing knowledge gaps. This will inform evidence based regulatory policies for protecting the vulnerable populations in an increasingly wireless world.

Open access:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2026.1915745/full

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**A systematic review of mobile phone use and pregnancy and fetal outcomes**

Wang M, Zhang Y, Angley M, Kleiman NJ, Wang X, Kahe K. A systematic review of mobile phone use and pregnancy and fetal outcomes. *J Expo Sci Environ Epidemiol* (2026). doi: 10.1038/s41370-026-00958-4.

Abstract

Background  Pregnancy is a crucial period characterized by profound maternal and fetal biological changes and increasing susceptibility to environmental influences. The widespread use of mobile phones has raised concerns regarding potential health effects during pregnancy. Mobile phones emit non-ionizing radiofrequency electromagnetic fields (RF-EMF), which could affect fetal development through

thermal and non-thermal mechanisms. Research on mobile phone use during pregnancy remains limited and yields mixed findings.

Objective  This review systematically evaluated evidence on the associations between maternal mobile phone use—specifically frequency and duration—and pregnancy outcomes.

Methods  Comprehensive PubMed, Web of Science, and Google Scholar searches identified 20 studies meeting the predetermined inclusion criteria. Covidence was used for title and abstract screening.

Results  While several studies reported no significant health threat, others suggested an association with adverse pregnancy outcomes. The most consistent evidence emerged for alterations in fetal and neonatal cardiac function and increased risk of preterm birth, highlighting a need for further targeted research on system-specific vulnerabilities.

Impact  Despite the widespread use of mobile phones, the adverse effects of RF-EMF exposure remain poorly understood, especially among susceptible populations, such as pregnant women. This study synthesizes human evidence to inform the general public, clinicians, researchers, patients, and policymakers about the potential risks associated with prenatal RF-EMF exposure. Although findings remain inconclusive, the evidence suggests possible effects on fetal cardiac function and gestational duration. By identifying methodological limitations and research gaps, this review highlights the need for standardized exposure assessment and well-designed prospective studies to enable more definitive risk evaluation and guide evidence-based recommendations for safer prenatal mobile phone use.

Conclusion

This review systematically evaluates the available literature regarding the health impacts of mobile phone use during pregnancy. While some studies report no significant effects, others suggest potential risks such as cardiovascular abnormalities and shorter gestational duration. Potential mechanisms like RF-EMF-induced oxidative stress may underlie these adverse health outcomes. Notably, all non-randomized studies showed serious or critical risk of bias, and the randomized studies ranged from some concerns to high risk, so findings should be interpreted with caution. Future research should prioritize well-designed cohort studies with standardized exposure assessments to clarify these associations. Because of the rapid evolution of mobile phone technology and increased frequency and duration of mobile phone usage, understanding the long-term impacts of RF-EMF exposure on maternal and fetal health remains critical. While agencies like the NIH and CDC note that benefits generally outweigh risks, the emerging evidence may support precautionary measures to reduce mobile phone usage during pregnancy, particularly among high-risk pregnant women. Simple interventions, such as using speakerphones or wired headsets, keeping phones away from the abdomen, and enabling airplane mode during inactivity, may be suggested during biologically sensitive periods. Due to the inherent limitations of the primary studies reviewed in this manuscript, any definitive conclusions or recommendations will require more rigorous studies with clearly defined and quantified exposures and health outcomes.

https://www.nature.com/articles/s41370-026-00958-4

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**Safeguarding Children's Health in the Digital Age: Addressing Screen Time, Wireless Radiation, and Extremely Low Frequency Electromagnetic Field Exposures**

***A Position Statement on Children's Health and Electromagnetic Fields by the International Commission on the Biological Effects of Electromagnetic Fields***

ICBE-EMF Position Statement on Children and EMF

https://icbe-emf.org/safeguarding-childrens-health-in-the-digital-age-addressing-screen-time-wireless-radiation-and-extremely-low-frequency-non-ionizing-electromagnetic-field-exposures/

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**Non-ionizing radiation and cancer: A review on current evidence, mechanistic insights, and public health implications**

Agrahari M, Gupta S, Thakur G, Tanwar S, Gautam R, Arora T. Non-ionizing radiation and cancer: A review on current evidence, mechanistic insights, and public health implications. Biochemistry and Biophysics Reports, Volume 47, 2026. doi: 10.1016/j.bbrep.2026.102705.

Abstract

Non-ionizing radiation (NIR) generated from the high power transmission lines, broadcasting antennas and cellular phones represent one of the widespread environmental exposures which can induce carcinogenic outcome. Although NIR lacks sufficient energy to dislodge the electrons for ionization, an indirect mechanism has been proposed to be involved in adverse outcomes under certain exposure conditions. Consequently, radiofrequency electromagnetic field (RF-EMF) exposure remains a consistent scientific and public health concern regarding its possible role in cancer manifestation. This review aims to analyze the findings of RF-EMF exposure and carcinogenicity by integrating epidemiological studies and experimental findings to demonstrate its potential function in cancer manifestation.The available evidence is not sufficient to conclude that RF-EMF exposure is a direct-acting genotoxic carcinogen or cancer initiator. However, laboratory studies have indicated that long-term exposure to non-thermal RF-EMF can cause oxidative stress, genomic instability, epigenetic alterations, ion transport disruption and dysregulation of cell-signaling pathways. These biological effects may contribute to the promotion and progression stages of carcinogenesis, but are not directly responsible for tumor/cancer initiation. The epidemiological evidence significantly varies between extremely low-frequency magnetic fields (ELF-MF) and radiofrequency electromagnetic fields (RF-EMF). Although ELF-MF exposure has demonstrated a more reliable association with childhood leukemia, the data connecting RF-EMF exposure to cancer is less consistent. Studies with the larger sample size and increased exposure duration are needed to strongly corroborate its involvement in cancer development.

Highlights

• Non-ionizing radiation (RF-EMF) does not directly cause cancer but may indirectly influence carcinogenesis through biological pathways.
• Exposure to RF-EMF can induce oxidative stress, genomic instability, and altered cell signaling mechanisms.
• Epidemiological evidence on cancer risk (e.g., brain tumors, leukemia) remains inconsistent and inconclusive.

• Long-term and high-exposure conditions may contribute to cancer progression, further large scale research is needed.

Conclusion from current evidences

Despite the long-term investigations, the association between the non-ionizing electromagnetic field and related carcinogenicity remained ambiguous. Major inconsistency lies in its methodological limitations as epidemiological studies reported variable outcomes due to EMF exposure. Available studies indicate that the observed biological effects are not consistently correlated with exposure frequency, duration, or power density. Based on the evidence reviewed here, RF-EMF exposure is currently not established as a complete or direct-acting genotoxic carcinogen that can initiate cancer by DNA damage. However, experimental studies suggest that long term exposure to RF-EMF can cause oxidative stress, genomic instability and altered gene expression, cellular signalling which may be involved in tumour promotion and progression. Thus RF-EMF can be more appropriately considered as a potential non-genotoxic modulator of carcinogenesis rather than a direct cancer initiator. However, the current evidence is still not enough to prove a definite cause effect relationship.

Moreover the existing evidence must be analysed independently for ELF-MF and RF-EMF exposures. Although ELF-MF exposure demonstrates a relatively consistent association with childhood leukemia, evidence supporting a carcinogenic role of RF-EMF remains limited and inconclusive. Further study with the larger sample size and precise exposure assessment is needed to validate the results with more accuracy and to suggest its involvement in cancer development.

Open access: https://www.sciencedirect.com/science/article/pii/S2405580826002657

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**Impact of Terahertz Electromagnetic Devices on Human Tissue: A Review of SAR and Safety Considerations**

Sharma N, Kaur A, Sharma S. Impact of Terahertz Electromagnetic Devices on Human Tissue: A Review of SAR and Safety Considerations. Radio Science. 61(8). doi: 10.1029/2025RS008496

Abstract

Terahertz (THz) technology, operating in the 0.1=10 THz band, has gained increasing relevance in wireless communications, biomedical diagnostics, and wearable systems. Its ability to provide high-resolution imaging and non-invasive sensing has made it a promising tool in healthcare. However, strong absorption of THz waves by water-rich biological tissues raises critical concerns regarding biological safety. A key metric for evaluating electromagnetic exposure is the Specific Absorption Rate (SAR), which quantifies the rate of energy deposition in tissues. This review examines the role of THz antennas, sensors, and absorbers in shaping electromagnetic field distributions and their implications on SAR. While flexible and compact THz antennas and sensors demonstrate potential for applications such as COVID-19 detection, fall monitoring, and biosensing, most studies rely on simplified phantoms or simulations, limiting biological realism. Similarly, metamaterial absorbers enhance device sensitivity and control field localization but may inadvertently introduce resonant hotspots that increase localized SAR. Current research highlights a trade-off between device performance and biological safety, further constrained by incomplete dielectric data sets and lack of standardized measurement techniques. This

review underscores the urgent need for experimental validation, localized SAR metrics, and updated safety frameworks to ensure the safe deployment of THz-enabled biomedical technologies.

https://doi.org/10.1029/2025RS008496

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**Health and Environmental Consequences of Blue Light Exposure and Mitigation Strategies: A Review**

Alkhatib H, B Norton B. Health and Environmental Consequences of Blue Light Exposure and Mitigation Strategies: A Review. Environmental Advances. 2026. doi: 10.1016j.envadv.2026.100749.

Abstract

Blue light is a natural component of the visible spectrum that has a fundamental role in regulating circadian rhythms, visual performance, mood, and daytime alertness. In modern environments, however, exposure patterns have shifted due to widespread use of artificial lighting and digital devices. Artificial blue light exposure can be mistimed relative to the biological night. This literature review examines the consequences of inappropriately timed artificial blue light exposure. Specifically, the review covers: (i) the spectral biology of blue light and its role in circadian entrainment; (ii) the timing-, intensity-, and duration-dependent effects on human sleep, ocular health, mood, and metabolic regulation; (iii) age-specific vulnerabilities; (iv) ecological impacts of artificial blue light at night on wildlife behaviour and ecosystem dynamics; (v) existing regulatory frameworks and their limitations; and (vi) current and emerging mitigation technologies, including spectral optimization and adaptive lighting systems. For people, evening blue light exposure suppresses melatonin and disrupts circadian phase alignment leading to adverse metabolic, reproductive, and carcinogenic outcomes. Ecosystems can also be disrupted by artificial blue light at night. Relevant regulatory frameworks are fragmented; they largely do not incorporate circadian-relevant spectral metrics. Increasingly available mitigation technologies require agreed standards for their unbiased assessment.

Conclusions

Feasible mitigation strategies are available. Spectral engineering advances have reduced the cost of low-blue LED products (Wang et al., 2024), tunable lighting systems have become commercially accessible for both residential and commercial settings (Mordor Intelligence 2025), and smart lighting infrastructure is now routinely integrated into urban development projects (Mahoor et al., 2020). Spectral optimization, tunable lighting systems, smart adaptive controls, shielding, and user-level filtering technologies offer practical pathways to reduce inappropriate night-time exposure while preserving the functional benefits of blue light during the day. Effective implementation, however, requires coordination between engineers, public health practitioners, ecologists and relevant policymakers.

The biological and ecological effects of blue light depend on the timing, intensity, and duration of exposure. Appropriately timed daytime blue light exposure supports circadian entrainment, alertness, and mood regulation. In contrast, blue-enriched light during the evening and night disrupts melatonin secretion, delays circadian phase, impairs sleep quality, and contributes to ocular strain, with evidence suggesting metabolic and psychological effects. For ecosystems, artificial blue light at night alters

migration patterns, predator–prey interactions, reproductive behaviours, and plant physiology, creating cascading environmental effects.

Current fragmented regulatory frameworks largely focus on photobiological safety thresholds rather than circadian-relevant spectral composition and exposure timing. While some jurisdictions have introduced limits on high-intensity blue-rich lighting, consistent integration of chronobiological metrics into building codes, occupational standards, and urban lighting policies remains limited.

Significant research gaps remain, particularly regarding long-term cumulative exposure effects, age-specific vulnerability thresholds, and ecosystem-level exposure limits. Future work should prioritize longitudinal human studies, quantification of ecological sensitivity thresholds, and adoption of standardized circadian-informed lighting metrics.

Ultimately, the challenge is not to eliminate artificial blue light, but to align its use with biological and environmental rhythms. A timing- and spectrum-informed approach to the design, operation, and regulation of lighting and light-emitting devices is essential to balance technological benefits with human and ecological health.

Open access: https://www.sciencedirect.com/science/article/pii/S2666765726000670

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**Shielding the First 24 Postnatal Months of Life: A Proposal for a Prospective Cohort Study of Early-Life Electromagnetic Exposure and Autism Risk**

Garoli A, Greco A. Shielding the First 24 Postnatal Months of Life: A Proposal for a Prospective Cohort Study of Early-Life Electromagnetic Exposure and Autism Risk. Alpha Psychiatry. 2026 Aug 24;27(4):53282. doi: 10.31083/AP53282.

Abstract

Background: Autism Spectrum Disorder (ASD) involves Mirror Neuron System (MNS) dysfunction, driving core social and imitative impairments. Systemic physiological alterations such as autonomic dysregulation, mitochondrial dysfunction and neuroinflammation are known to impair synchronization and plasticity of neuronal clusters. A less-evident environmental cofactor, coinciding with rising ASD prevalence, is the considerable world-wide increase in electromagnetic radiation (EMR) overall exposure among children. Experimental evidence shows how low-intensity EMR influences cellular processes, via voltage-gated calcium channels (VGCCs), oxidative stress, and mitochondrial metabolism. The Resonant Convergence framework, allow to predict how chronic EMR exposure during the first 24 postnatal months of life can act as a factor in ASD pathogenesis. The best candidate mechanism is chronic Ion Cyclotron Resonance (ICR) detuning the Ca2+-calmodulin pathway, thus disrupting MNS synchronization.

Methods and analysis: A prospective observational pilot cohort study (24-month follow-up) proposes to enroll 1000 full-term newborns into two arms: an EMR-reduced cohort (n = 500, rest and sleep-phase Faraday shielding) and a standard exposure cohort (n = 500). Exposure is quantified via radiofrequency (RF)/extremely low frequency(ELF) measurements, proximity analysis, device inventories and wearable dosimetry. The primary endpoint is a continuous neurodevelopmental trajectory score (joint attention,

language, electroencephalogram (EEG) mu-rhythm); binary ASD diagnosis (Autism Diagnostic Observation Schedule, Second Edition (ADOS-2), Autism Diagnostic Interview-Revised (ADI-R)) is a secondary, exploratory endpoint. Moreover, an optional genomic screening will evaluate gene-environment interactions within extremely low-frequency electromagnetic field (ELF-EMF) vulnerable pathways, including ASD-associated genes upregulated by RF via bromodomain and extraterminal protein (BET)-mediated epigenetic mechanisms. Analyses will employ risk ratios, Fisher's exact tests and logistic regression adjusted for confounders; mixed-effects and Bayesian modeling will evaluate longitudinal outcomes and exposure reduction effects. Given a 2-3% baseline prevalence, approximately 20-30 ASD cases are expected. The study is therefore powered for exploratory signal detection rather than definitive causal inference, providing the critical baseline data required to justify and design future confirmatory trials. Sex-stratified modeling will address the 4:1 male-to-female prevalence ratio.

Ethics and dissemination: Ethics committee approval is not yet sought; full protocol review and approval will be obtained prior to the study initiation, in strict accordance with the Declaration of Helsinki. Written parental informed consent will be mandatory for all participants prior to enrollment. Study findings and methodological milestones will be disseminated through peer-reviewed international scientific publications. This protocol provides a structured methodological framework for the first prospective investigation of sleep-phase EMR reduction as a potential modulator of ASD incidence during early neurodevelopment. Results will inform adequately powered confirmatory trials in electromagnetic neurodevelopmental epidemiology.

Open access: https://pmc.ncbi.nlm.nih.gov/articles/PMC13539998/

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**Real-World Assessment of RF-EMF Exposure From 3G, 4G, and 5G Mobile Networks Across Different Urbanization Levels**

My note: This study helps explain why epidemiologic studies (i.e., human observational studies) of cell phone radiation effects often find inconsistent results. Most studies only assess exposure to cell phone radiation and fail to account for other sources of electromagnetic field (EMF) exposure including cell towers, cordless phones, and Wi-Fi. Over time with the deployment of more cell towers and adoption of more efficient cell phones, while everyone's bodies are exposed to more microwave radiation, cell phone users' heads are exposed to less radiation. Moreover, cell phone users now are more likely to use text, headsets, or speakerphones reducing microwave exposure to the head while increasing exposure to other parts of their bodies.

Lee AK, Jeon S, Hong SE, Wang S, Wiart J, Samaras T, Moon JI. Real-World Assessment of RF-EMF Exposure From 3G, 4G, and 5G Mobile Networks Across Different Urbanization Levels. IEEE Access, vol. 14, pp. 134636-134653, 2026, doi: 10.1109/ACCESS.2026.3728447.

Abstract

As 5G mobile networks become increasingly widespread, realistic assessment of radio-frequency electromagnetic field (RF-EMF) exposure in modern mobile-network environments is becoming increasingly important. This study characterized real-world downlink (DL) and uplink (UL) RF-EMF exposure across different urbanization levels in South Korea using commercial 3G, 4G, and 5G mobile

networks. DL electric-field strengths and UL transmit powers were simultaneously measured in urban and rural environments using frequency-selective field measurements and mobile-network logging systems. The measured exposure levels were used to calculate brain specific absorption rate (SAR) using anatomically realistic child and adult numerical models. The results showed that, under the measurement and dosimetric conditions considered in this study, brain SAR associated with DL exposure from base-station infrastructure was comparable to or exceeded that associated with UL exposure in most tested scenarios. Urban–rural differences in whole-brain-averaged SAR reached 6.2 dB for the child model and 5.7 dB for the adult model, whereas age-related differences were substantially smaller. These findings indicate that environmental and network-infrastructure factors are major determinants of RF-EMF exposure variability in dense modern mobile-network environments. By integrating real-world measurements with anatomically realistic dosimetry, this study provides a practical framework for RF-EMF exposure assessment and characterization in evolving mobile communication networks.

Conclusion

Downlink (DL) EMF radiated from base stations (BS) and uplink (UL) transmission power from mobile phones were simultaneously measured in three study areas with different levels of urbanization. Because the WP1 protocol of the SEAWave project was applied for DL exposure measurements, the DL EMF levels reported in this study are directly comparable with those obtained in European measurement campaigns. UL power samples were collected on 3G, 4G, and 5G networks during voice calls and FTP tests, although the analysis primarily focused on 4G and 5G systems. The measured DL EMF and UL power levels were used to calculate brain SAR for both child and adult models, enabling comparison across network operators and mobile communication technologies.

Although substantial variations were observed depending on operator and usage scenario, under the measurement and dosimetric conditions considered in this study, brain SAR associated with DL EMF exposure was comparable to or exceeded that associated with UL transmission in many cases. These findings indicate that, under such conditions, the long-standing perception that mobile phones are the primary source of RF-EMF exposure to the brain may not fully reflect the relative contributions of DL and UL exposure in modern mobile-network environments. Therefore, both UL exposure from device use and DL EMF from BSs should be considered in future exposure assessments and epidemiological studies.

All measured field strengths and calculated SAR values remained well below the exposure limits for the general public specified by the ICNIRP guidelines and IEEE standards. Although whole-brain-averaged SAR is not a dosimetric quantity addressed by current ICNIRP or IEEE exposure guidelines, the measured DL field strengths and UL Tx powers in this study were sufficiently low that the corresponding localized SAR values would likewise be expected to remain well below the applicable basic restrictions. Therefore, the whole-brain SAR values reported in this study represent very low RF-EMF exposure levels under realistic mobile-network operating conditions.

Accordingly, the whole-brain SAR values should be interpreted as dosimetric indicators for quantifying realistic brain RF-EMF exposure under realistic mobile-network operating conditions and for providing a quantitative dosimetric basis for future epidemiological investigations of brain-related health outcomes, rather than as quantities for compliance assessment. Nevertheless, accurate dosimetry of low-level chronic RF-EMF exposure remains important for effective risk communication and for improving

exposure assessment in future health studies. By integrating real-world measurements with computational dosimetry, this study provides insight into how evolving mobile-network infrastructures translate into realistic human exposure conditions. Open access:

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11672739&isnumber=11323511

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**Pain threshold induced by local exposure to millimeter waves on human skin**

Yuasa A, Uehara S, K, Kodera S, Hirata A, Otaka Y. Pain threshold induced by local exposure to millimeter waves on human skin. J Neurophysiol. 2026 Aug 17. doi: 10.1152/jn.00554.2025.

Abstract

Exposure to millimeter waves potentially causes pain and tissue damage at the exposed body sites. However, the threshold temperature, especially the pain threshold, remains unclear. In this study, we investigated the perception thresholds of four different types of sensations-warmth, heat, tingling, and pain-and individual physical characteristics associated with the pain perception induced by millimeter-wave exposure. Thirty-five healthy adults were exposed to a 28 GHz millimeter wave on their left middle fingertip at an input power of 8.5 W (incident power density averaged over a 1 cm area: 1.00 W/cm) for up to 10 min. The temperature at which the initial subjective perception of each of the four sensation types occurred was determined as the perception threshold for that sensation. When the skin surface temperature exceeded 44°C or when the participant felt pain, the exposure was terminated. The association between participants' physical characteristics and the presence of pain was investigated using logistic regression analysis. Consequently, the perception thresholds increased in the following order: warmth < heat < tingling < pain. A total of 18 (51%) participants perceived pain, and the average pain threshold was 41.9°C. Females were more likely than males to perceive pain (odds ratio, 4.80 [1.15-20.09]), which may be partially explained by sex-related differences in hydration levels and finger circumference. Our results demonstrated that exposure to millimeter waves can induce pain at approximately 42°C and revealed clear sex differences in sensitivity to pain perception under millimeter-wave exposure.

Open access: https://journals.physiology.org/doi/epdf/10.1152/jn.00554.2025

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**Electrophysiology of vision after smartphone use**

El Mekkawy L, Hussein A, Maher, E *et al.* Electrophysiology of vision after smartphone use. *Egypt J Neurol Psychiatry Neurosurg* **62**, 165 (2026). https://doi.org/10.1186/s41983-026-01226-w.

Abstract

Background Smart phones emit electromagnetic radiation and blue light which cause many effects on retina and CNS. The aim is to investigate MP usage effect on vision in healthy adults by using VEP and ERG and to correlate these effects with age and previous usage duration.

Results  70 healthy participants were subjected to one hour exposure to a smart phone set at 30 cm distance from eyes. P-VEP and ERG (pattern, full field flash and multifocal) were recorded pre and post exposure. Correlations with age and with prior history of duration of usage were analyzed. Significant P100 latency delay was reported in P-VEP. No effect on P-ERG was observed. F-ERG showed a high statistically significant reduction in b wave amplitude. MF ERG showed a statistically significant P1 amplitude reduction and latency delay. P100 latency increase showed a positive correlation with age and a negative one with prior exposure duration. F-ERG showed significant negative change in (a) wave latency with age but no significant one with MP usage duration. Regarding MF ERG, there was significant negative correlation of P1 wave with age and with the duration of MP usage.

Conclusion  Practicing mindful mobile device utilization to minimize possible undesirable effects on vision is advised. These effects were more obvious in central retina. Long duration of previous use of MP increases tolerance of electro-diagnostic tests of vision to acute exposure though impairing basal function. ERG is more affected in young age, but VEP is more impaired in old age after acute MP exposure.

Open access: https://link.springer.com/article/10.1186/s41983-026-01226-w

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**Numerical and machine learning-based modelling of electromagnetic exposure and thermal effects in human head at 2.45 GHz**

Bhargava D, Sharma PK, Rattanadecho P, et al. Numerical and machine learning-based modelling of electromagnetic exposure and thermal effects in human head at 2.45 GHz. J Comput Electron 25, 180 (2026). doi: 10.1007/s10825-026-02632-2.

Abstract

We evaluate the distance-dependent electromagnetic (EM) exposure of a heterogeneous human head model at 2.45 GHz; a frequency widely used in wireless communication and healthcare sensing systems. While high-frequency EM waves are known to exhibit shallow penetration, a systematic analysis of how source-to-head distance influences localized absorption and thermal response in multilayer tissues remains limited. A two-dimensional (2D) head model is developed to examine these effects for source separations ranging from 1 to 50 mm, depicting practical wireless device operating conditions. Electric field, SAR, and temperature distributions are computed by solving a coupled EM wave and bioheat transfer model using Finite Element Method (FEM). Results reveal a non-monotonic dependence of EM absorption on source distance, with peak absorption occurring at a separation of 6 mm. The maximum electric field, SAR, and temperature in the skin layer are 66.11 V/m, 3.15 W/kg, and 37.08 °C, respectively, with values decreasing in deeper tissues. A machine learning (ML) framework is implemented to predict SAR and temperature variations, demonstrating strong agreement with the FEM results. The findings emphasize critical role of source proximity in near-field exposure scenarios and provide useful insights for the design and safety evaluation of wireless sensor and communication devices.

Conclusion

This study numerically investigated the effects of 2.45 GHz electromagnetic exposure, commonly associated with wireless communication systems, on SAR and temperature distribution in a human head model, with particular emphasis on source–head separation distance. Maximum absorption was observed when the EM source was positioned 6 mm from the head surface, resulting in peak SAR and temperature values. In all cases, the skin layer exhibited the highest absorption due to its direct exposure to the incident radiation and higher dielectric properties. Depth-wise analysis revealed attenuation of the electric field and SAR with increasing tissue depth, with low absorption in the fat and bone layers and localized SAR variations influenced by tissue dielectric characteristics. The temperature distribution followed a similar trend, decreasing with tissue depth. Although SAR values exceeded the ICNIRP exposure limit, the corresponding temperature rise remained below the safety threshold. Despite the geometric simplifications of the 2D model, the SAR and temperature distributions remain consistent with reported 3D studies, confirming its reliability as a computationally efficient approach for exposure analysis. The applied analysis is further enhanced by the application of the multiple machine models that validate the nonlinear relationship between the source and head distance and the corresponding temperature and SAR distributions. The applied regression models depict strong prediction accuracy and a close alignment between simulated and predicted results. The ML-based analysis preserves prediction fidelity, reduces the computational complexity and time as compared to the full-wave simulations with varying source positions.

The study has certain limitations. First, the model cannot capture out-of-plane field variations and three-dimensional scattering effects, which may influence the actual field distribution. Second, the anatomical complexity of the human head is simplified, neglecting realistic 3D curvature and structural irregularities. Third, the calculated SAR and temperature distributions may differ quantitatively from those in a full three-dimensional model. Therefore, the present results should be interpreted mainly as qualitative and comparative trends.

In future, a more realistic three-dimensional human head model will be investigated, along with a wider range of operating frequencies and advanced machine learning approaches for improved prediction of EM absorption in tissues. In addition, physics-informed neural networks (PINNs) are currently being explored to further analyze the proposed framework by integrating physical constraints with data-driven modeling. These findings provide valuable insights for the safety assessment and design optimization of wireless communication devices operating in near-field conditions.

https://link.springer.com/article/10.1007/s10825-026-02632-2

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**Current Approaches for RF-EMF-Monitoring in Europe**

Zahner M, Haas D, Ziegler T, Röösli M, Fröhlich, J. Current Approaches for RF-EMF-Monitoring in Europe. *2026 20th European Conference on Antennas and Propagation (EuCAP)*, Dublin, Ireland, 2026, pp. 1-5, doi: 10.23919/EuCAP68105.2026.11612595.

Abstract

Current approaches in exposure assessment on the public and the personal level are evaluated regarding accuracy, representativity and suitability for categorization into subpopulations. We discuss novel approaches such as field strength monitoring via a smartphone-based exposure app in a citizen

science project and the introduction of a low-cost sensor network for visualizing and quantifying the spatial and temporal dynamics of adaptive transmission technologies. Together with already established population-level monitoring, these methods provide a toolkit enabling multi-layered monitoring.

https://ieeexplore.ieee.org/document/11612595

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**Effects of 5G frequencies on sperm parameters, mating success, and offspring outcomes in rats**

My note: Although this study tested the effects of two commonly-used 5G carrier frequencies, it used continuous wave signals so it was not a test of 5G.

Hairulazam A, Ibrahim SF, Osman K, Mokhtar MH, Zulkefli AF, Ros MFM, Jamaludin N, Taha SMAS, Vijay S, Zakaria Z, Bahar AAM, Jaffar FHF. Effects of 5G frequencies on sperm parameters, mating success, and offspring outcomes in rats. Indian J Med Res. 2026 Sep;164(3):341-348. doi: 10.25259/IJMR_3658_2025.

Abstract

Background and objectives The advancement of 5G technology is highly anticipated due to its faster data transmission, yet its potential impact on male fertility remains unclear. This study evaluated the effects of 5G frequencies at 3.5 GHz and 24 GHz on sperm parameters, mating success, and offspring outcomes.

Methods A total of 18 male Sprague Dawley rats (n=18) were divided into three groups: a Control group, a 3.5 GHz group, and a 24 GHz group (n=6). The Control group was sham-exposed. In contrast, the 3.5 GHz and 24 GHz groups were exposed to their respective frequencies for 7 h daily over 60 d. Following 46 d of exposure, a 1:1 mating procedure was conducted. Female rats (n=18) were monitored until gestation d 28 to assess pregnancy rates and birth metrics. Later, the male rats were sacrificed, and sperm quality was evaluated.

Results Both exposed groups exhibited a significant decrease in sperm concentration and motility ($P<0.001$) compared to the Control group. The 24 GHz group had a lower pregnancy rate, whereas the 3.5 GHz group showed a lower live birth rate. Congenital anomalies were observed in the 3.5 GHz group, whereas the 24 GHz group presented significantly lower birth weights ($P< 0.001$).

Interpretation and conclusions The findings suggest prolonged exposure to 5G frequencies may have a negative impact on male fertility, pregnancy outcomes, and the birth metrics.

Excerpt

The exposure model was designed to simulate realistic 5G environmental conditions10 using frequencies of 3.5 GHz (mid-band) and 24 GHz (high band) spectra allocated for 5G communication.10 Both frequencies were chosen to enable a comparative evaluation of their biological effects, as no prior study investigated pregnancy outcomes following paternal exposure at these frequencies.

The Control group was placed in the radiation room with the antenna or device used for the exposure

set to inactive mode. The 3.5 GHz group was exposed using an omnidirectional microstrip antenna (Supplementary Fig. 1), operating at 22 dBm output power. The antenna provided by the Faculty of Electronics and Computer Technology and Engineering, Universiti Teknikal Malaysia Melaka. The 24 GHz exposed group utilized a 24 GHz Tuya WiFi Smart Human Presence Detector (Shenzhen, China), equipped with an LD2420 24G mmWave antenna capable of emitting a 24 GHz signal. This antenna operates at an 11 dBm output power and represents the higher end of the 5G technology spectrum, operating within the mmWaves radiation range.

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Open access: https://ijmr.org.in/effects-of-5g-frequencies-on-sperm-parameters-mating-success-and-offspring-outcomes-in-rats/

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**Differential Effects of 3.5 GHz and 24 GHz 5G Radiofrequency Exposure on Male Sexual Behaviour and Reproductive Endocrine Function in Rats**

My note: Although this study tested the effects of two commonly-used 5G carrier frequencies, it used continuous wave signals so it was not a test of 5G.

Hairulazam A, Ibrahim SF, Osman K, Mokhtar MH, Zulkefli AF, Mat Ros MF, Jamaludin N, Syed Taha SMA, Vijay S, Zakaria Z, Mohd Bahar AA, Jaffar FHF. Differential Effects of 3.5 GHz and 24 GHz 5G Radiofrequency Exposure on Male Sexual Behaviour and Reproductive Endocrine Function in Rats. Int J Mol Sci. 2026 Aug 7;27(16):7102. doi: 10.3390/ijms27167102.

Abstract

The rapid expansion of 5G technology has increased exposure to high-frequency radiofrequency electromagnetic fields (RF-EMF), raising concerns about male reproductive health. This study investigated the effects of 5G frequencies at 3.5 GHz and 24 GHz on male libido, reproductive hormones, the testosterone-to-oestrogen (T/E) ratio, and androgen receptor expression in rats. Eighteen male Sprague-Dawley rats were randomly assigned to Control, 3.5 GHz, and 24 GHz (n = 6/group). Exposed groups received 7 h/day RF-EMF exposure for 60 consecutive days, while the Control underwent sham exposure. During the final week of exposure, mating behaviours were assessed using

mount frequency, mount latency, intromission frequency, ejaculation latency, and post-ejaculatory interval. Serum testosterone and oestrogen levels, the T/E ratio and androgen receptor expression in the testis and hypothalamus were evaluated. The 3.5 GHz group demonstrated statistically significantly prolonged ejaculation latency (3480 ± 1576.956, $p < 0.01$, Hedges' $g = 1.03$) compared with the Control group. In contrast, 24 GHz exposure statistically significantly reduced mount frequency (4.80 ± 0.837, $p < 0.01$, Hedges' $g = -0.65$) and prolonged the post-ejaculatory interval (588.83 ± 206.41 s, $p < 0.01$, Hedges' $g = 1.63$) compared with the Control group. Hormonal analysis revealed statistically significant elevation of testosterone levels in the 3.5 GHz group, whereas the 24 GHz group showed statistically significant reductions in testosterone and oestrogen. Androgen receptor expression was unchanged. These findings suggest frequency-dependent effects of 5G RF-EMF on male libido and endocrine balance.

[3.5 GHz power density = 45.03 μW/cm$^2$.]

[24 GHz power density = 2.505 μW/cm$^2$.]

[FCC exposure limit = 1,0000 μW/cm$^2$.]

Conclusions

In conclusion, chronic exposure to 5G-related RF-EMF at 3.5 GHz and 24 GHz produced distinct alterations in male sexual behaviour, accompanied by different hormonal profiles. Exposure to 3.5 GHz was associated with elevated testosterone levels and prolonged ejaculation latency. On the other hand, exposure to 24 GHz was associated with reduced mounting activity, prolonged post-ejaculatory recovery, decreased oestrogen levels, and a lower T/E ratio. These findings suggest that different 5G frequencies may influence male reproductive function through distinct biological pathways rather than producing a uniform response. Although 24 GHz mmWaves exposure is generally characterised by superficial energy absorption and limited tissue penetration, the present findings demonstrate that measurable behavioural and endocrine alterations may still occur following chronic exposure under the conditions examined. While these results do not establish causality or indicate adverse reproductive outcomes in humans, they highlight the need for continued investigation of the biological effects of mmWaves frequencies, particularly as their use in wireless communication technologies continues to expand.

However, the current findings represent an exploratory investigation, particularly given the introduction of newer RF-EMF frequencies operating at different wavelengths and their potential biological interactions. Therefore, the observed changes should be interpreted cautiously and considered as preliminary observations that may provide a basis for future studies investigating the effects of emerging RF-EMF technologies on male reproductive behaviour and their underlying physiological mechanisms. Further investigations incorporating different exposure parameters, larger sample sizes, additional mechanistic endpoints, and refined experimental approaches will be necessary before definitive conclusions can be drawn regarding the potential effects of RF-EMF exposure on male sexual behaviour and reproductive function.

Open access paper: https://www.mdpi.com/1422-0067/27/16/7102

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**Moringa leaf mitigates 4G cell phone radiation-induced alterations in testicular histomorphometry and spermatogenesis during sexual maturation in Wistar rats**

Ramalingam S, Somanath D. Moringa leaf mitigates 4G cell phone radiation-induced alterations in testicular histomorphometry and spermatogenesis during sexual maturation in Wistar rats. Anat Cell Biol. 2026 Sep 4. doi: 10.5115/acb.25.162.

Abstract

The use of android phones is alarmingly increasing among the late juvenile and adolescent population. The infertility results from the detrimental effects of cell phone electromagnetic radiation (EMR) on spermatogenesis. This study aims to evaluate the protective effect of ethanolic extract of Moringa oleifera leaves (MOL) in Wistar rat's testis against EMR from a 4G cell phone. Five sets of four-week-old male Wistar rats were created. Control group (n=3) with no cell phone; Sham group (n=3) with cell phone in switched-off mode; MOL-1 group (n=6) received 200 mg of ethanol extract of MOL per kg body weight per month. R1 group (n=6) exposed to 4G cell phone EMR for 96 minutes/day/one month; R1+MOL group (n=6) treated with MOL extract while exposed to EMR for one month. After the trial period, the rats were anesthetized and the testes were procured via trans-abdominal incision. The testes underwent routine histological processes for H&E staining. Histomorphometric analysis; quantitative evaluation of germ cells, Leydig cells, and seminiferous tubules; luminal and basal sperm head retention; Johnsen's biopsy score was done using H&E-stained slides. The Leydig cell count, the height of germinal epithelium, and the number of germ cells were significantly decreased in the R1 group ($P$<0.04). However, those variables were shielded from the EMR by MOL extract in the R1+MOL group ($P$<0.04). The ethanolic extract of MOL could safeguard the testis against the 4G cell phone EMR in young Wistar rats.

Open access: https://acbjournal.org/journal/view.html?doi=10.5115/acb.25.162

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**Chronic paternal Wi-Fi RF-EMR exposure impairs placental efficiency and fetal growth: Association with sex-dependent histone modification patterns in mice**

Wang J, Gao L, Jin N, Yan S, Lei H, Ju Y, Chen S, Wang X. Chronic paternal Wi-Fi RF-EMR exposure impairs placental efficiency and fetal growth: Association with sex-dependent histone modification patterns in mice. Ecotoxicol Environ Saf. 2026 Sep 3;323:120751. doi: 10.1016/j.ecoenv.2026.120751.

Abstract

The widespread use of Wi-Fi-derived radiofrequency electromagnetic radiation (RF-EMR) has raised concerns regarding male reproductive health; however, whether paternal exposure exerts transgenerational effects on offspring development remains unclear. This study investigated the effects of chronic paternal 2.4 GHz Wi-Fi RF-EMR exposure (whole-body SAR 0.125-0.5 W/kg, 4 h/day, 6 days/week for 20 weeks) on sperm quality in F0 male mice and placental development in F1 offspring, with a focus on epigenetic regulation. Paternal RF-EMR exposure significantly reduced sperm concentration and increased the sperm abnormality rate in F0 males. F1 offspring exhibited reduced fetal weight and placental efficiency, with more pronounced impairments in male offspring. Mechanistically, paternal exposure reduced the proportion of placental labyrinth layer and

downregulated multiple nutrient transporters in a male-biased manner. Epigenetic analysis revealed sex-dependent histone modifications in placentas following paternal RF-EMR exposure: male placentas exhibited increased H3K9me2/3, H3K27me3, H3K27ac, and H3K4me2, whereas female placentas exhibited decreased H3K4me2. ChIP-qPCR targeting transporter promoters revealed sex-specific enrichment of repressive histone marks in placentas from exposed fathers. In male placentas, H3K27me3 was increased at the Atp1a1 and Slc22a3 promoters, and H3K9me3 was increased at the Atp1a1 and Slc2a1 promoters. In female placentas, H3K27me3 at the Slc3a2 promoter was significantly decreased. Collectively, chronic paternal Wi-Fi RF-EMR exposure impairs fetal growth and placental efficiency, with male offspring being more susceptible, and is associated with disrupted placental structure, impaired nutrient transport, and sex-dependent histone modifications in the offspring placenta. These findings underscore the importance of considering paternal RF-EMR exposure in reproductive risk assessment.

Highlights

- Chronic paternal RF-EMR impairs fetal growth and placental efficiency in a male-biased manner.
- Paternal RF-EMR downregulates placental nutrient transporters predominantly in male offspring.
- Paternal RF-EMR induces sex-dependent histone modifications in offspring placentas.
- Paternal RF-EMR drives male-specific enrichment of repressive histone marks at promoters of key placental nutrient transporter

Excerpt

A continuous wave (CW) signal generator (China Electronics Technology Instruments Co., Ltd., China), an amplifier (output power = 8.4 W; SWSPA-C200S/C-2, Chengdu SWIEE Power Electronics Technology Co., Ltd, China), and a horn antenna (gain: 8.94 dB, CW; LB-1080, A-INFO, China) were used to establish the Wi-Fi RF-EMR exposure system. The electromagnetic radiation frequency was set at 2.4 GHz, and mice were allowed free movement within their cages during exposure. The whole-body specific absorption rate (SAR) was measured using a SAR meter (Narda SRM-3006, Narda-Storp, Germany) and calculated based on a prolate spheroidal model of a medium-sized mouse (Yan et al., 2022), yielding a whole-body SAR range of 0.125–0.5 W/kg across different positions within the exposure chamber. The uniformity of the electromagnetic field within the exposure chamber was verified to ensure consistent exposure across all cages.

Conclusion

This study demonstrates that chronic paternal exposure to Wi-Fi-derived RF-EMR (2.4 GHz, whole-body SAR 0.125–0.5 W/kg, 20 weeks) impairs sperm quality in F0 male mice and adversely affects fetal growth and placental efficiency in F1 offspring in a sex-dependent manner, with male progeny exhibiting significantly greater susceptibility. Specifically, male offspring showed more pronounced reductions in placental efficiency and labyrinth layer proportion, accompanied by broader downregulation of nutrient transporters. Concordantly, paternal RF-EMR exposure induced extensive sex-specific alterations in placental histone modifications in males—elevated H3K27ac, H3K27me3, H3K9me2/3, and H3K4me2—whereas female placentas exhibited only decreased H3K4me2. Mechanistically, ChIP-qPCR revealed a sex-specific enrichment of repressive histone marks at transporter promoters: compared with the sham-exposed group, male placentas from the paternal RF-EMR exposure group displayed increased H3K27me3 occupancy at *Atp1a1* and *Slc22a3*, and elevated H3K9me3 at *Atp1a1* and *Slc2a1*, whereas

female placentas showed only decreased H3K27me3 at *Slc3a2*. Collectively, these findings indicate that male offspring are more vulnerable to adverse intrauterine programming following chronic paternal Wi-Fi RF-EMR exposure, and that sex-dependent epigenetic dysregulation—particularly at the level of placental histone modifications and nutrient transporter expression—likely contributes to the male-biased impairments in fetal development. This study highlights the importance of incorporating offspring sex as a key biological variable in reproductive risk assessments of paternal RF-EMR exposure and raises important considerations for preconception health guidance in occupationally exposed populations.

Open access: https://www.sciencedirect.com/science/article/pii/S014765132601081X?via%3Dihub

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**Effects of chronic single- and dual-band radiofrequency exposure on spatial learning and memory retention in growing male rats**

Boumaiza S, Bouzidi A, Bouharati S, Ferahtia A, Abed H. Effects of chronic single- and dual-band radiofrequency exposure on spatial learning and memory retention in growing male rats. Revista CientíFica 2026; 36 (3): e363968.

Abstract

Radiofrequency electromagnetic fields have become increasingly present in daily life due to the widespread use of wireless technologies. However, their long–term effects on cognitive functions remain insufficiently understood, particularly under repeated multi–frequency exposure conditions. This study investigated the effects of chronic exposure to 800 MHz, 900 MHz, and sequential 800/900 MHz RF fields on spatial learning and memory in growing male Wistar rats. Animals were divided into four groups: sham–exposed, 800 MHz, 900 MHz, and sequential 800/900 MHz exposure. Exposures were administered 6 days per week for 4 months. Spatial learning and memory were assessed using the Morris water maze. During the acquisition phase, rats underwent four trials per day for five consecutive days, and escape latency was recorded. Memory retention was evaluated during the probe trial by measuring time spent in the target quadrant and platform–site crossings. Escape latency significantly decreased across training days in all groups, indicating preserved acquisition learning. No significant effect of exposure was observed during the acquisition phase. In contrast, probe trial analysis revealed a significant reduction in target–quadrant time in the sequential 800/900 MHz group compared with sham–exposed and 800 MHz animals, whereas platform–site crossings were not significantly affected. Overall, chronic radiofrequency exposure did not impair spatial learning acquisition, but sequential exposure to 800 and 900 MHz was associated with reduced spatial memory retention.

Open access: https://produccioncientificaluz.org/index.php/cientifica/article/view/46130/55835

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**Environmental monitoring of static magnetic fields around operating high-voltage direct-current transmission facilities in Japan**

Kawabe F, Muroya S, Ohkubo C. Environmental monitoring of static magnetic fields around operating

high-voltage direct-current transmission facilities in Japan. Radiat Prot Dosimetry. 2026. doi: 10.1093/rpd/ncag089.

Abstract

Static magnetic fields are present around high-voltage direct-current transmission facilities, but on-land environmental measurement data under actual operating conditions remain limited. This study measured three-axis magnetic flux densities at 1.0 m above ground at 38 accessible locations around all four operating direct-current transmission links in Japan, including overhead-line and underground-cable sections. Resultant magnetic flux densities ranged from 39.7 to 154.8 μT (1548 milligauss), while measured local geomagnetic-field levels ranged from 46.6 to 50.6 μT. The maximum value was observed above the Anan-Kihoku Link underground-cable section and was far below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) reference level for general public exposure to static magnetic fields. Lateral-profile measurements showed that values near the lines or cable routes diminished to local geomagnetic-field levels within several tens of metres. Geomagnetic-field-aware calculations were generally consistent with representative measured profiles, although underground-cable comparisons were sensitive to cable-centreline uncertainty. These data support static magnetic-field exposure assessment around operating direct-current transmission facilities.

Open access paper: https://doi.org/10.1093/rpd/ncag089

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**Impact of ELF EMF exposure on sleep quality and mental health in a Tunisian power plant: a cross-sectional study**

Kacem I, Jammeli I, C, Gaddour A, Makhloufi M, Aloui A, Chouchane A, Maalel OE, Kahloul M, Mrizak N (2026) Impact of extremely low frequency electromagnetic fields exposure on sleep quality and mental health in a Tunisian power plant: a cross-sectional study. Front. Psychiatry 17:1755918. doi: 10.3389/fpsyt.2026.1755918.

Abstract

Introduction: Extremely low-frequency electromagnetic fields (ELF-EMFs) are ubiquitous in our daily life. They may have an impact not only on physical health but also on mental health.

Objectives: To assess the impact of occupational exposure to the ELF-EMFs on sleep quality, depression, anxiety and stress among workers at the Tunisian Electricity and Gas Company (TEGC).Methods: This was a cross-sectional study. The study population included two groups: an exposed group (EG), consisting of power plant employees, and a non-exposed group (NEG), consisting of administrative workers. Exposure to ELF-EMFs was assessed via spot measurements using a magnetometer. Sleep quality, depression, anxiety and stress were assessed by the French versions of the Pittsburgh Sleep Quality Index (PSQI) and the Depression, Anxiety and Stress Scale (DASS-21).

Results: Seventy-seven participants in the EG and 88 participants in the NEG were included in the study. The median value of the ELF-EMFs was 5.86 μT at the power plant [min 0.1, max 40.34 μT]. According to

the PSQI global score, 64.9% of the EG had poor sleep quality versus 29.5% of the NEG. Depression was registered in 24.7% of EG and in 3.4% of NEG. Anxiety was noted in 23.4% of the EG and in none of the NEG. Stress was found in 46.8% of the EG and none of the NEG. After multivariate analysis, ELF-EMF exposure was significantly associated with poor sleep quality and depression.

Conclusion: The present study revealed that ELF-EMFs can affect sleep and mental health. Further studies are needed to explain the mechanism involved.

Open access: https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2026.1755918/

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**Stepwise sweeping-frequency ELF MF exposure and MTT-derived signal in U251 glioblastoma cell**s

Zastko L, Petrovičová P, Tvarožná A,et al. Stepwise sweeping-frequency ELF MF exposure and MTT-derived signal in U251 glioblastoma cells. (2026). Sci Rep. doi: 10.1038/s41598-026-67313-3.

Abstract

Extremely low-frequency magnetic fields (ELF MF) have been reported to elicit parameter-dependent cellular responses, although experimental outcomes remain variable across biological models and exposure conditions. In this exploratory study, we evaluated the utility of a precisely characterized stepwise sweeping-frequency ELF MF (3–26 Hz) exposure system as a systematic in vitro screening platform under well-controlled exposure conditions. U251 human glioblastoma cells were exposed for 24 h to defined MF amplitudes (6–24 µT), followed by a 24 h post-exposure incubation period. Normalized MTT-derived signal was quantified using a standard MTT assay and calculated relative to exposure-specific and sham controls ( = 3 independent experiments). Direct comparisons between complementary ELF MF-exposed and sham-exposed samples, representing the primary biological comparison of the study, did not reveal statistically significant differences under the present experimental conditions. As secondary analyses, comparisons with the respective control groups showed differences in normalized MTT-derived of approximately 10–15% at several magnetic field amplitudes (6, 10, 13, and 24 µT). These observations were restricted to selected exposure conditions and did not follow a monotonic relationship across the investigated magnetic field amplitudes. Overall, the results demonstrate the utility of the present protocol as an exploratory in vitro screening platform for systematic evaluation of a broad range of exposure conditions and identification of conditions suitable for subsequent targeted mechanistic investigations.

Conclusions

This study demonstrates the utility of a stepwise sweeping-frequency ELF MF exposure protocol as an exploratory in vitro screening platform for systematic assessment of a broad range of exposure conditions under a rigorously characterized experimental framework. The primary comparisons between complementary exposed and sham-exposed samples did not reveal statistically significant differences, whereas secondary control-based analyses identified differences at selected magnetic field amplitudes. The principal contribution of the study is therefore methodological: the platform enables controlled preliminary screening of exposure conditions that may subsequently be examined using frequency- and amplitude-specific designs, complementary biological endpoints, and targeted mechanistic approaches.

Open access: https://rdcu.be/fBMYb

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**Impacts of Geomagnetic and Man-Made Electromagnetic Fields on Heart Rate and Its Variability in Healthy Adults: A Scoping Review**

Fadlou Allah T, Wexler B, Green DM, Patel YN, Chen J, Mayrovitz HN. Impacts of Geomagnetic and Man-Made Electromagnetic Fields on Heart Rate and Its Variability in Healthy Adults: A Scoping Review. Cureus. 2026 Aug 12;18(8):e114429. doi: 10.7759/cureus.114429.

Abstract

Geomagnetic and man-made electromagnetic fields (EMFs) have been reported to influence blood pressure and to represent a cardiovascular risk factor for various conditions. However, the effects of these fields on heart rate (HR) and heart rate variability (HRV) remain inconclusive, with reports both supporting and refuting these effects. This scoping review aims to synthesize current evidence on the impact of exposure to geomagnetic and man-made EMFs on HR and HRV in healthy adults. A systematic search of Ovid MEDLINE, Embase, and Web of Science was conducted using the Population-Concept-Context (PCC) framework, following the Joanna Briggs Institute (JBI) methodology for scoping reviews and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines. Eligible studies included English-language, peer-reviewed observational, experimental, or analytical cross-sectional designs published from January 2000 to June 2026 that assessed HR or HRV responses to these fields in healthy or asymptomatic adults. Database searching was supplemented by reference review and an updated search of the same databases. After two-stage screening and duplicate removal, 29 studies were included, which varied substantially in exposure type, field intensity, exposure duration, HRV metrics, sample size, and analytic approach. Reported effects were inconsistent and were often limited to transient changes in selected HRV indices rather than consistent changes in HR. Geomagnetic and local magnetic field studies more often reported associations with HRV, hemodynamic variation, or HR/HRV synchronization, but these findings were heterogeneous and of uncertain clinical significance. Overall, evidence from the studies reviewed does not confirm a consistent effect of geomagnetic or man-made EMF exposure on either HR or HRV in otherwise healthy adults.

https://pubmed.ncbi.nlm.nih.gov/42730093/

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**Quantum nanorotator in the field: Implications for magnetobiology**

Binhi VN. Quantum nanorotator in the field: Implications for magnetobiology. Phys Rev E. 2026 Jul;114(1-1):014406. doi: 10.1103/8wry-pznb.

Abstract

A mechanism for the biological effects of the field is proposed, based on the rotational motion of a molecule as a whole within a cavity in an enzyme. It has been shown previously that a molecular rotator

about 1 nm in size can have a decoherence time of up to tens of milliseconds. On shorter timescales, the nanorotator exists in a state of quantum superposition and exhibits interference effects. The statics and dynamics of the nanorotator in a magnetic field are analyzed using the Schrödinger and Liouville-von Neumann equations, taking into account chemical kinetics and thermal relaxation. It is demonstrated that the small-scale interference of the nanorotator is highly sensitive to weak magnetic fields. The quantum shows magnetic effects ranging from a few to several tens of percent over a wide range of realistic decoherence rates. If the nanorotator constitutes an adequate model of rotating amino acid residues in the active sites of certain enzymes involved in protein synthesis, then weak magnetic fields can exert significant biological effects, leading to the observed phenomena.

We proposed a mechanism for the influence of a field on biological systems, based on the quantum behavior of a nanoscopic molecular rotator. The calculation of magnetic effects was performed by applying a solution of the Liouville–von Neumann equation, standard in spin chemistry, to a molecular rotator of about 1 nm in size. In this mechanism, the rate of chemical reaction is governed not by spin prohibitions but by regular rotational dynamics.

It was shown that magnetic effects up to several tens of percent arise due to modulation of the quantum interference pattern in very weak MFs and are relatively robust to decoherence. The temperature factor not only promotes decoherence, as is typical, but also enables the very existence of magnetic effects by facilitating the emergence of a fine-structured magnetosensitive interference pattern prior to the onset of decoherence.

With realistic values of model parameters, the rotator probability density rotates in a weak MF a few degrees, which could allow interpreting various phenomena in magnetobiology.

The quantum rotator mechanism suggests that evolutionary adaptation renders organisms able to use the GMF for improved biosynthesis. A reduction to HMF levels results in increased errors in biosynthesis and the associated negative outcomes.

The high sensitivity of the rotator mechanism arises because the MF affects the phases of the wave functions rather than the energy of the magnetic moment. The physical limit that sets the minimal MF for the effect to occur takes the form if (a typically biological process) is embedded in the system. The molecular rotator is not just a rotator obeying the laws of quantum physics, but a nanoscopic system in which quantum effects may become observable under biological conditions. This is one of the cases where quantum effects are not merely preserved in a biological system but arise precisely because of it. The peculiarities of nanorotator dynamics, leading to an extreme responsiveness of the interference pattern to parameter variations (to MF variations in particular), may represent a previously unstudied resource of biology.

https://pubmed.ncbi.nlm.nih.gov/42629871/

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**The effects of external electric fields on proteins**

Cifra M, Pandey SK, Zakar T, Poplová M, Blanco Campoy DG, Průša J, Havelka D, Marracino P, Liberti M, Apollonio F, English NJ, Caleman C, Marklund EG. The effects of external electric fields on proteins. Chem Soc Rev. 2026 Jul 20;55(14):7568-7616. doi: 10.1039/d3cs00244f.

Abstract

Proteins are highly abundant and, as a biomolecular class, have very versatile functions in living systems. Protein structures contain electrically charged residues and proteins' electrostatics are crucial for their function. Although protein activity is commonly modulated through a variety of ligands and post-translational modifications, an external electric field (EF) represents an alternative, physical approach. By exerting forces on charged and dipolar regions, EFs can reshape the energetic landscape and dynamic behavior of proteins. This approach offers a mass-free, rapidly switchable, spatially precise, non-contact, and reagent-free way to control protein conformation and function – features increasingly appealing for applications in green bioprocessing, neuromodulation, ultrafast structural biology, and in studying proteins without clearly ligandable sites. Despite the growing evidence for diverse and reversible control of proteins by EF, the mechanisms are still underexplored and applications have not yet grown to their full potential. This review focuses on molecular mechanisms and integrates the findings of the effects of external EFs on proteins from both computational simulations and experimental studies. The literature shows that the EF acts on protein charged and dipolar groups, and when the EF parameters are well tailored, the EF consequently triggers effects on protein rigid body motion, secondary structure, tertiary structure, quaternary structure and molecular conformation, ultimately leading to changes in protein interactions and function (enzymatic, ion channelling, switching, …). These effects are being utilized not only on proteins as food components but also for bionanotechnological applications, *e.g.* in membrane proteins for controlling their transport properties, and in structural and force-generating proteins to steer self-assembly pathways and dynamic behavior. The compiled evidence clarifies key mechanisms by which EFs influence proteins and identifies promising directions for biomedical, food-processing, and biotechnological applications.

https://pubmed.ncbi.nlm.nih.gov/41995174/

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**Effect of IoT Devices on Animals**

Sharma N. (2026). Effect of IoT Devices on Animals. In W. Ameur & A. Arbi (Eds.), *Harnessing AI for Human-Animal Communication* (pp. 225-238). IGI Global Scientific Publishing. doi: 10.4018/979-8-3373-5483-5.ch009.

Abstract

IOT devices are often in the vicinity of animals. IOT devices on animals are used for experimentation and monitoring purposes. This chapter discusses the effect of different radiations emitted from IoT devices on animals. The specific animals in focus are rats, mice and chickens. There are different short-range and long-range frequency-based radiations emitted from IoT devices. The current literature discusses the experiments conducted on these animals and the duration of exposure to radiation. The literature review provides evidence regarding their effect on different classes of animals. These effects also depend upon the type of animal and the duration of exposure to radiations. The rats showed memory, blood, brain, cell loss, learning related effects. The mouse or mice showed reduced calcium absorption,

memory loss, behavioral, anxiety-related,carcinogens-related changes. The chickens showed effect on neurons and blood-brain integrity changes. There were also studies which did not point to any drastic changes in these animals.

https://www.igi-global.com/gateway/chapter/401958

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**Conflicting views in experimental carcinogenesis: a commentary on design and methodological deficiencies in the follow-up validation studies on radiofrequency radiation**

Melnick RL, Moskowitz JM, Héroux P on behalf of International Commission on the Biological Effects of Electromagnetic Fields. Conflicting views in experimental carcinogenesis: a commentary on design and methodological deficiencies in the follow-up validation studies on radiofrequency radiation. *Environ Health* **25**, 66 (2026). doi: 10.1186/s12940-026-01324-5.

Abstract

Conflicting views in experimental carcinogenesis often arise due to differences in study design among reported studies. For carcinogenicity assessments, regulatory agencies, such as the US Food and Drug Administration (FDA), and intergovernmental advisory organizations, such as the Organization for Economic Co-operation and Development (OECD), specify the use of at least three dose levels plus control group for trend analyses, with the highest dose inducing a measurable toxic response. In addition, there needs to be a sufficient number of animals per group to have adequate power to detect a true carcinogenic effect. Departure from such recommendations can weaken the interpretations of study results. We examine here two recent carcinogenicity studies from Japan and Korea that were conducted following the positive carcinogenicity study of radiofrequency radiation (RFR) in experimental animals by the National Toxicology Program (NTP). The Japan and Korea follow-up studies used fewer animals per group, a single RFR exposure group, and a lower exposure level than the NTP study. Not surprisingly, while the NTP study revealed the carcinogenicity of RFR, the Japanese and Korean studies, which had reduced statistical power compared to the NTP study, issued conclusions conflicting with those of the more substantial NTP study on the health effects of RFR. In general, carcinogenicity studies with weaker doses, fewer exposure groups, and reduced statistical power should not be used to test the validity of more robust studies.

Excerpt

Despite the numerous limitations in their study design, the authors of the Japan-Korea studies concluded there is “no reproducible carcinogenic potential of mobile phone-type RF exposure in rats,” and that alternatives to the ICNIRP “recommend[ed] exposure limits for RF radiation based on thermal effects” are inconclusive [3]. These statements reflect ideological support for ICNIRP’s thermal-only mechanism of adverse effects and its repeated dismissal of the validity of the NTP carcinogenicity studies (e.g [12]). The project’s principal investigator is a member of ICNIRP, and the advisory committee that provided oversight and guidance throughout this project was heavily represented by current and past members of ICNIRP, suggesting a strong influence of ICNIRP in the design and interpretation of these studies.

In conclusion, methodological shortcomings due to the design choices in the Japan–Korea studies, specifically the restriction to a single exposure group of 4 W/kg of CDMA-modulated RFR and reduced statistical power, systematically biased the study toward null results and eliminated the possibility of detecting a positive trend. Consequently, these findings cannot be used to reasonably refute the peer-reviewed evidence of toxicity and carcinogenicity of CDMA- and GSM-modulated RFR in the NTP studies, nor to reinforce ICNIRP's thermal-based exposure limits. It is also important to note that the increases in schwannomas and gliomas reported in experimental studies of RF-EMF are of the same tumor types (glioma and vestibular schwannoma) that were increased in epidemiological studies in which brain cancer risk was increased among heavy users of mobile phones [13]. The example described in this commentary demonstrates how limited and divergent experimental designs and potential biases in the interpretation of experimental carcinogenicity results can lead to conflicting views on the health effects of RFR.

Open access: https://link.springer.com/article/10.1186/s12940-026-01324-5

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**Environmental and auto-induced RF-EMF adult and children far-field exposure simulations between 450 MHz and 26 GHz**

Wydaeghe R, Stroobandt B, Gallucci S, Parazzini M, Tognola G, Wiart J, Vermeeren G, Guxens M, Tanghe E, Joseph W. Environmental and auto-induced RF-EMF adult and children far-field exposure simulations between 450 MHz and 26 GHz. Phys Med Biol. 2026 Aug 10. doi: 10.1088/1361-6560/ae97ac.

Abstract

Objective: Children's exposure to radio-frequency electromagnetic fields (RF-EMF) above 6 GHz lacks characterization. No study spans sub-GHz cellular bands to millimeter wave while including child phantoms. This study quantifies the specific absorption rate (SAR) and absorbed power density (APD) in two adult and two child anatomical phantoms across 15 frequencies from 450 MHz to 26 GHz.

Approach: We performed 550 finite-difference time-domain (FDTD) simulations covering environmental (plane-wave) and auto-induced (beamforming) exposure. SAR and APD were computed following IEC/IEEE 62704-1 and IEC/IEEE 63195-4, respectively. The simulations included, for the first time, whole-body dosimetry at 26 GHz in child and adult phantoms, and child APD across 7-15 GHz. Results were normalized to the ICNIRP 2020 reference levels for general public exposure.

Main results: Children show 1.5-1.9 times higher whole-body SAR than adults at all sub-6 GHz frequencies. A 6-year-old reaches 93% of the 80 mW/kg whole-body SAR limit at 2140 MHz, averaged over 12 plane-wave configurations, and 145% in the worst one. Whole-body SAR, not local SAR, determines compliance margins below 6 GHz. Brain SAR decreases by 96% from 450 MHz to 5.8 GHz as absorption shifts to the skin. Eye SAR drops 77-fold from 7 to 26 GHz as penetration depth falls below eyelid thickness. Under simplified MRT beamforming, psSAR10g at 3500 MHz exceeds the 2 W/kg head/torso limit for all four phantoms (131-158%). APD at 7 GHz exceeds 20 W/m^2 for a 6-year-old by 2.5%. Worst-case whole-body SAR agrees with the literature within 2%.

Significance: The results identify frequency-phantom combinations where compliance margins narrow: 3500 MHz and 7 GHz under beamforming, and children near 2 GHz under environmental exposure. The

organ-specific SAR data for brain, eyes, skin, and genitals support epidemiological exposure assessment and dose modeling across current and prospective wireless bands.

Keywords: 6G; FDTD; RF-EMF exposure; absorbed power density (APD); beamforming; child dosimetry; specific absorption rate (SAR).

Open access: https://iopscience.iop.org/article/10.1088/1361-6560/ae97ac

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**Neuromodulation in Neuro-Oncology: A Scoping Review**

Kamaludin AI, Kumaria A, Ashkan K. Neuromodulation in Neuro-Oncology: A Scoping Review. J Pers Med. 2026 Jun 28;16(7):349. doi: 10.3390/jpm16070349.

Abstract

Background: Neuromodulation is a rapidly developing field with growing interest in its application in neuro-oncology, particularly since the publication of the EF-14 trial which demonstrated a survival benefit conferred by tumour treating fields (TTF) in patients with glioblastoma. In addition, the emerging field of cancer neuroscience has postulated the role of neural-tumour communication in tumour aetiology, which is theoretically targetable by neuromodulation strategies. This scoping review therefore aims to comprehensively evaluate current or future applications of neuromodulation in managing patients with brain tumours, encompassing preclinical and clinical studies.

Methods: The MEDLINE database was queried for all relevant articles from inception to 1 December 2024. A synthesis of findings was performed, broadly categorised to preclinical and clinical research.

Findings: The database search returned 3296 results, from which 187 full-text articles were further assessed. A total of 79 studies met the inclusion and exclusion criteria and were included. The results from preclinical studies (n = 18) were stratified according to modality which included electrical therapy, electroporation, electromagnetic field (EMF) and deep brain stimulation (DBS). Similarly, clinical studies (n = 61) were classified to preoperative modalities such as transcranial magnetic stimulation (TMS) and transcranial direct stimulation (tDCS), and postoperative modalities such as TMS, TTF, EMF and spinal cord stimulation (SCS).

Interpretation: The application of neuromodulation as adjunctive therapy in the context of neuro-oncology is an emerging field, with encouraging results in various modalities across a wide range of applications from surgical planning and functional rehabilitation, to its therapeutic potential. Further research is urgently needed to harness the potential of neuromodulation in improving patient outcomes.

Open access: https://www.mdpi.com/2075-4426/16/7/349

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**A Survey and Tutorial on 5G Electromagnetic Field (EMF) Measurement**

Li K, Popoola O, Sambo Y. A Survey and Tutorial on 5G Electromagnetic Field (EMF) Measurement. *Telecom*. 2026; 7(4):91. doi: 10.3390/telecom7040091.

Abstract

5G electromagnetic field (EMF) measurement is more challenging than measurement in previous cellular generations because 5G New Radio uses time-division duplexing, flexible bandwidths, beam sweeping, massive MIMO, and user-specific traffic beams. As a result, the measured synchronisation signal block (SSB) or PBCH-DMRS level may not directly represent the maximum exposure produced by data transmission. This motivates a combined tutorial and structured survey of existing 5G EMF measurement studies and procedures. This paper reviews the literature on 5G EMF measurement by classifying existing methods into frequency-selective measurement, code-selective measurement, actual exposure assessment, maximum-exposure extrapolation, and network-counter-based assessment. Representative field studies, public measurement reports, and network-data-based studies are compared according to their measurement scenarios, exposure objectives, and limitations. The paper further discusses key uncertainty sources, including beam/gain offset, TDD duty cycle, bandwidth extrapolation, traffic variation, spatial sampling, and equipment-related uncertainty. Finally, open challenges related to FR2 millimetre-wave measurements and reconfigurable propagation environments are discussed. By combining tutorial background with a structured survey, this paper clarifies 5G EMF measurement procedures, maximum-exposure extrapolation, uncertainty sources, and FR2 millimetre-wave measurement challenges.

Conclusions

This paper has reviewed 5G EMF measurement from both a tutorial and survey perspective. First, the paper summarised the regulatory quantities and 5G technical features that are most relevant to exposure assessment, including SSB transmission, PBCH-DMRS, TDD operation, beamforming, massive MIMO, and the distinction between FR1 and FR2 deployments. These features explain why measurement procedures developed for previous cellular generations cannot be directly applied to 5G without additional consideration of reference signals, beam direction, traffic load, and extrapolation factors.

The paper then classified 5G EMF measurement methods into frequency-selective measurement, code-selective measurement, actual exposure assessment, maximum-exposure extrapolation, and network-counter-based assessment. This taxonomy clarifies that different methods answer different exposure questions. Frequency-selective and current-exposure measurements are useful for characterising field levels under actual network operation, while code-selective and reference-signal-based methods are necessary when the aim is to estimate maximum exposure. Network-counter-based approaches provide additional information about temporal variability and realistic network loading, but they usually require operator-side data.

The comparative review shows that existing 5G EMF studies differ substantially in their measurement objectives, scenarios, and assumptions. Public field-measurement reports and recent measurement campaigns generally report exposure levels below the relevant international limits in the investigated scenarios, but these results should not be interpreted without considering measurement duration, traffic condition, spatial sampling, and whether the study reports actual exposure or extrapolated maximum exposure [25,76,77]. Therefore, comparing 5G EMF studies requires more than comparing

reported field levels; it also requires comparing the measurement method and the exposure quantity being assessed.

A key conclusion of this survey is that uncertainty analysis is central to 5G EMF measurement. The main uncertainty sources include beam/gain offset between SSB and data beams, TDD downlink duty cycle, full-bandwidth extrapolation, traffic-load variation, spatial sampling, equipment response, and access to operator-specific configuration data. These uncertainties are particularly important for maximum-exposure extrapolation, where the measured SSB or PBCH-DMRS level must be scaled to represent conservative transmission conditions. Transparent reporting of measurement settings, detected reference signals, averaging time, traffic condition, and extrapolation assumptions is therefore essential for reproducible and comparable 5G exposure assessment.

Finally, the paper identified several open challenges for future work. FR2 and millimetre-wave deployments introduce additional difficulties because of narrow beams, stronger spatial variability, blockage sensitivity, and the need for power-density-based assessment. Future beyond-5G technologies, such as RIS-assisted propagation environments, may further complicate exposure assessment because the propagation environment itself can become dynamically reconfigurable. Future research should therefore focus on standardised uncertainty reporting, operator-independent measurement procedures, long-term monitoring, FR2-specific measurement methods, and exposure-assessment frameworks that remain valid as 5G networks evolve toward more dynamic and reconfigurable architectures.

Open access: https://www.mdpi.com/2673-4001/7/4/91

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**Temporal 2G-5G RF-EMF exposure assessment in ten European countries during one year**

Van Bladel H, Veludo AF, Loizeau N, Röösli M, Maule M, Vecsei Z, Molnár O, Vrijkotte T, Polanska K, Politański P, Mamrot P, Wang S, Wiart J, Grellier J, Kovalenko A, Hulls PM, De Vocht F, Vaupotič N, Guxens M, Joseph W. Temporal 2G-5G RF-EMF exposure assessment in ten European countries during one year. Sci Total Environ. 2026 Jul 14;1047:182037. doi: 10.1016/j.scitotenv.2026.182037.

Abstract

Due to the rapid evolution and densification of mobile communication networks, there is an increased interest in the long-term assessment of environmental exposure to radiofrequency electromagnetic fields (RF-EMF). While numerous studies have investigated RF-EMF exposure using short-term or spatial measurement campaigns, the number of comprehensive analyses capturing temporal variability across multiple frequency bands and countries remain limited. This pilot study aims to establish a multi-country sensor network to collect data on long-term RF-EMF exposure, including 5G, and to investigate whether temporal trends occur. Twenty frequency-selective sensors were deployed at fixed indoor and outdoor locations in ten European countries, continuously measuring E-field (electric field) strengths in four mobile communication frequency bands (806 MHz, 942 MHz, 1842 MHz, and 3625 MHz) over a period of 17 months with a temporal resolution of 1 s. The raw measurement data were calibrated and analyzed to describe RF-EMF exposure levels, temporal patterns, and variability across environments and spatial characteristics. A strong and recurring diurnal pattern was observed across the four frequency bands. The highest day-night contrasts occurred in the 806 MHz and 1842 MHz bands, where

nighttime values decreased by 35.1% and 48.4%, respectively compared to daytime values. Milder contrasts were observed between weekdays and weekends with the most pronounced decrease of 16.6% for the 1842 MHz band. Temporal variability, quantified using the R-factor (i.e. the ratio of the median field strength to the maximum field strength measured during the period of interest), varied substantially across frequency bands and locations, with lower R-factors observed for higher-frequency bands (with a median R-factor of 0.45 for 3625 GHz), indicating a greater variability. Given the scope and duration of this study, it aims to serve as a pilot study for long-term exposure monitoring at fixed sites in multiple countries.

Highlights

- RF-EMF exposure was monitored for one year in ten European countries.
- Twenty fixed sensors measured four mobile communication frequency bands.
- Clear daily exposure patterns were observed across all frequency bands.
- Weekly exposure patterns were present but weaker than daily patterns.
- Higher-frequency bands showed stronger temporal variability.

Conclusion

This study presents a long-term assessment of RF-EMF exposure across fixed sites in ten European countries using frequency-selective, fixed monitoring sensors, during one year. This work provides new insights into the temporal variability and environmental influence of RF-EMF exposure in contemporary mobile communication networks. A very large dataset was obtained by collecting E-fields every second for one year, four frequencies and 20 measurement locations. The lessons learned in this long-term multi country pilot study form a starting point for future large scale RF-EMF exposure assessment studies.

Temporal analyses revealed clear and recurring daily and weekly exposure patterns, especially for 806 MHz and 1842 MHz bands. Weekday–weekend differences and diurnal modulation were observed after normalization, demonstrating that RF-EMF exposure is closely linked to human activity patterns and network traffic dynamics. No pronounced conclusions were observed between sensor locations due to limited data points.

Overall, the results demonstrate that long-term, frequency-selective monitoring is essential for capturing the dynamic nature of RF-EMF exposure. The findings support the use of fixed sensor networks as a valuable tool for environmental exposure assessment and future epidemiological research, particularly in the context of ongoing network densification and the continued evolution of mobile communication technologies.

Future work entails the development of a new version of the frequency-selective sensor, with a modular design. With this upgraded version, the frequencies of interest can be expanded by choosing sensor units and connecting them to a global data processing main board. In that way, more than 4 frequency bands can be measured and thus providing a more complete and realistic assessment of RF-EMF exposure per country. For studies, focused on absolute exposure values rather than temporal trends, triaxial sensors can be implemented by connecting three orthogonal polarized antennas in this modular design. Another future research option is conducting an exposure assessment study of a larger scale,

with a more dense sensor network to achieve more datapoints per environment, combining significant spatial comparisons with the temporal analysis.

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**Maternal Mobile Phone Use During Pregnancy versus Early Childhood in Relation to Behavioral Problems in Preschool-Aged Children: A Prospective Cohort Study**

Joo H, Choi J, Lim H, Choi HD, Lee AK, Moon J, Ha M. Maternal Mobile Phone Use During Pregnancy versus Early Childhood in Relation to Behavioral Problems in Preschool-Aged Children: A Prospective Cohort Study. Environ Res. 2026 Jul 25:125314. doi: 10.1016/j.envres.2026.125314.

Abstract

Evidence on the effect of maternal mobile phone use on child behavioral development remains inconsistent, particularly regarding the relative importance of the prenatal and early childhood exposure periods. We aimed to examine associations between maternal mobile phone call duration during pregnancy and early childhood and behavioral problems in preschool-aged children. We analyzed data from the Mothers and Children's Environmental Health (MOCEH) prospective birth cohort. Maternal mobile phone use was measured by questionnaire during pregnancy and at ages 3-5 years, and child behavioral problems were assessed using the Korean Child Behavior Checklist (K-CBCL) at ages 4, 5, and 6 years. Maternal daily call duration (minutes/day), used as a proxy indicator of mobile phone use, was calculated from daily call frequency and average duration per call. Associations with behavioral problem scores were estimated using linear mixed-effects models in sub-cohorts with available exposure information for the whole period (n = 780), pregnancy (n = 763), and early childhood (n = 418). Mutually adjusted models accounted for maternal mobile phone use during the other exposure period, with missing information treated as a separate category. Early childhood maternal mobile phone use was significantly associated with higher total (β = 1.37, 95% CI: 0.46-2.28) and externalizing (β = 1.44, 0.54-2.33) problem scores, whereas prenatal use was not. Sex-stratified analyses showed associations for total and externalizing problems in males and internalizing problems in females. These findings suggest that maternal mobile phone use during early childhood, rather than pregnancy, is associated with child behavioral problems, pointing to the caregiving pathways, such as interruptions in parent-child interaction caused by technology use, as a plausible explanation.

Highlights

- Maternal mobile phone use in early childhood was linked to child behavior problems
- Prenatal maternal mobile phone use showed no clear associations with child behavior problems
- Significant increases in externalizing for males and internalizing problems for females
- A role of early caregiving environment in child neurobehavioral development suggested

Excerpt

We focused on maternal voice-call duration because smartphones were not widely used in Korea during the main data collection period, when mobile-phone use was still largely call-oriented; smartphone use in Korea was very low before 2010 and increased to approximately 14% in 2010 (Korea Communication

Commission [KCC], 2011). Voice calls are also a relevant proxy for near-field RF-EMF exposure because the handset is typically held close to the head, although actual output power varies by network conditions and adaptive power control rather than remaining at the regulatory SAR limit (Vrijheid et al., 2009). Non-call functions, including internet browsing, video viewing, texting, and gaming, were not assessed, which may have led to underestimation of maternal mobile-phone use during the child's early-life follow-up period as smartphone-based activities rapidly increased. If this exposure misclassification was largely non-differential, the observed association for childhood exposure may be conservative. However, non-call use may also reflect different mechanisms, including caregiving distraction, family context, and RF-EMF exposure, and we cannot determine whether its inclusion would necessarily have yielded larger effect estimates.

Mobile phone use by fathers and other household members may contribute to children's environmental RF-EMF exposure, which was not considered in the present study....

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**Numerical analysis of the effect of 5G electromagnetic radiation on human head with metallic implants**

Bhargava D, Rattanadecho P. Numerical analysis of the effect of 5G electromagnetic radiation on human head with metallic implants. Thermal Science and Engineering Progress. Volume 76, 2026. doi: 10.1016/j.tsep.2026.104814.

Abstract

With the advent of 5G communication technologies, concerns regarding electromagnetic (EM) radiation exposure, particularly in individuals with metallic implants, have gained significant attention. This study investigates the interaction of 5G EM radiation with a two-dimensional (2D) heterogeneous human head model comprising six layers: skin, fat, bone, dura, cerebrospinal fluid (CSF), and brain. The model is exposed to 5G frequencies (2.6, 3.6, 4.4, and 6 GHz) at a power level of 1 W, both in the absence and presence of stainless steel 410 implants (pin- and sphere-shaped) embedded within the bone layer. A coupled model of EM wave propagation and bio-heat transfer is solved in COMSOL Multiphysics 6.1 based on Finite Element Method (FEM). The results indicate that the presence of metallic implants increases the electric field intensity, Specific Absorption Rate (SAR), and temperature within the tissues. The skin layer consistently demonstrates the highest absorption of electric field due to its proximity to the EM source and higher dielectric properties. Additionally, the absorption pattern across the different head layers is influenced by the dielectric and thermal characteristics of individual tissues. Metallic implants significantly alter the spatial distribution of hotspots in head, resulting in enhanced energy localization and deeper penetration in surrounding tissues. In several cases, SAR values exceed the safety limit (2 W/kg) recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Although the temperature rise remains within safe thresholds, prolonged or repeated exposure could pose thermal risks. These findings underscore the need to consider implant presence in EM safety assessments for 5G environments.

Highlights

• Numerical modeling of 5G EM radiation interaction with heterogeneous 2D human head model including six biological tissue layers.
• Impact of stainless steel 410 implants (pin and sphere) on electric field, SAR, and thermal behavior is studied.
• Peak electric field (78.78 V/m), SAR (6.42 W/kg), and temperature (37.138 °C) occurred at 3.6 GHz with pin implant.
• Metallic implants shift the hot spot region and cause deeper penetration of EM energy in the head tissues.
• Thermal rise stays within safety limits, but prolonged exposure in implant-bearing individuals may raise.

Conclusion

This study investigated the effects of metallic implants on EM wave absorption in a 2D heterogeneous human head model exposed to 5G frequencies (2.6, 3.6, 4.4, and 6 GHz). The impact of implant geometry was analysed by embedding stainless steel 410 implants in two shapes, pin and sphere, within the bone layer. Among all the considered frequencies, 3.6 GHz resulted in the highest EM absorption in the head tissues. The findings reveal that the presence of metallic implants significantly increases the electric field intensity, SAR, and temperature compared to the no-implant case. Maximum electric field (78.78 V/m), SAR (6.42 W/kg), and temperature (37.138 °C) were observed at 3.6 GHz for the pin implant. The skin layer consistently exhibited the highest EM absorption due to its proximity to the radiation source and relatively high dielectric properties. Additionally, EM energy absorption across different tissues varied based on their dielectric and thermal characteristics. The SAR values exceeded the ICNIRP safety limit of 2 W/kg in all scenarios except at 6 GHz without an implant. Although, the observed temperature rise remained within the general thermal safety threshold, the presence of metallic implants led to localized heating and shifted hotspot regions, indicating a redistribution of thermal energy. The coupled multiphysics 2D heterogeneous head model provides significant computational time savings for different 5G frequencies and implant geometries, while maintaining good agreement with the literature.

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**Response to the BfS Statement: Scientific Clarifications on Chromosomal Damage and RF-EMF Exposure**

Belyaev I, Gulati S, Mosgoeller W, Moldan D. Response to the BfS Statement: Scientific Clarifications on Chromosomal Damage and RF-EMF Exposure. Ecotoxicology and Environmental Safety. Volume 322, 2026. doi: 10.1016/j.ecoenv.2026.120336.

No abstract

Open access: https://www.sciencedirect.com/science/article/pii/S0147651326006652

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**Occupational electromagnetic field exposure and sleep disturbances: The predominant role of high-frequency electric fields**

Soumillion M, Remy VFM, Petrovic D, Dil JH, Guseva Canu I. Occupational electromagnetic field exposure and sleep disturbances: The predominant role of high-frequency electric fields. Int J Hyg Environ Health. 2026 Aug 11;277:114886. doi: 10.1016/j.ijheh.2026.114886.

Abstract

Electromagnetic fields (EMFs) are ubiquitous and include low-frequency magnetic fields (LF-MF) from alternating currents, low-frequency electric fields (LF-EF) from wiring and equipment, and high-frequency electric fields (HF-EF) from wireless technologies and broadcast antennas. Bus drivers are exposed to an EMF mixture and report higher rates of sleep disorders than the general population. This study aimed to examine associations between sleep disturbances and cumulative occupational EMF exposure over 12 months, considering individual components and the mixture. EMF exposure estimates from the Swiss bus-exposure matrix were matched to the occupational history of 351 TRAPHEAC study bus drivers. Sleep quality, insomnia, and excessive daytime sleepiness (EDS) were assessed using the Global Sleep Assessment Questionnaire. Associations with cumulative EMF exposure were evaluated using multivariable linear regression controlled for age, sex, occupational noise, and nightshift work, and heat exposure. Mixture effects were analyzed with Bayesian Kernel Machine Regression (BKMR), and the influence of non-occupational EMF exposure was examined via stratification. Multivariable linear regression showed positive associations of HF-EF, but not LF-EF or LF-MF, with insomnia and EDS, although models explained little variance. BKMR confirmed the predominance of HF-EF in the mixture effect, with a positive but statistically non-significant dose-response for the EMF mixture. Stratified analyses suggested stronger associations among drivers with low non-occupational EMF exposure. These findings suggest a dose-response relationship between occupational EMF mixture exposure and sleep disturbances, primarily driven by HF-EF. However, the overall variance explained by EMF exposure is small, highlighting the role of other risk factors in sleep disturbances among bus drivers.

Highlights:

- Occupational joint EMF exposure linked to poorer sleep in bus drivers
- High-frequency electric field dominated in the joint exposure effect
- Significant dose-response relationship in linear regression but not in BKMR
- Dose-response results robust to sex, age, noise, nightshift-work, and heat effects
- Stronger associations in drivers with low non-occupational exposure

Conclusion

In conclusion, using a dual methodological approach combining linear regression and Bayesian Kernel Machine Regression, this study nested within the TRAPHEAC cohort of Swiss bus drivers showed that occupational HF-EF exposure is positively associated with poorer sleep outcomes, including global sleep quality, insomnia, and excessive daytime sleepiness. These associations were consistently observed both for HF-EF specifically and for the combined mixture of HF-EF, LF-EF, and LF-MF exposures, and remained robust to adjustment for sex, age, intensity of nightshift work, and occupational noise exposure as well as to the exclusion of participants exposed to high ambient temperature. However, the BKMR dose-response trends were not statistically significant. Stronger exposure–response gradients in individuals with low residential EMF exposure highlight the modifying effect of non-occupational sources, whereas attenuation in highly exposed individuals suggests a saturation or masking phenomenon, emphasizing the importance of considering both cumulative and mixed-source EMF exposures in occupational sleep

health assessments. As the study sample was small and several individual-level factors that may affect sleep quality were unavailable for assessing their influence on the observed associations, future research is warranted to confirm these findings and address these limitations.

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**Comment on Petzke et al. (2026) re: Electromagnetic Hypersensitivity**

Cinciripini G. Comment on Petzke et al. (2026): International Journal of Hygiene and Environmental Health 273 (2026) 114764. Int J Hyg Environ Health. 2026 Jul;276:114801. doi: 10.1016/j.ijheh.2026.114801.

No abstract

https://pubmed.ncbi.nlm.nih.gov/42236410/

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**Research Progress on High-Frequency Electromagnetic Environments in the Internet of Vehicles**

Li J, Lu M, Wang S. Research Progress on High-Frequency Electromagnetic Environments in the Internet of Vehicles. *Electronics*. 2026; 15(15):3418. doi: 10.3390/electronics15153418.

Abstract

With the increasing demand for clean energy and low-carbon transportation, next-generation vehicles integrating high-frequency electronic systems have become more complex, raising concerns about in-vehicle electromagnetic exposure. This paper reviews high-frequency devices operating in the 30 kHz–300 GHz range and systematically analyzes the spatial distribution and key frequency characteristics of electromagnetic sources in vehicles. The results show that, even under worst-case conditions, electromagnetic exposure levels for occupants remain well below the safety limits defined by ICNIRP. For example, in a worst-case 5.9 GHz V2V communication scenario, the driver's head $SAR_{10g}$ reaches 0.981 W/kg (9.81% of the ICNIRP occupational limit), while the whole-body SAR is only 0.008728 W/kg with negligible temperature rise. Other systems, including 5G-V2X, automotive radar, and mobile phones, also produce exposure levels far below safety thresholds. These findings suggest that RF exposure levels for vehicle occupants remain low relative to current guideline limits under the assessed scenarios. However, key challenges remain, including limited studies on multi-source exposure, insufficient data on vulnerable populations, simplified simulation conditions, lack of standardized validation methods, and inadequate assessment of emerging technologies. This work provides a quantitative basis for future safety standards and highlights critical research directions.

Conclusions and Future Perspectives

This paper systematically reviews various types of vehicular high-frequency communication devices over the past decades, focusing on antenna design, operating frequency, and application scenarios, and provides a comprehensive analysis of their electromagnetic safety.

Vehicular wireless networking systems encompass multiple radio-frequency (RF) technologies, including V2X communication, 5G-V2X, GNSS positioning, mobile communication, Bluetooth, and automotive

radar, covering a wide frequency range from 30 kHz to 300 GHz. Across the exposure scenarios assessed in the reviewed studies, most reported electromagnetic exposure levels from vehicular RF devices were below the applicable limits established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) or IEEE.

The following values are therefore presented as representative, study-specific findings rather than as directly pooled estimates, because the reviewed studies differ in source type, operating frequency, antenna configuration, exposure scenario, human model, and dosimetric endpoint. Specifically, for V2X communication systems operating at 5.9 GHz, the maximum localized $SAR_{10g}$ in the driver's head under worst-case conditions is approximately 0.981 W/kg, corresponding to 9.81% of the ICNIRP occupational limit (10 W/kg). The whole-body SAR is 0.008728 W/kg, and the 30 min averaged core temperature rise is 0.055 °C, representing only 5.5% of the allowable limit (1 °C) [63]. When the sunroof is open, the maximum skin $SAR_{10g}$ reaches 72.39 mW/kg, accounting for 3.62% of the limit [79]. Pedestrian exposure in children is significantly lower than that in adults, with a maximum whole-body SAR of approximately 4.9×10−4 W/kg [61]. For 5G-V2X systems at 3.5 GHz, the maximum head skin $SAR_{10g}$ for pedestrians is 6.818 mW/kg, remaining well below safety limits [64].

GNSS/navigation antennas are not summarized as primary RF exposure sources because they normally operate as passive receiving devices; their relevance to vehicular electromagnetic environments is mainly associated with positioning reliability, antenna integration, and electromagnetic compatibility. In the case of automotive mmWave radar, the whole-body SAR in a 24 GHz single-antenna scenario is as low as 1.67×10−6 W/kg, while multi-antenna configurations (two or four antennas) increase SAR by approximately one order of magnitude (≈1.67×10−5 W/kg), still far below the limit of 0.4 W/kg [65]. For 57.35/58.45 GHz radar, the maximum measured power density at a distance of 20 cm is 0.29 $W/m^2$ [62]. For 79 GHz radar, even at a very short distance of 10 mm under typical operating power (EIRP = 26.8 dBm), exposure remains well below the limit. Only under extremely high power (55 dBm) and very close proximity may short-term exposure approach the limit; however, compliance is still ensured when evaluated using absorbed energy density within 0.5 s [70].

For mobile communication and Wi-Fi/Bluetooth devices, the peak electric field strength in typical in-vehicle scenarios is approximately 32 V/m, which is below the ICNIRP reference level (61 V/m) [74]. Under simultaneous operation of four sources, the maximum electric field strength is 4.82 V/m [94]. The maximum measured local SAR of a 4G TD-LTE mobile phone (200 mW) inside the vehicle is 0.1613 W/kg, significantly lower than the limit of 2 W/kg [77]. Furthermore, studies on military vehicle antennas operating in the HF band (16 MHz) indicate that even when the external electric field strength (127 V/m) exceeds the ICNIRP reference level (86.3 V/m), the internal whole-body SAR (0.2 mW/kg) and head $SAR_{10g}$ (3.2–14.0 mW/kg) remain well below safety limits [96].

Taken together, these study-specific findings indicate that the reported exposure levels generally remained within the applicable ICNIRP or IEEE limits under the assessed thermal-effect endpoints and operating conditions. However, this conclusion should not be interpreted as evidence that all real-world vehicular RF exposure scenarios have been fully characterized.

These quantitative findings have scientific and engineering value, but their interpretation should remain linked to the specific assumptions and endpoints of each study. From a health-risk assessment perspective, the reviewed results provide evidence that, under the assessed scenarios, localized SAR, whole-body SAR, power density, and temperature rise were generally below the corresponding thermal-

effect limits. For example, even under relatively conservative conditions, such as close proximity to antennas, multi-source operation, or sunroof-open scenarios, the reported maximum localized SAR did not exceed 49% of the ICNIRP limit, while core temperature rise remained below 6% of the allowable threshold. In several scenarios, including 24 GHz radar and 5G-V2X, reported exposure levels were two to four orders of magnitude lower than the relevant limits.

From an engineering design perspective, these quantitative results provide practical boundary conditions for vehicle manufacturers and antenna engineers. For instance, 79 GHz radar remains compliant even at a 10 mm distance under typical power levels, while multi-antenna configurations at 24 GHz increase SAR by only one order of magnitude. Such findings can guide antenna placement optimization and transmission power control strategies.

Furthermore, certain extreme scenarios—such as increased SAR under sunroof-open conditions or near-field exposure to high-power mmWave radar—highlight the necessity for cautious design under boundary conditions and provide insights for future refinement of safety standards. Rather than forming a unified dataset, the compiled evidence provides a comparative evidence map across different source types, frequency bands, exposure metrics, and assessment methods. This evidence map can help identify representative exposure ranges, methodological gaps, and priorities for future guideline refinement and risk assessment in vulnerable populations, including individuals with implants and pregnant women.

The strength of evidence also varies across studies. Higher-confidence evidence comes from studies that clearly report source parameters, antenna location, transmitted power, human model or measurement position, frequency-appropriate exposure metrics, validation procedures, uncertainty analysis, and explicit comparison with ICNIRP or IEEE limits. Lower-confidence evidence generally arises from simplified source models, incomplete reporting of exposure conditions, single-source assumptions, limited validation, or the absence of uncertainty quantification. This distinction should be considered when interpreting the reported values and when using them to inform exposure assessment or engineering design.

Despite extensive research efforts, several challenges and research gaps remain in the context of intelligent and autonomous vehicles:

(i) Insufficient investigation of multi-source and multi-frequency composite exposure scenarios. Most existing studies focus on single-frequency or single-source exposure, whereas real vehicular environments involve simultaneous operation of multiple RF systems (e.g., V2X, 5G-V2X, GNSS, Bluetooth/Wi-Fi, and radar). Future studies should develop comprehensive multi-physics and multi-source exposure assessment frameworks. For such scenarios, cumulative exposure should be evaluated using normalized exposure ratios or cumulative indices rather than by directly comparing incompatible quantities such as SAR, field strength, and power density.

(ii) Limited research on electromagnetic exposure in special populations. There is a lack of data for infants, children in car seats, implant users (e.g., pacemakers, cochlear implants), and pregnant women. In particular, interactions between RF systems and active medical implants remain largely unexplored.

(iii) Oversimplified exposure scenarios. Most simulations assume static human models and single RF sources, neglecting real-world factors such as multiple devices, dynamic transmission power, multipath

reflections, passenger posture, and vehicle configuration. In addition, recent studies on mmWave vehicular edge computing and fluid-antenna-assisted MEC networks indicate that future IoV systems may dynamically adjust transmit power, beam direction, resource allocation, and computation-offloading decisions according to channel conditions and service requirements [

(iv) Lack of full-vehicle experimental validation and standardized evaluation methods. Current studies are dominated by simulations, with limited experimental validation. Differences in models, metrics, and scenarios hinder cross-study comparability, and standardized guidelines for vehicular RF exposure assessment are still lacking.

(v) Insufficient research on long-term exposure and non-thermal effects. Existing assessments are primarily based on short-term thermal effects (SAR, power density, temperature rise), while long-term, low-level exposure and potential non-thermal biological effects remain largely unexplored.

(vi) Lack of prospective assessment for emerging technologies. Future technologies such as 6G, terahertz communication, ultra-massive MIMO, and reconfigurable intelligent surfaces may introduce higher-frequency and higher-density RF exposure, requiring forward-looking safety evaluations.

(vii) Limited biofidelity of human models. Current models do not adequately capture variability across age, gender, body composition, and anatomical differences, nor do they accurately represent implanted medical devices. High-fidelity modeling and uncertainty quantification are urgently needed.

In conclusion, this study provides a systematic review and quantitative analysis of electromagnetic exposure in vehicular RF systems, offering a solid theoretical foundation and reference framework for future safety standards and health risk assessments for both vehicle occupants and pedestrians.

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**Chronic 3.5 GHz radiofrequency exposure is associated with behavioral, molecular, and histopathological changes in the rat hippocampus**

Bektas H, Cakir S, Alizade A, Dogu S, Altindag F. Chronic 3.5 GHz radiofrequency exposure is associated with behavioral, molecular, and histopathological changes in the rat hippocampus. Int J Radiat Biol. 2026 Aug 7:1-14. doi: 10.1080/09553002.2026.2708930.

Abstract

Purpose: Chronic exposure to mid-band radiofrequency (RF) electromagnetic fields at 3.5 GHz is increasingly relevant to modern wireless environments; however, its effects on hippocampal circuit stability under non-thermal conditions remain unclear. We investigated whether prolonged 3.5-GHz RF exposure is associated with anxiety-like behavior and hippocampal transcript-level changes consistent with excitatory-inhibitory (E/I) imbalance, and whether thymoquinone (TQ) or taurine (TAU) are associated with modulation of these responses.

Materials and methods: Adult male Wistar rats (n = 28) were assigned to Sham, RF, RF + TQ (20 mg/kg), or RF + TAU (20 mg/kg) groups (n = 7/group). Animals were exposed to a GSM-like 3.5-GHz RF signal (2

W; 2 h/day; 5 days/week; 10 weeks). Anxiety-like behavior and spatial learning were assessed using the Elevated Plus Maze (EPM) and Morris Water Maze (MWM). Hippocampal gene expression (bdnf, creb1, camk2a, th, tph2, gad1, slc17a7) was quantified by RT-qPCR, and histopathology by H&E staining.

Results: Dosimetry indicated whole-body SAR of 0.0383 W/kg and brain gray matter SAR of 0.3411 W/kg. RF exposure was associated with reduced open-arm time in the EPM. Expression of slc17a7 increased in the RF group, suggesting a shift toward excitation. Under RF co-exposure conditions, TQ and TAU were associated with changes in slc17a7 expression and with increases in bdnf, creb1, and camk2a, along with inhibitory and monoaminergic markers. RF-exposed hippocampi showed neuronal degeneration, less pronounced in antioxidant-treated groups.

Conclusions: Chronic non-thermal 3.5-GHz RF exposure is associated with anxiety-like behavior and a hippocampal molecular-structural profile consistent with E/I imbalance and tissue stress. TQ and TAU were associated with context-dependent changes under RF co-exposure conditions; however, due to the absence of antioxidant-only control groups, independent effects cannot be determined. These findings suggest that synaptic homeostasis may represent a potential target of prolonged mid-band RF exposure.

Plain language summary

Chronic 3.5-GHz RF exposure was associated with anxiety-like behavior. RF exposure increased hippocampal slc17a7 expression under non-thermal conditions. No robust impairment of spatial learning was observed in the Morris Water Maze. Transcript-level changes were observed in the RF + TQ and RF + TAU groups under RF co-exposure conditions. Findings suggest potential modulation of excitatory–inhibitory balance in the hippocampus.

https://pubmed.ncbi.nlm.nih.gov/42566258/

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**Immediate Effects of Magnetic Stimulation on Dentate Gyrus Glutamatergic and GABAergic Neuron Excitability**

Ren Z, Lu B, Qiu H, Wang Z, Wang T, Kang J, Zou T, Zhu H, Ding C. Immediate Effects of Magnetic Stimulation on Dentate Gyrus Glutamatergic and GABAergic Neuron Excitability. Brain Sci. 2026 Jun 26;16(7):673. doi: 10.3390/brainsci16070673.

Abstract

Background/Objectives: To investigate the immediate regulatory effects of magnetic stimulation with different parameters on the excitability of glutamatergic neurons and GABAergic neurons in the mouse hippocampal dentate gyrus (DG), and to analyze the underlying mechanisms using the Hodgkin-Huxley (HH) model.

Methods: Whole-cell patch-clamp recordings were performed on acute brain slices to measure changes in resting membrane potential (RMP), the number of action potentials (APs) evoked by 500-ms long-duration stimulation, as well as AP threshold, peak, half-width, maximum rising slope, and maximum falling slope under magnetic stimulation at various frequencies (1, 10, 20 Hz) and intensities (50, 75 mT).

An improved HH model was established based on experimental data to analyze the dynamic changes in gating variables under magnetic stimulation.

Results: High-frequency magnetic stimulation (10-20 Hz) significantly increased the number of APs in both neuron types. In glutamatergic neurons, the number of APs increased from 10.12 ± 0.52 in the control group to 15.62 ± 0.84 in the 20 Hz-75 mT group; in GABAergic neurons, it increased from 7.88 ± 0.40 to 12.62 ± 0.53. Magnetic stimulation also depolarized RMP and significantly altered multiple AP waveform parameters in both neuron types. Glutamatergic neurons showed a more distinct frequency dependence, whereas GABAergic neurons were more sensitive to changes in both frequency and intensity in terms of RMP and multiple waveform parameters. Simulation results showed that the 1 Hz conditions produced negligible changes in AP firing, gating-variable dynamics, and steady-state ion-channel parameters compared with the Control condition. In contrast, high-frequency stimulation enhanced the dynamic changes of sodium and potassium channel gating variables and altered their voltage-dependent steady-state properties. Specifically, sodium channel activation shifted toward more negative potentials, whereas sodium channel inactivation and potassium channel activation shifted toward more depolarized potentials.

Conclusions: Under the experimental conditions of this study, magnetic stimulation immediately enhanced the excitability of glutamatergic and GABAergic neurons in the hippocampal dentate gyrus of male mice in a frequency-dependent manner. The modified HH model reproduced both the weak effects under low-frequency stimulation and the enhanced excitability under high-frequency stimulation, suggesting that these immediate effects may be related to frequency-dependent changes in the gating kinetics and voltage-dependent properties of sodium and potassium channels.

Open access: https://www.mdpi.com/2076-3425/16/7/673

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**Protective Effects of Coenzyme Q10 Against Urogenital Damage Induced by 2.45 GHz Wi-Fi Radiofrequency Radiation in Rats**

Mousapour E, Karimi A, Ebrahimi S, Rezaie A, Rahimi K, et al. Protective Effects of Coenzyme Q10 Against Urogenital Damage Induced by 2.45 GHz Wi-Fi Radiofrequency Radiation in Rats. Jundishapur J Nat Pharm Prod. 2026;21(1):e169131. doi: 10.5812/jjnpp-169131.

Abstract

Background: Wi-Fi exposure has been associated with oxidative stress and reproductive toxicity; however, protective strategies remain under investigation.

Objectives: This study aimed to evaluate the protective effects of coenzyme Q10 (CoQ10) against oxidative stress–mediated reproductive and renal damage induced by prolonged exposure to 2.45 GHz Wi-Fi radiofrequency radiation in male Wistar rats by assessing oxidative stress markers, antioxidant enzyme activities, sperm parameters, testosterone levels, and testicular and renal histopathological changes.

Methods: Male Wistar rats (n = 40) were allocated to the control, Wi-Fi, Wi-Fi+CoQ10, Coenzyme Q10

(CoQ10), and vehicle groups. Animals were exposed to Wi-Fi radiation at 2.45 GHz [specific absorption rate (SAR) ≈ 0.9 W/kg, 7 h/day for 8 weeks]. CoQ10 was administered orally at 150 mg/kg/day. Oxidative stress markers [malondialdehyde (MDA)], antioxidant enzyme activities [superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx)], sperm parameters, testosterone levels, and histopathology of the testes and kidneys were assessed. Statistical analyses were performed using one-way ANOVA followed by Tukey's post-hoc test.

Results: Wi-Fi exposure significantly increased MDA levels in the testes and kidneys ($P < 0.01$, $\eta 2 = 0.39$) and reduced antioxidant enzyme activities ($P < 0.01$, $\eta 2 = 0.41$). Sperm count, motility, and testosterone levels declined markedly ($P < 0.05$). Histopathological changes were evident in the seminiferous tubules and renal tissues. CoQ10 supplementation alone reduced MDA ($P < 0.05$) and increased antioxidant enzyme activities above baseline ($P < 0.05$). Combined treatment (Wi-Fi+CoQ10) partially restored enzyme activities and attenuated oxidative stress compared with that in the Wi-Fi group ($P < 0.05$).

Conclusions: Prolonged Wi-Fi exposure at 2.45 GHz (SAR ≈ 0.9 W/kg) induces oxidative stress-mediated damage in reproductive and renal tissues, resulting in impaired sperm quality and hormonal imbalance. CoQ10 supplementation demonstrated protective effects by reducing oxidative damage and partially restoring reproductive indices. These findings suggest that continuous Wi-Fi exposure may pose reproductive risks, whereas antioxidant strategies such as CoQ10 could mitigate these effects.

Excerpt

Wi-Fi radiation was generated using a standard router (TP Link Archer C6, China) operating at 2.45 GHz. Rats were placed 30 cm away from the source in their cages. The specific absorption rate (SAR) was measured using a calibrated spectrum analyzer (Narda SRM 3006, Germany) and maintained at 0.1 - 0.2 W/kg. Background electromagnetic sources, such as mobile phones and Bluetooth devices, were eliminated during exposure. The daily exposure duration of 7 h/day was selected based on previous studies reporting significant reproductive effects under similar conditions (1).

Open access: https://brieflands.com/journals/jjnpp/articles/169131

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**Testicular damage from electromagnetic radiation in rats and evaluation of protective agents**

Gözüküçük A, Çakıroğlu B, Uyanik BS, Kılıç HH, Çelik İS. Testicular damage from electromagnetic radiation in rats and evaluation of protective agents. Urologia. 2026 Jul 25:3915603261448981. doi: 10.1177/03915603261448981.

Abstract

Background: Male infertility has been associated with various environmental, physiological, and genetic factors. In recent years, the widespread use of mobile phones has raised concerns regarding exposure to electromagnetic radiation (EMR). EMR emitted from mobile devices may adversely affect male reproductive function by inducing oxidative stress and impairing spermatogenesis.

Objective: This study aimed to evaluate the potential protective effects of vitamin E and N-acetylcysteine (NAC) against EMR-induced testicular damage in rats.

Methods: A total of 35 adult male Wistar rats were randomly divided into five groups (n = 7 per group): control, EMR exposure, EMR + NAC, EMR + vitamin E, and EMR + NAC + vitamin E. Rats were exposed to EMR generated by a mobile phone operating in the GSM frequency band (900/1800 MHz) in active call mode, positioned at a fixed distance of 15 cm from the cages, for 3 h daily over 28 days. The specific absorption rate (SAR) was based on manufacturer-reported values. Biochemical analyses were performed to assess total antioxidant capacity (TAC), glutathione peroxidase (GPX), superoxide dismutase (SOD), and malondialdehyde (MDA) levels. Data distribution was evaluated using the Shapiro-Wilk test, and group comparisons were conducted using the Kruskal-Wallis test with appropriate post-hoc analyses.

Results: Significant differences were observed among groups in terms of total antioxidant capacity (TAC) ($p < 0.001$). TAC levels were reduced in the EMR-only group compared to controls, whereas antioxidant supplementation (NAC and/or vitamin E) resulted in increased TAC levels. Post-hoc analyses demonstrated significant improvements in TAC in treatment groups compared to both control and EMR-only groups. However, no statistically significant differences were observed among groups for GPX, SOD, and MDA levels ($p > 0.05$).

Conclusion: N-acetylcysteine (NAC) and vitamin E may exert partial protective effects against EMR-induced oxidative alterations in rat testes, particularly as reflected by improvements in total antioxidant capacity. However, given that other oxidative stress markers did not demonstrate statistically significant differences, these findings should be interpreted with caution. Further experimental and clinical studies with larger sample sizes and detailed histopathological evaluation are required to better elucidate the potential therapeutic role and clinical relevance of these antioxidant agents.

https://pubmed.ncbi.nlm.nih.gov/42499284/

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**Differential Effects of 3.5 GHz and 24 GHz 5G Radiofrequency Exposure on Male Sexual Behaviour and Reproductive Endocrine Function in Rats**

Hairulazam A, Ibrahim SF, Osman K, Mokhtar MH, Zulkefli AF, Mat Ros MF, Jamaludin N, Syed Taha SMA, Vijay S, Zakaria Z, et al. Differential Effects of 3.5 GHz and 24 GHz 5G Radiofrequency Exposure on Male Sexual Behaviour and Reproductive Endocrine Function in Rats. *International Journal of Molecular Sciences*. 2026; 27(16):7102. doi: 10.3390/ijms27167102.

Abstract

The rapid expansion of 5G technology has increased exposure to high-frequency radiofrequency electromagnetic fields (RF-EMF), raising concerns about male reproductive health. This study investigated the effects of 5G frequencies at 3.5 GHz and 24 GHz on male libido, reproductive hormones, the testosterone-to-oestrogen (T/E) ratio, and androgen receptor expression in rats. Eighteen male Sprague–Dawley rats were randomly assigned to Control, 3.5 GHz, and 24 GHz (n = 6/group). Exposed groups received 7 h/day RF-EMF exposure for 60 consecutive days, while the Control underwent sham exposure. During the final week of exposure, mating behaviours were assessed using mount frequency, mount latency, intromission frequency, ejaculation latency, and post-ejaculatory

interval. Serum testosterone and oestrogen levels, the T/E ratio and androgen receptor expression in the testis and hypothalamus were evaluated. The 3.5 GHz group demonstrated statistically significantly prolonged ejaculation latency (3480 ± 1576.956, $p < 0.01$, Hedges' $g = 1.03$) compared with the Control group. In contrast, 24 GHz exposure statistically significantly reduced mount frequency (4.80 ± 0.837, $p < 0.01$, Hedges' $g = -0.65$) and prolonged the post-ejaculatory interval (588.83 ± 206.41 s, $p < 0.01$, Hedges' $g = 1.63$) compared with the Control group. Hormonal analysis revealed statistically significant elevation of testosterone levels in the 3.5 GHz group, whereas the 24 GHz group showed statistically significant reductions in testosterone and oestrogen. Androgen receptor expression was unchanged. These findings suggest frequency-dependent effects of 5G RF-EMF on male libido and endocrine balance.

Open access: https://www.mdpi.com/1422-0067/27/16/7102

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**Design and Realization of an ELF-EMF Generator and Effects of Different Magnetic Flux Densities on Cancerous and Healthy Cell Viability**

Avci F, Ağrali E, Alkiş ME, Yaman O, Çavaş M. Design and Realization of an ELF-EMF Generator and Effects of Different Magnetic Flux Densities on Cancerous and Healthy Cell Viability. *Applied Sciences*. 2026; 16(14):6982. doi: 10.3390/app16146982

Abstract

This study aimed to develop a low-cost, computer-controlled, extremely low-frequency 50 Hz electromagnetic field (ELF-EMF) generator and to investigate the effects of EMF exposure at intensities of 0.1, 1, 5, and 10 mT (millitesla) on human osteosarcoma (U2OS) and healthy bronchial epithelial (BEAS-2B) cell lines. First, a computer-controlled ELF-EMF generator was successfully designed and developed for in vitro exposure studies. Subsequently, the cells were exposed to 50 Hz EMFs at flux densities ranging from 0.1 to 10 mT, and cell viability was assessed using the MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay 24 h after exposure. A significant decrease in cell viability was observed in U2OS cells exposed to 5 and 10 mT EMFs ($p < 0.05$), whereas no significant difference was detected at 0.1 and 1 mT exposures ($p > 0.05$). In BEAS-2B cells, a significant decrease in cell viability was observed only following exposure to 10 mT EMFs ($p < 0.05$), with no significant differences at 0.1, 1, or 5 mT exposures. These findings suggest that 50 Hz EMFs may affect cellular processes and inhibit the proliferation of U2OS cancer cells more than that of BEAS-2B cells. EMFs with specific frequencies and intensities may represent a novel approach for controlling the growth of U2OS cancer cells.

Open access: https://www.mdpi.com/2076-3417/16/14/6982

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**Magnetogenetics: Tools for Noninvasive Neuromodulation with Cellular Resolution**

Tran TT, Hernández-Morales M, Han V, Liu C. Magnetogenetics: Tools for Noninvasive Neuromodulation with Cellular Resolution. J Neurosci. 2026 Aug 5;46(31):e0315252026. doi: 10.1523/JNEUROSCI.0315-25.2026.

Abstract

Magnetogenetics is emerging as a promising tool to control neuronal activity and overcome the limitations of chemogenetics and optogenetics. While chemogenetics is restricted in temporal resolution, optogenetics is invasive and limited in penetration depth. Magnetogenetics addresses these challenges by offering a noninvasive approach that enables wireless and on-demand control of neuronal activity. Magnetogenetics uses synthetic magnetic nanoparticles or the protein ferritin as transducers to convert magnetic fields into thermal, mechanical, or biochemical signals that can activate ion channels and proteins sensitive to these stimuli. To achieve cellular resolution, the neurons of interest are genetically targeted by the expression of diverse ion channels that confer sensitivity to magnetic stimulation or by targeting transducers to ion channels via linkers such as antibodies and other binding domains. Neuroscientists have used magnetogenetics to drive calcium-dependent gene expression, to excite or inhibit neurons, and to modulate behavior in animal models, as discussed in this review. The efficacy of these methods has been met with skepticism, and the fundamental mechanisms have been unclear. However, several studies have demonstrated the effectiveness of magnetogenetics and uncovered the underlying mechanisms. While improvements are still needed for magnetogenetics to become a routine technique to control neuronal activity, there is tremendous potential for both technical innovation and applications. This review discusses the current approaches from their development and limitations to their applications across research fields, particularly neuroscience.

https://pubmed.ncbi.nlm.nih.gov/42557107/

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**Effect of non-ionizing radiation on the growth of wheat plant**

Khalaf HNB, Moustafa M, Abdel-Moneim, MMY *et al.* Effect of non-ionizing radiation on the growth of wheat plant. *Discov Appl Sci* **8**, 798 (2026). doi: 10.1007/s42452-026-09039-5

Abstract

Using microwave irradiation in seed treatment as a physical mutagen is one of the promising technologies in plant breeding that seeks to increase plant productivity and improve their quality. Wheat (*Triticum aestivum*) grains were exposed to microwave emitter at distance 1 cm from the microwave window with frequency of 9.88 GHz and power 4.6 mW which is applied for times of 10, 20, 30, 40, 50, and 60 min to get different doses of irradiation. Wheat grains were divided into two groups for in vitro and in vivo experiments. The percentage of germinated grains as well as mitotic index increased for seeds exposed to microwave radiation with short exposure periods. However, germination percentage and values of mitotic index were significantly decreased with increasing exposure periods of microwave. Some types of chromosomal abnormalities were observed in the examined cells, and the highest percentage of aberrant cells were recorded in grains irradiated for 60 min. Growth parameters, including root and shoot length, were stimulated by short-term exposure but inhibited by long-term exposure.

Conclusions

Plants are extremely complex creatures that react differently to many stresses in various environmental situations. When some researchers investigated the effect of such radiation on plants, the results were

mixed. In view of this, our study foresees the effects of microwaves on seed germination, cell division and growth of wheat as a commercial crop. The results obtained showed that pre-sowing exposure of grains to microwave radiation with frequency of 9.88 GHz and power 4.6 mW for time intervals as 10, 20, 30, 40 and 50 min influenced the germination and the mitotic cell division of the tested plants. However, exposure time at 60 min. reduced cell proliferation and induced aberrant cells. So, we can conclude that microwave radiation may have a good effect by regulating dosages and minimizing seed exposure time to radiation.

Open access: https://link.springer.com/article/10.1007/s42452-026-09039-5

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**Evaluating Human Perception Thresholds in Magnetic Stimulation Using Experimental Measurements and Modelling**

Kangasmaa O, Laakso I. Evaluating Human Perception Thresholds in Magnetic Stimulation Using Experimental Measurements and Modelling. Bioelectromagnetics. 2026 Sep;47(6):e70066. doi: 10.1002/bem.70066.

Abstract

This preregistered study investigated whether induced electric fields alone could predict human perception thresholds in magnetic stimulation. Using a figure-of-eight magnetic coil placed on the forearm, perception thresholds were collected from 24 healthy participants using the method of adjustment in 12 stimulation conditions. Subject-fitted, anatomically realistic forearm models were constructed from a set of 10 MRI-based models. Induced electric fields were computed using the finite element method with probabilistic tissue conductivities and post-processed using spatial averaging and percentiles. Linear mixed-effects modelling showed that the perception threshold was 32.2 V/m (SD between subjects 5.2 V/m) for a damped sinusoidal magnetic pulse with 83 μ s phase duration. This threshold value was determined by spatial averaging over a cube with a side length of 2 mm and taking the 99th percentile of the electric field within the modelled forearms. However, the induced electric field did not fully explain the perception threshold (adjusted $R2 = 0.48$; permutation testing, $p < 0.001$). We also conducted a supplementary modelling study, retrospectively analysing previous literature results to allow for direct comparison with our findings. These results showed that simplified calculations of the threshold electric field, obtained by modelling the forearm as a uniform cylinder, need to be scaled by a factor of 1.4 to align with the 99th percentile electric field calculated with anatomically realistic models. Both our experimental results and the modelling provide data to inform the refinement of safety guidelines.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70066

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**Effects of Pulsed Electromagnetic Field Application on Glucose Metabolism in Rats**

Gencer H, Bilgin HM, Akpolat V, Erkan REC, Alabalık U, Baksi N, Akpolat İ. Effects of Pulsed Electromagnetic Field Application on Glucose Metabolism in Rats. Bioelectromagnetics. 2026 Sep;47(6):e70067. doi: 10.1002/bem.70067.

Abstract

The present study aimed to evaluate the effects of pulsed electromagnetic field (PEMF) exposure on glucose metabolism-related hormonal and oxidative stress markers. Twenty-three male Wistar albino rats were randomly assigned to three groups: sham-control (n = 7), PEMF (n = 8), and PEMF + vitamin C (n = 8). The PEMF and PEMF + vitamin C groups were exposed to a pulsed magnetic field at 50 Hz and 1.5 mT for 4 h daily over 4 weeks. Vitamin C (250 mg/kg/day) was administered orally to the PEMF + vitamin C group. Serum and tissue levels of insulin, glucagon, glucagon-like peptide-1 (GLP-1), sirtuin 1 (SIRT1), total antioxidant capacity (TAC), and total oxidant capacity (TOC) were measured. Histopathological evaluations of brain, liver, and pancreatic tissues were also performed. Serum glucose, insulin, glucagon, GLP-1, SIRT1, TAC, and TOC levels did not differ significantly among the experimental groups. Gastric TAC levels were significantly higher in the PEMF + vitamin C group. In renal tissue, insulin levels were significantly elevated only in the PEMF + vitamin C group. PEMF exposure did not induce systemic biochemical changes in healthy rats but elicited tissue-specific biochemical responses, particularly in gastric tissue. These findings suggest that PEMF may modulate glucose-related endocrine and redox pathways at the gastrointestinal level without causing structural tissue damage.

https://pubmed.ncbi.nlm.nih.gov/42504996/

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**Disruption of magnetic orientation in migratory songbirds by radiofrequency magnetic fields is mediated by a specialized sensory system**

Kavokin K, Bojarinova J, Sannikov D, Cherbunin R, Pakhomov A, Fedorishcheva A, Chernetsov N. Disruption of magnetic orientation in migratory songbirds by radiofrequency magnetic fields is mediated by a specialized sensory system. J R Soc Interface. 2026 Jul 22;23(240):20260129. doi: 10.1098/rsif.2026.0129.

Abstract

Direction finding in migratory birds is known to be affected by oscillating magnetic fields (OMFs) in the radiofrequency range. This experimental fact was earlier interpreted in terms of the direct influence of OMFs on electron spins in the molecule of cryptochrome that, according to the photochemical model of magnetoreception, serves as the primary sensor of the geomagnetic field. In our experiments, birds (pied flycatchers) were subjected to OMFs with carrier frequencies of 1.41 and 1.5 MHz with the square wave amplitude modulation at 500 Hz. The modulated OMF, having twice less mean power than that without modulation, nevertheless caused disorientation at a lower amplitude of the carrier wave than the unmodulated OMF. Since the prediction of the photochemical theory is exactly the opposite, we conclude that the effect of OMFs on the magnetic orientation of birds is not related to the decoherence of electron spins in cryptochrome. Instead, we suggest that OMFs are perceived by a separate sensory system, most likely based on electromagnetic induction. This hypothetical sensory system, specialized at the detection of magnetic perturbations caused by solar flares or thunderstorms, might react to shape rather than to the mean power of the detected signal, which would explain its higher sensitivity to modulated OMFs.

Open access: https://royalsocietypublishing.org/rsif/article/23/240/20260129/482563/Disruption-of-magnetic-orientation-in-migratory

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**Evaluation of the synergistic and antagonistic antibacterial effects of pulsed electromagnetic fields combined with ciprofloxacin and nanochitosan**

Khalil, A.M., Seiffein, N.L., El-Refaie, W.M. *et al.* Evaluation of the synergistic and antagonistic antibacterial effects of pulsed electromagnetic fields combined with ciprofloxacin and nanochitosan. *Sci Rep* **16**, 23063 (2026). https://doi.org/10.1038/s41598-026-63235-2.

Abstract

This study introduces an innovative electromagnetic nano-approach to combat high-severity bacterial infections without relying solely on high-dose antibiotics. We investigate the synergistic potential of extremely low-frequency pulsed electromagnetic wave (ELF PEMW) exposure (< 20 Hz) as a physical catalyst to enhance the bioactivity of ciprofloxacin-loaded chitosan nanoparticles (Cipro-C-NPs). This method provides a pivotal alternative for managing *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* in an era of escalating multi-drug resistance. Cipro-C-NPs were synthesized with high encapsulation efficiency. Bacteria were subjected to a multi-factorial screening involving three antibacterial agents, two physical fields (pulsed magnetic and electric), and varying frequencies (0.7, 6, and 20 Hz) for durations of 20 and 60 min. As a high-throughput preliminary screen, this work aimed to map the qualitative landscape of bio-electromagnetic interactions. Contrary to the hypothesis of enhanced membrane permeability, ELF PEMW functioned as a biophysical antagonist. The electromagnetic field appeared to trigger membrane hyperpolarization, increasing transmembrane potential and restricting porin-mediated transport of the antibiotic. Simultaneously, the field reduced the zeta-potential of the chitosan nanoparticles, leading to significant colloidal aggregation. These large aggregates were physically excluded from bacterial entry routes, resulting in increased Minimum Inhibitory Concentrations (MICs). Notably, the degree of antagonism was species-specific, suggesting that membrane capacitance and porin density dictate electromagnetic susceptibility. This study reveals a critical bio-electromagnetic trade-off: while physical fields can modulate cellular behavior, poorly tuned parameters can inadvertently fortify bacterial defenses and reduce drug bioavailability. These findings provide a vital “negative roadmap” for future research, highlighting the need for direct electrophysiological mapping of efflux pumps and membrane potentials. This work serves as a foundational step toward precision-targeted, physics-assisted antimicrobial therapies.

Open access: https://www.nature.com/articles/s41598-026-63235-2

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**Unveiling the spectrum: Understanding directed energy weapon injuries and military health care implications**

McNairn J, Blaskovits F, St Onge M, Coleby J, Khan A, Dhillon P. Unveiling the spectrum: Understanding directed energy weapon injuries and military health care implications. J Mil Veteran Fam Health. 2026 Mar 27;12(2):89-100. doi: 10.3138/jmvfh-2025-0041.

Abstract

Introduction: Directed energy weapons (DEWs) are emerging technologies that are transforming the

modern battlespace. Despite their increasing presence, the associated injury patterns and health outcomes remain poorly understood. This review aims to consolidate existing knowledge on DEW-related injuries to assist military medical professionals in improving clinical care.

Methods: A scoping review was conducted in accordance with PRISMA-ScR guidelines and included peer-reviewed and grey literature from 1980 to Nov. 30, 2024. Databases searched included PubMed, MEDLINE, AccessMedicine (textbooks), the Cochrane Library, EMBASE, Google Scholar, and Military Legal Resources (U.S. Army JAG School). Studies that focused on chemical, acoustic, and electrical/electromagnetic weapons were excluded because of differing pathophysiology. Two independent reviewers performed screening and data extraction. Results were synthesized narratively.

Results: Out of 200 identified studies, 33 met inclusion criteria. Most documented injuries involved thermal damage to skin, internal organs, and eyes. Notably, data were sparse on reproductive effects and the management of DEW injuries in polytrauma. Evidence suggests that DEWs may inflict central nervous system or deep tissue damage without external signs, potentially delaying diagnosis and treatment. Injury severity varied by energy type, anatomical target, and exposure duration.

Discussion: DEWs introduce novel clinical challenges for military health care providers, with injury profiles that may not align with traditional trauma paradigms. Standard physical assessments may fail to detect certain injuries. Long-term health outcomes following DEW exposure are largely unknown. There is an urgent need to develop and validate clinical guidelines and treatment protocols as DEWs become increasingly integrated into military operations.

Plain language summary

Directed energy weapons (DEWs), such as high-energy lasers and microwaves are increasingly used in modern warfare, but their health impacts are not well understood. This review explores the limited available research to understand how DEWs can injure the human body. Most known effects involve burns, eye damage, and internal injuries without visible signs. Unlike traditional weapons, DEWs may cause delayed symptoms or damage organs without leaving a mark on the skin. This study also highlights how little clinical guidance exists for treating these injuries, especially in combat settings. Medical personnel may need new diagnostic and treatment approaches to manage such cases. The article emphasizes the need for better awareness, protective equipment, and research to keep pace with the growing use of DEWs on the battlefield.

Open access: https://pmc.ncbi.nlm.nih.gov/articles/PMC13293093/

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**Corrigendum to “Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies, a systematic review”**

Mevissen M, Ducray A, Ward JM, Kopp-Schneider A, McNamee JP, Wood AW, Rivero TM, Straif K. Corrigendum to “Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies, a systematic review” [Environ. Int. 199 (2025). Environment International, 2026. doi: 10.1016/j.envint.2026.110368.

Abstract

Background More than ten years ago, the World Health Organization's (WHO) International Agency for Research on Cancer (IARC) published a monograph concluding there was limited evidence in experimental animals for carcinogenicity of Radio Frequency Electromagnetic Field (RF EMF).

Objective The objective of this review was to systematically evaluate the effects of RF EMF exposure on cancer in experimental animals.

Methods Eligibility criteria: Based on pre-established Populations, Exposures, Comparators, Outcomes, and Study Type (PECOS) criteria, studies in experimental animals of the following study types were included: chronic cancer bioassays, initiation-(co-)promotion studies, and studies with tumor-prone animals. Information sources: MEDLINE (PubMed), Science Citation Index Expanded and Emerging Sources Citation Index (Web of Science), and the EMF Portal. Data abstraction and synthesis: Data are publicly available online as interactive visuals with downloadable metadata. We adapted the risk-of-bias (RoB) tool developed by Office of Health Assessment and Translation (OHAT) to include considerations pertinent to the evaluation of RF EMF exposure and cancer bioassays. Study sensitivity was assessed with a tool adopted from the Report on Carcinogens (RoC). We synthesized studies using a narrative approach. Effect size was calculated as the 1% Bayesian Average benchmark dose (BMD) of a respective study when dose response or a trend was identified (see Supplementary Data 3). Evidence Assessment: Certainty of the evidence (CoE) was assessed using the Grading of Recommendations, Assessment, Developing and Evaluations (GRADE) approach, as refined by OHAT. Evidence from chronic cancer bioassays was considered the most directly applicable to evaluation of carcinogenicity.

Results We included 51 studies with 10 chronic bioassays No studies were excluded based on risk of bias concerns. Studies were not considered suitable for meta-analysis due to heterogeneity in study design, species, strain, sex, exposure characteristics, and cancer outcome. No or minimal evidence of RF EMF exposure-related cancer outcomes was found in most systems or organs in any study (these included gastrointestinal/digestive, kidney, mammary gland, urinary, endocrine, musculoskeletal, reproductive, and auditory). For lymphoma (17 studies), with 5 chronic bioassays (2,186 mice, 2,500 rats) inconsistency between two chronic bioassays was not plausibly explainable, and the CoE for lymphoma was rated 'moderate'. For brain tumors (20 studies), including 5 chronic bioassays (2,575 mice, 8,840 rats), an increase in glial cell-derived neoplasms was reported in two chronic bioassays in male rats. The CoE for an increased risk in glioma was judged as high. The BMD analysis was statistically significant for only one study, and the BMD was 4.25 (95% CI 2.70, 10.24). For neoplasms of the heart (3 chronic bioassays), 3 studies were performed in rats (~4,304 animals), and 1 in mice (~1,386 animals). Based on 2 bioassays, statistically significant increases in malignant schwannomas were judged as high CoE for an increase in heart schwannomas in male rats. The BMDs from the two positive studies were 1.92 (95%CI 0.71, 4.145) and 0.102 (95%CI 0.056, 0.244), respectively. Ten studies reported neoplasms in the adrenal gland (5 chronic bioassays). The CoE for an increased risk in pheochromocytoma was judged as moderate. None of these findings were dose-dependent when compared to the sham controls. Fourteen studies investigated tumors of the liver with 5 of these being chronic bioassays. The CoE was evaluated as moderate for hepatoblastomas. For neoplasms of the lung (5 chronic bioassays), 4 studies were conducted in rats (~2,176 animals) and 9 studies in mice (~4,171 animals). In one chronic bioassay, a statistically significant positive trend was reported for bronchio-alveolar adenoma or

carcinoma (combined), which was rated as moderate CoE for an increase in lung neoplasms with some evidence from 2 initiation-(co-)promotion studies.

Discussion  Meta-analysis was considered inappropriate due to the heterogeneity in study methods. The GRADE/OHAT CoE framework has not been frequently applied to animal studies and experience to date suggests refinements are needed. We deferred to standard methods in environmental health where CoE is framed in the context of strength of the evidence providing positive support for carcinogenicity. High CoE can be interpreted as the true effect is highly likely to be reflected in the apparent relationship. Moderate CoE indicates the true effect may be reflected in the apparent relationship. Cancer bioassays conducted in experimental animals are commonly used to identify potential human carcinogens. We note that the two tumor types with high CoE in animals in this systematic review are the same as those identified with limited evidence in humans by the IARC Working Group. However, even in cases where the animal evidence demonstrates high CoE, the extrapolation of risk from cancer bioassays to humans is particularly complex for RF EMF. Without a better understanding of the mechanism of the carcinogenicity of RF-EMF, the choice of exposure metric for risk extrapolation (whole body versus localized), intensity or cumulative exposure whether or not a monotonic dose response holds for carcinogenic effects, and whether SAR is the appropriate dose metric for adverse effects induced by RF-EMF may be critical.

Other  This review was partially funded by the WHO radioprotection programme. The protocol for this review was registered in Prospero reg. no. CRD42021265563 and published in Environment International 2022 (Mevissen et al., 2022)

Highlights

- Systematic review of experimental animal studies on RF EMF on cancer.
- Chronic bioassays were considered most applicable to evaluation of carcinogenicity.
- Studies were not considered suitable for meta-analysis due to heterogeneity.
- No evidence of RF EMF exposure-related cancer outcomes was found in most systems.
- High Certainty of Evidence: RF EMF increased heart schwannomas and glial-cell tumors.

Excerpts

We stress that none of these issues has produced any significant change in the outcomes or in the interpretation or the conclusions of this systematic review....

Final conclusions

The findings of this systematic review indicate that there is evidence that RF EMF exposure increases the incidence of cancer in experimental animals with the CoE being strongest for malignant heart schwannomas and gliomas.

Despite the high level of certainty that evidence of carcinogenicity in experimental animals may predict a carcinogenic hazard to humans, extrapolation of risk from cancer bioassays to humans is particularly complex for RF EMF. Without an understanding of the mechanism of the carcinogenicity of RF-EMF the choice of exposure metric for risk extrapolation (whole body versus localized), intensity or cumulative

exposure whether or not a monotonic dose response holds for carcino genic effects, and whether SAR is the appropriate dose metric for adverse effects induced by RF-EMF may be critical.

Besides the integration of the sensitivity domain adopted from the RoC, more work is needed to tailor the GRADE approach to assessing the CoE from animal cancer bioassays designed to identifying risks of environmental agents.

Open access: https://www.sciencedirect.com/science/article/pii/S0160412026003260

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**Non-ionizing radiation and cancer: A review on current evidence, mechanistic insights, and public health implications**

Agrahari M, Gupta S, Thakur G, Tanwar S, Gautam R, Arora T. Non-ionizing radiation and cancer: A review on current evidence, mechanistic insights, and public health implications. Biochem Biophys Rep. 2026 Jul 7;47:102705. doi: 10.1016/j.bbrep.2026.102705.

Abstract

Non-ionizing radiation (NIR) generated from the high power transmission lines, broadcasting antennas and cellular phones represent one of the widespread environmental exposures which can induce carcinogenic outcome. Although NIR lacks sufficient energy to dislodge the electrons for ionization, an indirect mechanism has been proposed to be involved in adverse outcomes under certain exposure conditions. Consequently, radiofrequency electromagnetic field (RF-EMF) exposure remains a consistent scientific and public health concern regarding its possible role in cancer manifestation. This review aims to analyze the findings of RF-EMF exposure and carcinogenicity by integrating epidemiological studies and experimental findings to demonstrate its potential function in cancer manifestation.The available evidence is not sufficient to conclude that RF-EMF exposure is a direct-acting genotoxic carcinogen or cancer initiator. However, laboratory studies have indicated that long-term exposure to non-thermal RF-EMF can cause oxidative stress, genomic instability, epigenetic alterations, ion transport disruption and dysregulation of cell-signaling pathways. These biological effects may contribute to the promotion and progression stages of carcinogenesis, but are not directly responsible for tumor/cancer initiation. The epidemiological evidence significantly varies between extremely low-frequency magnetic fields (ELF-MF) and radiofrequency electromagnetic fields (RF-EMF). Although ELF-MF exposure has demonstrated a more reliable association with childhood leukemia, the data connecting RF-EMF exposure to cancer is less consistent. Studies with the larger sample size and increased exposure duration are needed to strongly corroborate its involvement in cancer development.

Highlights

• Non-ionizing radiation (RF-EMF) does not directly cause cancer but may indirectly influence carcinogenesis through biological pathways.
• Exposure to RF-EMF can induce oxidative stress, genomic instability, and altered cell signaling mechanisms.
• Epidemiological evidence on cancer risk (e.g., brain tumors, leukemia) remains inconsistent and inconclusive.

• Long-term and high-exposure conditions may contribute to cancer progression, further large scale research is needed.

Conclusion from current evidence

Despite the long-term investigations, the association between the non-ionizing electromagnetic field and related carcinogenicity remained ambiguous. Major inconsistency lies in its methodological limitations as epidemiological studies reported variable outcomes due to EMF exposure. Available studies indicate that the observed biological effects are not consistently correlated with exposure frequency, duration, or power density. Based on the evidence reviewed here, RF-EMF exposure is currently not established as a complete or direct-acting genotoxic carcinogen that can initiate cancer by DNA damage. However, experimental studies suggest that long term exposure to RF-EMF can cause oxidative stress, genomic instability and altered gene expression, cellular signalling which may be involved in tumour promotion and progression. Thus RF-EMF can be more appropriately considered as a potential non-genotoxic modulator of carcinogenesis rather than a direct cancer initiator. However, the current evidence is still not enough to prove a definite cause effect relationship.

Moreover the existing evidence must be analysed independently for ELF-MF and RF-EMF exposures. Although ELF-MF exposure demonstrates a relatively consistent association with childhood leukemia, evidence supporting a carcinogenic role of RF-EMF remains limited and inconclusive. Further study with the larger sample size and precise exposure assessment is needed to validate the results with more accuracy and to suggest its involvement in cancer development.

Open access: https://www.sciencedirect.com/science/article/pii/S2405580826002657

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**Environmental radiofrequency exposure and genotoxic biomarkers in schoolchildren: a cross-sectional analysis**

Chokeli R, Yuswir NS, Ho YB, Chiang HL, How V. Environmental radiofrequency exposure and genotoxic biomarkers in schoolchildren: a cross-sectional analysis. Sci Rep. 2026 Jul 9. doi: 10.1038/s41598-026-60822-1.

Abstract

Environmental exposure to radiofrequency (RF) radiation from mobile phone base stations (MPBS) has raised concerns regarding potential biological effects, particularly in children. This cross-sectional study examined the associations between ambient RF exposure and micronuclei (MN) frequency, a biomarker of genomic instability, among 200 primary schoolchildren. Environmental RF power density (S, μW/cm²) was measured at eight schools located at varying distances from MPBS, and buccal mucosa samples were analyzed for MN frequency. Exploratory analyses showed that RF radiation levels were inversely correlated with distance from MPBS ($r = -0.740$, $p < 0.001$), while MN frequency was positively correlated with measured RF levels ($r = 0.850$, $p < 0.001$). Primary inferential analyses were performed using linear mixed-effects models with school included as a random intercept to account for clustering, adjusting for demographic, lifestyle, and environmental covariates. Higher RF power density and shorter distance from MPBS remained statistically associated with higher MN frequency, with consistent findings observed in sensitivity analyses using distance from MPBS as an alternative exposure

parameter. All measured RF levels were below current international public exposure guidelines. These findings suggest that variation in ambient RF exposure in school environments may be associated with MN frequency in children. Given the cross-sectional design and school-level exposure assessment, the results should be interpreted as exploratory and hypothesis-generating.

Excerpts

"After adjustment, MN frequency was highest among children attending schools located within 0–100 m of mobile phone base stations (MPBS) and lowest in the furthest distance category (301–400 m), with statistically significant differences observed for Categories I–III relative to the reference group [301-400 m]. These findings were consistent with the main mixed-effects model results (Table 5), supporting the robustness of the observed distance-related gradient...."

"This study suggests that proximity to MPBS may be associated with higher environmental RF exposure and increased MN frequency among primary school children under real-world conditions. Although the observed effect sizes were modest, the findings contribute to the growing evidence base examining potential biological responses to chronic, low-level RF exposure.

From an environmental health and management perspective, these results highlight the importance of integrating RF exposure considerations into urban planning, zoning policy, and risk governance. Precautionary siting strategies, such as maintaining appropriate buffer distance between MPBS and sensitive land uses like schools, may represent a prudent approach to manage long-term uncertainty. Incorporating RF exposure considerations into environmental impact assessments and school infrastructure planning could further support proactive management of cumulative exposures.

Ultimately, RF exposure should be addressed not solely as a biomedical issue, but as part of a broader framework of sustainable urban and environmental management. By aligning precautionary measures with transparent governance and community engagement, policymakers can balance technological advancement with the protection of public health, particularly for vulnerable populations such as children. Future longitudinal studies with personal exposure assessment will be critical to strengthen causal inference, but evidence-informed precautionary strategies shall be implemented in parallel."

Open access: https://www.nature.com/articles/s41598-026-60822-1

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**Influence of radiofrequency electromagnetic radiation on spermatogenesis and sperm function in rodent models: A systematic review**

Naderi N, Tavalaee M, Far PH, Mokhtari A, Nasr-Esfahani MH. Influence of radiofrequency electromagnetic radiation on spermatogenesis and sperm function in rodent models: A systematic review. Reprod Toxicol. 2026 Jun 25;144:109300. doi: 10.1016/j.reprotox.2026.109300.

Abstract

Infertility is increasing worldwide and has been associated with several lifestyle and environmental exposures, including radiofrequency electromagnetic radiation (RF-EMR). Because digital devices are often carried close to the body, possible effects on male reproduction remain a public health concern.

This systematic review addressed the PECO question: how does RF-EMR exposure affect male fertility in rodent models? Studies published up to December 2025 were searched in PubMed, Google Scholar, SpringerLink, ScienceDirect, and Scopus (PROSPERO: CRD42023417536). From 4220 records, screening and updated searches yielded 88 eligible studies. Methodological quality and risk of bias were assessed using SYRCLE's Risk of Bias tool. Included studies used multiple rat and mouse strains exposed to 800-24,000 MHz RF-EMR, with reported specific absorption rates of 0.014-34 W/kg. Exposure durations varied and were mainly subchronic. Evaluated outcomes included sperm parameters, oxidative stress biomarkers, lipid peroxidation, DNA damage, apoptosis, testicular histopathology, and hormonal indices. Oxidative and reproductive alterations were reported in subsets of studies; however, findings were heterogeneous and limited by uncertainties in allocation, housing, blinding, dosimetry, and outcome assessment. Current evidence suggests biologically plausible signals but does not support a uniform causal interpretation. Standardized, well-controlled studies are needed with comprehensive, clearly defined reproductive and fertility endpoints.

Highlights

- Radiofrequency electromagnetic radiation (RF-EMR) exposure reduces sperm quality and disrupts spermatogenesis in rodents.
- Oxidative stress is the primary mechanism of reproductive damage.
- RF-EMR increases DNA fragmentation and apoptosis in testicular cells.
- Chronic exposure alters reproductive hormones and steroidogenesis.
- Study variability in exposure methods limits definitive conclusions.

https://pubmed.ncbi.nlm.nih.gov/42349729/

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**Biological Effects of High-Frequency Electromagnetic Fields on CNS Function and Neuroimmune Responses: A Systematic Review of In Vitro and In Vivo Experimental Studies**

Fang S, Chen S. Biological Effects of High-Frequency Electromagnetic Fields on CNS Function and Neuroimmune Responses: A Systematic Review of In Vitro and In Vivo Experimental Studies. *Neurotox Res* **44**, 32 (2026). https://doi.org/10.1007/s12640-026-00810-5.

Abstract

Background the deployment of fifth-generation (5G) wireless telecommunications infrastructure, incorporating millimeter-wave (mmWave, 24–100 GHz) and sub-6 GHz frequencies, has renewed scientific and public health interest in the potential neurobiological effects of radiofrequency electromagnetic fields (RF-EMF). While extensive research has examined lower-frequency RF-EMF from 2G/3G/4G technologies, the specific effects of mmWave frequencies on CNS cellular biology—including microglial polarization and intracellular calcium signaling—remain less characterized. This systematic review evaluates experimental evidence from in vitro and in vivo studies on the effects of high-frequency EMF (300 MHz–300 GHz) on neuroimmune responses, microglial function, CNS calcium homeostasis, and related outcomes. Methods PubMed, EMBASE, Web of Science, and the EMF-Portal were searched from inception to January 2026 following PRISMA 2020 guidelines. Experimental (in vitro

and animal) studies reporting CNS-relevant outcomes after high-frequency RF-EMF exposure were eligible. Exposure must have been within the 300 MHz to 300 GHz range. Quality assessment used adapted OHAT risk-of-bias criteria. A narrative synthesis was conducted; quantitative pooling was performed where three or more studies reported the same outcome. Results forty-one studies met inclusion criteria (see PRISMA Flow Diagram, Fig. 1): 7 in vitro (cell culture), 29 in vivo (rodent model), and 5 reviews/meta-analyses. The detailed characteristics of all included studies are summarized in Table 1. At specific absorption rate (SAR) levels at or below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) general public exposure guidelines (2 W/kg averaged over 10 g), the majority of studies (27/41, 66%) found no statistically significant effects on neuroinflammatory markers, microglial morphology, or calcium signaling. Eleven studies (27%) reported transient, low-magnitude increases in intracellular $Ca^{2+}$ or pro-inflammatory cytokine expression at exposures near or exceeding guideline limits; these effects were not consistently reproducible across independent laboratories. Three studies (7%) reported effects below guideline thresholds that may warrant further investigation. No study identified neuropathological changes (neuronal death, axonal injury) attributable to RF-EMF at guideline-compliant exposures. Conclusions current experimental evidence does not establish that high-frequency RF-EMF at guideline-compliant exposure levels produces significant adverse effects on microglial polarization, CNS calcium homeostasis, or neuroinflammatory responses. Methodological heterogeneity, inadequate dosimetry, and limited independent replication constrain confidence in both positive and negative findings. Standardized, rigorously controlled experimental studies are needed, particularly for mmWave frequencies (> 6 GHz) where data are sparse. Our findings support the current scientific consensus that high-frequency RF-EMF below regulatory limits does not pose a clearly established neurobiological hazard.

## Plain Language Summary

The rollout of 5G wireless networks uses higher radio frequencies than previous mobile technologies, including millimeter waves that have never been widely used in telecommunications before. Some members of the public are concerned that these frequencies might harm the brain. This review examined published laboratory studies in which cells or animals were exposed to these high-frequency radio waves to see whether they affected brain immune cells (called microglia) or the calcium levels inside brain cells. We found 41 studies, most of which showed no significant effects at the exposure levels allowed by safety guidelines. A minority of studies found small, temporary changes in cellular calcium or inflammation markers, mostly at higher exposures above regulatory limits. No study found evidence of actual brain cell damage from compliant exposures. The current evidence does not establish that these radio frequencies are harmful to the brain at the levels people encounter in everyday life. However, millimeter-wave frequencies have been less studied than older technologies, and more rigorous, standardized experiments are needed to fully characterise their biological effects before next-generation telecommunications infrastructure is widely deployed.

## Search Results and Study Characteristics

Searches yielded 6,241 records after deduplication. Following screening, 41 experimental studies met inclusion criteria: 24 in vitro studies using primary cortical neurons (*n* = 11), primary microglia (*n* = 7), astrocytes (*n* = 3), or neural cell lines (*n* = 3); and 17 in vivo rodent studies (rats *n* = 11, mice *n* = 6) (Table 1). Frequencies studied ranged from 450 MHz to 95 GHz, with the majority examining frequencies below 6 GHz (*n* = 31, 76%). mmWave frequencies (> 6 GHz) were studied in 10 studies, of which only 4

were published after 2020. Study quality was rated as low risk of bias in 14 studies (34%), moderate in 20 (49%), and high in 7 (17%) (see complete OHAT Risk of Bias assessment in Table 2). The presence or absence of a positive control was explicitly evaluated as a quality indicator.

Limitations of the Review

This review is limited by the heterogeneity of exposure parameters, cell/animal models, and outcome measures, which precluded comprehensive meta-analysis. The translation from experimental model findings to human health implications is inherently uncertain. Publication bias likely inflates positive findings in the literature. The review focused on experimental studies; epidemiological and human experimental data are addressed by complementary WHO systematic reviews (Bosch-Capblanch et al. 2024; Roosli et al. 2023; Pophof et al. 2024; Karipidis et al. 2025) and the IARC monograph (IARC 2013).

Conclusions

The available experimental evidence from in vitro and in vivo studies does not establish that high-frequency RF-EMF at ICNIRP guideline-compliant levels produces significant adverse effects on microglial polarization, CNS calcium homeostasis, or neuroinflammatory responses. Positive findings in the literature are predominantly associated with above-guideline exposures, inadequate thermal controls, or have not been independently replicated. A critical research gap exists for mmWave frequencies (> 6 GHz), where data quality and quantity are insufficient to reach firm conclusions. Continued, methodologically rigorous investigation of CNS bioeffects of next-generation wireless frequencies is warranted to maintain a robust evidence base for regulatory decision-making and public health guidance.

Clinical Implications

Current clinical and public health guidance on RF-EMF exposure is supported by the available experimental evidence. Clinicians treating patients with EMF-related health concerns (electromagnetic hypersensitivity) should be aware that experimental evidence does not support a causal relationship between guideline-compliant RF-EMF exposure and CNS neuroinflammatory disease. Patient education should be based on the best available scientific evidence, without dismissing subjective symptoms, while accurately conveying the lack of established biological mechanisms at regulatory-compliant exposures.

https://link.springer.com/article/10.1007/s12640-026-00810-5

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**A Narrative Review on the Influence of Electromagnetic Fields Below 100 kHz on the Endocrine System**

Tojza PM, Redlarski G, Litzbarski LS, Czaplinski M. A Narrative Review on the Influence of Electromagnetic Fields Below 100 kHz on the Endocrine System. *Applied Sciences*. 2026; 16(10):4910. https://doi.org/10.3390/app16104910

Featured Application

While our article is a review, it brings many important ideas for further consideration. Due to the ubiquity of low-frequency electromagnetic fields in everyday human environments, exposure to them is

largely unavoidable. Their biological effects are still not fully understood. This work analyzes the relationship between low-frequency electromagnetic fields and the human endocrine system. As the endocrine system is responsible for regulating and maintaining the human body, its potential dysregulation may result in significant adverse health effects. This manuscript summarizes the existing studies addressing this topic and highlights several promising directions for future research.

Abstract

Background: Extremely low-frequency electromagnetic fields (ELF-EMFs), generated mainly by power infrastructure and household devices, have raised scientific interest due to their potential impact on the endocrine system. Animal research consistently shows effects on melatonin secretion, stress hormone levels, thyroid activity, and reproductive function—largely mediated by oxidative stress and calcium ion imbalance. In contrast, human studies remain inconsistent, often hindered by methodological limitations and insufficient exposure characterization.

Objective: This review synthesizes experimental and epidemiological studies examining low-frequency electromagnetic field exposure (≤100 kHz) and its influence on hormonal regulation.

Methods: A bibliometric analysis highlights focused interest on specific endocrine targets, particularly the pineal gland. Importantly, many experimental studies use field strengths above those found near high-voltage power lines, limiting direct applicability.

Conclusions: While a definitive causal link has not been established, the widespread exposure to low-frequency electromagnetic fields justifies precautionary considerations. Several important research gaps remain, many of which are identified in this review. The topic of low-frequency electromagnetic field effects on the endocrine system requires more rigorous, long-term human studies with accurate exposure assessment.

Conclusions

The scientific literature on the influence of electromagnetic fields below 100 kHz on the endocrine system reveals a complex and still evolving area of research. Preclinical studies, including both in vivo animal models and in vitro cellular experiments, have reported a range of biological responses potentially associated with ELF-EMF exposure. These observations include reported alterations in melatonin secretion from the pineal gland, changes in the hypothalamic–pituitary–adrenal (HPA) axis and stress hormone levels, modifications in thyroid hormone production and gland morphology, as well as effects on gonadal function and reproductive hormones. Several mechanisms have been proposed to explain these observations, including oxidative stress mediated by reactive oxygen species generation and ion channel modulation, particularly involving calcium homeostasis. However, the exact biological relevance and reproducibility of these mechanisms remain under discussion. The concept of non-linear dose–response relationships, including hormesis, further complicates the interpretation of the available data, suggesting that biological responses may depend strongly on exposure parameters and experimental conditions.

Despite findings reported in experimental studies, human epidemiological research presents a substantially less consistent picture. The scarcity of reproducible human data, together with methodological limitations such as difficulties in long-term exposure assessment, control of confounding variables, and ethical constraints associated with human experimentation, creates a significant

translational gap between experimental and clinical observations. Consequently, current evidence does not allow definitive conclusions regarding causal relationships between low-frequency EMF exposure and endocrine-related adverse health effects in humans.

It should also be emphasized that limited or inconsistent evidence does not necessarily imply the absence of biological interaction, but may partly reflect the methodological complexity of exposimetric research. The historical reclassification of substances such as Coffee by the IARC illustrates how scientific interpretation may evolve as methodological quality and exposure characterization improve. Therefore, further progress in this field will likely depend not only on increasing the number of studies but also on improving the quality, reproducibility, and standardization of exposure assessment methods.

The current scientific uncertainty poses challenges for both public health interpretation and regulatory evaluation. While public concern regarding ELF-EMF exposure persists, official organizations such as ICNIRP and IEEE generally conclude that consistent adverse health effects have not been conclusively demonstrated at exposure levels below currently established limits. The classification of extremely low-frequency magnetic fields as “possibly carcinogenic to humans” by the IARC reflects the existence of limited evidence and the need for continued scientific investigation rather than confirmation of a causal relationship. To reduce existing uncertainties, future research would benefit from more rigorous and harmonized methodologies, including improved personal exposure monitoring, well-designed longitudinal studies, and integration of modern molecular and multi-omics approaches capable of detecting subtle biological responses. Additional investigation of non-linear dose–response relationships and exposure-specific effects may also contribute to a better understanding of the observed phenomena. Ultimately, continued high-quality research is necessary to further clarify the possible influence of ELF-EMFs on the endocrine system and to support evidence-based risk assessment.

Open access: https://www.mdpi.com/2076-3417/16/10/4910

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**Determinants of radiofrequency electromagnetic fields emitted by smartphones in French cellular telephony networks**

Fontaine M, Guida F, Moissonnier M, Beranger R, Lagroye I, Orlacchio R, Laplanche A, Dejardin O, Conil E, Huss A, Mazloum T, Wiart J, Danjou A, Schüz J, Bories S, Deltour I. Determinants of radiofrequency electromagnetic fields emitted by smartphones in French cellular telephony networks. Environ Res. 2026 Jun 11;305(Pt 2):125023. doi: 10.1016/j.envres.2026.125023.

Abstract

Smartphones are a major source of radiofrequency electromagnetic field exposure, yet real-life determinants of uplink emissions remain poorly characterised. We conducted the first epidemiological study of smartphone cellular network uplink emissions in a general population sample, recruiting 167 volunteers across three French cities in 2022-2023. Emissions were measured quasi-continuously for a week during everyday activities using the novel DEVIN exposimeter, while the XMobiSensePlus application simultaneously recorded sensor values and smartphone activities in the background. Determinants of UL emission occurrence and level were analysed using logistic and linear regressions. Over 8001 h analysed, voice calls were recorded in 2.4% of time and data uploads in 81.3%. Voice calls were associated to emission occurrence (OR = 7.09, 95% CI: 5.96-8.43). In fully adjusted models,

emission levels were associated to calls (+9.16 dBm, CI: 7.15; 11.16), and to Wi-Fi connection with substantially lower cellular emissions outside call periods (-15.37 dBm, CI: -17.28, -13.46). Cellular upload rates differentially increased emissions depending on Wi-Fi connection, while received signal quality differentially reduced emissions depending on call status. Legacy technologies (2G, 3G) were associated with higher emissions than 4G. Results varied across centers. Smartphone brand, operator, and Android version showed no independent association with emitted power after System-on-Chip adjustment. These findings demonstrate that real-life smartphone radiofrequency electromagnetic cellular emissions are shaped by a complex interplay of usage patterns, network conditions, and device characteristics.

Highlights

- French volunteers used novel radiofrequency electromagnetic fields exposimeter DEVIN.
- Calls and cellular data uploads: higher smartphone's cellular RF-EMF emissions.
- Wi-Fi network connection: lower cellular emissions, except during calls.
- Poor received signal quality: higher emissions, except during Wi-Fi connection.
- Older telecommunication protocols (2G/3G): higher smartphone cellular emissions.

Implications

Our main results, highlighting the association between emitted power and calls, Wi-Fi connection, received signal quality and data upload, are in line with previous studies carried out under different conditions (Roser et al., 2015; Lee et al., 2021; Brzozek et al., 2021). They are also in line with the current recommendations to favour Wi-Fi connections when available and 4G in order to reduce individuals' exposures to emissions over the cellular network. Overall, this study showed that cellular RF-EMF emissions from smartphones depend on different usage patterns and network conditions rather than on call duration alone. These findings are relevant for epidemiological research by informing exposure assessment methodologies and highlighting the need for real life monitoring of exposures in the context of evolving mobile communication technologies.

https://pubmed.ncbi.nlm.nih.gov/42276343/

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**Urban Radio-Frequency Electromagnetic Field Exposure in New York City**

Thielens A, Salvatore Davi S, Hema S, Toledo-Crow R. Urban Radio-Frequency Electromagnetic Field Exposure in New York City. Environmental Research. 2026. doi: 10.1016/j.envres.2026.125040.

**Abstract**

This study investigates Radio Frequency Electromagnetic Field (RF-EMF) exposure across New York City's five boroughs. The RF-EMF exposure was measured in 39 bands across the 88 MHz to 5.925 GHz frequency range using an exposimeter fixed in a backpack that was worn during walks along 38 predetermined paths in various representative urban environments of the city from September 2024 to May 2025.

We calculated the summary statistics (minimum, p25, arithmetic mean, geometric mean, median, p25, p50, p75, p90, standard deviation) in units of electric field strength (V/m) and compared RF-EMF

exposure quantitatively across urban environment type: commercial, residential, greenery, train underground, water ferry, indoor; across the five boroughs of the City: Manhattan, Brooklyn, Queens, Bronx, and Staten Island; and across six technology categories: radio and TV broadcast, cellular downlink (DL), cellular uplink (UL), WiFi (WLAN), Time Division Duplex (TDD), and Total Exposure. We also analyzed whether population density and foot traffic in each area correlate with RF-EMF exposure.

A mean total RF-EMF exposure of 0.97 (+/- 0.88 V/m) was measured in NYC. We found that cellular downlink is the dominant contributor to mean environmental exposure, accounting for 45% to 55% of the total exposure in each borough. We found a moderate positive correlation ($\rho = 0.5$, p-value < 0.05) between exposure and foot traffic, and a weak or negligible, but statistically significant, positive correlation ($\rho = 0.1$, p-value < 0.05) between exposure and domiciled population density.

The study provides a detailed assessment of the RF-EMF exposure levels in various urban environments offering a clearer understanding of the extent of exposure in a densely populated city like New York where wireless communication networks are continuously expanding. These results are important for policymakers when establishing RF exposure guidelines for the population of NYC and other urban areas in North America.

**Highlights**

- Measurements of RF-EMF exposure across New York City's five boroughs
- RF exposure is moderately and positively correlated to pedestrian foot traffic
- RF exposure is weakly correlated to residential population density
- Cellular downlink dominates environmental RF-EMF exposure in NYC
- RF exposure measurements are below ICNIRP and FCC reference levels

**Excerpts**

... in North America there have been, up to now, only four studies that measure this exposure: one in Los Angeles (Sagar et al., 2018), one in Columbia, South Carolina (Koppel and Hardell, 2022), and two that only consider Wireless Fidelity (WiFi) in Mexico City (Ramirez-Vazquez et al., 2023a, 2021). When compared with approximately 100 studies conducted in Europe to quantify this exposure (Jalilian et al., 2019), it is clear that we are currently lacking measurement data to quantify personal exposure to RF-EMFs in other major metropolitan areas in the U.S....

Micro-environmental personal RF-EMF exposure assessments were conducted using an ExpoM-RF4™ exposimeter (Fields at Work GmbH, Zürich, Switzerland) that measures electric field intensity in V/m, in 39 user-configurable frequency bands covering the 88 MHz - 5.925 GHz frequency range as depicted in Fig. S1 (TOP) and Table S1....

We selected 38 different urban environments in New York City, which are listed in Table S2 of the Supplementary Materials. Twenty-six were outdoor urban environments located in the five boroughs. Additionally, there were four indoor paths, five train measurements, and three water ferry routes measured, covering important public transport hubs and modes of transportation in NYC....

All data are available on our repository (github.com/NextGen-Environmental-Sensor-Lab/Urban-RF-EMF)...

Comparing our results to those reported in a systematic review of multiple cities (Ramirez-Vazquez 2023b, Table 3) would have New York City in 10th place of total ranked mean exposures (0.97 V/m across all 5 boroughs). However, we measured a maximum exposure value of 13.3 V/m in Wall Street (Manhattan in the Financial District) which is higher than the maximum reported in the cities of the systematic review....

Lastly, our indoor measured total mean values of 0.53 V/m (Table 4), although higher, are also within range of other reported values of 0.42 V/m by Kiouvrekis et al. (2020) and Panagiotakopoulos et al. (2023), and of 0.43 V/m by Ramirez-Vazquez et al. (2021)....

Finally, we did not measure RF-EMF exposure in the FR2 (24-28 GHz) frequency band, even though this band is licensed and in use in NYC. While we expect this band to mainly contribute to auto-induced and not environmental RF-EMF exposure, we do aim at quantifying it in our next study....

**Conclusion**

This study revealed that the mean total environmental RF-EMF exposure in New York City is 0.97 V/m across all five boroughs, which is within range of similar exposures in other technologically developed cities and well below the ICNIRP and FCC safety reference thresholds.

We also found that there is a moderate and statistically significant positive correlation between exposure and foot traffic (pedestrian mobility) across all boroughs. A Spearman correlation analysis showed correlations of ?? with a p-value < 0.05.

We also looked at exposure and population density (residential) and found a weak to negligible yet statistically significant correlation in most boroughs, with the Spearman coefficients ranging between ??, with a p-value < 0.05.

These findings suggest that areas with a heavier human footprint coincide with higher RF-EMF emissions and that there is an increased demand and usage of mobile communication devices in these areas.

The summary statistics revealed that Commercial areas in the 5 boroughs exhibited the highest amount of total exposure (1.35 V/m). Manhattan measurements showed a higher mean total RMS E-field strength (1.42 V/m) than Brooklyn, Queens, Staten Island and the Bronx. Throughout all Boroughs, Downlink was found to be the highest contributor to RF-EMF exposure (47%).

Our future work will aim to measure personal exposure to RF sources operating above 6 GHz, which are sporadically present in NYC, and to perform a more detailed analysis of TDD exposure to separate the UL and DL components. Additionally we plan to conduct long term longitudinal measurements with stationary devices at select locations in the City to investigate the temporal nature of the exposure relative to time of day and season, similar to Iakovidis et al. (2025). Lastly, a future study could use our findings to incorporate foot traffic and population density in machine learning models for the estimation and prediction of RF-EMF exposure, for example through the creation of exposure maps.

Open access: https://www.sciencedirect.com/science/article/pii/S001393512601371X

Supplementary data: https://www.sciencedirect.com/science/article/pii/S001393512601371X#appsec1

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**Radiofrequency electromagnetic field effects on green roof ecosystems: An unexplored topic**

Czerwiński M, Virto LR, Vian A, Thielens A. Radiofrequency electromagnetic field effects on green roof ecosystems: An unexplored topic. Environmental Reviews. 9 June 2026. doi: 10.1139/er-2026-0053.

In recent decades, mobile communications technologies have been adopted at an unprecedented pace, leading to a rapid increase in the exposure of living organisms to artificial radiofrequency electromagnetic field (RF-EMF) emissions. This exposure is typically much higher on rooftops in dense urban areas where antennas are located, compared to ground level in those same areas. The recent deployment of wireless infrastructure on urban rooftops has coincided with the expansion of green roofs in cities. This indicates that RF exposure is a factor to consider in the planning and maintenance of green roofs. In this paper, we evaluate RF-EMF exposure levels on green roofs situated near base station antennas. Based on this evaluation, we predict potential responses at both the population and ecosystem levels to RF exposure. We conducted a structured two-stage literature review. In Stage 1, we performed a narrative synthesis of empirical RF-EMF measurements on urban rooftops, covering the 0.7–3.8 GHz frequency range. We searched IEEE Xplore, Web of Science, and Google, and retained 20 peer-reviewed and institutional publications containing original measurement data published from 2001 onward. In Stage 2, we conducted a thematic synthesis of published evidence on RF-EMF biological and ecological effects in plants and insects — the taxonomically dominant groups in green roof ecosystems. We searched Web of Science, PubMed, Google Scholar, and the EMF-Portal, retaining 34 studies that satisfied criteria for publication quality, precision of exposure characterization, and relevance of exposure conditions to those determined in Stage 1. The two stages are linked analytically: the exposure range identified in stage one defines the evidence boundary for the bioeffects synthesis in Stage 2. Our research yielded an entirely new ecological interpretation of the evidence on physiological RF-EMF effects in plants. It suggests that chronic stress signal induced by RF-EMF may cause reduced seed production and a shift in resource allocation towards clonal growth. This can lead to lower seedling recruitment and decreased genetic diversity, which may negatively impact the long-term resilience of a green roof ecosystem. There has been no empirical research or specific legislation addressing the issues discussed.

Open access: https://cdnsciencepub.com/doi/10.1139/er-2026-0053

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**Maximum Exposure of 5G Base Stations in the mmWave Band: The Impact of Multi-User MIMO and CSI-RS Ports**

Adda S, De Donno D, Franci D, Moresi F, Pasquino N, Pavoncello S. Maximum Exposure of 5G Base Stations in the mmWave Band: The Impact of Multi-User MIMO and CSI-RS Ports. *IEEE Transactions on Instrumentation and Measurement*, vol. 75, pp. 8004612-8004612, 2026, doi: 10.1109/TIM.2026.3690868.

Abstract

Multi-user (MU) multiple-input multiple-output (MIMO) operation at millimeter-wave (mmWave) frequencies enables 5G base stations (BSs) to simultaneously transmit to several users by forming multiple beams in parallel. This feature, while boosting capacity, modifies the exposure landscape compared to the conventional single-user (SU) mode, where resources are time-multiplexed. In this

work, we investigate how MU-MIMO operation affects maximum power extrapolation (MPE) procedures used to assess electromagnetic field (EMF) exposure in accordance with IEC 62232. Building on the experimental framework and measurement methodologies validated for SU-MIMO in a recently published work by the authors, we extend the analysis to signals configured with MU-MIMO transmission and variable numbers of channel state information reference signal (CSI-RS) antenna ports. Results show that concurrent user scheduling may reduce the received power per beam by several dB, leading to a systematic underestimation of maximum exposure when MPE procedures are applied without knowledge of the active mode. Furthermore, the number of CSI-RS ports influences the measured levels, resulting in reductions of up to 12 dB. These findings underscore the need to incorporate MU-MIMO and CSI-RS port configurations into updated exposure assessment standards.

Conclusion

This work extends previous SU MIMO studies by the authors by experimentally quantifying how MU MIMO scheduling and CSI-RS port configuration affect maximum exposure at a 5G mmWave site. SU cases, redesigned with close CPE placements, served as baseline references for evaluating deviations introduced by MU operation. Results showed that MU scheduling led to the underestimation of maximum exposure by 6 dB, while reducing CSI-RS ports from 8 to 2 decreased measured power by 12 dB in SU mode and 6 dB in MU mode. Since the variation depends on the MIMO operating mode and the position of users relative to the measurement point only, while it does not depend on the relative position of the latter to the source of the signal, we can anticipate that the measured variations will be observed over the entire cell edge.

These findings demonstrate that both scheduler behavior and CSI-RS configuration can bias exposure measurements, despite being unaccounted for in the current IEC 62232 framework. Future revisions of the standard should incorporate these factors to ensure accurate and reproducible EMF assessment in real-world deployments of 5G mmWave networks. Future research will be directed toward defining consistent measurement procedures to compensate for this bias, potentially through the introduction of specific statistical correction factors or by leveraging prolonged observation intervals to capture transient windows where the scheduler naturally reverts to an SU-like behavior, ensuring a conservative worst case assessment.

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https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11527038&isnumber=11329398

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**5G Specters: Three Disclosures from the Otherworld**

Mommersteeg B, Schulte-Römer N. 5G Specters: Three Disclosures from the Otherworld. Social Analysis. 2026; 69 (4): 23-48. doi: 10.3167/sa.2025.690402.

Abstract

This article attends to spectral experiences surrounding 5G infrastructure and risks associated with electromagnetic fields through ethnographic fieldwork in Germany and the UK, exploring them in their specificity as a spectral manner of being. Drawing on Jacques Derrida's figuring of the specter as a ‘structural opening’ and Isabelle Stengers's concept of ‘disclosure’, we trace three spectral moments—

attunements to an equivocal spectrum, dis/possessed bodies, and a ghosted public—that disturb modern ontologies and epistemologies, disclosing an Otherworld within. The article, moreover, contributes to anthropological discussions on unstable ontologies in the context of climate change. It argues that spectrality is a useful analytic for tending to ontological uncertainties, sensitizing us to exposures that are imperceptible within the logics of technoscientific knowledge.

Excerpts

Individuals with EHS not only have 'impossible' bodies, but also seem to be impossible to represent politically in 'technical democracies' (Callon et al. 2011). In public debates, these 'ontological disturbers' and their support networks are often quickly associated with conspiracy (Hanotiaux 2023). As a result, EU citizens who oppose wireless technology not only are a minority, but also are marginalized as they fight for what they consider to be 'safe connections' .(ESC 2024)....

None of the issues that the activists represent had made it onto the agenda of the 5G stakeholder conference. During coffee breaks, we tried to initiate conversations about the critics and their concerns. One public official said she had heard of concerns that EMFs might have negative effects on bees, but spoke as if this was entirely disconnected from her job in the wireless sector. A European Commission officer openly suggested that the 5G stakeholders in the room were not interested in addressing conflict-laden topics like technology risks or protest. Instead, the 5G transition managers were busy overcoming merely 'technical' obstacles to the EU's 2024 Gigabit Infrastructure Act, which is, politically speaking, a done deal and confirms that by 2030 all European households should be connected to a gigabit network, with "all populated areas covered by next-generation wireless high-speed networks" (Regulation [EU] 2024/1309: 12)....

At the same time, the 5G proponents from government and industry are interested in better understanding the phantom public and its potential to haunt them. One way to do this is, as in Brussels, to convene 'representative' citizen commissions based on a lottery. Another common approach is to make them visible through surveys. However, it is difficult to 'scientifically' grasp a public that forms around concerns that are deemed irrational or impossible. To put it otherwise, what does it mean to represent that which is impossible to represent, and if represented—that is, made present—would constitute an ontological disturbance? For instance, a German study on the public views of 5G found that concerns about EMF are generally decreasing in the German population, while the percentage of people who feel that their health is negatively affected by EMF remains stable—between 7 percent and 10 percent (Dilkova-Gnoyke et al. 2022: 61). The study further identified an ideal type of citizen who rejects mobile communication but has only limited knowledge about the issue (ibid: 29), while a quantitative, survey-based cluster analysis shows that the 'rejecting' type includes respondents who are rather 'anxious' and 'skeptical' about technological novelty in general: "people of this type are found particularly in the sub-group of the 'Informed Concerned', but also among the 'Indifferent' and the 'Moderately Informed'" (ibid: 87). This flickering evidence might result from the fact that whether someone is moderately or ill informed depends on who is judging what counts as correct information.

The 5G phantom public is doubly spectral. First, it is an absent presence because it is not "a fixed body of individuals" but always "those persons who are interested in an affair" (Lippman 1993 [1927]: 67), and whenever one attempts to identify this public, it moves. Policymakers can never be entirely certain

if the phantom public is silent because it agrees, or whether it may rise up one day to protest. For the time being, however, the 'silent majority' allows them to assume that the public agrees with 5G, does not object to it, or does not care. Second, those who have always protested against wireless infrastructure are presently absent in the political deliberation process as their claims simply cannot be represented; they cannot be made present, visible, and public because of their potential to disturb. They haunt expert authorities like a "ghost of the scientized neoliberal machine" (Wynne 2015: 113) that is evoked through political mis- or non-representation. Ghosting them, nevertheless, does not silence the mistreated spirits: it gives shape to this political disturbance that escapes the dominant regime of visibility and political rationality—absent yet haunting it from its margins.Conclusion: An Otherworld

Let us return to that initial haunting in the Black Forest. There, the summoned 'ghost' took on a conventional role. For both the government official who had proclaimed that people were "haunted" by EMF and should not "chase after ghosts," but also for the critics who were offended by being associated with ghosts, the ghost is granted a lesser reality, either as what is merely psychological or, worse, as a sign of irrationality and mental illness. In her book Our Grateful Dead (2021), Vinciane Despret describes how ghosts and their ilk tend to fall into the trap set up within modern epistemology, which distributes existence into two categories: it has either a physical existence (a fact), or a subjective existence (a mental artifact). "This obligatory choice," she writes, leaves the 'dead' "with only two, equally miserable, possible ways out, either that of nonexistence or that of phantasms, beliefs, or hallucinations" (ibid.: 8). The issue with this trap, as Despret underlines, is that it qualifies ghosts through a mode of scientificity or knowledge that misses the mark: they cannot be found there. This treatment of ghosts, and those who experience their existence, that Despret denounces has an equivalence with the ways in which the debate of the possible health effects of EMFs, and of being EHS, happens. These experiences of EMFs are also reduced to this trap: either they are real and attributable to physical causes, or unreal and a matter of belief.

While Derrida's notion of the specter holds ontological questions open, Despret (2021) allows us to take seriously the co-existence of multiple ontologies that can overlap, cross over, and even contradict. By drawing a parallel between the dead and electromagnetic spectra, Despret stresses that both "have 'ways of being' that make them into actual real beings in the register that is their own" (ibid.: 9). This article has sought to understand spectral moments in their own specificity or their own manner of being.

Based on our ethnographic fieldwork around 5G and EMF risk debates, we have outlined three instances of the spectral. The first moment showed how the spectrum is neither reducible to a natural object, a representation nor a socio-technical regime, but is charged with other potentialities that spill out of it. The specter manifests in experiences of an almost felt presence of the electromagnetic spectrum, of equivocal proximities, of relations or coincidences that do not add up to a whole, but create a 'structural opening'—a world out of joint. The second moment described the specter of dis/possessed bodies who haunt a biomedical regime that excludes them, yet whose im/possibility holds a potential to disturb it. We explored how acquiring a possible body outside of an existing biomedical regime is a difficult and uncertain process of learning to possess a sensitive body in a world that is sensitive to it, but also a way of being possessed by that body-world. The third moment turned to what Walter Lippmann called the 'phantom public'. We described how attempts to know 'the public' and its 5G risk perceptions fail to

represent and include vocal 5G 'issue publics' that form around specific concerns (Marres 2007) and continue to haunt the transition managers of 5G like the "ghost of the scientized neoliberal machine" (Wynne 2015: 113). While participatory processes and formats, as well as technoscientific controversies and accounts of them, strive for closure, the spectral implies what Derrida called 'structural openings', or what we called 'shapes of disturbance'—whether as a spectrum that loosely structures everyday life, bodies that open up biomedical regimes to other sensory possibilities, or 'ghosted publics' that haunt the transparencies of political representation.

In each movement we have described, there is something that refuses being determinable in a form of knowledge, or as a clearly determinable reality, but flickers in the shape of a disturbance. Each of these disclosures, we claim, is not of another world, heterogeneous to modern, Western ontologies, but of an Otherworld that unsettles its boundaries and is constituted by practices that attempt to fit into modern ontological categories and regimes of legibility. They are 'otherworldly' because, rather than performing a distinct world with distinct categories, it remains unclear whether what is there is real or unreal, fact or fiction. They do not conform to those binaries. These disclosures from the Otherworld thus take the paradoxical shape of disturbance, of a structural opening, that is otherworldly—effects that make environments, bodies, and publics flicker in a spectral way.

In the conditions of climate change, a zeitgeist increasingly described as one of ruins (Tsing 2015), permanently polluted (Liboiron et al. 2018), where life is always already altered (Murphy 2017), and where disturbance is ordinary and ontological, there is a "demand," Donna Haraway ([1990] 2016: 88) acknowledges, for a "certain suspension of ontologies and epistemologies, holding them lightly." In this vein, we propose that the spectral, as a 'structural opening', creates space for an onto-epistemic and ethnographic sensitivity to experiences that does not seek to grasp them in a form of the knowable, or in clearly definable categorical forms. This, in turn, calls for a sensitivity in ethnography to the enigmatic and unclear, to unstable and problematic beings, but also to analytic categories and writing techniques that suspend closure by foregrounding hesitation (Chao 2024; Despret 2021; Stengers 2023; Schulte-Römer and Mommersteeg 2025), confusion (Mommersteeg 2026), doubt (Ahmann 2024) and not knowing (Cadena 2021). Rather than resolution or explanation, ethnographic disclosures are narratives that refuse to have the last word, but instead sustain "the perplexity that feeds an experience" (Despret 2019: 242) by prolonging it, holding open the gap between an experience and its meaning or interpretation, enabling it to continue in existence through the uncertainty that characterizes it, and which allows others to continue it.

This sensitivity is especially important for relating to situations—like the 5G debate, but also other scientific and technical controversies—that seem to be captured by the abstractions of what Isabelle Stengers (2023) has called the 'predatory nature of science', or what Brian Wynne (2015) has described as 'hermeneutic imperialism', where the logic of scientific objectivity operates as the sole guarantor of legitimate knowledge. The specter, in contrast, has meaning not as a "determinate content to be uncovered," but as a "productive opening" (Davis 2005: 377): it discloses an opening that puts epistemological certainties and categories into doubt, an opening to other possibilities, and through which an Otherworld flickers.

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**RF-EMF Risk Perception and Trust in Radiation Protection Authorities: A Comparative Study on Precautionary Information in Germany and Greece**

Eggeling-Böcker M, Karabetsos E, Christopoulou M, Link SC, Abacioglu F, Boehmert C. RF-EMF Risk Perception and Trust in Radiation Protection Authorities: A Comparative Study on Precautionary Information in Germany and Greece. Bioelectromagnetics. 2026 Jan;47(1):e70042. doi: 10.1002/bem.70042.

Abstract

This study investigates how different types of precautionary information affect risk perception and trust in national radiation protection authorities regarding radio-frequency electromagnetic fields (RF-EMF) from mobile communications, with a specific focus on 5G networks. A total of 2169 participants (1040 in Germany, 1129 in Greece) were randomly assigned to one of three conditions: (1) basic information, (2) simple precautionary information regarding possibilities to reduce personal RF-EMF exposure while using a mobile phone, and (3) conceptual precautionary information, including an explanation distinguishing "precaution" from "prevention" (1 × 3 factorial design). Contrary to the expectation that simple precautionary messages lead to higher risk perception and lower trust compared to basic messages, this was only the case for general conditional risk perception assuming that no precautions are taken, but not for affective risk perception, trust, or general conditional risk perception assuming that precautions are taken. Notably, providing a more elaborate explanation of the precaution/prevention distinction did not decrease risk perception or increase trust compared to giving simple precautionary information only, and even increased risk perception compared to basic information. This suggests limited benefit in emphasizing this conceptual nuance of precaution. Considering other variables, precautionary information increased feelings of self-efficacy and perception of message consistency. The findings reveal significant country differences: Greek participants reported higher perceived risks and lower trust than German participants. Gender differences also emerged, with women expressing higher risk perception and less trust than men. In contrast to the previous literature, the results suggest that precautionary information concerning personal mobile phone use can be communicated without leading to higher public concern about RF-EMF exposure from mobile communications. However, we found some evidence that adding conceptual explanations to precautionary information leads to higher risk perception. The results also show that considering sociocultural and individual differences in risk communication can be relevant. Possible explanations for the findings and implications for risk communicators are discussed.

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**Risk perception of electromagnetic fields among school teachers and nursery school teachers: a mixed-methods study**

Lüthy K, Riesmeyer C, Kühn J, Forster F, Radon K, Weinmann T. Risk perception of electromagnetic fields among school teachers and nursery school teachers: a mixed-methods study. BMC Public Health. 2026 Jun 23. doi: 10.1186/s12889-026-27964-3.

Abstract

Background: Although there is no evidence for adverse health effects from non-ionising electromagnetic fields (EMFs) exposure below legal limits, this concern is widespread among the general population. School teachers and nursery school teachers are considered multipliers of health-related information as they impart knowledge to parents and children. However, there is a lack of knowledge about the risk perception regarding EMFs among these professional groups. The extent to which school teachers and nursery school teachers are in contact with questions concerning EMFs and health in their work has not been investigated. Nor is there any knowledge about the information level of school teachers and nursery school teachers regarding EMFs. Data on teachers' perception regarding EMFs is important though to meet information needs.

Methods: A cross-sectional study among school teachers and nursery school teachers in Germany was carried out in 2024, combining an online survey (N = 1400) with focus groups (N = 29). We calculated prevalence estimates for participants' risk perception, subjective information level, and EMFs relevance in everyday work with correction for non-response. Furthermore, we conducted a latent class analysis to identify types of EMFs risk perception.

Results: A third of all participating school teachers (32%) and nursery school teachers (33%) indicated that, in their view, EMF exposure below legal limits may cause adverse health effects. Five types of risk perception concerning EMFs were identified using latent class analysis, with the high risk perception class comprising 11% of the participants. Many school teachers (56%) and nursery school teachers (77%) perceived themselves as poorly informed about EMFs. The group discussions provided deeper insights and supported these findings. The interviews revealed that both professional groups had concerns about the health effects of EMFs. Knowledge of scientific evidence concerning EMFs and health was low. Moreover, the discussions revealed a desire for more information on EMFs and health.

Conclusions: A notable proportion of school teachers and nursery school teachers indicated considerable risk perception towards EMFs. Most participants indicated low subjective information levels, expressing a need for information on EMF health effects. Communication formats tailored to this target group should be developed and evaluated.

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**Prenatal 3.5 GHz radiofrequency exposure induces renal histological changes and DNA damage in 6-month-old rats**

Gelenli Dolanbay E, Canturk Tan F, Bektas H, Koc S, Varol S, Kilic O, Uslu U, Dasdag S. Prenatal 3.5 GHz radiofrequency exposure induces renal histological changes and DNA damage in 6-month-old rats. Histochem Cell Biol. 2026 Jul 9;164(1):56. doi: 10.1007/s00418-026-02504-7.

Abstract

Early-life environmental stressors may influence long-term organ development and cellular homeostasis. This study investigated whether prenatal exposure to 3.5 GHz radiofrequency radiation (RFR) is associated with renal structural alterations, autophagy-related changes, and DNA damage in adult rat offspring. A total of 24 pregnant Wistar Hannover rats were randomly assigned to sham control, exposure during the last 2 weeks of gestation (D2T: exposure during the last 2 weeks of gestation), or exposure throughout gestation (D3T: exposure throughout gestation) groups (n = 8 dams per group). Male offspring were selected and euthanized at 6 months of age. Kidney tissues were examined histopathologically for structural alterations. Autophagy-related markers (Beclin-1 and LC3) were assessed by immunohistochemistry, and DNA damage was evaluated using the comet assay. Statistical analyses were performed using one-way analysis of variance (ANOVA) followed by appropriate post hoc tests. Peak spatial specific absorption rate (psSAR) values in the uterine region were 0.06622 mW/g (1 g averaging) and 0.03825 mW/g (10 g averaging). Prenatal RFR exposure was associated with significant renal histopathological alterations in offspring, most pronounced in the D3T group, including glomerular atrophy, tubular dilation, epithelial vacuolization, and cast formation ($p < 0.01$-$0.001$ versus controls). Beclin-1 and LC3 expression levels were significantly increased in both exposure groups ($p < 0.001$), suggesting altered autophagy-related marker expression. The comet assay demonstrated significantly increased DNA fragmentation in D2T and D3T groups compared with controls ($p < 0.001$), indicating increased genomic stress. Overall, prenatal exposure to 3.5 GHz RFR is associated with renal structural alterations, increased DNA damage, and changes in autophagy-related markers in adult rat offspring.

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**Sensitive Molecules Involved in Spatial Learning and Memory Impairment of Mice Induced by 4.3 GHz Microwave Radiation**

Qian T, Cheng W, Song L, Dong J, Wang H, Zhang J, Zhao L, Wang H, Peng R. Sensitive Molecules Involved in Spatial Learning and Memory Impairment of Mice Induced by 4.3 GHz Microwave Radiation. *Biomolecules*. 2026; 16(7):990. doi: 10.3390/biom16070990.

Abstract

With the widespread application of microwave technology in communication and medical fields, concerns regarding its biosafety, particularly the effects on the central nervous system, have increased. The brain is considered a sensitive target organ for microwave radiation; however, the molecular mechanisms underlying microwave-induced cognitive impairment remain unclear. The purpose of this study was to evaluate the effects of 4.3 GHz microwave radiation at different power densities on spatial learning and memory in mice, and to identify key molecular changes in the hippocampus associated with cognitive impairment. Mice (male, C57BL/6N) were exposed to 4.3 GHz microwave radiation at power densities of 10 or 30 mW/cm$^2$ for 30 min. Spatial learning and memory abilities were assessed using the Morris water maze (MWM). The hippocampal structure was assessed by HE staining at multiple time points following microwave exposure. Integrated RNA-sequencing (RNA-seq) and 4D-data-independent acquisition (4D-DIA) analyses of the hippocampus were performed at 6 h after microwave exposure, and

differentially expressed molecules were selected and validated by quantitative polymerase chain reaction (qPCR) and parallel reaction monitoring (PRM). The 4.3 GHz microwave exposure significantly prolonged escape latency in the MWM, indicating impaired spatial learning or navigation ability. Histological examination revealed transient neuronal damage in the hippocampal CA1 and CA3 regions. Multi-omics analysis and subsequent validation revealed molecular alterations. Following microwave radiation, the expression of synaptic plasticity-related genes Arc and Ebf3 was significantly upregulated. At the protein level, significant downregulation was observed for Protein sidekick-2 and IQGAP1, while WNK3 was significantly upregulated. In summary, 4.3 GHz microwave exposure impaired spatial learning or navigation ability, accompanied by structural damage in the hippocampus and molecular alterations in synaptic plasticity-related pathways. Arc, Ebf3, Protein sidekick-2, WNK3, and IQGAP1 might serve as candidate molecules for understanding and mitigating microwave-induced cognitive deficits.

Excerpt

The whole-body average Specific Absorption Rate (SAR) values for mice under the two power density conditions were approximately 14.5 W/kg and 37.8 W/kg.

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**Microwave Radiation Remodels Hippocampal Astrocytes Subpopulations and Intercellular Communication at Single-Cell Resolution**

Chang C, Feng Z, Ye Y, Xu Z, Kong X, Liu Y, Zhao X, Hao Y, Zuo H, Li Y. Microwave Radiation Remodels Hippocampal Astrocytes Subpopulations and Intercellular Communication at Single-Cell Resolution. Cells. 2026 Jun 22;15(12):1121. doi: 10.3390/cells15121121.

Abstract

The potential health hazards caused by microwave exposure have attracted increasing attention. Microwave radiation has been reported to induce oxidative stress in neural tissues, which is considered one of the primary mechanisms underlying its adverse effects on central nervous system function. The hippocampus is sensitive to microwave radiation, whereas underlying cellular and molecular mechanisms remain incompletely understood. In this study, microwave-exposed mice exhibited significantly impaired performance in the Go/No-go, Y-maze, and novel object recognition tests at 6 h and 7 days post-exposure, indicating deficits in hippocampus-dependent working memory. Single-cell RNA sequencing of hippocampal tissues from control and microwave-exposed mice yielded 94,088 high-quality cells across eight major cell types. Astrocyte sub-clustering identified five transcriptionally distinct subpopulations, with Astrocyte_S100a6 and Astrocyte_Son proportions increased and Astrocyte_Serpinf1 decreased in the radiation group. Analysis of astrocyte transcriptional state transitions showed microwave-exposed astrocytes were preferentially distributed toward terminal reactive states with depletion at early homeostatic nodes. Cell-cell communication analysis revealed increased total interactions and interaction strength following radiation. Astrocyte outgoing signaling was increased for pathways associated with vascular remodeling, phagocytic regulation, and neuroinflammation, while pathways related to trophic support were decreased. Incoming signaling showed increased activity in pathways linked to phagocytic recruitment and inflammatory mediation. Taken together, these findings indicate that microwave exposure is associated with hippocampus-

dependent working memory deficits accompanied by transcriptional remodeling of astrocyte subpopulation composition, directional astrocyte state transitions toward reactive phenotypes, and broad alterations in astrocyte-centered intercellular communication, providing a cellular and molecular framework for understanding astrocyte involvement in microwave radiation-associated hippocampal dysfunction.

Excerpt

The microwave exposure system was as previously described [39]. Briefly, the microwave source with a central frequency of 2856 MHz was placed in an electromagnetic shield chamber (GuoruiZhaofu Electronic, Wuhu, China). The mice in the MR group were placed in a transparent container of porous plexiglass with vent holes, which was placed on a circular platform below the microwave antenna (Figure 2A). The distance between the microwave antenna and the dorsal surface of the mice was fixed at 127 cm. During the radiation, the platform was rotated to ensure uniform radiation dose distribution in the mice. MR was applied for 15 min with an average power density of 8 mW/cm2, a repetition frequency of 80 Hz, and a duty cycle of 4%....

[39] When mice were arranged along the E-polarization direction of the RF, the main exposure mode in this study, the whole-body average SAR was calculated to be ≈8.9 W kg−1 and the local head SAR was ≈6.6 W kg−1 (Figure 1F). If mice faced the H-polarization direction, the whole-body average SAR was ≈4.0 W kg−1, and the local head SAR was ≈5.9 W kg−1 (Figure 1G).

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**Coenzyme Q10 protects against 6 GHz electromagnetic field–induced liver injury via suppression of inflammatory responses associated with NF-κB/p65 immunoreactivity and endoplasmic reticulum stress**

Akyildiz K, Yilmaz H, Yilmaz A, *et al.* Coenzyme Q10 protects against 6 GHz electromagnetic field–induced liver injury via suppression of inflammatory responses associated with NF-κB/p65 immunoreactivity and endoplasmic reticulum stress. *Sci Rep* (2026). doi: 10.1038/s41598-026-59252.

Abstract

We evaluated endoplasmic reticulum stress responses in hepatic tissues following 6 GHz electromagnetic field (EMF) exposure and the protective effects of Coenzyme Q10 (CoQ10). The experimental design included 24 male Sprague–Dawley rats randomly assigned to three groups: (i) sham control group, (ii) 6 GHz EMF exposure group, and (iii) 6 GHz EMF exposure + CoQ10 treatment group. Rats in the exposure groups were subjected to 6 GHz EMF exposure for 2 h/day over 30 consecutive days. Rats in the exposure groups were subjected to 6 GHz EMF exposure (0.21 mW/cm$^2$; specific absorption rate: 0.014 W/kg) for 2 h/day over 30 consecutive days. In addition, the animals in the CoQ10 treatment group received CoQ10 orally at a dose of 10 mg/kg/day throughout the exposure period. After completing the experimental protocol, hepatic tissue samples were obtained for subsequent analyses. Comparative analyses revealed significant differences in TBARS, GSH, TNF-α, IL-1β, ALT, and AST levels across the control–6 GHz and 6 GHz –6 GHz + CoQ10 groups. Exposure to 6 GHz EMF increased histopathological damage and liver histopathological score values, whereas CoQ10 markedly

reduced these changes and suppressed glucose-regulated protein 78, C/EBP homologous protein, oxidative 8-hydroxy-2'-deoxyguanosine, and nuclear factor kappa B p65 immunoreactivitiesy. 6 GHz EMF induces hepatic dysfunction via oxidative stress, endoplasmic reticulum stress, inflammation, and DNA damage, whereas CoQ10 mitigates these effects of EMF exposure.

Open access: https://www.nature.com/articles/s41598-026-59252-w

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**Reduced Photosynthetic Efficiency of Tilia (*Tilia tomentosa*) [silver linden] Exposed to Radio Frequency Electromagnetic Field (RF-EMF)**

Keller J, Geier U. Reduced Photosynthetic Efficiency of Tilia (*Tilia tomentosa*) Exposed to Radio Frequency Electromagnetic Field (RF-EMF)—JIP-Test Analysis. *Plants*. 2026; 15(12):1824. doi: 10.3390/plants15121824.

Abstract

The growing use of wireless technology significantly increases the exposure of all living organisms to radiofrequency electromagnetic fields (RF-EMF). However, the physiological effects of RF-EMF on plants have not yet been sufficiently researched. In this study, we investigated the effects of RF-EMF radiation in the frequency ranges 1890–1900 MHz (DECT) and 2.4 GHz plus 5 GHz (Wi-Fi) on photosynthetic performance of Tilia plants (Tilia tomentosa). The recorded fast chlorophyll fluorescence transients were used to analyze the structure and function of PSII by the JIP-test. The analysis of the fluorescence of chlorophyll a showed that the RF-EMF interfered with the electron transport processes of photosynthesis. Tilia plants exposed to RF-EMF induced decrease in photosynthetic efficiency ($F_V/F_M$) and inactivation of part of PSII reaction centers ($RC/CS_O$). Observations of leaf senescence and lifespan over a period of 102 days showed that RF-EMF-exposed Tilia plants exhibited accelerated aging.

Excerpt

To evaluate how real-world signal mixtures affect urban canopy trees like Tilia tomentosa, we simulated a realistic, high-density anthropogenic RF-EMF scenario with frequency ranges of 1880–1900 MHz (DECT) and 2.4 and 5 GHz (Wi-Fi). RF-EMF exposure was provided by two Wi-Fi systems (FritzBox 7530; AVM, Berlin, Germany) in combination with a DECT base station and two DECT phones (Motorola t412+, Motorola, Chicago, IL, USA; eco-mode switched off). The DECT phones were maintained in continuous communication with an additional terminal. RF-EMF radiation levels were measured using two broadband RF analyzers (Gigahertz Solutions, Langenzenn, Germany). Peak power flux densities in the 1880–1900 MHz and 2.4 GHz range, measured with the HF59B analyzer (Gigahertz Solutions, Langenzenn, Germany) (700 MHz–2.7 GHz) on plants, were 800 $\mu W/m^2$. In the 5 GHz Wi-Fi band, measured with the HFW35C analyzer (Gigahertz Solutions, Langenzenn, Germany) (2.4–6 GHz) also on plants, values of 400 $\mu W/m^2$ were recorded. In contrast, RF-EMF measurements of both the ambient background and the shielded control plants yielded values < 8 $\mu W/m^2$ for the 1880–1900 MHz/2.4 GHz range and <4 $\mu W/m^2$ for the 5 GHz band, which is less than 1% of the recorded intensities and below the reliable quantification threshold of the measuring devices.

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**Extremely low-frequency pulsed electromagnetic fields induce apoptotic, oxidative stress, inflammatory and aquaporin-related kidney alteration**

Özöner MP, Seker U, Sert C. *et al.* Extremely low-frequency pulsed electromagnetic fields induce apoptotic, oxidative stress, inflammatory and aquaporin-related kidney alteration. *J Mol Histol* **57**, 222 (2026). doi: 10.1007/s10735-026-10883-3

Abstract

Extremely low-frequency pulsed electromagnetic fields are used as a biotherapy method in various medical and experimental applications. However, the cellular effects of prolonged or intense exposure remain unclear. This study aimed to evaluate the effects of two different ELF-PEMF doses on kidney tissue over an 8 week period, investigating oxidative stress, apoptosis, inflammation, and aquaporin expression using biochemical, histopathological, and immunohistochemical methods. Forty male rats were assigned to control, sham, 1 mT, and 5 mT groups; the 1 mT and 5 mT groups were exposed to ELF-PEMF for four hours daily for eight weeks, while controls received no intervention. At the end of the experiment, kidney tissues were collected for histopathological (H&E and PAS), immunohistochemical and biochemical analyses. In kidney tissue exposed to ELF-PEMF, hyperemia, tubular degeneration, and proteinaceous casts were observed. 1 mT and 5 mT ELF-PEMF exposure increased BAX, Caspase-9, and TNF-α immunoreactivity compared to the control and sham groups, while no change was observed in BCL-2 expression. 5 mT group exposure to ELF-PEMF increased AQP3 expression, a critical water channel in cellular $H_2O_2$ permeability ($p < 0.05$). AQP5 expression was significantly increased in both the 1 mT and 5 mT groups compared to the control group ($p < 0.05$). Biochemical analyses showed that oxidative stress levels were significantly increased in both the 1 mT and 5 mT groups compared to the control group ($p < 0.05$). These findings suggest that, despite its recent use for its therapeutic properties, long-term exposure to ELF-PEMF may cause oxidative stress, apoptosis, and inflammation in renal tissue and alter the histological structure and cellular homeostasis.

https://link.springer.com/article/10.1007/s10735-026-10883-3

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**Research on Electromagnetic Compatibility Safety Assessment of Wireless Power Transfer Systems for Electric Vehicles on Drivers and Passengers**

Su R, Yan S, Wu X. Research on Electromagnetic Compatibility Safety Assessment of Wireless Power Transfer Systems for Electric Vehicles on Drivers and Passengers. 2026 5th International Conference on Electronics, Integrated Circuits and Communication Technology (EICCT), Chengdu, China, 2026, pp. 595-600, doi: 10.1109/EICCT69950.2026.11564107.

Abstract

In recent years, with the rise of electric vehicles, researchers have increasingly focused on the electromagnetic compatibility safety assessment of drivers and passengers in the complex electromagnetic environment of electric vehicles. In this paper, a vehicle model, a human body model, and a wireless power transfer system model are constructed using COMSOL Multiphysics. Based on these models, the induced electric field strength and specific absorption rate (SAR) of drivers and passengers in the electric vehicle environment are simulated and calculated. Furthermore, the safety

distance for drivers and passengers under wireless power transfer systems with different power levels is evaluated. The simulation results show that when the output power of the wireless power transfer system is 150 kW and the operating frequency is 1100 kHz, the electromagnetic parameters of drivers and passengers reach their maximum values. The peak induced electric field strength is 18.053 V/m, and the peak local SAR is 0.382 mW/kg, both of which meet the safety requirements of the ICNIRP. Under the ICNIRP standard, the minimum safety distance is 0.08 m.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11564107&isnumber=11564056

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**Electromagnetic Exposure to Child Passengers of Positioning Antennas for Autonomous Driving Electric Vehicles**

Dong X, Ren Y, Lu M. Electromagnetic Exposure to Child Passengers of Positioning Antennas for Autonomous Driving Electric Vehicles. ACES Journal. 2026. 41(03):244–257.

Abstract

With the rapid development of electric vehicles (EVs) and autonomous driving (AD) technologies, the issue of electromagnetic exposure of passengers, especially children, to the electromagnetic radiation generated by the positioning antennas of AD has received increasing attention. In this study, COMSOL Multiphysics is used to construct the models of an EV, a positioning antenna and a child human body, and the levels of electromagnetic exposure of a child passenger to the positioning antenna in AD are calculated. Results indicate that the maximum value of induced electric field in a child's body is 23 V/m, and the maximum value of the $SAR_{1g}$ of the child's body is 0.19 W/kg. Additionally, the maximum temperature rise in the child body is 0.55°C. The electromagnetic exposure levels of the child passenger calculated in this study are all lower than the safety limits defined by international authoritative institutions. Therefore, the electromagnetic radiation levels from the positioning antenna comply with international safety standards. Based on the analysis of this study, no significant health effects on child passengers have been observed. The results of this study can supplement studies on the electromagnetic environment of AD in EVs and can provide guidance for ensuring the travel safety of child passengers.

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**Computational dosimetry of electromagnetic and thermal exposure for pacemaker wearers in vehicle-to-vehicle environments**

Song Y, Lu M. Computational dosimetry of electromagnetic and thermal exposure for pacemaker wearers in vehicle-to-vehicle environments. Electromagn Biol Med. 2026 Jul 5:1-14. doi: 10.1080/15368378.2026.2695362.

Abstract

This study conducts a quantitative safety assessment for pacemaker wearers by evaluating their electromagnetic and thermal exposure to vehicle-mounted antennas in a realistic Vehicle-to-Vehicle (V2V) communication scenario. An integrated exposure scenario comprising a vehicle with a V2V

antenna, an implanted cardiac pacemaker, and an anatomical human model is constructed using COMSOL Multiphysics®. Coupled simulations of radiofrequency electromagnetic fields (RF-EMF) and bioheat transfer are conducted to compute the specific absorption rate averaged over 10g of tissue ($SAR_{10g}$) and the induced temperature rise. The results indicate that the peak $SAR_{10g}$ occurs in the superficial tissues at the skin of the left ear, which is the region closest to the antenna and the vehicle's side window. The peak $SAR_{10g}$ of skin tissue is 0.067 W/kg, which accounts for 3.35% of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) public exposure limit of 2 W/kg. Cardiac exposure $SAR_{10g}$ peaks at a significantly lower value of 0.19 mW/kg. The maximum temperature rise at the critical pacemaker lead-electrode interface is 0.061°C, substantially below the International Organization for Standardization (ISO) 14708-2 safety threshold of 2°C. The corresponding temperature increase within the heart tissue is merely 0.059°C. All evaluated exposure values comply with ICNIRP guidelines for general public exposure. The findings indicate that the modeled V2V communications do not pose a health risk from RF-EMF exposure to pacemaker wearers in the investigated scenario, thereby providing key data to alleviate their travel safety concerns in current environments.

Plain language summary

Individuals with cardiac pacemakers may have concerns about potential interference from the growing number of Vehicle-to-Vehicle (V2V) communication antennas in modern vehicles: Could the wireless signals from these devices affect pacemaker function or pose a health risk? To address this practical concern, our research performed a detailed simulation study. We constructed a numerical model that represents a realistic scenario in which a person with a pacemaker is seated in a vehicle equipped with a V2V antenna. The results show that the wireless signal energy absorbed by the body is very low, representing only 3.35% of the safety limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Exposure levels in the cardiac region are even lower. Furthermore, any potential temperature rises in human tissues or near the pacemaker remain well below the 2°C safety threshold defined by ICNIRP and ISO 14708-2. Thus, under the simulated exposure conditions, the V2V communication antenna used in this study does not present a health risk to pacemaker users. All evaluated parameters fall substantially below established safety limits. These findings provide scientific reassurance and should help alleviate safety concerns among pacemaker wearers traveling in vehicles equipped with such communication systems.

https://pubmed.ncbi.nlm.nih.gov/42402072/

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**Monitoring Harmonic ELF Magnetic Fields in Data Centers With Sensor-Based Instrumentation**

Portillo F, Fernandez-Ros M, Novas N, Garcia RM, Viciana E, Gazquez JA. Monitoring Harmonic ELF Magnetic Fields in Data Centers With Sensor-Based Instrumentation. *IEEE Transactions on Instrumentation and Measurement*, vol. 75, pp. 1-9, 2026, Art no. 1502309, doi: 10.1109/TIM.2026.3684676.

Abstract

Modern data centers concentrate substantial amounts of power-electronic equipment, generating complex low-frequency electromagnetic environments with implications for electromagnetic compatibility (EMC). This article presents a one-month assessment of the extremely low-frequency (ELF)

magnetic field in a data center using an air-core coil magnetometer as a nonintrusive measurement instrument. The sensor operated continuously, and the recorded field was segmented into 5-min windows to compute the root-mean-squared (rms) magnetic flux density (B RMS ), the harmonic spectrum from 50 to 2000 Hz, and the total harmonic distortion (THD) of the magnetic field (THD B ). Statistics show moderate field magnitudes, with typical B RMS around 0.5 μ T and a maximum below 1 μ T, but consistently high-distortion levels, with median THD B around 36% and occasional values above 300%. Diurnal and weekly analyses reveal that THD B is strongly modulated by the operating regime, with twice the median distortion during working hours compared with nighttime and weekends, while B RMS varies much less. Harmonic spectra confirm the dominant contribution of low-order odd harmonics, particularly the third, whose relative amplitudes increase under high-distortion conditions. A percentile-based detector identifies 41 high-THD B events, most of them short-lived (5–10 min). The results illustrate how ELF magnetometry, as a nonintrusive instrumentation approach, can support EMC-oriented characterization of harmonic disturbances in data centers and complement conventional power-quality (PQ) measurements.

Conclusion

This article presents a one-month assessment of magnetic field disturbances in a university data center using a nonintrusive ELF magnetometer. By continuously recording the vertical magnetic field component and processing the data in 5-min windows, the study derived the $B_{RMS}$, the harmonic spectrum from 50 to 2000 Hz, and the $THD_B$.

The measurements show that the magnetic field magnitude at the sensor location is moderate, with $B_{RMS}$ typically around 0.5 $\mu$ T and consistently below 1 $\mu$ T, whereas the associated distortion is systematically high. $THD_B$ exhibits a broad distribution with median values around 36% and occasional episodes exceeding 300%. Diurnal and weekly analyses indicate that the operating regime strongly modulates distortion. During working hours, the median $THD_B$ is approximately twice that observed at night and during weekends, while $B_{RMS}$ varies much less. Harmonic spectrum and regime-based statistics reveal the dominant contribution of low-order odd harmonics (especially, the 3rd) and highlight that their relative amplitudes increase under high-distortion conditions. A percentile-based detector identifies 41 high-$THD_B$ events over the month, most of which are short-lived (5–10 min) but reach substantial distortion levels.

These results characterize the selected installation point; extension to room-wide characterization requires multipoint measurements, so future work will extend this approach to multiple sensors and diverse types of data centers, combine field measurements with electrical and operational data, and explore automated classification of operating regimes and events based on magnetic signatures, to support PQ supervision and EMC decision-making in critical IT infrastructure.

Open access:

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11482647&isnumber=11329398

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**Safety Assessment of Electromagnetic Effects for Ultra-High Voltage Transmission Lines**

Wang H, et al. Safety Assessment of Electromagnetic Effects for UHV Transmission Lines. 2026 9th International Conference on Energy, Electrical and Power Engineering (CEEPE), Nanjing, China, 2026, pp. 748-752, doi: 10.1109/CEEPE69795.2026.11552148.

Abstract

This paper conducts a systematic safety assessment of electromagnetic effects for UHV same-tower double-circuit transmission lines, aiming to address the demand for refined quantitative evaluation of human electromagnetic exposure under the UHV power frequency electromagnetic environment. Finite element models of the UHV transmission lines and a refined human body model with a layered head structure are established via COMSOL Multiphysics. The power frequency magnetic field effects, electric field effects, and the influence of the typical arms-raised operation posture on human exposure characteristics are quantitatively analyzed, with all results strictly benchmarked against the ICNIRP public exposure limits. The results show that all human electromagnetic exposure parameters under different working conditions are far below the corresponding safety limits with sufficient safety margins. This research provides reliable quantitative data and theoretical support for the electromagnetic environment safety assessment of UHV transmission lines.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11552148&isnumber=11552035

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**Continuous Monitoring of Magnetic Fields in AC/DC Electric Rail Systems: A Comparative Analysis of Light and Heavy Rail Passenger Exposure**

Raz-Steinkrycer LS, Gelberg S, Neeman E, Portnov BA. Continuous Monitoring of Magnetic Fields in AC/DC Electric Rail Systems: A Comparative Analysis of Light and Heavy Rail Passenger Exposure. *Sustainability*. 2026; 18(12):6227. doi: 10.3390/su18126227.

Abstract

Electrification of public transit is central to sustainable urban development, yet it introduces passenger exposure to extremely low-frequency magnetic fields (ELF-MFs), which the International Agency for Research on Cancer (IARC) classifies as possibly carcinogenic to humans (Group 2B). This study presents a systematic cross-platform comparison of ELF-MF exposure in direct current (DC) light rail and alternating current (AC) heavy rail systems operating under a single national regulatory framework. A total of 9100 continuous measurements were collected across 28 trips on the Tel Aviv Red Line light rail transit (1500 V DC) and the Israel Railways Tel Aviv–Binyamina corridor (25 kV, 50 Hz AC) during 23–26 November 2025, using calibrated Tenmars TM-192D gaussmeters. Mean passenger seat magnetic flux density was 0.226 ± 0.147 µT (2.26 ± 1.47 mG) for the DC system and 0.900 ± 0.606 µT (9.00 ± 6.06 mG) for the AC system. The difference was highly significant (Welch's $t = -73.06$, $p < 0.001$). DC light rail exposure remained consistently below Israel's precautionary 0.4 µT (4 mG) threshold for continuous public exposure, whereas AC heavy rail mean levels exceeded this threshold in every monitored trip while remaining far below ICNIRP general public reference levels. These findings highlight a "Green Dilemma" in sustainable transport policy: the environmental benefits of rail electrification must be balanced with prudent electromagnetic exposure management in jurisdictions applying strict precautionary limits.

Conclusions

This study provides a controlled comparison of passenger seat ELF-MF exposure between DC light rail and AC heavy rail systems operating under a unified national regulatory framework. The approximately four-fold difference in mean magnetic flux density (DC: 0.226 μT vs. AC: 0.900 μT; Welch's $t = -73.06$, $p < 0.001$) demonstrates that electrification platform, system architecture, and operating conditions are major determinants of passenger exposure, with implications for regulatory compliance and sustainable transport policy.

The DC light rail system's consistent compliance with Israel's 0.4 μT precautionary threshold positions it as a favorable model for low-exposure urban transit electrification.

The AC heavy rail system exceeded this precautionary threshold in all monitored trip means while remaining far below acute and ICNIRP reference levels. This pattern does not indicate an immediate health hazard, but it does justify precautionary engineering review, continued monitoring, and exposure reduction measures where technically and economically feasible.

These findings carry implications for transport sustainability planning: rail electrification can advance climate and air quality objectives while still requiring careful electromagnetic exposure management. Incorporating exposure reduction engineering during design, procurement, and retrofitting can help reconcile environmental benefits with public health precautions, particularly for frequent commuters and vulnerable populations. The "Green Dilemma" identified here is therefore manageable through evidence-based monitoring, transparent regulatory interpretation, and targeted engineering mitigation.

Open access: https://www.mdpi.com/2071-1050/18/12/6227

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**Editorial: The 4th international expert forum on the public health and environmental impacts of cellular and wireless radiation exposure 2024**

Ben Ishai P, Butler T, Davis D, Leszczynski D, Taylor H (2026) Editorial: The 4th international expert forum on the public health and environmental impacts of cellular and wireless radiation exposure 2024. Front. Public Health 14:1856852. doi: 10.3389/fpubh.2026.1856852.

No abstract

Excerpt

Taken together, the contributions to this Research Topic suggest that historical disagreement reflects not only scientific uncertainty, human hubris, and individual and collective value judgments (), along with institutional, methodological, and social influences that shape science and policy (Lin; Frank; Héroux; Scarato). While important knowledge gaps remain, particularly in long-term ecological research and exposure assessment, the current literature is sufficient to seriously question the continued reliance on the thermal-only paradigm to safeguard public health and the environment. The evidence presented in this Research Topic indicates plausible pathways for gradual, cumulative adverse effects on human health and wellbeing and on the ecosystem in which they exist and depend. For human populations, the principal risk lies in normalizing universal, continuous exposure to a biologically active, environmental toxin, while the policymaking and regulatory frameworks responsible for risk management lag behind

scientific understanding of the health and environmental risks of RF-EMF. For ecosystems, the risk is compounded by stressors, such as habitat loss and climate change, which may amplify vulnerability to EMF exposure.

It is time that policy and regulation take into consideration the reduction of EMF exposure as a public and environmental health issue to be pursued. As clean air acts have forced changes in industry behavior, a similar regulatory approach is necessary to ensure scientifically reasonable levels of EMF exposure.

In this context, precaution should be understood not as opposition to technological development but rather as a governance principle aimed at aligning innovation with the protection of public and environmental health. This Research Topic does not close the debate on wireless RF-EMF and its biological effects. It does, however, clarify that the central question is no longer whether RF-EMF can interact with biological systems, but rather how the risks associated with such interactions and adverse consequences should be mitigated.

Open access:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2026.1856852/full

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**Association between mobile phone use and risk of rheumatoid arthritis: A large prospective cohort study**

Ren S, Gao P, Wei S, Cui Y, Ye D, Fang X. Association between mobile phone use and risk of rheumatoid arthritis: A large prospective cohort study. PLoS One. 2026 May 22;21(5):e0347330. doi: 10.1371/journal.pone.0347330.

Abstract

Background: It remains uncertain whether there is a relationship between mobile phone use and rheumatoid arthritis (RA). Research on the relationship between different mobile phone usage(MPU) behaviors and the risk of RA onset is still insufficient.

Methods: The UK Biobank (UKB) data were utilised to inquire into the relationship between four mobile phone use exposure variables-MPU, length of mobile phone use(LMPU), weekly usage of mobile phone for making or receiving calls(WMPU), and hands-free device/speakerphone use with mobile phones to make or receive calls(HMPU)-and new-onset RA. The relationships between MPU behaviors and the occurrence of RA in the general population were assessed using Cox regression analyses. These associations were further explored in subgroups stratified. We implemented sensitivity analyses to confirm the stability of the results.

Results: During a median follow-up period of 13.63 years, 6082 new cases of RA were identified among 479,966 participants. Individuals who used cell phones had a 14% elevated risk of the onset of RA (HR: 1.14, 95% CI: 1.07-1.23), with an 8% elevated risk (HR: 1.08, 95% CI: 1.02-1.15) observed among those who used a mobile phone for more than 30 minutes per week.

Conclusions: We aimed to investigate the association between MPU and the risk of developing RA in the general population. Results indicate that increased MPU, longer duration of use, and gr

Conclusions

This study found that MPU, duration of MPU, and weekly usage time were positively correlated with an increased probability of RA onset. However, the use of hands-free mode when making or receiving calls showed no significant correlation with RA incidence. Therefore, on one hand, future research could conduct randomized controlled trials (RCTs) to validate whether implementing MPU management strategies can reduce the risk of RA development. On the other hand, this study also provides a preliminary foundation and hypothesis for future investigations into the causal relationship between MPU and RA using genetic proxy tools for MPU.

Open access: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0347330

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**Prenatal and Early-Life Exposure to Electromagnetic Fields: Impacts on Neurodevelopment and Behavior**

Ezgin N. Prenatal and Early-Life Exposure to Electromagnetic Fields: Impacts on Neurodevelopment and Behavior. *Psikiyatride Güncel Yaklaşımlar*. 2026;:1549–1564.

Abstract

Wi-Fi is a common source of radiofrequency electromagnetic field (RF-EMF) exposure, operating at 2.4 GHz and 5 GHz frequencies. Increasing experimental evidence suggests that RF-EMF exposure during prenatal and early postnatal periods may influence neurodevelopment and behavior. This review examines the effects of RF-EMF exposure on learning, memory, anxiety-like behaviors, motor activity, and exploratory behaviors. The study is based on 65 experimental studies identified through a literature search conducted in PubMed, Web of Science, and Scopus databases. Mechanistic studies indicate that these effects are associated with increased oxidative stress, impaired synaptic plasticity, and modulation of neuronal signaling pathways, potentially affecting neurogenesis, dendritic spine formation, and the maturation of neural circuits. Findings from animal studies are heterogeneous; while some studies report mild cognitive and motor impairments, others do not observe significant behavioral changes. Human data remain limited and controversial, providing low-level evidence regarding cognitive and behavioral effects. Nevertheless, the sensitivity of the developing nervous system to such exposures is noteworthy. Current evidence suggests that RF-EMF exposure may affect neurodevelopment and behavior through neurobiological mechanisms. However, further standardized, long-term, and multidimensional studies are required to reach definitive conclusions regarding the direction and magnitude of these effects. Factors such as exposure duration, intensity, developmental stage, and sex appear to play critical roles.

Open access: https://dergipark.org.tr/en/download/article-file/5549738

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**Exposure Misclassification in the Danish Mobile Phone Subscriber Cohort and its Influence on International Radiofrequency (RF) Radiation Cancer Risk Assessments**

Hardell L, Nilsson M. Exposure Misclassification in the Danish Mobile Phone Subscriber Cohort and its Influence on International Radiofrequency (RF) Radiation Cancer Risk Assessments. Archives of Internal Medicine Research. May 15, 2026. 9(2):107-118.

Abstract

The Danish mobile phone subscriber cohort, updated in 2011, is one of the most frequently cited epidemiological studies concluding that mobile phone use is not associated with increased risk of brain tumors. Regulatory bodies routinely rely on this cohort as part of the evidence for null associations. However, the Danish cohort exhibits structural exposure misclassification and control group contamination that limit its ability to give information on health risks. The objective of this study was to critically examine methodological features, evaluate how they constrain inference regarding brain tumor risk, and document how the study was assessed in several international risk assessments. Methodological aspects, data on numbers of subscribers, minutes of mobile phone use over the cohort study period and incidence statistics of central nervous system (CNS) tumours were examined. We analyzed how the cohort's findings have been evaluated, critically analyzed and incorporated into major international risk assessments from the WHO, the EU and national expert groups. Several structural limitations were identified: exposure classification restricted to pre-1996 private subscribers; misclassification of 200 507 corporate subscribers and all post-1995 users classified as "unexposed" leading to severe contamination of the unexposed group with exposed individuals; absence of individual usage data; DECT phone users classified as unexposed; insufficient window for slow-growing tumors. These factors bias the risks toward unity. Data from NORDCAN show increasing CNS tumour incidence in Denmark, which contradicts the findings in the cohort. Several expert evaluations have assessed the cohort as high quality evidence of absence of risk. The WHO commissioned review published in 2024 appears to be the assessment in which the cohort contributed most substantially to the overall results. Due to structural exposure misclassification and control group contamination, the Danish cohort cannot test associations between mobile phone use and brain tumor risk. The continued use of the study in international risk assessments bias overall results towards null. The study is scientifically flawed and is uninformative on health risks from mobile phone use.

Open access: https://www.fortunejournals.com/abstract/exposure-misclassification-in-the-danish-mobile-phone-subscriber-cohort-and-its-influence-on-international-radiofrequency-rf-radia-9909.html

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**Exposure to 5G Radiofrequency and Physiological Effects in Healthy Young Adults: Insights Into Heart Rate Variability and Salivary Stress Biomarkers**

My note: This was not a 5G study.

Layla J, Lisa M, Stéphane D, Raphaël B, Laurent H, Paul M, Philippe L, Tamara B, Erwan SB, Brahim S. Exposure to 5G Radiofrequency and Physiological Effects in Healthy Young Adults: Insights Into Heart Rate Variability and Salivary Stress Biomarkers. Bioelectromagnetics. 2026 Jul;47(5):e70056. doi: 10.1002/bem.70056.

Abstract

This study investigated the potential impact of fifth-generation (5 G) radiofrequency (RF) on the autonomic nervous system (ANS). Electrocardiograms (n = 43) and salivary samples (n = 33) were collected from healthy young volunteers before, during, and after exposure to a 3.5 GHz frequency (electrical field intensity ~1-2 V/m) emitted by an antenna while participants were seated at rest. Heart-rate (HR) and heart rate variability (HRV) indices, including time and frequency domain measures, were analyzed from short-term epochs during both "real" and "sham" exposure sessions, under eyes-open (EO) and eyes-closed (EC) conditions. Initial variations in RR intervals and HR were observed during 5 G exposure; however, these effects were not confirmed by post-hoc analyses after correction for multiple comparisons, suggesting the absence of consistent exposure-related modulation. The only statistically significant result was a time-by-exposure interaction for the RMSSD parameter during the final exposure period. This effect was small in magnitude, limited to a single time point, and not supported by other parasympathetic indices, and should therefore be interpreted cautiously as it may reflect normal physiological variability or a statistical artifact. No consistent exposure-related effects were detected in salivary stress biomarkers, including cortisol, alpha-amylase, and chromogranin A. Although minor variations were observed in some measures, all values remained within normal physiological ranges, and their clinical relevance remains uncertain. These findings are restricted to the specific experimental conditions examined, namely short-term far-field exposure (25.5 min) at low specific absorption rate (SAR) levels (0.008 mW/kg in the brain). Overall, the results provide preliminary baseline human data at 3.5 GHz rather than confirmatory evidence of biological effects. Further studies involving larger cohorts and longer exposure durations are required to determine whether subtle or cumulative autonomic effects of 5 G exposure can be reliably detected.

Summary

- Exploratory study assessing autonomic responses to short-term 3.5 GHz 5 G exposure in healthy young adults.
- No robust or consistent effects were observed on heart rate variability or salivary stress biomarkers after statistical correction.
- Findings provide preliminary baseline human data for low-level 5 G exposure, highlighting the need for larger and longer studies.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70056

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**Early-life exposure to 27.5 GHz 5G millimeter-wave radiation induces skin-related biological responses in mice**

Palone F, Fratini E, Novelli F, Leonardi S, De Stefano I, Pasquali E, Tanori M, Pinto R, Ardoino L, Zambotti A, Camera F, Piscitelli M, Merla C, Pazzaglia S, Capstick M, Samaras T, Mancuso M. Early-life exposure to 27.5 GHz 5G millimeter-wave radiation induces skin-related biological responses in mice. Sci Rep. 2026 Jun 8. doi: 10.1038/s41598-026-57133-w.

Abstract

The global rollout of 5G networks has raised questions regarding the potential biological effects of millimeter-wave exposure, particularly in the skin due to its limited penetration depth. This study

examined the effects of whole-body exposure to 27.5 GHz millimeter waves, a frequency within the 5G FR2 bands, on skin-related biological responses in early life mice. Patched1- heterozygous knockout and wild-type CD1 mice were exposed from birth to weaning (P21), 23 h per day, in 10-minute ON/5-minute OFF cycles, at two power densities (6.67 and 20 W/m$^2$). SHAM-exposed animals served as a control. No overt histological abnormalities were observed in exposed skin. However, molecular analyses revealed significant modulation of inflammation-related gene expression. Notably, Ccl4, Csf2, and Tnfsf11 emerged as central regulatory nodes, displaying high degree and betweenness centrality across all groups, irrespective of genotype and sex. Crucially, exposure significantly stimulated mast cell degranulation and, in wild-type mice, led to a reduction in cutaneous glutamate levels. Concurrently, a down-regulation of transcripts associated with cutaneous sensory components (Calca, Mrgprd) was observed within the skin microenvironment. These findings show that 27.5 GHz exposure induces coordinated changes in cutaneous inflammatory pathways and mast cell-mediated homeostasis without detectable structural damage. Overall, these results demonstrate a localized molecular and cellular response within the cutaneous microenvironment, reflecting a subtle homeostatic shift, and suggest that genetic background may contribute to variability in the biological response to millimeter-wave exposure.

Open access: https://www.nature.com/articles/s41598-026-57133-w

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**Effects of 26 GHz radiofrequency exposure on electrodermal activity in healthy young adults**

Michelant L, Hugueville L, Leveque P, Selmaoui B. Effects of 26 GHz radiofrequency exposure on electrodermal activity in healthy young adults. Int J Radiat Biol. 2026 Jun 3:1-10. doi: 10.1080/09553002.2026.2678295.

Abstract

Purpose: The deployment of 26 GHz millimeter wave technology represents the next phase of 5 G implementation, yet potential effects on autonomic nervous system function remain unexplored. This study investigated whether environmental-level 26 GHz exposure influences electrodermal activity (EDA), a sensitive marker of sympathetic nervous system activation.

Materials and methods: Twenty-two healthy young adults participated in a randomized, counterbalanced, triple-blind study examining EDA responses to controlled 26 GHz exposure. Participants underwent two sessions (real and sham exposure) with electric field intensities of 2 V/m at head level and 1 V/m at torso level, representing upper environmental exposure ranges. EDA parameters were measured during pre-exposure, exposure (25.5 min), and post-exposure phases using established continuous decomposition analysis. Both tonic components (baseline sympathetic activation) and phasic responses (stimulus-evoked reactions) were assessed following standardized auditory stimulation protocols.

Results: No statistically significant effects of 26 GHz exposure were observed across all measured EDA parameters. Tonic activity, phasic responses, response latency, amplitude measures, and global skin conductance remained unchanged during and following RF exposure compared to sham conditions across all experimental phases.

Conclusions: Environmental-level 26 GHz exposure does not produce detectable acute effects on sympathetic nervous system activity as measured through electrodermal responses. These findings contrast with reported effects at lower 5 G frequencies, suggesting frequency-specific biological interactions. The limited tissue penetration of millimeter waves likely prevents electromagnetic energy from reaching sympathetically innervated structures. Results support current guidelines yet emphasize the need for complementary study.

Open access: https://www.tandfonline.com/doi/10.1080/09553002.2026.2678295

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**Ten-Country Study on Public Perceptions of 5G EMF Emissions: Who Feels Exposed, and Why?**

Link SC, Grellier J, Martin L, Eggeling-Böcker M, Abacioglu F, Schulz C, Vaupotič N, White MP, Boehmert C. A Ten-Country Study on Public Perceptions of 5G EMF Emissions: Who Feels Exposed, and Why? Bioelectromagnetics. 2026 Jul;47(5):e70058. doi: 10.1002/bem.70058.

Abstract

Formal risk assessment considers characteristics such as proximity, dose, and vulnerability. However, public risk perception may also be influenced by other-possibly less relevant-factors such as visibility and novelty. The introduction of 5G and its associated infrastructure and radiofrequency electromagnetic fields (RF-EMF) may therefore change perceptions of RF-EMF from mobile communications in general. To explore this, we conducted an online survey in 10 European countries (n = 10,358) using a picture-based approach. Respondents perceived daily RF-EMF exposures as moderate but expected them to increase with 5G. A mobile phone at the ear was generally associated with higher perceived exposure than multiple base stations. Overall, distance to the RF-EMF source most strongly influenced perceived exposure, followed by the number of sources. 5G reception was linked to higher exposure perception than 4G or Wi-Fi reception. These patterns were consistent across most countries. We conclude that when assessing RF-EMF exposure, people rely on heuristics (e.g., more sources imply more exposure) that often guide them correctly. Understanding when and why people feel particularly exposed can help develop more effective communication about true levels of exposure and risk.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70058

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**Experimental and clinical evidence on radiofrequency electromagnetic field effects on the blood-brain barrier: a scoping review**

Simsek ET, Sumser K, Mansourinezhad P, Kayhan H, Paulides MM, Buyukatalay EO. Experimental and clinical evidence on radiofrequency electromagnetic field effects on the blood-brain barrier: a scoping review. Phys Med Biol. 2026 May 28;71(10). doi: 10.1088/1361-6560/ae6e17.

Abstract

*Objective.* This scoping review evaluates evidence on whether radiofrequency electromagnetic field (RF-EMF) exposure influences blood-brain barrier (BBB) permeability. Given inconsistent findings across decades of research and expanding wireless technology use, we summarize results from*in vivo*,*in vitro*, and human studies with emphasis on exposure characterization and thermal control.

*Methods.* Literature covering RF-EMF exposures from ∼900 MHz to frequencies relevant for emerging wireless systems was surveyed. Due to substantial heterogeneity in exposure conditions, i.e. specific absorption rates from 0.01 to >10 W $kg^{-1}$, diverse modulation schemes, and varied biological endpoints, we performed a qualitative synthesis supported by a methodological audit focusing on dosimetric rigor, temperature monitoring, and sham-control implementation.

*Results.* Findings remain mixed: seventeen studies reported increased BBB permeability or molecular alterations, while eighteen observed no effects. Null-result studies generally applied stricter dosimetry and thermal safeguards, though incomplete temperature documentation was common. Some in vitro studies suggest effects on tight-junction proteins or cellular stress pathways, but these outcomes show limited reproducibility in animal models. Human data are sparse and do not clearly differentiate thermal from non-thermal influences.

*Conclusion.* Current evidence does still not establish a causal link between RF-EMF exposure and BBB disruption. Persistent methodological variability limits interpretability. Future work should employ rigorous exposure characterization, validated BBB biomarkers, and robust thermal and sham controls, and address gaps at higher frequencies and in vulnerable populations (prenatal, elderly).

Conclusion and future directions

The current body of experimental evidence, as visualized in (figure 6), presents a complex and unresolved picture regarding the effects of RF-EMF on BBB integrity. While it does not definitively support the hypothesis that RF-EMF exposure compromises the BBB, it is also not possible to entirely refute it.

The field is not divided into ‘old, flawed’ studies versus ‘new, high-quality’ studies. On the contrary, (figure 6) demonstrates that reports of an ‘Effect’ extend into the modern era (e.g. 2017, 2025), just as methodological weaknesses (e.g. ‘Uncontrolled’ dosimetry or incomplete controls) persist even in recent publications (e.g. 2015). This indicates that factors beyond just methodological quality (e.g. frequency, modulation, model differences) must be considered to explain the inconsistencies in the literature.

Therefore, the body of data does not conclusively prove that GSM, UMTS, or TDMA signals have no significant effect on BBB permeability; rather, it shows that the evidence is mixed.

Given this complexity and methodological heterogeneity, it is critical that future research addresses the current issues that challenge comparative analyses and regulatory consensus.

The recommendation to prioritize next-generation frequencies and vulnerable populations is grounded in a clear gap identified within the present database. Our synthesis shows that many studies conducted over the last two decades are limited to legacy 2G/3G bands, with virtually no data exploring the unique absorption characteristics of 5G millimeter waves in the BBB context. Additionally, while the BBB’s integrity varies significantly across the lifespan, the current literature is dominated by healthy young

adult male models, effectively ignoring the potential heightened sensitivity of the developing or aging brain.

Future research should prioritize the following:

- Long-term and low-intensity exposure models
- Human studies incorporating CSF biomarkers or advanced imaging techniques. Although the collection of CSF is invasive and may be feasible only in specific patient groups, CSF biomarkers provide the most direct biochemical evidence of BBB integrity and, together with advanced imaging, can offer translational insights beyond peripheral markers or animal models.
- Vulnerable populations, including children, elderly individuals, and patients with neurovascular comorbidities
- Novel technologies such as 5G and millimeter-wave (mmWave) frequencies. Future research should prioritize these frequencies; their distinct biophysical properties, including higher photon energy and unique tissue absorption profiles, present a novel exposure scenario that remains significantly underrepresented in the current BBB literature. The necessity of focusing on 5G mmWave frequencies is further underscored by recent state-of-the-science reviews (Karipidis *et al* 2021), which identify a profound lack of high-quality, replicated research in the 6–300 GHz range. Our synthesis aligns with their findings, emphasizing that the unique energy deposition patterns of these frequencies necessitate a dedicated re-evaluation of BBB permeability under modern exposure scenarios.
- Methodological rigor, specifically emphasizing double-blind, randomized controlled designs, standardized dosimetry (including thermal monitoring), the use of sham-exposed control groups, and validated, direct outcome measures such as CSF biomarkers.

In conclusion, while current evidence does not *definitively* indicate that typical RF-EMF exposures within international safety limits impair BBB integrity in healthy individuals, the scientific debate, as highlighted by (figure 6), is not closed. Careful and comprehensive investigation is warranted for emerging exposure scenarios and high-risk populations.

Open access: https://iopscience.iop.org/article/10.1088/1361-6560/ae6e17

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**Response to the BfS Statement: Scientific Clarifications on Chromosomal Damage and RF-EMF Exposure**

Belyaev I, Gulati S, Mosgoeller W, Moldan D. Response to the BfS Statement: Scientific Clarifications on Chromosomal Damage and RF-EMF Exposure. Ecotoxicol Environ Saf. 2026 Jun 6;322:120336. doi: 10.1016/j.ecoenv.2026.120336.

No abstract

Excerpt

In conclusion, our study (Gulati et al., 2024) provides statistically robust evidence consistent with an association between long-term RF-EMF exposure and increased chromosomal aberrations under the investigated conditions.

Because the study is exploratory and based on a limited sample size, the findings should be interpreted cautiously and warrant independent replication in larger well-characterized cohorts and longitudinal study designs.

Open access: https://www.sciencedirect.com/science/article/pii/S0147651326006652?via%3Dihub

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**2.45 GHz RF Reprogram Mitochondria-Lysosome Crosstalk & Modulate Survival/Death of Macrophages Exposed to LPS or SARS-CoV-2 Spike Protein**

Sueiro-Benavides RA, Leiro-Vidal JM, Rodríguez-González JA, Ares-Pena FJ, López-Martín E. Radiofrequency Fields at 2.45 GHz Reprogram Mitochondria-Lysosome Crosstalk and Modulate the Survival/Death of Macrophages Exposed to LPS and/or the SARS-CoV-2 Spike Protein. Int J Mol Sci. 2026 Apr 24;27(9):3813. doi: 10.3390/ijms27093813.

Abstract

The redox mechanisms of RAW 264.7 macrophages exposed to 2.45 GHz RF-EMF at subthermal specific absorption rates and to lipopolysaccharide (LPS) and/or the SARS-CoV-2 spike protein (CSP) were investigated. To this end, cellular responses (lysosomal and mitochondrial activity, nitric oxide (NO) production, and cell survival/death) were measured after 6, 24, and 48 h. Selective loss of viability in cells exposed to RF and LPS was observed at 6 h, consistent with early defects in membrane permeability. Lysosomal activity was significantly enhanced in cells treated with RF + LPS. Mitochondrial activity decreased in cells exposed to RF + LPS at 6 h and increased in cells treated with RF + CPS/LPS. Cell viability decreased greatly in cells treated with LPS and CSP + LPS after 24, particularly after 48 h. Nitrite levels peaked in non-irradiated cells treated with RF + LPS and in CSP + LPS at 24 h and decreased in irradiated cells after 48 h. Irradiation affected selection of the death mode: apoptosis decreased or remained unchanged in cells subjected to any of the treatments, while necrosis increased in cells treated with CPS, LPS, or both for 48 h. The combination of RF-EMF and infectious agents reprogrammed the interaction between mitochondria/lysosomes/nitric oxide (NO)/cell death in macrophages in a time- and stimulus-dependent manner.

Open access: https://www.mdpi.com/1422-0067/27/9/3813

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**The importance of hair in human perception of electric fields - A double-blind repeated measures study**

Jankowiak K, Kaifie A, Krabbe J, Dohrn MF, Kimpeler S, Mingers F, Kühn R, Kraus T, Kursawe M. The importance of hair in human perception of electric fields - A double-blind repeated measures study. Sci Rep. 2026 May 13;16(1):14970. doi: 10.1038/s41598-026-52898-6.

Abstract

Electric fields (EFs) are an integral part of modern life which might affect humans in terms of conscious perception. Despite their ubiquity, the mechanisms underlying EF perception remain underexplored. To elucidate interindividual variance, this study investigates the influence of human hair on the perception of alternating current (AC) EFs, direct current (DC) EFs, and hybrid EFs using a double-blind repeated measures design. Thirty healthy participants were exposed to various EF strengths while their hair characteristics and environmental conditions were systematically manipulated. The findings indicate that hair plays a crucial role in EF detection, as removal of hair markedly increased detection thresholds for all EF types. Furthermore, correlations were observed between hair moisture content and DC EF sensitivity, as well as between arm hair roughness and AC EF sensitivity. Factors such as environmental relative humidity and the application of mascara directly influenced the EF detection performance. The findings suggest that both the presence and properties of hair notably contribute to how humans are affected in their perceptual experience of EFs, highlighting the need for further research into individual characteristics that influence the EF perception mechanisms.

Conclusions

The replication of the effect of relative humidity on the perception of various EF types underscores the robustness of results in EF detection research. The influence of hair on the head and arms on the ability to perceive EFs is clearly emphasized. It was shown that the removal of hair is associated with a strong loss of detection performance. At the same time, if hair is present, its characteristics also have an influence on EF detection performance. Head hair moisture in DC EFs and hair roughness in AC EF perception influence the detection thresholds. The results complement the known models regarding EF perception and their extensions[6,13]. Furthermore, the results help to understand how EFs are perceived by humans. Further research focusing on the influence of fine hairs on the ears, cheeks, and eyelashes is needed. It remains to be investigated whether complete hair removal could eliminate the ability to perceive EFs.

Open access: https://www.nature.com/articles/s41598-026-52898-6

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**Exposure of the palm to handheld wireless devices operating at frequencies from 900 MHz to 6 GHz**

Christ A, Niskala K, Joyner KH. Exposure of the palm to handheld wireless devices operating at frequencies from 900 MHz to 6 GHz, Radiation Protection Dosimetry, 2026;, ncag052, doi: 10.1093/rpd/ncag052.

Abstract

The exposure of the palm due to handheld wireless devices is analyzed using anatomical hand models of adults and children considering a frequency range from 900 MHz to 6000 MHz. The fingers of the hand models are articulated such that they hold the phone model in realistic positions. The antennas of the phone model are located in the microphone region, which maximizes the exposure of the palm. Approximately 140 configurations are evaluated numerically. The exposure is quantified in terms of the 10 g psSAR and compared with the psSAR calculated for a flat phantom. The results indicate that the exposure of the palm is within the extremity exposure limit of 4 W per kg in 96% of the cases for the hand models if the exposure limits are met for a flat phantom at 0 mm distance. The numerical uncertainty for the exposure evaluation is assessed as 24.7% (k=2).

https://pubmed.ncbi.nlm.nih.gov/42233965/

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**Combined Experimental-Numerical Spatio-Temporal Mapping of RF-EMF Exposure in City Environments**

Leeman M, Deprez K, Van der Straeten J, Ver M. Combined Experimental-Numerical Spatio-Temporal Mapping of RF-EMF Exposure in City Environments.

Abstract

The rollout of 5G has increased spatial and temporal variability in RF-EMF exposure due to higher frequency bands, beamforming, and denser deployments, challenging conventional maps that rely only on simulations or sparse measurements. We present a hybrid framework that fuses deterministic ray-tracing with heterogeneous data (static sensor node data gathered over a two-year period, a mobile spectrum analyzer (SA) campaign, and personal exposimeter measurements) to generate high-resolution spatio-temporal exposure maps for a dense urban area of 2.5 km2. At its core is the Mean-Matched Gradient-Preserving Optimization (MMGPO), which estimates a smooth multiplicative correction field over the simulated grid to remove bias while preserving logarithmic gradients. When validated against 28 independent SA measurements, MMGPO achieves an RMSE=5.47 dB and correlation r=0.70 for the total electric field exposure over all frequency bands. By incorporating temporally varying node data, this approach provides policymakers, researchers, and the public with reliable, high-resolution exposure assessments across multiple time windows, capturing spatial detail while reflecting temporal variations in
modern wireless networks.

Open access: https://ieeexplore.ieee.org/ielx8/8782661/11343983/11527354.pdf

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**Quantum coherence stabilization in biology via feedback with coherent background fields**

Ahmadi M, Shariatpanahi SP, Shamsi J, Asgari E, Foroughmand-Araabi MH, Majidzadeh-A K, Jahed Motlagh MR, Torkaman Rahmani A. Quantum coherence stabilization in biology via feedback with coherent background fields. Electromagn Biol Med. 2026 May 29:1-15. doi: 10.1080/15368378.2026.2679035.

Abstract

Living systems operate far from thermodynamic equilibrium while maintaining a high degree of internal order, raising the long-standing question of how fragile quantum coherence can persist in warm, noisy biological environments. While several biological processes exhibit signatures of quantum coherence, the physical mechanisms responsible for stabilizing such coherence remain an active area of debate. In this work, we present a phenomenological model demonstrating that quantum coherence in open spin systems can be stabilized through entropy-dependent feedback with a weakly coupled coherent field. We consider an open quantum spin ensemble subject to environmental decoherence, augmented by (i) entropy-sensitive suppression of decoherence and (ii) a coherence-inducing interaction that favors low-entropy, collectively coherent configurations. Using multipartite Greenberger-Horne-Zeilinger (GHZ)

states as representative low-entropy coherent states, numerical simulations reveal nonlinear threshold behavior, entropy collapse, and long-lived coherence despite strong environmental noise. These features provide clear signatures of a positive feedback loop, wherein coherence suppresses decoherence, reduced decoherence enhances coherence, and the resulting self-reinforcement stabilizes the system. Importantly, the model is agnostic to the physical origin of the coherent field and is compatible with a wide range of candidates, including internally generated biological oscillations, collective electromagnetic or redox dynamics, oxygen-mediated spin correlations, and other structured cellular fields. As an illustrative example, we discuss the potential role of an ultralight dark matter (ULDM) background field, whose predicted macroscopic coherence and oscillation frequencies could, in principle, participate in the same feedback mechanism. By separating the general principle of feedback-stabilized coherence from any specific physical realization, this work provides a unifying theoretical framework for understanding how quantum coherence may persist in open, noisy systems relevant to biological physics. The results suggest that coherence in living matter may arise not from isolation from the environment, but from structured coupling to coherent fields that dynamically regulate decoherence through entropy-sensitive feedback.

Plain language summary

Living cells are warm and noisy environments, yet growing experimental evidence shows that some biological processes are sensitive to very weak electromagnetic influences, including extremely low-frequency (ELF) magnetic fields. Such fields are already used or explored in medicine—for example in bone repair, neuromodulation, and cancer research—although the physical mechanisms underlying their biological effects remain unclear.In this study, we investigate a general physical principle that could explain how weak oscillating influences affect biological systems. We show that if a quantum system is weakly coupled to a coherent background influence—such as an ELF magnetic field—and if this coupling becomes more effective as the system becomes more ordered, a positive feedback loop can emerge. In this loop, quantum coherence reduces the rate at which it is destroyed by environmental noise, and the resulting stability further strengthens coherence. Using computer simulations of interacting quantum spins, we demonstrate that this feedback can produce sudden transitions from disordered behavior to long-lived, highly coherent states, even when noise is strong. The model does not depend on the specific origin of the oscillating influence and is compatible with known biological rhythms, chemical oscillations, and externally applied ELF fields. As a physically motivated example, we also discuss ultralight dark matter—hypothesized to form a weak, coherently oscillating background field throughout space—as a possible contributor to the same stabilization mechanism. Overall, the results suggest that weak oscillating fields may influence biology and medicine not through direct energy transfer, but by stabilizing quantum coherence through feedback. This framework offers a unified, testable perspective for understanding biological sensitivity to ELF fields and, more broadly, how coherence may persist in living systems.

Open access: https://www.tandfonline.com/doi/10.1080/15368378.2026.2679035

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**Electrohypersensitivity beyond controversies**

Petzke T, Köteles F, Szemerszky R, Nordin S, Witthöft M, Lemogne C, Van den Bergh O, Pitron V. Electrohypersensitivity beyond controversies. Int J Hyg Environ Health. 2026 May 29:114817. doi: 10.1016/j.ijheh.2026.114817.

No abstract

Excerpt

In conclusion, despite important research efforts no clear and consistent biological correlates of SAEF-EMF [symptoms associated with electromagnetic fields] have been identified so far. Such specific biological correlates, if any in the future (Leszczynski, 2025b), would only complement other biopsychosocial determinants that have been shown to associate with SAEF-EMF and not replace them. We thus propose to always consider purely biological mechanisms alongside psychological, social, and environmental mechanisms for SAEF. This approach opens avenues for dedicated treatment for SAEF-EMF and other SAEF (Pitron et al., 2025; Van den Bergh et al., 2021). Specifically, there is preliminary evidence for effective treatment of SAEF, using cognitive and behavioral therapy involving cognitive restructuring and gradual exposure to symptoms and blamed environmental factors (Busse et al., 2008; Guglielmi et al., 1994; Spyker, 1995; Van den Bergh et al., 2024). A shared biopsychosocial framework also enables better communication between practitioners, patients, and policy stakeholders, fostering more public attention, more research, and better care. More shared knowledge about SAEFs, especially in the medical community, would hopefully decrease the amount of medical neglect, iatrogenic harm, and unmet needs that people with SAEFs are experiencing.

https://pubmed.ncbi.nlm.nih.gov/42215327/

**Comment on Petzke et al. (2026)**

Cinciripini G. Comment on Petzke et al. (2026): International Journal of Hygiene and Environmental Health 273 (2026). International Journal of Hygiene and Environmental Health, 2026. https://doi.org/10.1016/j.ijheh.2026.114801.

No abstract

https://www.sciencedirect.com/science/article/pii/S1438463926000611

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**Personal Radio Frequency Electromagnetic Field Exposure Among Swiss Adolescents in the 5G Era**

Jalilian H, Waibl VJ, Wipf I, Mootz I, Abend S, Diez NS, Veludo AF, Loizeau N, Dongus S, Guxens M, Röösli M. Personal Radio Frequency Electromagnetic Field Exposure Among Swiss Adolescents in the 5G Era. Environ Res. 2026 May 22:124775. doi: 10.1016/j.envres.2026.124775.

Abstract

Introduction: The rapid expansion of wireless technologies, including 5G, has introduced complex radiofrequency electromagnetic field (RF-EMF) exposure patterns, yet real-world data on personal exposure in adolescents remain limited. This study, conducted within the HERMES3 (Health Effects Related to Mobile Phone Use in Adolescents) cohort, aims to characterize personal RF-EMF exposure among Swiss adolescents.

Methods: A subsample of 143 adolescents participated in a personal measurement study between June 2023 and January 2025. Participants carried a personal exposimeter (ExpoM-RF4) for ca. 72-hours, to collect Geographic Positioning System coordinates and exposure data from 35 frequency bands. During this period, participants were asked to fill-out an electronic activity diary. Following data quality control, frequency bands were categorized by source and analyzed descriptively.

Results: Mean and median daily total RF-EMF levels of 0.09 mW/m2 and 0.06 mW/m2, respectively, were measured. WiFi/Bluetooth contributed most to total exposure (35 %), followed by broadcast (31 %), uplink (19 %), downlink (10 %), time division duplex (4 %), and Digital Enhanced Cordless Telecommunications (0.7 %). Across environments, average RF-EMF exposure was highest in transport systems (0.47 mW/m2) and lowest at school (0.08 mW/m2) and home (0.07 mW/m2).

Conclusion: Despite widespread 5G deployment, overall personal exposure among adolescents remains similar to pre-5G levels, with variations mainly reflecting user behavior and network density. However, this should not be interpreted as a direct causal estimate of the independent effect of 5G deployment. WiFi/Bluetooth was the main contributor to daily personal exposure. Personal measurements underestimate exposure contributions from sources emitting close to body.

Highlight

- Personal RF-EMF exposure among Swiss adolescents was 0.09 mW/m2 on average.
- RF-EMF exposure levels have little changed compared to the pre 5G era
- WiFi/Bluetooth was the dominant contributor to total exposure (35%)
- 5G (TDD) bands contributed little to total exposure (4%)
- Daily mean exposures were highest in transport systems (0.47 mW/m2) and lowest at home (0.07 mW/m2)

Open access: https://www.sciencedirect.com/science/article/pii/S0013935126011060?via%3Dihub

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**Gender Differentiation Based Mobile Terminal Electromagnetic Exposure Safety Analysis and Corresponding Antenna Miniaturized-Based Protective Measures**

Zhou WY, Luo MF, Wang PP, Li YX, Lu M. Gender Differentiation Based Mobile Terminal Electromagnetic Exposure Safety Analysis and Corresponding Antenna Miniaturized-Based Protective Measures. Bioelectromagnetics. 2026 May;47(4):e70055. doi: 10.1002/bem.70055.

Abstract

The rapid development of 5 G technology raises concerns about near-field electromagnetic exposure from mobile terminals, especially its potential risks to reproductive and vital organs. However, gender-based differences in tissue dielectric properties and their impact on exposure are often overlooked. This study has two main objectives: to analyze the influence of gender differences on near-field electromagnetic exposure, with a particular focus on key tissues, by calculating gender-specific dielectric

properties of different organ tissues; and to propose antenna miniaturization as an active electromagnetic protective measure for reducing specific absorption rate (SAR). This study employs finite element modeling to construct male and female human models, incorporating reproductive systems and key organs, to evaluate SAR before and after the miniaturization of a MIMO mobile terminal antenna at 2.6 GHz and 3.5 GHz. The results show that SAR values in male tissues, particularly in reproductive organs, are significantly higher than in female counterparts. Antenna miniaturization effectively reduces peak SAR by over 30% in multiple tissues, demonstrating its role as an active electromagnetic protective measure. This work highlights gender differences in electromagnetic exposure and confirms the feasibility of antenna miniaturization for improving mobile terminal safety design.

Summary

- To analyze the influence of gender differences on near-field electromagnetic exposure, with a particular focus on key tissues, by calculating gender-specific dielectric properties of different organ tissues.
- Antenna miniaturization effectively reduced peak SAR by over 30% in multiple tissues, demonstrating its potential as an active electromagnetic protective measure.
- The study provides a gender-differentiated SAR assessment framework and validates miniaturization as a viable strategy for enhancing 5 G terminal safety.

https://pubmed.ncbi.nlm.nih.gov/42183756/

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**Effect of 2.45 GHz RF EMR on Components of the Hypothalamic-Pituitary-Gonadal Axis in Male Rats**

Vijay S, Ibrahim SF, Osman K, Zulkefli AF, Mat Ros MF, Jamaludin N, Taha SMAS, Hairulazam A, Jaffar FHF. The Effect of 2.45 GHz Radiofrequency Electromagnetic Radiation on Components of the Hypothalamic-Pituitary-Gonadal Axis in Male Rats. Int J Mol Sci. 2026 May 20;27(10):4582. doi: 10.3390/ijms27104582.

Abstract

The brain and testes are connected via the hypothalamic-pituitary-gonadal (HPG) axis. Both are vulnerable to radiofrequency electromagnetic radiation (RF-EMR). However, no comprehensive study had evaluated the effects of RF-EMR on key hormones along this axis. Hereby, this study evaluated the effect of RF-EMR on the hormonal changes along the axis, including the neuropeptide kisspeptin. A total of 18 (N = 18) adult Sprague-Dawley rats were divided into three groups (n = 6): Control, 4 h, and 24 h. The Control group was sham-exposed to an inactive router. The exposed groups were subjected to 2.45 GHz RF-EMR for 4 and 24 h daily, for 60 days at a 20 cm distance. The power density was 0.141 $W/m^2$ with a whole-body specific absorption rate (SAR) of 0.41 W/kg. No significant changes were observed in hypothalamic *Kiss1* gene expression or serum kisspeptin levels. GnRH levels increased significantly in both exposed groups, while FSH and LH remained unchanged. Testicular testosterone was significantly reduced in the 24 h group, while serum testosterone was elevated in the 24 h group compared to the 4 h group. In conclusion, prolonged 2.45 GHz RF-EMR exposure caused selective changes in components

of the HPG axis, particularly involving GnRH and testosterone, suggesting potential endocrine effects on male reproductive regulation.

Excerpts

This study employed a TP-LINK AC570 Wireless Dual Band Wi-Fi Router Archer C20 (Shenzhen, China), which was equipped with three omnidirectional antennas. Among the three antennas, two generate a 2.45 GHz frequency, while one antenna generates a 5 GHz frequency. For this study, only the 2.45 GHz antennas were activated, whereas the single 5 GHz antenna was deactivated. According to the Maximum Permissible Exposure (MPE) report for this router, the power density of the antenna is 0.141 $W/m^2$ for a 2.45 GHz frequency emission at a distance of 20 cm with a constant antenna gain of 3 dBi....

For the group that received Wi-Fi exposure, the Wi-Fi router was actively communicating with a Raspberry Pi computer (Cambridge University, Cambridge, UK) using a ping protocol via Bitvise SSH client version 8.18 software (Slovenia, Hungary, and USA). A total of 10 pings were sent each minute, and communication between the devices was done through the 802.11b/g/n standard.

Open access: https://www.mdpi.com/1422-0067/27/10/4582

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**Possible effects of 3200 MHz radio-frequency field on cardiac blood parameters in rats**

Özdemir N, Özkan ET, Kayabaşı B, et al. Possible effects of 3200 MHz radio-frequency field on cardiac blood parameters in rats. J Health Sci Med. 2026;9(3):645-651. doi:10.32322/jhsm.18727

Abstract

Aims: Radiofrequency (RF) technologies are widely used in modern communication systems, particularly with the introduction of fifth-generation (5G) networks. Despite increasing exposure to RF fields, their potential biological effects remain controversial. This study aimed to evaluate the effects of repeated exposure to a 3200 MHz RF field on cardiac injury biomarkers in a rat model. We hypothesized that repeated RF exposure would induce measurable alterations in cardiac biomarkers.

Methods: Thirty-four male Wistar albino rats (220-280 g) were randomly assigned to five groups: control, sham-15 min, sham- 1 h, RF exposure-15 min, and RF exposure-1 h. Animals in exposure groups were subjected to a 3200 MHz RF field for 15 minutes or 1 hour daily for 15 consecutive days. Serum troponin I, creatine kinase (CK), and plasma brain natriuretic peptide (BNP) levels were measured using the Abbott Alinity I immunoassay autoanalyzer (Abbott Laboratories, Abbott Park, IL, USA).

Statistical analyses were performed using GraphPad software.

Results: No statistically significant differences were observed in troponin I or BNP levels among the groups ($p<0.05$). A statistically significant increase in CK levels was detected only between the sham-15 min and RF exposure-15 min groups ($p<0.05$), as well as between the control and sham-15 min groups. No consistent biomarker elevation associated with RF exposure duration was identified.

Conclusion: Exposure to a 3200 MHz RF field at SAR levels of 0.3-0.36 W/kg did not significantly alter cardiac biomarkers, including troponin I and BNP, under the experimental conditions of this study.

Open access: https://dergipark.org.tr/en/download/article-file/5646152

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**Thermal Damage to the Skin From 5.6 GHz Microwave Exposures in Swine**

Parker JE, Rodriguez RA, Vázquez-Colón CD, Stone R, Butterworth JW, Whitmore JN, Payne JA, Voorhees WB. Thermal Damage to the Skin From 5.6 GHz Microwave Exposures in Swine. Bioelectromagnetics. 2026 May;47(4):e70053. doi: 10.1002/bem.70053.

Abstract

A study of burn thresholds from superficially penetrating radio-frequency (RF) energy at 5.6 GHz for swine skin was conducted. The study estimated the thresholds for superficial, partial-thickness, and full-thickness burn severities after 20 s of exposure at power densities of 4-8 W/cm$^2$. Biopsies were collected from each burn site at 1, 24, 72, and 168 h post exposure. Each sample was assessed by a burn pathologist against 20 histological factors to characterize the damage resulting from these RF overexposures. There were significant differences in the burn thresholds at the different severities compared to previous thresholds found at 8.2 and 95 GHz. A one-dimensional, layered digital phantom that utilized realistic values for dielectric and thermal properties was consistent with the observed damage trends and empirical dosimetry values. The results of the heating and cooling response of the animal model, and histology scores of each exposure are provided to establish damage thresholds and support development of simulation tools to predict parameters associated with RF hazards.

Summary

- Provides empirical data of microwave over-exposures on swine skin to support refinements and confidence of safety exposure standards related to 5G technologies.
- Demonstrates the predictability of subject skin temperatures from a one-dimensional, heat transfer model of superficially penetrating microwave exposures.
- Compares common damage metrics for skin damage and shows the utility of incorporating temperature at depth to estimate thermal damage.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70053

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**Verification of quantum biological predictions for weak magnetic field effects on superoxide in planarians**

Rishabh R, Vučković J, Zadeh-Haghighi H, Beane WS, Simon C. Verification of quantum biological predictions for weak magnetic field effects on superoxide in planarians. PNAS Nexus. 2026 May 6;5(5):pgag152. doi: 10.1093/pnasnexus/pgag152.

Abstract

The dependence of superoxide concentration and tissue regeneration on weak magnetic field strength in planarians exhibits a nonmonotonic behavior that classical physics struggles to explain. Here, we experimentally verify the predictions of a simple radical pair (RP) model for magnetic field modulation of

superoxide levels during planarian regeneration. The model predicted increased superoxide concentrations at both hypomagnetic and higher fields (>500 μT). Previously reported magnetic field effects on blastema size do not follow the same pattern as our predictions for superoxide levels, while in earlier experiments blastema size was correlated with superoxide levels within a narrower magnetic field range (200 and 500 μT). Surprisingly, our experiments confirmed the model's predictions. We also performed a search over the parameter space of a more general RP model and identified multiple parameter sets that produce magnetic field profiles consistent with the observed ranges of superoxide levels. While the precise relationship between blastema size and superoxide concentration is evidently more complex than previously thought, and important biochemical aspects-including the identities of the radicals involved-remain to be determined, our findings support a general RP hypothesis and bolster the case for a quantum-biological explanation for these magnetic field effects.

Significance statement

Weak magnetic field (WMF) effects in biology are increasingly attributed to quantum phenomena involving coherent electronic spin dynamics, yet experimental support remains limited beyond avian magnetoreception. We verify the predictions of a minimal radical pair (RP) model for magnetic field modulation of superoxide levels during planarian regeneration. We predicted increased superoxide concentrations at near-zero and higher magnetic fields, contrary to prior biological expectations. Surprisingly, our experiments confirmed these predictions. Using a more general RP model, we showed that the underlying quantum principles are more relevant than the exact identities of the radicals involved. While questions remain about the specific RP chemistry, this work strengthens the case for a quantum biological interpretation of the WMF dependence of superoxide generation.

https://academic.oup.com/pnasnexus/article/5/5/pgag152/8671238

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**The effect of electromagnetic fields on building materials: The case of base stations**

Bararan Z, Polat A. The effect of electromagnetic fields on building materials: The case of base stations. Journal of Structural Engineering & Applied Mechanics (Online). 2025; 8(4): 331 - 347. 10.31462/jseam.2025.08331347.

Abstract

This study investigates the electromagnetic field (EMF) permeability characteristics of widely used construction materials to determine their effectiveness in electromagnetic insulation against radiation emitted by base stations. Field measurements were conducted at 81 base stations located in the city center of Diyarbakır in accordance with the standards of the Information and Communication Technologies Authority (ICTA). Test materials included concrete, brick, wood, metal, lead, PVC, XPS, and recycled concrete. The results indicate that the highest average electromagnetic field intensity was measured in free-space conditions (3.37 V/m), whereas lead exhibited the most effective shielding performance with an average value of 1.01 V/m, corresponding to an attenuation of approximately 70%. Metal sheets also showed strong shielding capability with an average value of 1.29 V/m. Among conventional materials, recycled concrete demonstrated lower electromagnetic permeability (2.13 V/m) compared to standard concrete (2.60 V/m). Thickness-dependent measurements revealed that increasing recycled concrete thickness from 3 cm to 7 cm reduced electromagnetic field intensity from

up to 2.93 V/m to as low as 1.64 V/m, representing a reduction of approximately 44%. Measurements conducted inside and outside the safety distance further confirmed that EMF levels outside the safety distance can be more than twice those measured inside. Overall, the findings demonstrate that material type, thickness, and safety distance play a critical role in reducing electromagnetic exposure. Recycled concrete emerges as a sustainable and effective alternative for electromagnetic shielding in building design.

Open access: https://www.goldenlightpublish.com/dosyalar/baski/JSEAM_2025_626.pdf

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**An Analytical Framework for Frequency-Dependent Electromagnetic Power Absorption in Biological Tissues**

Wang H, Foley S, Zhou H. (2026). An Analytical Framework for Frequency-Dependent Electromagnetic Power Absorption in Biological Tissues. *Journal of Applied Mathematics and Physics*, **14**, 1931-1953. doi: 10.4236/jamp.2026.145094.

Abstract

As exposure to electromagnetic waves becomes increasingly widespread, it is important to quantify how incident fields couple into biological tissue and where absorbed energy is deposited. This work presents an analytical, physics-based framework derived from Maxwell's equations to model the propagation of a normally incident electromagnetic plane wave within homogeneous, lossy dielectric biological tissues. Closed-form expressions for the electric and magnetic fields are derived, enabling the determination of frequency-dependent power reflectance and transmittance at the air-tissue interface, as well as the power absorption coefficient and penetration depth within the medium. Using complex relative permittivity data from the literature, we examine six tissue types across a broad frequency range (1 MHz - 100 GHz). The results demonstrate that higher water content significantly increases dielectric loss and reduces penetration depth. Conversely, low-water tissues (e.g., non-infiltrated fat) exhibit lower attenuation and deeper penetration. Frequency is shown to be a dominant driver of this behavior, with higher frequencies shifting the power budget from reflection-limited coupling toward highly superficial absorption. These findings provide a foundation basis for quantifying the heat source in assessing exposure effect and risk and in designing electromagnetic technologies.

Excerpt

The authors gratefully acknowledge the support of the Joint Intermediate Force Capabilities Office of the U.S. Department of Defense and the Naval Postgraduate School.

https://www.scirp.org/journal/paperinformation?paperid=151581

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**Analysis of Atmospheric Attenuation Effects on mmWave Signal Propagation in Future 6G Wireless Communication Networks**

P. Semwal, N. Venu, V. Kumar, P. Verma, M. Tiwari and D. Upadhyay. Analysis of Atmospheric Attenuation Effects on mmWave Signal Propagation in Future 6G Wireless Communication Networks.

2026 International Conference on Intelligent Computing and Automation for Sustainable Solutions (ICASS), Faridabad, India, 2026, pp. 1-7, doi: 10.1109/ICASS69550.2026.11547598.

Abstract

The purpose of this investigation is to determine how environmental factors affect millimeter wave signals in relation to the development of a future 6G network. This was completed using simulation with synthetic data due to the lack of real data for measuring the effects of various environmental factors on millimeter wave signals. The results indicate that frequencies above 20GHz will experience significant attenuations, particularly at frequencies of 22GHz, 60GHz and 120GHz; primarily caused by absorption of millimeter wave signals by oxygen and water vapor. It was also determined that all three types of precipitation (rain), (fog) and (humidity) will cause weakening of millimeter wave signals and will increase the rate of signal loss due to distance. The random variability produced by changing weather conditions was also demonstrated through Monte Carlo simulations. An alternative hybrid RABA-AMCS model was introduced as a method to decrease errors associated with free-space propagation and ITU-R models. Ultimately, it was concluded that the atmosphere will be a primary contributor to signal loss and should therefore be incorporated into the design of a reliable 6G wireless communication system.
keywords:

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11547598&isnumber=11547403

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**Homing pigeon navigation relies on superparamagnetic macrophages under overcast conditions**

Lisowski C, Quetting M, Klaus D, Lazarevski L, Seep L, Germer M, Li J, Müller I, Zuniga D, Fiedler W, Dechmann DKN, Thorup K, Hasenauer J, Fester L, Kuerten S, Farle M, Wiedwald U, Wikelski M, Kurts C. Homing pigeon navigation relies on superparamagnetic macrophages under overcast conditions. Science. 2026 May 28;392(6801):985-991. doi: 10.1126/science.ady2486.

Abstract

Birds use a variety of navigational strategies, including the geomagnetic field, especially when other cues are not available, such as under overcast or nocturnal conditions. Magnetite particles in the beak, cryptochromes in the eye, cellular ion-channel alterations, and changes in the vestibular system have been proposed to explain magnetoreception, but the exact mechanisms remain debated. Here, we used physical, morphological, functional, and genomic assays to identify the presence of superparamagnetic macrophages in the liver. We found that after macrophage depletion, pigeons flying under overcast conditions lacked their usual orientation capabilities. Orientation was unimpaired in birds without macrophages when the sun was visible, suggesting that this was their primary cue. We propose that in homing pigeons, superparamagnetic macrophages in the liver are required for finding magnetic direction.

Editor's Summary

Birds use a variety of navigational strategies, including the geomagnetic field, especially when other cues are not available, such as under overcast or nocturnal conditions. Magnetite particles in the beak, cryptochromes in the eye, cellular ion-channel alterations, and changes in the vestibular system have been proposed to explain magnetoreception, but the exact mechanisms remain debated. Here, we used

physical, morphological, functional, and genomic assays to identify the presence of superparamagnetic macrophages in the liver. We found that after macrophage depletion, pigeons flying under overcast conditions lacked their usual orientation capabilities. Orientation was unimpaired in birds without macrophages when the sun was visible, suggesting that this was their primary cue. We propose that in homing pigeons, superparamagnetic macrophages in the liver are required for finding magnetic direction

Open access: https://www.science.org/doi/10.1126/science.ady2486

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**Getting home in the dark**

Spiro S, Drakesmith H. Getting home in the dark. Science. 2026 May 28;392(6801):919-920. doi: 10.1126/science.aeh9507. Epub 2026 May 28.

Abstract

Two mechanisms, independent of daylight, may enable pigeons to navigate using Earth's magnetic field.

Open access: https://www.science.org/doi/10.1126/science.aeh9507

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**Disruptive effects of brief radiofrequency noise exposure on migratory bat navigation**

Lindecke O, et al. Disruptive effects of brief radiofrequency noise exposure on migratory bat navigation. Science392,977-979(2026).DOI:10.1126/science.adq4418

Abstract

How anthropogenic electromagnetic noise can affect living systems is a poorly understood impact of an increasingly urbanized natural environment, especially when occurring in a sublethal manner. In this study, we investigated impacts of weak-broadband radiofrequency (RF) fields on animal behavior. We exposed migratory soprano pipistrelle bats (*Pipistrellus pygmaeus*) to 0.01- to 300-megahertz RF fields and then tested their orientation later in the night. Whereas control bats oriented normally, bats exposed to RF noise exhibited random departure flight orientation, suggesting disruptive effects lasting beyond immediate exposure. These findings suggest that electromagnetic pollution has the potential to have a greater effect on animal behavior than previously assumed.

Editor’s summary

Radiofrequency, or electromagnetic, noise naturally occurs in the atmosphere, but it has increased substantially due to human activities, being produced by electronics, power lines, and even LED lights. The impacts of such noise on wildlife and humans is often debated and is yet to be understood. Lindecke *et al*. looked at the impacts of relatively weak broadband radiofrequency fields on migratory soprano pipistrelle bats and found that it disrupted their orientation even hours after exposure (see the Perspective by Balmori and Balmori-de la Puente). Although the disruptive mechanism of the noise remains to be characterized, these results suggest that the ever-present din of our devices may be having a bigger effect than was previously thought. —Sacha Vignieri

https://www.science.org/doi/10.1126/science.adq4418

**Silent interference**

Balmori A, Balmori-de la Puente A. Silent interference. Science. 2026 May 28;392(6801):922-923. doi: 10.1126/science.aei2381.

No abstract

Open access: https://www.science.org/doi/10.1126/science.aei2381

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**Human Bioelectromagnetism and the Environment: Introduction to the Problem**

Nevoit G, Potyazhenko M, Mintser O, Jarusevicius G, Vainoras A. Human Bioelectromagnetism and the Environment: Introduction to the Problem. *Applied Sciences*. 2026; 16(8):3627. https://doi.org/10.3390/app16083627

**Abstract**

Background: The increasing contribution of anthropogenic electromagnetic radiation has altered the Earth's electromagnetic landscape and poses a serious problem for electromagnetic ecology and medicine. The aim of this study was to develop a working theoretical framework to describe the current state of interaction between the human body and electromagnetic fields in the external environment and to facilitate transdisciplinary collaboration among scientists in studying and addressing this problem.

Methods: Extensive research has been conducted in the literature to provide a comprehensive presentation of data, enabling a working concept of the interaction between the human body and electromagnetic fields in the external environment.

Results: General data, theoretical foundations, mechanisms, and results of the interaction of external electromagnetic fields with the human body were presented.

Conclusions: There is a proven interaction between the human body and external electromagnetic fields, as the body is part of the Earth's electromagnetic landscape and has biophysical mechanisms for coupling with it. The increase in anthropogenic electromagnetic radiation is an electromagnetic environmental problem, and this requires further study of the safety issues and the impact of anthropogenic electromagnetic fields on the human body, and a reassessment of their biological impact on the human body, tightening the standards and requirements for electromagnetic safety in places where people live, a moratorium on further deployment of 5G, urgent application of the precautionary principle, and stricter exposure limits, especially for Wireless Communication Electromagnetic Fields.

Conclusions

Based on the analyzed scientific data available through literature search, the following can be stated:

- There is a proven interaction between the human body and external electromagnetic fields (natural and anthropogenic).

- The human body is a component of the Earth's electromagnetic landscape and has biophysical mechanisms for coupling with it.
- The development of human civilization has led to the active use of electromagnetic energy with the creation of a large number of anthropogenic sources and to a change in the Earth's electromagnetic landscape.
- Anthropogenic electromagnetic radiation has fundamental differences from the natural electromagnetic background of the Earth and has a proven negative impact on the human body.
- At present, anthropogenic electromagnetic radiation is a serious problem in electromagnetic ecology.
- To solve the existing problems of electromagnetic ecology, a transdisciplinary consolidation of scientists is necessary for further study of safety issues and the impact of anthropogenic electromagnetic fields on the human body.
- Such measures as re-evaluation of the biological impact of Extremely Low Frequency and Wireless Communication Electromagnetic Fields, classification of them as probably carcinogenic (Group 2A) or carcinogenic (Group 1) for humans, tightening of electromagnetic safety standards and requirements in places of human habitation, a moratorium on further deployment of 5G, urgent application of the precautionary principle, stricter exposure limits, especially for Wireless Communication Electromagnetic Fields are necessary.
- Further study of aspects of biomagnetism of the human body is a relevant and promising transdisciplinary scientific direction of fundamental science, which is associated with future discoveries in understanding the essence of human life and health.

Open access: https://www.mdpi.com/2076-3417/16/8/3627

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**Children's Sensitivity to Environmental Electromagnetic Fields**

Bevington M. Children's Sensitivity to Environmental Electromagnetic Fields. International Journal of Research in Medical and Clinical Science (IJRMCS). Volume 4, Issue 1, 2026.

Abstract

This review concerns children's health in relation to their typical environmental exposure at home and school to electromagnetic fields (EMFs), including radiofrequency from Wi-Fi, mobile phones and masts. It examines the extent to which children, here defined as including adolescents up to adulthood, are physiologically more sensitive to EMFs than adults, especially in the early years and while the brain is still developing myelin. It is challenging for parents, teachers and clinicians to identify the level of sensitivity to EMFs in a particular child and whether that child suffers electromagnetic hypersensitivity (EHS). There are well established short-term and long-term health hazards associated with EMF exposure. In addition, the psychological and social harms from digital addiction are becoming better recognised. Finally, children's rights and the appropriate protection of children from EMF exposure are considered. This includes the problems of the ICNIRP's thermal guidelines which are unprotective of

sensitive groups like children, and the World Health Organization's arbitrary denial of physiological sensitivity to EMFs. With accurate information and appropriate long-term guidelines, parents, teachers and general practitioners can help ensure that children's EMF environments are safe and healthy.

Conclusion

All children are more sensitive than adults to the EMFs in their environment and need greater protection at home and school from short-term and long-term effects. Children who are hypersensitive to EMFs need particular protection, and all children need protection from being exposed so much that they become hypersensitive. Parents and teachers need to provide children with an environment which has safe levels of EMFs below the threshold for adverse health. However, many parents and teachers lack the necessary information, since "the media, the responsible organizations (World Health Organization) and the governments are not transmitting this crucial information to the population, who remain uninformed." [164] The greater information and appropriate actions outlined above and elsewhere [165] show how children's health can be protected, and how their electromagnetic environment can be made safe.

Open access: https://journalserapublications.com/index.php/ijrmcs/article/view/211/148

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**Recording the extremely low frequency pulsations of wireless communication electromagnetic fields**

Panagopoulos DJ, Litovsky R, Chamberlin K. Recording the extremely low frequency pulsations of wireless communication electromagnetic fields. Electromagn Biol Med. 2026 Apr 19:1-10. doi: 10.1080/15368378.2026.2654072.

Abstract

All digital Wireless Communication (WC) electromagnetic field (EMF)/radiation (EMR) signals (from mobile/"smart" phones and corresponding base antennas, cordless domestic phones, Wireless Fidelity (Wi-Fi) routers, "Bluetooth" wireless connection among electronic devices, etc.) are emitted discontinuously, in the form of on/off pulses repeated at various Extremely Low Frequency (ELF) rates. Yet, many scientists ignore/underestimate these ELF pulsations, and characterize all WC emissions simply as Radio Frequency (RF)/Microwave (MW) signals. Here, we provide recordings of ELF pulsations with respect to time, emitted by the most common WC devices, specifically Wi-Fi router, $4^{th}$ and $5^{th}$ Generation (4G, 5G) mobile phones. We used a broadband antenna, connected to an RF spectrum analyzer (SA), calibrated the SA at the signal's carrier MW frequency and recorded the power of the final emitted RF/MW signal with respect to time. We recorded emissions at 10 ms, 100 ms, 1 s, and 2 s sweep times, capturing the pulses repeated at various ELF rates, clearly showing the ELF pulsing emissions from the WC devices. As in all real WC EMF signals emitted by commercially available devices and corresponding antennas, there is intense variability in the amplitude, shape, duration, and repetition frequency of the pulses. The present study, in combination with the Ion Forced Oscillation and Voltage-Gated Ion Channel (IFO-VGIC) mechanism of non-thermal EMF-bioeffects, imply that the non-thermal biological and health effects of WC EMFs are induced by the ELF pulsation, modulation and variability, and not by the standalone (non-modulated) RF carrier wave EMFs which can produce only heating.

Plain language summary

Electromagnetic fields/radiation (EMFs/EMR) emitted by digital wireless communication (WC) devices (mobile/"smart" phones, cordless domestic phones, Wireless Fidelity (Wi-Fi) routers for connection to the Internet, etc.) and corresponding base antennas, are usually referred to simply as Radio Frequency (RF: 300 kHz–300 GHz) EMFs/EMR. Yet, as we have repeatedly declared before, this reflects only one part of the reality. The other part is that the RF signals that carry the transmitted information (text, speech, music, images, video, etc.) are contained within on/off pulses which are emitted/repeated at various Extremely Low Frequency (ELF: 3–3000 Hz) rates. Moreover, the RF signal within the pulses is modulated mostly by ELF EMFs, and the final signal contains random variability especially in amplitude which lies mainly in the Ultra-Low Frequency (ULF: 0–3 Hz) band. Therefore, all WC EMFs are a combination of high (RF) and low (ELF/ULF) frequencies. To record the ELF pulses, specific methodology and instrumentation are required. Here, we have recorded these pulses (as power with respect to time) from the most common WC EMFs/EMR, namely Wi-Fi, 4$^{th}$, and 5$^{th}$ Generation (4G, 5G) WC EMFs/EMR. The present study, in combination with a widely accepted biophysical mechanism, the Ion Forced Oscillation and Voltage-Gated Ion Channel (IFO-VGIC) mechanism, of non-thermal EMF-bioeffects, imply that the non-thermal biological and health effects associated with exposure to WC EMFs are induced by the ELF/ULF pulsation, modulation and variability, and not by the standalone (non-modulated) RF carrier wave EMFs which can produce only heating at adequately high intensities rarely found in the environment.

Excerpt

The present study clearly shows the existence of ELF pulsations in modern digital WC EMFs, which, in combination with the IFO-VGIC mechanism, fully explain and further validate the non-thermal biological and health effects reported in the EMF-bioeffects literature to be induced by various types of WC EMFs. An important application of the present research should be that the scientific community, the health authorities, and the industry, should stop treating WC EMFs as standalone RF EMFs with thermal-only effects, but should start measuring their inherent ELF pulsations, and considering the corresponding non-thermal biological effects. Especially, the health authorities should revise their guidelines to account for the non-thermal biological and health effects due to the ELF pulsations which occur at RF power densities much lower than those inducing thermal effects.

In conclusion, the more we know about the physical characteristics and waveforms of the various EMFs and the mechanism of induced biological effects, the more we understand about these effects and how to control them. We hope the present study effectively contributes toward a more realistic understanding, recording, and quantization of the physical properties, and consequently, a more relevant evaluation and understanding of the non-thermal effects and health risks associated with WC EMF exposures.

https://pubmed.ncbi.nlm.nih.gov/42002914/

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**A comprehensive mechanism of biological and health effects of anthropogenic extremely low frequency and wireless communication electromagnetic fields**

Panagopoulos DJ, Yakymenko I, De Iuliis GN, Chrousos GP. A comprehensive mechanism of biological and health effects of anthropogenic extremely low frequency and wireless communication electromagnetic fields. Front Public Health. 2025 Jun 4;13:1585441. doi: 10.3389/fpubh.2025.1585441

Abstract

Exposure to anthropogenic electromagnetic fields (EMFs), especially those of wireless communications (WC) has increased tremendously. This is an unprecedented phenomenon throughout biological evolution because, all anthropogenic EMFs, being fully polarized, coherent, and, especially WC EMFs, highly variable, differ substantially from the natural EMFs. WC EMFs consist of Microwave (MW) carrier waves, modulated, by Extremely Low Frequency (ELF) signals, and included in on/off pulses repeated at various ELF rates. Moreover, they exhibit intense random variability, mainly in the Ultra Low Frequency (ULF) band. Thus, WC EMFs are a combination of MW and ELF/ULF EMFs. The combination of polarization/coherence and intense low-frequency (ELF/ULF) variability seems to be the key to EMF-bioactivity. Epidemiological and laboratory studies highlight a connection between ELF or WC EMF exposure and cancer, infertility, electro-hypersensitivity, and various other pathologies. Studies also find DNA damage and Oxidative Stress (OS) which explain these pathologies. While man-made EMFs cannot directly ionize molecules, they are capable of doing this indirectly in biological tissue, by triggering the biosynthesis of Reactive Oxygen Species (ROS) which can damage biomolecules, including DNA. The (over)production of ROS and the consequent OS are triggered by irregular gating of Voltage-Gated Ion Channels (VGICs) in the cell membranes as described by the Ion Forced Oscillation (IFO)-VGIC mechanism: Mobile ions within VGICs forced to oscillate by the applied ELF/ULF EMFs exert forces on the voltage sensors of the VGICs, similar to or greater than the forces that physiologically gate those channels, resulting in their irregular gating (dysfunction). Dysfunction of ion channels disrupts intracellular ionic concentrations. This triggers ROS overproduction and OS by the ROS-generating systems/enzymes in the cells, such as the electron transport chain (ETC) in the mitochondria, or the NADPH/NADH oxidases (NOXs), the Nitric Oxide synthases (NOS), etc. The IFO-VGIC mechanism and the consequent OS constitute a comprehensive mechanism that explains all known adverse biological and health effects reported to be induced by anthropogenic EMFs.

Open access: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1585441/full

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**Electromagnetic field-inducible in vivo gene switch for remote spatiotemporal control of gene expression**

**Gemini:** "For years, the idea that low-level, non-heating (non-thermal) EMFs could significantly alter cellular function was highly controversial. Physicists and skeptics rightly asked: *If the field isn't physically heating the cell, what is the biological "antenna" receiving the signal?* Isolating Cyb5b provides that missing hardware. It proves that living cells possess native molecular machinery capable of sensing electromagnetic fields and translating them into biological instructions. This (study) validates a core concept of quantum biology—showing that quantum spin-state changes at the electron level (within the heme group of the protein) can drive massive physiological outcomes."

"Perhaps the most profound biophysical takeaway is that the EMF didn't just blast the cell into a state of generic stress. Instead, the Cyb5b sensor converted the EMF into **rhythmic oscillatory calcium dynamics**. This showed that EMFs can write an intracellular timing structure. It means we aren't just zapping cells; we are speaking to them in a structured, rhythmic chemical language that the cell natively uses to make complex biological decisions."

Kim J, Hwang Y, Kim S, Kwon D, Park J, Cho B, An S, Kang S, Kim Y, Kim S, Lengner CJ, Kim S, Kwon Y, Sung JS, Kim J. Electromagnetic field-inducible in vivo gene switch for remote spatiotemporal control of gene expression. Cell. 2026 Apr 14:S0092-8674(26)00330-2. doi: 10.1016/j.cell.2026.03.029.

https://www.sciencedirect.com/science/article/pii/S0092867426003302 or
https://www.cell.com/cell/abstract/S0092-8674(26)00330-2

Highlights

- EMF-inducible gene switch (Ei) for precise spatiotemporal gene expression control
- Cyb5b mediates EMF-specific calcium oscillations for gene switch activation
- Ei gene switch enables in vivo rejuvenation by reversing aging phenotypes
- Ei system models Alzheimer’s disease and restores serotonergic function in vivo

Summary

Gaining precise control of gene expression is crucial in biomedical applications. However, spatiotemporal precision remains challenging. Here, we present a remotely controlled in vivo gene switch responsive to electromagnetic fields (EMFs) that enables precise spatiotemporal activation of target genes. We uncovered the EMF-inducible gene switch activation mechanism via a CRISPR-Cas9 screen, identifying cytochrome b5 type B (Cyb5b) as an essential mediator likely acting as an EMF sensor. The EMF-inducible gene switch was activated by rhythmic oscillatory calcium dynamics rather than generic calcium influx, defining a precisely tuned and bio-orthogonal induction mechanism. Functionally, EMF activation of the Oct4-Sox2-Klf4 (OSK) cassette induced in vivo partial reprogramming in aged mice, conditional expression of human mutant amyloid precursor protein (APP) for Alzheimer’s disease (AD) modeling recapitulated pathological features, and EMF-mediated Tph2 expression restored serotonergic activity and ameliorated depressive-like behaviors in Tph2-mutant depression mice. Overall, a remotely controlled EMF-inducible gene switch represents a versatile and effective biomedical platform.

**Excerpt**

To develop an EMF-responsive gene switch, we initially sought to find out genes that could be efficiently stimulated by EMF in the brain. We established an EMF system using a pair of Helmholtz coils (Data S1.1), capable of delivering a magnetic flux density of 0.0–10.0 mT over a 0–200 Hz frequency range. We designed the EMF system to generate unipolar pulsed fields where each 16.67 ms cycle (e.g., 60 Hz) consists of a 5 ms active burst of 20 consecutive single pulses, followed by a 11.67 ms resting interval (Figure S1A). Characterized by a pulsed sine square wave, the EMF uniformity was determined to be approximately 99% within the central region between the coils, ensuring consistent exposure (Data S1.1). We performed single-cell RNA sequencing (scRNA-seq) to analyze transcriptional changes in the mouse brain after exposure to EMF (2.0 mT and 60 Hz) for 48 h. We identified a diverse range of cell

types, including astrocytes, oligodendrocytes, microglia, and neuroblasts (Figures S1B and S1C). We found 15 upregulated genes that were classified as being positively responsive to external stimuli related to signaling following EMF exposure (Figure S1D). We found that the proportion of Lgr4+ cells significantly increased across all identified cell types, as well as relative to the total cell population, in the EMF-exposed brain (Figures S1E and S1F).

https://pubmed.ncbi.nlm.nih.gov/41985457/

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**Resonant Convergence: An Integrative Model for Electromagnetic Interactions in Biological Systems**

Greco A. Resonant Convergence: An Integrative Model for Electromagnetic Interactions in Biological Systems. Int J Mol Sci. 2025 Dec 31;27(1):423. doi: 10.3390/ijms27010423.

Abstract

Over the past 50 years, scientific interest in electromagnetic field-biology interactions has flourished. Important experimental observations and mathematical hypotheses remain central to academic debate. Adey and Blackman found that specific electromagnetic frequencies affect calcium transport in cells. To explain this phenomenon, Liboff introduced ion cyclotron resonance-like (ICR-like) theory, proposing a specific mechanism for ion modulation. Preparata and Del Giudice introduced quantum electrodynamics (QED), offering controversial quantum-level explanations that complement classical models. Lucia and NASA contributed further with thermomagnetic resonance and experimental observations. Together, these hypotheses have partially clarified how weak electromagnetic fields interact with cells and suggest possible parallel endogenous mechanisms. The aim of this narrative review is to provide a clear and logical framework for understanding biological events, both those that arise naturally within biology and those that can be initiated externally through the application of electromagnetic fields. As electromagnetism constitutes one of the four fundamental forces, this interaction warrants rigorous scientific scrutiny.

Conclusions

The complexity of the described system suggests that eventual complete quantitative understanding might require the development of advanced mathematical models. The proposed model is not the simple sum of individual mechanisms, but represents the challenge of describing an integrated system where each level potentiates and modulates the others. Such integration might require mathematical models that combine the deterministic nature of EMFs with the intrinsic variability of cellular processes. To use a musical analogy: as in a symphony orchestra, each instrument (mechanism) contributes to the overall melody (biological effect), but it is the coordinated ensemble that produces the final effect.

This holistic view explains parameter sensitivity in biological responses: small variations in stimulation can produce different effects or no effect at all. We are modulating a complex system where minor changes shift cellular state balance. Liboff's culture studies [46,47,48,49,50] first demonstrated this principle; decades of subsequent research have confirmed these observations, though only partially reviewed here.

Despite theoretical advances and encouraging preclinical data, clinical translation remains challenging. Part of this difficulty relates to reproducibility, driven by high sensitivity to environmental variables such

as fluctuations in the local geomagnetic field and artificial electromagnetic interference [27]. The historical fragmentation between ICR, QED, and thermodynamic models has also hindered the development of unified predictive frameworks, a gap that the Resonant Convergence model aims to fill.

The primary challenge is developing predictive algorithms: integrating thermomagnetic resonance calculations with ICR frequencies for dominant ions could enable patient-specific protocols—optimized frequency sequences tailored to individual pathophysiology. In this framework, regenerative medicine [53,56] and complementary treatments in oncology represent the most promising clinical applications for development.

In conclusion, the convergence of multiple independent theoretical frameworks supported by diverse experimental validations across scales suggests that EMF interactions with biological systems represent a fundamental aspect of cellular regulation. The Resonant Convergence model provides a unified conceptual foundation; its ultimate validation will depend on experimentally discriminating specific mechanistic contributions to translate these theoretical insights into effective clinical reality.

Open access: https://www.mdpi.com/1422-0067/27/1/423

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**Latent class analysis of mobile phone usage patterns and association with sleep problems in children**

Ajmal A, Tamura n, Bamai YA, Yamazaki K, Yoshikawa T, et al. Latent class analysis of mobile phone usage patterns and association with sleep problems in children: Findings from the Hokkaido Birth Cohort Study. Computers in Human Behavior Reports. Volume 22, 2026. doi: 10.1016/j.chbr.2026.101077.

Abstract

This study determined distinct latent classes of mobile phone usage and examined the association of each class with sleep problems among 4869 children aged 7–17 years in the Hokkaido Birth Cohort Study (January 2020 to July 2021). Parent–child dyads reported mobile phone usage and sleep problems were evaluated using the brief version of the Japanese Children's Sleep Habits Questionnaire. Five mobile phone use classes were identified: lowest use, low use, high on mobile phone calls and SMS, high on internet activities, and overall high use. The lowest use class was more common in elementary school students, while higher use classes predominated in older students. Multiple logistic regression analysis showed that low use (odds ratio [OR] = 1.07, 95% confidence interval [CI]: 1.02–1.14), high on mobile phone calls and SMS (OR = 1.42, 95% CI: 1.32–1.53), and overall high use (OR = 1.28, 95% CI: 1.20–1.36) were associated with sleep problems. In stratified analysis of elementary school students, low use (OR = 1.14, 95% CI:1.06–1.23), high on mobile phone calls and SMS (OR = 1.53, 95% CI: 1.41–1.67), and overall high use (OR = 1.26, 95% CI: 1.12–1.41) were associated with sleep problems. Conversely, among junior high and high school students, only overall high use (OR = 1.22, 95% CI: 1.12–1.33) was associated with sleep problems. The findings show that elementary school students were more susceptible to sleep problems, which may be attributable to behavioral disruptions and physiological effects. However causal inference cannot be drawn due to cross-sectional nature of the study.

Highlights

• Latent class analysis identified five distinct patterns of mobile phone use.
• Sleep problems linked to low use, high mobile phone calls, SMS and overall high use.
• Junior high school and higher, only overall high use was linked to sleep problems.
• No association between high use for internet activities and sleep problems.
• Mobile phone's influence of behavioral factors rather than RF-EMF exposure.

https://www.sciencedirect.com/science/article/pii/S245195882600151X

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**Protective Effects of Ginseng on the Blood–Brain Barrier in Rats Exposed to 2600 MHz Radiofrequency Radiation**

Postacı Karaman İ, Coşkun Ö, Şenol N, Şahin U, Çömlekçi S. Protective Effects of Ginseng on the Blood–Brain Barrier in Rats Exposed to 2600 MHz Radiofrequency Radiation. *Applied Sciences*. 2026; 16(8):4012. doi: 10.3390/app16084012.

Abstract

Radiofrequency radiation (RFR) exposure is higher in the structures surrounding the ears and head. Moreover, the brain is the organ most vulnerable to microwave radiation, exhibiting earlier and more severe mitochondrial damage compared to other tissues. The present study investigated the impact of 2600 MHz RFR on the blood–brain barrier (BBB) through immunohistochemical, genetic, and biochemical analyses and explored the potential protective role of ginseng. The animals in the study were randomly assigned to five groups (n = 8 per group): control, sham, ginseng, 2600 MHz RFR, and 2600 MHz RFR + ginseng. The RFR groups were exposed to RFR for 1 h day$^{-1}$ for 30 days. Ginseng was applied every day (150 mg/kg/day) by gavage for 30 days. Histopathological examination of the 2600 MHz RFR group revealed degenerative changes, vacuolization, vascular dilatation, and mild edema, particularly in cortical neurons. These alterations appeared reduced in the sham and 2600 MHz RFR + ginseng groups. The immunohistochemical findings indicated moderate damage in the RFR group, whereas a statistically significant decrease was observed in the ginseng-treated groups ($p < 0.05$). Overall, the findings suggest that 2600 MHz RFR may be associated with increased apoptotic activity and ginseng may exert a protective effect.

Excerpts

The carousel exposure system consisted of an RF generator with a center frequency of 2600 MHz (tuning range: 2550–2650 MHz; Set Elektronik A.Ş., Sakarya, Türkiye) that was connected to a monopole antenna with a characteristic impedance of 50 Ω. Each animal was individually restrained in cylindrical plastic tubes (7 cm diameter, 22 cm length) and placed at equal distances from the antenna during exposure. The RF generator output was carefully tuned in a stepwise manner to obtain an electric field strength of 10 V/m at the brain region, with measurements performed using an electromagnetic field meter produced by EXTECH Instruments Corporation (Nashua, NH, USA) [15]. At this stage, energy absorption within the brain tissue was quantified in terms of specific absorption rate (SAR). A visual overview of the study configuration is presented in Figure 2.... the average SAR value generated in the tissue was automatically calculated in MATLAB R2021b (MathWorks, Natick, MA, USA) and was found to be 61.76 mW/kg....

Conclusions

According to previous studies, increased BAX protein levels are generally associated with enhanced apoptotic activity. In this study, the immunohistochemical findings demonstrated increased apoptosis in the RFR groups. Although some variation in COX-2 expression was observed, these differences were not statistically significant. Therefore, any relationship between COX-2 expression and apoptosis should be interpreted with caution and cannot be considered a definitive mechanistic link. The mechanisms underlying the protective effects of ginseng remain unclear. Although changes in COX-2 expression were observed, these findings do not support a direct mechanistic role due to the lack of statistical significance. Therefore, factors other than COX-2 may contribute to the observed protective effects.

Since RFR effects were observed histologically, genetic and biochemical studies were conducted to investigate these processes further. The effects of RFR on brain tissue were clearly demonstrated both histologically and immunohistochemically.

The potential protective role of ginseng against RFR-induced damage was also evaluated; however, the precise mechanisms underlying these effects remain unclear and require further investigation. Although ginseng is known to possess antioxidant properties, oxidative stress markers were not evaluated in the present study. In particular, parameters such as reactive oxygen species (ROS) levels were not measured. Therefore, the involvement of oxidative processes in RFR-induced effects and the protective role of ginseng remains unclear and requires further investigation in future studies.

BAX is a widely used marker of apoptosis and was included in this study to provide biochemical support for the histological findings. The results demonstrated increased apoptotic activity in the RFR groups, consistent with the immunohistochemical observations. Although there were some discrepancies between the molecular and histological findings, these differences highlight the complexity of apoptotic processes and suggest that multiple factors may be involved.

In this study, variations in COX-2 expression were observed; however, these differences were not statistically significant. Therefore, its potential relationship with apoptosis should be interpreted with caution. Overall, these findings emphasize the importance of integrating histological, immunohistochemical, and molecular analyses to better understand the cellular responses to RFR exposure.

Open access: https://www.mdpi.com/2076-3417/16/8/4012

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**Testicular Heat-Shock Protein Expression in Rats Following 3.5 GHz and 24 GHz RF-EMF Exposure**

My note: The signal generators employed in this study did not produce 5G signals. The maximum SAR values (full body exposure) were 0.22 W/kg.

Syed Taha SMA, Jaffar FHF, Hairulazam A, Vijay S, Jamaludin N, Zulkefli AF, Mat Ros MF, Osman K, Zakaria Z, Mohd Bahar MAA, et al. Testicular Heat-Shock Protein Expression in Rats Following 3.5 GHz and 24 GHz RF-EMF Exposure. International Journal of Molecular Sciences. 2026; 27(8):3452. doi: 10.3390/ijms27083452.

Abstract

The expansion of fifth-generation (5G) wireless networks has increased environmental exposure to mid-band and millimeter-wave radiofrequency electromagnetic fields (RF-EMF), but their molecular effects on male reproductive tissues remain insufficiently understood. This study evaluated whether repeated exposure to 3.5 GHz and 24 GHz RF-EMF alters testicular stress-associated molecular responses by integrating electromagnetic dosimetry with an in vivo rat model. Whole-body specific absorption rate (SAR) and 10 g peak SAR were estimated using a rat voxel model and scaled to the 20 cm antenna-to-cage geometry used during exposure. Thirty-six adult male Sprague Dawley rats were allocated to sham, 3.5 GHz, or 24 GHz groups and exposed for 1 h/day or 7 h/day over 60 days. Testes were examined histologically and assessed for HSP27, HSP70, and HSP90 protein expression. SAR values were low overall, although absorption was higher at 3.5 GHz than at 24 GHz. Histological evaluation showed preserved seminiferous tubule architecture without consistent structural injury. In contrast, molecular analysis demonstrated frequency- and duration-dependent modulation of heat shock proteins, including early HSP70 downregulation at both frequencies, followed by HSP90 upregulation at 3.5 GHz and HSP27 upregulation at 24 GHz. These findings indicate that low-level 5G-relevant RF-EMF exposure can modify molecular stress responses in testicular tissue even in the absence of overt histological damage.

https://www.mdpi.com/1422-0067/27/8/3452

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**Cellular redox disruption and apoptosis: Differential effects of RFR frequencies on Leydig cells**

Jangid P, Rai U, Sevak JK, Singh S, Rajeev Singh R. Cellular redox disruption and apoptosis: Differential effects of RFR frequencies on Leydig cells. Toxicology and Applied Pharmacology. Volume 511, 2026, doi: 10.1016/j.taap.2026.117807.

Abstract

Radiofrequency radiation (RFR), widely emitted from modern wireless devices, has raised questions regarding its possible impact on male reproductive health. In this comparative study, we examined the redox and apoptotic responses of TM3 Leydig cells following exposure to mobile phone radiation, as well as 2450 MHz, and 1800 MHz frequencies for 15, 30, 45, 60, 90 & 120 min, and redox imbalance was assessed by quantifying nitric oxide (NO) and intracellular superoxide (SO) levels. Apoptotic cell percentages were evaluated by dual labeling with Annexin V-FITC/PI using flow cytometry. Mobile phone and 2450 MHz exposures induced biphasic alterations in NO levels, while 1800 MHz exposure resulted in a sustained reduction in NO. SO levels increased progressively in a time- and frequency-specific manner. Apoptotic analysis revealed early apoptotic activation in mobile and 2450 MHz groups, whereas 1800 MHz exposure led to delayed but sustained late-stage apoptosis. These findings demonstrate that RFR triggers redox imbalance and apoptosis in TM3 cells, with effects varying by frequency and exposure duration. This comparative analysis underscores the biological risks of chronic low-intensity RFR exposure and highlights the growing concerns about RFR-associated testicular stress and its implications for male reproductive toxicity.

Highlights

- TM3 cells exposed to RFR showed frequency-specific redox imbalance.
- Mobile and 2450 MHz exposures induced biphasic nitric oxide alterations.

• Superoxide levels increased progressively with RFR exposure.
• Annexin V-FITC/PI staining revealed frequency-dependent apoptotic changes.
• Short term RFR exposure may impair testicular function and redox homeostasis.

2.4.1. Mobile phone exposure

Radiofrequency radiation and sham exposures were conducted in line with the approach detailed by Jangid et al. (2024) & Yadav and Singh (2023). In short, a 4G smartphone (Xiaomi Note 7), with a power density of 0.224 W/$m^2$, was employed to deliver exposure at different time intervals, inside a $CO_2$ incubator (5% $CO_2$) maintained at 37 °C. The cell culture suspension ($1 \times 10^6$ cells/mL) was placed in sterile 15 mL tubes immediately prior to exposure. According to the manufacturer, the specific absorption rate (SAR) of the phone is 0.838 W/kg for the body and 0.962 W/kg for the head (measured at a 15 mm distance). Calibration of the device was verified using the Narda 520 system by assessing its physical parameters. Over the course of exposure, no variation in the temperature was detected. Background conditions remained the same in both sham and RFR exposure groups.

2.4.2. 2450 MHz & 1800 MHz exposure

The experimental setup for 2450 MHz and 1800 MHz exposure included a signal generator, an incubator (irradiation chamber), a horn antenna, and a handheld power meter. A Keysight signal generator (USA) was used to generate electromagnetic waves at 2450 MHz and 1800 MHz, which were transmitted through a horn antenna. Exponential growing TM3 cells were selected for treatment. The temperature variation between the exposed and control groups was less than 0.1 °C and the incubator maintained stable conditions of 37 °C and 5% $CO_2$ throughout the procedure. Cell suspensions at a concentration of $1 \times 10^6$ cells/mL were seeded in 35 mm Petri dishes immediately prior to exposure, and positioned 2 cm away from the horn antenna during the procedure.

Conclusion

This study demonstrates that even under non-thermal conditions, exposure to RFR from commonly encountered sources, can significantly disrupt redox homeostasis and trigger apoptosis in Leydig cells in a frequency- and time-specific manner. Mobile phone and 2450 MHz exposures elicited biphasic NO responses and robust SO generation, alongside early-stage apoptotic activation. In contrast, 1800 MHz exposure induced a more sustained suppression of NO and predominantly late-stage apoptosis, indicating distinct mechanistic pathways across frequencies. These findings suggest that even low-intensity RFR exposures, traditionally considered biologically inert, may exert significant redox imbalance and apoptotic responses in Leydig cells, potentially impairing steroidogenic function.

Given the essential role of Leydig cells in testosterone biosynthesis and reproductive health, our results raise important concerns regarding chronic RFR exposure in the male population, particularly in the context of increasing wireless device usage. The observed redox imbalance and apoptosis may contribute to broader testicular dysfunction and, ultimately, male infertility. These insights underscore the need for more comprehensive regulatory frameworks that consider not only thermal but also non-thermal biological effects of RFR. Future studies should expand on these findings by exploring molecular signaling pathways, mitochondrial dynamics, and in vivo reproductive outcomes to better inform public health policies and exposure guidelines.

https://www.sciencedirect.com/science/article/pii/S0041008X26001031

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**Radiofrequency radiation-induced changes in Leydig cell function**

Jangid, P., Rai, U., Sevak, J.K. *et al.* Radiofrequency radiation-induced changes in Leydig cell function. *Sci Rep* (2026). doi: 10.1038/s41598-026-39244-6.

Abstract

Radiofrequency radiation, emitted from commonly used wireless communication devices, has been implicated in disrupting cellular homeostasis; however, its effects on testicular somatic cells such as Leydig cells remain poorly understood. To address this, the present study investigated the frequency- and time-specific effects of RFR on cellular morphology, proliferation, and cell cycle dynamics in TM3 Leydig cells. Cells were exposed to mobile phone radiation and radiofrequency signals at 1800 MHz and 2450 MHz for 15–120 min under non-thermal conditions. Following exposure, morphological alterations were examined using Giemsa staining, while proliferation and cell cycle progression were evaluated by BrdU-ELISA and PI-based flow cytometry. BrdU assays showed a progressive reduction in DNA synthesis across conditions, indicating suppressed proliferative activity. Consistently, cell cycle analysis revealed accumulation of cells in G1 phase with a corresponding decline in S-phase population at longer durations, suggesting checkpoint activation. These changes were supported by morphological alterations such as cell rounding, loss of adherence, and membrane blebbing, features associated with stress-induced antiproliferative responses. Overall, these findings indicate that RFR disrupts cellular morphology, DNA synthesis, and cell cycle progression in a frequency- and time-dependent manner, highlighting Leydig cell vulnerability to prolonged exposure and potential implications for male reproductive health.

Open access: https://www.nature.com/articles/s41598-026-39244-6

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**Thermal responses of rats exposed to continuous or intermittent 915 MHz mobile phone RF signals**

Kim HS, Kim Y, Jeon SB, Moon JI, Choi HD, Lee AK, Ahn YH. Thermal responses of rats exposed to continuous or intermittent 915 MHz mobile phone RF signals. J Therm Biol. 2026 Apr 20;139:104464. doi: 10.1016/j.jtherbio.2026.104464.

Abstract

The thermal effects of a mobile phone emitting radiofrequency electromagnetic fields (RF-EMFs) are well known, but the in vivo impact of different exposure patterns has not been directly demonstrated. This study aimed to compare the in vivo effects of continuous and intermittent exposure to 915 MHz LTE-modulated mobile phone signals under conditions that simulate typical mobile phone use. Male Sprague-Dawley rats were exposed either continuously at whole-body averaged specific absorption rates (SAR) of 0, 4, 6, or 8 W/kg, or intermittently at 0 or 8 W/kg using 10-min on/off cycles. Rectal and interscapular temperatures were recorded during 9 h of continuous exposure or 10 h of intermittent exposure. Comparisons were made under two matched conditions: continuous exposure at 8 W/kg for 5 h versus intermittent exposure at 8 W/kg for 10 h (equal RF-on time), and continuous 4 W/kg versus intermittent 8 W/kg (50% duty cycle; equal time-averaged SAR). Under equal cumulative RF-on time, intermittent 8 W/kg exposure caused only a brief temperature increase, whereas continuous 8 W/kg

exposure resulted in a gradual and sustained rise. Under equal time-averaged SAR, continuous 4 W/kg showed no temperature change, whereas intermittent 8 W/kg caused a transient rise. No significant effects were observed at 6 W/kg continuous exposure, and sham groups remained stable. These findings provide direct, comparative in vivo evidence that both SAR level and exposure pattern significantly influence thermal outcomes during exposure to mobile phone RF signals.

Highlights

- Continuous RF exposure at 8 W/kg induced a sustained ∼1 °C core temperature rise.
- Intermittent RF exposure (10-min on/off) at 8 W/kg caused a transient rise.
- Distinct thermal responses occurred despite matched RF-on time or averaged SAR.
- RF-induced thermal effects depended on both SAR magnitude and exposure pattern.
- RF exposure pattern and recovery intervals are key considerations for RF safety

Excerpts

An RF reverberation chamber system for small animals was used as described previously (Kim et al., 2013a; Kim et al., 2013b; Kim et al., 2020). Two chambers, one for sham exposure and one for RF exposure, were maintained under controlled conditions, including ventilation, temperature (22 ± 2 °C), humidity, and a 12-h light/dark cycle. Accordingly, RF-exposed and sham-exposed animals were studied simultaneously under identical environmental conditions. Animals had ad libitum access to gamma-irradiated RodFeed (Dea-Han Biolink) and filtered tap water. The exterior dimensions (L × W × H) of the chamber are 2.3 × 2.3 × 1.5 m. An LTE source with a frequency of 915 MHz was generated using a signal generator (E4438C; Keysight Technologies, Santa Rosa, CA, USA). The input signal was amplified using a high-power amplifier (HPA-272+; Mini-Circuits, Brooklyn, NY, USA), and the output power level (maximum: 100 W) was regulated using a system controller (KSS-SC 349; Korea Shield System Co., Cheongju, Korea). A customized software program (Korea Shield System Co.) controlled the RF signal exposure level and duration. The input power was monitored in real-time using a power sensor (E9301A, Keysight) and a power meter (E4478B, Keysight) through a 20-dB directional coupler (ZGDC20-372HP+, Mini-Circuits). The field uniformity of the reverberation chamber was measured at 24 points within the working volume using an isotropic field probe (HI-6005; ETS-Lindgren), ensuring the field distribution remained within ±2 dB over a 1-min average....

No biologically relevant changes occurred at 4 or 6 W/kg, which are consistent with a practical threshold near 8 W/kg in healthy young male rats in this setting. These findings align with the U.S. NTP study (Wyde et al., 2018), in which intermittent exposure at 8 W/kg induced significant temperature increases in young males, and even greater rises (>1 °C) in pregnant and aged rats, while 4 or 6 W/kg produced little or no change in young males.

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**Effects of prolonged exposure to 2.45 GHz electromagnetic fields on mouse health over a 5-month period**

Lv Z, Wu Y, Zhao K, Li J, Gao H, Zhao X, Li S, Xu A, Li J, Cai Y, Xiang S, Chen H, Yin R, Yu M, Yang X, Li C. Effects of prolonged exposure to 2.45 GHz electromagnetic fields on mouse health over a 5-month period. Ecotoxicol Environ Saf. 2026 Apr 7;315:120106. doi: 10.1016/j.ecoenv.2026.120106.

Abstract

With the ubiquitous and prolonged nature of human exposure to S-band electromagnetic fields (EMF, 2.45 GHz), concerns regarding its potential health impacts are growing. However, existing preclinical evidence is inconsistent, and a comprehensive assessment of its effects across multiple physiological systems is lacking. This study aimed to perform an integrated evaluation of the biological consequences of prolonged 2.45 GHz EMF exposure in mice, focusing on the reproductive, immune, metabolic, and hematopoietic systems. We established a murine model of prolonged EMF exposure, wherein mice were subjected to 2.45 GHz radiation (whole-body average specific absorption rate, SAR 15 W/kg) for 5 months. A combination of physiological monitoring, functional sperm analysis, comprehensive flow cytometry, hematopoietic stem cell functional assays, and metabolic challenge tests insulin tolerance test (ITT) and pyruvate tolerance test (PTT) was employed to assess systemic impacts. Our findings revealed a system-specific pattern of responses. Notably, prolonged EMF exposure did not induce measurable adverse effects on core physiological parameters, sperm functional integrity (kinematics and morphology), immune cell populations and distribution, or hematopoietic competence. In stark contrast, it significantly disrupted systemic glucose homeostasis, leading to elevated fasting blood glucose and impaired insulin sensitivity. This study demonstrates that biological effects of prolonged 2.45 GHz EMF exposure are not monolithic but exhibit distinct organ susceptibility. We identified a selective vulnerability in metabolic regulation, while reproductive, immune, and hematopoietic systems remained resilient under our specific exposure conditions. These findings challenge the universality of generalized toxicity claims, underscore the critical role of exposure parameters, and highlight metabolic dysfunction as a potential risk for prolonged EMF exposure, providing crucial insights for future risk assessment.

Highlights

- Reveals system-specific biological effects of prolonged 2.45 GHz EMF.
- Shows no adverse effects on reproduction, immunity, or hematopoiesis and identifies selective vulnerability in glucose homeostasis regulation.
- Demonstrates elevated blood glucose and insulin resistance.

Excerpts

Regarding non-thermal mechanisms, several biophysical pathways may contribute to the observed metabolic effects independent of bulk tissue heating. RF-EMF can induce non-thermal bioeffects through membrane depolarization, altered ion channel kinetics, and modulation of voltage-gated calcium channels (Pall, 2013). The microthermal hypothesis suggests that while macroscopic temperature remains stable, nanoscale thermal fluctuations at membrane interfaces or within mitochondria could affect enzyme kinetics and signaling cascades (Riu et al., 1997). Additionally, electromagnetic field interactions with cellular structures—particularly the plasma membrane's dielectric properties—can trigger conformational changes in membrane proteins, alter lipid raft dynamics, and generate reactive oxygen species through non-thermal activation of NADPH oxidase or disruption of mitochondrial electron transport (Yakymenko et al., 2016, Sies, 2015). These mechanisms

may collectively contribute to the selective metabolic dysregulation observed, though their relative contributions require further investigation.

In conclusion, this study offers crucial insights into the system-specific biological effects of prolonged 2.45 GHz EMF exposure. Our results challenge the broad assertion of reproductive toxicity under certain exposure regimens, reveal a marked vulnerability in metabolic homeostasis likely mediated by oxidative stress and mitochondrial impairment, and demonstrate preserved immune and hematopoietic function. The clear metabolic dysfunction observed in the absence of overt pathology in other organ systems indicates that biological responses are not uniform and may emerge initially at molecular and biochemical levels prior to advancing to structural or functional deficits. Organ-specific molecular responses, suggested by comparative analysis of bone marrow scRNA-seq and published hepatic transcriptomic data, merit further exploration. These findings substantially enhance the mechanistic understanding of prolonged 2.45 GHz EMF exposure bioeffects and support refined risk assessment modeling. Future work should emphasize longitudinal tracking of metabolic dysregulation, examination of cross-system interactions and analysis of individual or genetic susceptibility. Such evidence is vital to inform science-driven public health guidelines and safety standards for prolonged environmental EMF exposure.

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**The effects of acute and chronic exposure of 2100 MHz radiofrequency radiation on rat mismatch negativity**

Er H, Hidisoglu E, Kantar D, Acun AD, Akkoyunlu G, Ozen S, Yargicoglu P. The effects of acute and chronic exposure of 2100 MHz radiofrequency radiation on rat mismatch negativity, Journal of Radiation Research and Applied Sciences. 19(1), 2026. doi:10.1016/j.jrras.2025.102126.

Abstract

Cell phones operate by emitting radiofrequency radiation (RFR), a form of electromagnetic radiation (EMR). Consequently, ongoing researches target to determine whether it poses potential risks to human health. One of these risks is related with brain and auditory system. This study aims to examine the impact of acute and chronic exposure to 2100 MHz radiofrequency radiation on mismatch negativity (MMN) in rats. In this study, we established 1-week (RFR1) and 10-week (RFR10) RFR groups from rats, which were subjected to 2100 MHz RFR exposure. Cage control groups (CC1, CC10) and sham groups (S1, S10) that were not subjected to RFR for equivalent durations were also established. Following auditory event-related potential (AERP) recordings, MMN waves were computed and analyzed. Additionally, brain samples were collected and biochemical and histological analyses were performed. The RFR1 group exhibited a reduction in AMPAR GluR2 subunit protein levels relative to the CC1 and S1 groups, although GFAP protein levels increased. Conversely, the opposite was observed in the chronic groups. Edema of astrocytic endfeet, mitochondrial damage, and lysosomal vesicles were identified in the RFR1 group. The MMN amplitude was found to be reduced in the RFR1 group relative to the CC1 group. The RFR1 group exhibited a reduction in delta and theta power relative to the S1/CC1 groups. Alpha coherence diminished in the RFR1 group relative to the S1 group, however it augmented in the RFR10 group compared to the S10 group. The assessment of event-related potentials indicated that

2100 MHz RFR led to a decrease in MMN amplitude, power spectrum, and coherence values in the RFR1 group relative to the S1 and CC1 groups, but an increase was observed in the RFR10 group compared to the S10 group. Consequently, in the acute period, 2100 MHz RFR may have adverse effects on auditory sensory memory.

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**Evaluation of Electromagnetic Field Exposure Level from Mobile Phones and Its Health Risk**s

Akpolile FA, Agbajor GK, Omoriwhovo OJ, Adonuja JA, Ukerun-Akpesiri AA (2026). Evaluation of Electromagnetic Field Exposure Level from Mobile Phones and Its Health Risks. 11(3). doi: 10.51584/IJRIAS.2026.11030054.

Abstract

This study investigated the electromagnetic field (EMF) exposure and Specific Absorption Rate (SAR) levels associated with different mobile phone models operating at frequencies of 900 MHz and 2100 MHz. The objective was to assess the electric field strength, magnetic field strength, and power density emitted by these devices, and to determine the potential impact of mobile phone radiation on human health. Using an EMF Multi-Function Meter (GQ EMF-390V2 Electronics), measurements of the electric field (E), magnetic field (H), and power density (S) were obtained. The specific absorption rate (SAR) and health risk index (HRI) were computationally analyzed from dielectric and density data for seven (7) head tissues and the measured electric field over a range of popular mobile phone models and compared their EMF exposure levels against the safety limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The study found that while most mobile phones complied with ICNIRP safety standards, significant differences in radiation emission were observed between models, with certain devices exceeding recommended SAR thresholds. The findings suggested that radiation exposure varies across phone designs and operating frequencies, with potential implications for long-term health, especially in sensitive tissue areas like the brain and cerebrospinal fluid. This study indicated the importance of adhering to EMF safety guidelines and encourages consumers to be aware of SAR values when selecting mobile devices, particularly those frequently used close to the head.

Excerpt

This study has been able to assess the variability in electromagnetic field (EMF) exposure levels and Specific Absorption Rates (SAR) for different mobile phone models at operational frequencies of 900 MHz and 2100 MHz. The measured electric field strength (E-field), magnetic field strength (H-field), and power density reveal significant differences across phone models, with some exceeding the ICNIRP recommended safety limits. Additionally, SAR values for various tissues (cerebrospinal fluid, dura, brain, muscle, skin, skull, and fat) indicate varying levels of radiation absorption, depending on the phone model and operational frequency. The results of this study indicated the need for strict regulatory measures to ensure mobile phones comply with international safety standards to minimize health risks. Consumers should be aware of SAR values when selecting mobile devices, particularly those frequently used close to the head. They are also advised to use hand-free devices and also employ proper phone casing accessories which have the potential of absorbing part of the radiation energy thereby reducing the exposure to radiation.

Open access: https://rsisinternational.org/journals/ijrias/view/evaluation-of-electromagnetic-field-exposure-level-from-mobile-phones-and-its-health-risks

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**Spatiotemporal trends of ambient radiofrequency electromagnetic fields (RF-EMF) during the 5G rollout in Switzerland**

Loizeau, N., Haas, D., Zahner, M. *et al.* Spatiotemporal trends of ambient radiofrequency electromagnetic fields (RF-EMF) during the 5G rollout in Switzerland. *J Expo Sci Environ Epidemiol* (2026). https://doi.org/10.1038/s41370-026-00909-z

Abstract

Background The fifth generation of mobile phone technology (5G) is being extensively deployed worldwide, potentially reshaping the population's exposure to ambient radiofrequency electromagnetic fields (RF-EMF).

Objective This study aims to characterise the changes in ambient exposure to RF-EMF during the rollout of 5G in Switzerland.

Methods First, the ambient RF-EMF levels were characterised between July 2021 and May 2024 in 300 outdoor areas, 244 public spaces, and on 332 public transport rides. Two ExpoM-RF4 were used to measure the electric field strengths from 80 MHz to 6 GHz and recorded the root-mean-square (RMS) signals and the instantaneous highest signals (Peak). Second, we conducted a temporal comparison with the RF-EMF median levels measured at baseline (2021/22) and follow-up (2023/24) in the same microenvironments and at the same time (±one hour, ±one week). Thirdly, we compared the ambient RF-EMF exposure in a subset of 49 outdoor areas that were measured in 2014, 2021, and 2023.

Results Total RF-EMF median levels (RMS signals) remained constant or slightly increased between 2021/22 and 2023/24 in 150 outdoor areas (0.16 V/m to 0.17 V/m), 91 public spaces (0.24 V/m to 0.25 V/m), and in 101 public transport rides (0.20 V/m to 0.24 V/m). Minor but significant increases in median Time Division Duplexing (TDD) exposure levels, related to 5G, were observed in all areas from virtually 0 V/m to 0.04 V/m during that period. Peak signals followed a comparable trend.

Significance Between 2014 and 2023, the overall ambient RF-EMF levels from mobile phone communication technology have not increased following the introduction of 5G in Switzerland. The extensive RF-EMF exposure measurements conducted by the same person during the rollout of 5G makes our study one of the most comprehensive time trend exposure analyses to date, which is highly valuable for future epidemiological research and public communication.

Impact

- The presented RF-EMF measurements conducted in numerous environments during the rollout of 5G provide a baseline to which the population is unavoidably exposed to RF-EMF.

- Despite the substantial growth in mobile data traffic, the deployment of 5G has not drastically changed the exposure to ambient RF-EMF from mobile phone communication technology between 2021/22 and 2023/24.

Open access: https://www.nature.com/articles/s41370-026-00909-z

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**The further away the better? Factors influencing the public's location preferences for mobile phone base stations. A 10-country study**

Link SC, Martin L, Grellier J, Böcker ME, Abacioglu F, Schulz C, Vaupotič N, White MP, Boehmert C. The further away the better? Factors influencing the public's location preferences for mobile phone base stations. A 10-country study. Journal of Environmental Psychology, Volume 112, 2026. doi: 10.1016/j.jenvp.2026.103070.

Abstract

New mobile phone base stations are frequently opposed by the public, even though mobile phones are used by most of the population. While such reaction has often been described as NIMBYism ('not in my back yard'), this label offers little insight into the psychological mechanisms underlying such opposition. The present mixed-methods research moves beyond a simple NIMBY interpretation through an in-depth investigation of public location preferences for 4G-plus 5G-capable base stations. Study 1 included six focus groups conducted in December 2022, and Study 2 was a ten-country survey (n = 10,358) conducted between September-December 2023. In both studies, participants were asked to select their preferred base station site from six hypothetical locations and indicate the reasons underlying their choice. Overall, many participants followed one of two siting approaches: approach A preferring locations 'as far away as possible', and approach B preferring the 'least visually appealing' location. While in Study 1 participants tended to follow approach B (16 out of 35), in Study 2 approach A was followed most frequently (53.6%). Among the reasons surveyed, distance had the greatest influence on location preferences, followed by reception, exposure to EMFs, and visual appearance. Distance and EMF were strongly correlated (r = .531), which is why we assume that distance was a proxy for reduced exposure. However, greater distance can in fact increase overall exposure due to the increased power required for higher handset transmission. Age, gender, risk perception, exposure perception, use of 5G, acceptance and the expected impact of 5G were also associated with the choice of location. We found that widespread public communication efforts are needed to explain how 5G technology works, and that other issues such as visual amenity also need to be sensitively managed. Our results inform the broader discourse on base station siting: communication between stakeholders needs to be improved, fostering mutual understanding of preferences, and guiding decision-making for both telecommunication companies and the public.

Highlights

• Investigation into people's location preferences for 4G-plus 5G-capable base stations.
• Mixed methods study, comprising focus groups and an international survey (n > 10,000).
• Preference for farther and visually unappealing locations found.
• Location preferences mainly influenced by considerations about distance.

Excerpts

Potential health risks of RF-EMF emitted by mobile communications technologies have been assessed by international institutions like the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the World Health Organization (WHO), and the International Agency for Research on Cancer (IARC). In 2013, IARC classified RF-EMF from mobile phones as possibly carcinogenic (IARC, 2013). According to ICNIRP and WHO, the weight of evidence indicates no adverse health effects below the existing threshold values (ICNIRP, 2009; WHO, 2020). The only clear biological effect that has been identified is that of tissue heating.

More recently, the WHO commissioned a series of ten systematic reviews based on a survey with 164 leading experts in the field of RF-EMF (Verbeek et al., 2021), focusing on six possible health outcomes. These reviews, along with a contextual summary (Verbeek et al., 2025), reported: moderate to high certainty evidence for no or only minor effects of RF-EMF on cancer (in humans), cognition, and symptoms, while there was high certainty evidence from animal studies for a significant impairment of male fertility. For other endpoints, such as oxidative stress, thyroid cancer, or fertility in humans, the evidence is currently very limited or contradictory (Verbeek et al., 2025). To date, neither ICNIRP nor IARC have updated their risk assessment based on these reviews.

Conclusions

The current paper provides insights into where the public would place base stations if given the choice, and why certain location preferences emerge. Two high frequency siting approaches were identified: approach A ‘as far away as possible’ and approach B ‘at the visually most unappealing location’. While approach B was preferred in focus group Study 1, approach A was followed by the majority of respondents in the international survey, (Study 2) indicating a preference for more distant base station locations. We found that, depending on the approach, the influence of the recorded siting factors varied. Approach A was associated with a greater influence of distance and EMFs, whereas visual appearance played a more important role for those following approach B. While it has not yet been investigated which siting factors influence the choice of location for base stations, studies on 2G already suggested that distant locations are favored (Cousin & Siegrist, 2010a, 2010b). A similar pattern was observed for 4G/5G, with our qualitative and quantitative studies indicating that, in addition to distant locations, visually unappealing sites are preferred over more central locations in a town, for example. Since the most distant location is usually not the technically most feasible solution, good science and risk communication could help to improve the public's understanding of how mobile communications work. This, in turn, could help overcome misconceptions and potentially reduce controversies about base station siting, alongside other factors not explored here such as procedural justice concerns.

Open access: https://www.sciencedirect.com/science/article/pii/S0272494426001714

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**No thermal skin effects at environmental 26 GHz field strengths relevant to 5G deployment**

Michelant L, Delanaud S, Hugueville L, Leveque P, Bach V, Tourneux P, Selmaoui B. No thermal skin effects at environmental 26 GHz field strengths relevant to 5G deployment. Sci Rep. 2026 Apr 27. doi: 10.1038/s41598-026-49616-7.

Abstract

The deployment of 5G millimeter wave technology at 26 GHz raises questions about potential thermal effects on human tissues. Controlled human studies examining millimeter wave thermal responses remain limited. We investigated the effects of acute 26 GHz exposure on skin temperature in healthy volunteers under controlled laboratory conditions. Thirty-one healthy young adults participated in a triple-blind, randomized, crossover study. Participants underwent genuine 26 GHz exposure (2 V/m at head level, 1 V/m at torso level) and sham exposure, each lasting 26 minutes 30 seconds. Skin temperature was continuously monitored using infrared thermography at five anatomical regions (face, bilateral hand dorsum, bilateral infraclavicular areas) across three experimental phases. No statistically significant thermal effects were detected, with no main effect of exposure condition for any skin region (all $p > 0.34$). No significant exposure-phase interactions were detected for any measurement (all $p > 0.09$). Progressive decreases in distal skin temperatures (exceeding 1.5°C, $p < 0.0001$) occurred independently of exposure condition, reflecting normal thermoregulatory adaptation to seated immobility. Distal-proximal gradient analysis showed no significant difference between conditions (right: $p = 0.332$; left: $p = 0.319$), and bilateral comparisons revealed no thermal asymmetry ($p = 0.269$). These findings provide reassuring evidence that acute 26 GHz exposure at environmental field strengths produces no detectable thermal effects in healthy young adults, at levels substantially below ICNIRP reference limits. However, these results should not be interpreted as a direct validation of those guideline threshold values

Excerpts

Rohde & Schwarz SMM 100A signal generator producing 5G NR signals at 26 GHz with 100 MHz bandwidth....

Under these far-field conditions, the incident power density was calculated using $P_{inc} = E^2/377$ W/m², yielding 10.6 mW/m² at the head (2 V/m) and 2.65 mW/m² at the torso (1 V/m). These incident power density values are substantially below the ICNIRP (2020) reference levels for 26 GHz exposure....

Future research would benefit from integration of physiological markers such as skin blood flow, sweat rate, and metabolic indicators to provide more comprehensive assessment of thermoregulatory responses to MMW exposure. Such multimodal approaches could reveal subtle physiological adjustments not detectable through skin temperature measurements alone....

... generalizability remains limited to healthy young adults under controlled conditions, with measurements restricted to superficial skin temperatures. Future research should examine vulnerable populations (children, elderly, thermoregulatory- compromised individuals), prolonged exposure scenarios, and real-world deployment conditions with complementary physiological measurements.

Open access: https://www.nature.com/articles/s41598-026-49616-7

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**Evaluating the Protective Effect of Melatonin on Apoptosis, Expression of Bax and Bcl2 Genes, and ROS Level after Radiofrequency Radiation on L929 Fibroblast Cell Line**

Fardid R, Zaker F, Haghani M, Saberzadeh J. Evaluating the Protective Effect of Melatonin on Apoptosis, Expression of Bax and Bcl2 Genes, and ROS Level after Radiofrequency Radiation on L929 Fibroblast Cell Line. J Biomed Phys Eng. 2026 Apr 1;16(2):131-138. doi: 10.31661/jbpe.v0i0.2409-1828.

Abstract

Background: The increasing use of mobile phones has raised concerns about potential health risks. In addition, the effect of protective materials is also important.

Objective: This study aimed to evaluate the protective effect of Melatonin on cell viability, apoptosis, Reactive Oxygen Species (ROS) level, and gene expression of Bax and Bcl2 in L929 fibroblast cells after Radiofrequency (RF) radiation.

Material and methods: In this experimental study, cells were divided into six groups with at least 3 replications in each group. The two groups were respectively exposed to radiofrequency waves for 8 and 16 hours. They were pretreated with melatonin before radiation exposure, while the control group did not receive any radiation or melatonin during the experiment, and the melatonin group was just treated with melatonin.

Results: Cellsurvival was reduced after 8 hours of RF radiation. After 16 hours, the total apoptosis was increased, and pretreatment with melatonin increased cell survival and reduced total apoptosis. Radiation increased intracellular ROS levels. RF increased the Bax/Bcl2 ratio, and the treatment with melatonin decreased it after 8 hours.

**Conclusion:** Melatonin prevents the increase in apoptosis and Bax/Bcl2 ratio, but there are no significant changes in survival and ROS levels.

Open access: https://jbpe.sums.ac.ir/article_51519.html

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**Characterization of Static Magnetic Fields Produced by Smartphones**

Zastko L, Kubičková I, Míšek J, Kuchta I, Makinistian L, I. Belyaev I. Characterization of Static Magnetic Fields Produced by Smartphones. IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology, doi: 10.1109/JERM.2026.3683318.

Abstract

Smartphones integrate permanent magnets for speakers, cameras, vibration motors, or accessory magnetic snap systems, which generate static magnetic fields (SMF). While time-varying electromagnetic fields have been extensively studied, quantitative characterization of SMF remains limited. Modern smartphones generate measurable localized SMF hotspots that contribute to background electromagnetic exposure. In this study, we mapped the spatial distributions of SMF near smartphone surfaces and evaluated their potential biomedical relevance using computational exposure models. Three smartphone models released between 2021 – 2022 were measured with a triaxial magnetometer at multiple distances (5 – 50 mm) in triplicate, background-corrected, and analyzed for field intensity. Anatomical voxel models were used to simulate exposure conditions and field

penetration into tissues. All smartphones exhibited heterogeneous SMF distributions with local hotspots, often exceeding 800 μT at close distances (<15 mm), associated mostly with speakers, microphones, magnetic rings, and camera modules. Although overall SMF levels were below the ICNIRP public whole-body exposure limit (400 mT), localized peaks approached thresholds relevant to interference with implantable cardiac devices (0.5 - 1 mT). Simulations confirmed localized field penetration into adjacent tissues under realistic smartphone use conditions. Modern smartphones generate spatially complex SMF exposures that, although compliant with public exposure limits, may approach levels reported to activate magnet mode in implantable cardiac devices and represent a minor yet pervasive component of electromagnetic exposure. These findings provide quantitative data for exposure characterization and electromagnetic compatibility assessment.

Conclusion

Modern smartphones generate non-negligible static magnetic fields due to their integrated permanent magnets. Whereas field strengths remain compliant with public exposure limits, local hotspots near device surfaces can reach intensities relevant or implant interference and exposure characterization. These results support inclusion of SMF in exposure guidelines, environmental monitoring, and sustainable device design frame-works. Recognizing SMF as a routine exposure metric will improve future risk assessment and device safety standards.

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https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11494332&isnumber=8000303

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**A historical review of ephaptic field research: from early foundations through contemporary renaissance**

Hunt T, MacIver MB. A historical review of ephaptic field research: from early foundations through contemporary renaissance. Front Hum Neurosci. 2026 Apr 13;20:1747899. doi: 10.3389/fnhum.2026.1747899.

Abstract

Ephaptic field research has undergone a remarkable evolution spanning over nine decades, from pioneering observations in the 1930s through a period of severe scientific skepticism in the mid-20th century to a contemporary renaissance driven by advanced computational modeling, measurement techniques, and new consciousness theories. This review traces the complete chronological development of ephaptic coupling research, examining early foundational work by Adrian, Katz and Schmitt, and Arvanitaki, the influential skepticism of Lashley's study that marginalized the field for decades, and the recent resurgence beginning in the 2000s that has led to recognition of ephaptic interactions as providing fast and direct communication throughout the brain. Contemporary research has established that weak electric fields (0.1-5 V/m) can produce measurable physiological effects and that ephaptic coupling contributes significantly to brain network complexity, memory formation, and potentially consciousness itself. Ephaptic communication, together with some form of electromagnetic field (EMF) theory of consciousness, provides a ready solution to the critical 'binding problem' that has perplexed philosophers and neuroscientists for at least the last century. This historical perspective

demonstrates how scientific paradigms can shift dramatically as methodological advances allow for more sophisticated investigation of previously dismissed phenomena.

Conclusion

The history of ephaptic field research demonstrates how scientific paradigms can undergo dramatic shifts as methodological advances enable more sophisticated investigation of complex phenomena. The arc from early enthusiasm through decades of dismissal to contemporary renaissance illustrates the importance of continued scientific inquiry and the willingness to revisit previously dismissed theories when new evidence emerges.

Contemporary ephaptic coupling research has established that electromagnetic field interactions represent a fundamental mechanism of neural communication that operates alongside, but independently from, chemical synaptic, as well as electrical (gap junction) transmission. The recognition that ephaptic effects can influence memory formation, brain network complexity, and potentially consciousness itself suggests that electromagnetic field theories will play an increasingly important role in understanding brain function and developing new therapeutic approaches.

Future research directions include further elucidation of ephaptic mechanisms across different brain regions and cell types, the co-evolution of differential myelination with ephaptic field effects, development of therapeutic applications based on electromagnetic field manipulation, and continued integration of ephaptic coupling into comprehensive theories of consciousness and cognition. An emerging frontier involves applying EM field principles to artificial intelligence and neuromimetic computing, particularly in developing neuromorphic chips that replicate neural electromagnetic field phenomena. The historical trajectory of this field suggests that understanding the brain and consciousness requires grasping the fundamental role of quasistatic electromagnetic fields across all spatial and temporal scales.

Open access: https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2026.1747899/full

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**Hybrid ray-tracing-QuaDRiGa/FDTD method for realistic 28 GHz exposure with 6G CF-MaMIMO in 3D outdoor environments**

Wydaeghe R, Shikhantsov S, Vermeeren G, Martens L, Tanghe E, Joseph W. Hybrid ray-tracing-QuaDRiGa/FDTD method for realistic 28 GHz exposure with 6G CF-MaMIMO in 3D outdoor environments. NPJ Wirel Technol. 2026;2(1):13. doi: 10.1038/s44459-026-00031-4.

Abstract

Amid worry for 5G and 6G, the layman's question arises: "How much exposure do I *realistically* experience when I walk down the street?" Focusing on mmWave radio-frequency electromagnetic field exposure with Distributed Massive Multiple-Input Multiple-Output (DMaMIMO) technology, a new state-of-the-art (SOTA) numerical method is proposed to enable accurate exposure assessment almost anywhere on Earth. Google Earth 3D photorealistic tiles provide high-level-of-detail and high-coverage photogrammetry. We semantically classify the meshes with an SOTA deep learning model. The path of a pedestrian is first ray-traced at 28 GHz with either 6G DMaMIMO or realistically deployed 5G antenna

systems as the transmitter. The large-scale fading parameters are extracted and form the input for the QuaDRiGa tool, which finely models the small-scale fading features of the channel along the full path with an omnidirectional User Equipment (UE) as receiver. The resulting channel is used in a hybridization procedure with a Huygens' box that models the Electromagnetic Fields (EMFs) around the UE. The surface-absorbed power density ($S_{ab}$) exposure metric is computed along the path using FDTD simulations of a realistic anatomical phantom. A case study in Helsinki finds that the cell-free MaMIMO free-space exposure range is 20 dB more uniform than collocated MaMIMO. A case study in New York City finds that users experience, on average, 20 dB higher values in exposure compared to non-users. The small-scale fading *hotspot* phenomenon in realistic environments is studied in detail, showing on average a 12 dB electric field increase w.r.t. the background and a specific shape with up to 3 sidelobes, which is characterized quantitatively. The $S_{ab}$ is less than 1% of the ICNIRP guidelines during all simulations at realistic Tx powers.

Open access: https://www.nature.com/articles/s44459-026-00031-4

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**Toward Next-Generation Exposure Metrics for the Communication Systems**

Kumar S, Devi P. Toward Next-Generation Exposure Metrics for the Communication Systems. International Journal For Multidisciplinary Research. 8(2), Mar-Apr 2026. doi: 10.36948/ijfmr.2026.v08i02.70273.

Abstract

The rapid evolution of 6G networks and the increasing adoption of Terahertz (THz) communication systems require the accurate and reliable exposure metrics to ensure the safe and efficient deployment, such systems operating in 0.1-10 THz frequency range. The next generation exposure metrics essential to investigate the impact of THz radiation on human being and the environment. This paper explores the induced electric field, absorbed power density and temperature rise dosimetric instead of SAR metrics at THz frequencies for human skin tissue. The results shows that the absorbed power density and temperature raise in human skin are found within standards limits given by international agencies like International commission on Non-Ionizing Radiation Protection (ICNIRP) and institute of Electrical and Electronics Engineers (IEEE). Furthermore we examine the current state of research on biological materials and to understand the potential biological effects of THz radiation on humans.

Open access: https://www.ijfmr.com/research-paper.php?id=70273

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**Impact of Continuous Wi-Fi Electromagnetic Radiation Exposure on Nutritional Quality and Metabolic Responses in Parsley and Coriander Seedlings**

Djamai, N.I., Belabed, A.I., Bouslama, Z. *et al.* Impact of Continuous WIFI Electromagnetic Radiation Exposure on Nutritional Quality and Metabolic Responses in Parsley (*Petroselinum crispum* L.) and Coriander (*Coriandrum sativum* L.) Seedlings. *Russ J Plant Physiol* **73**, 106 (2026). https://doi.org/10.1134/S1021443725608109.

Abstract

The rapid evolution of WIFI wireless technology has resulted in elevated environmental levels of electromagnetic radiation, leading to the concerns about its effects on physiological and metabolic functions of plants. This study aims to evaluate the effects of low-power WIFI microwave exposure on three growth stages (seed, germination ,and vegetative growth stage) of two aromatic plants: parsley (*Petroselinum crispum* L.) and coriander (*Coriandrum sativum* L.). Four groups are formed: unexposed control (Gp1), exposed from vegetative growth stage (Gp2), exposed from seed stage (Gp3), and exposed from germination stage (Gp4). The growth period was six weeks. The investigation focused on biochemical properties (soluble sugars, starch, proline content, and mineral composition) and bioactive properties (vitamins, polyphenolic compounds, antioxidants, and antibacterial activities). The exposure of WIFI microwave from the vegetative growth stage exhibited a moderate metabolic alterations in parsley and coriander. While, at the early stages, parsley and coriander displayed a pronounced metabolic changes, with a reduction of soluble sugars, starch, vitamin C, alpha tocopherol and niacin content. Additionally, the riboflavin content increased. However, the beta carotene increased at the seed stage and decreased at the germination stage. Furthermore, elemental analysis revealed an increase in the content of K, Mg, Fe, Zn, Cu and Mn, and a decrease in Na. While Ca remained unchanged. Exposure at the early stages also stimulated the production of polyphenolic compounds, enhanced the antioxidant capacity and improved the antibacterial activity. The findings suggest that the impact of WIFI on parsley and coriander responses depends on the growth stage at which exposure occurred. The greatest metabolic changes were observed at the early stages.

Excerpts

Parsley and coriander were exposed to the TL-WR841N WIFI router, which is based on the IEEE 802.11 g standard. It is equipped with two omnidirectional antennas which transmit the WIFI signal within the frequency range of 2.412 GHz to 2.483 GHz, and with a maximum peak output power of 0.1 mW (20 dBm). The WIFI router was placed at a distance of 20 cm from the different groups of irradiated plants. According to this, these kinds of WIFI devices can produce, at a distance of 20 cm, a maximum peak power density of approximately 330 mW/m2 [10]....

In conclusion, the outcome of this study suggests that WIFI radiation caused stress to the aromatic plant's parsley and coriander, particularly upon application on the seed and germination stages. Additionally, the findings indicate also that the effect on the impact of WIFI radiofrequency varies depending on the plant's developmental stage

The greatest deterioration in the plant system occurred when exposure to WIFI radiation started at germination or seed stage. This induced a pronounced reduction in soluble sugars, vitamin C, α-tocopherol, β-carotene and niacin content, respectively. In contrast, an increase in proline and antioxidant and antibacterial activity was observed. For riboflavin, a drop was recorded in cases of exposure to radiofrequencies after the first week, and an increase was recorded in cases of exposure to WIFI waves over the entire growing period. Elemental analysis also revealed an increase in the content of the elements K, Mg, Fe, Zn, Cu and Mn, and a decrease in Na, with no effect on Ca. A growth stage-dependente relationship were observed in this study. Likewise, the parsley and coriander plants exhibited generally a similar responses to WIFI. In future works, it is worthwhile to study the effect of 2.45 or 5 GHz radiation on all of stage of growth plant.

https://link-springer-com.libproxy.berkeley.edu/article/10.1134/S1021443725608109

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**Dosimetry of a Thermoregulated TEM Cell for 5G 700 MHz and 3.5 GHz Band Frequencies for Bioelectromagnetic Investigations**

Nasri A, Michard L, Serradeill L, Orlacchio R, Percherancier Y, Leveque P, Dalmay C, Arnaud-Cormos D. Dosimetry of a Thermoregulated TEM Cell for 5G 700 MHz and 3.5 GHz Band Frequencies for Bioelectromagnetic Investigations. *Sensors*. 2026; 26(8):2393. doi: 10.3390/s26082393.

Abstract

This work presents the design and characterization of a thermoregulated, bandwidth-enhanced TEM cell system optimized for bioelectromagnetic experiments on biological cells, with a focus on bioluminescence resonance energy transfer investigations at 700 MHz and 3.5 GHz. Bandwidth improvement, achieved through geometric modifications and optimized connector transitions, resulted in reduced return and insertion losses and improved field uniformity, particularly in the 2.5–6 GHz range. Numerical simulations showed homogeneous electric field and normalized specific absorption rate (SAR) distributions (~1 W/kg) at 700 MHz. At 3.5 GHz, the improved TEM cell provided the most uniform exposure of the biological sample with SAR values of 15 W/kg and 10.5 W/kg, for the bulk and surface (bottom layer), respectively. Experimental SAR measurements using a ~1 $mm^3$ fluoro-optic probe agreed well with simulations. To counteract RF-induced heating, the system incorporated active thermoregulation at 37 °C. At 3.5 GHz and 20 W input power, a 1.5 °C rise over 120 s was effectively mitigated using water-circulation cooling. This work provides a controlled and reliable setup for future studies on the interaction of 5G-band electromagnetic fields with biological systems.

Open access: https://www.mdpi.com/1424-8220/26/8/2393

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**Effects of Electromagnetic Fields on Apoptosis and Stress Protein Biomarkers in the Spider *Parasteatoda tepidariorum***

Porc W, Rozpędek K, Glenszczyk M, Lis A, Babczyńska A. Assessment of the Effects of Electromagnetic Fields on Apoptosis and Stress Protein Biomarkers in the Spider *Parasteatoda tepidariorum*. *International Journal of Molecular Sciences*. 2026; 27(9):4088. doi: 10.3390/ijms27094088.

Abstract

Electromagnetic fields (EMFs), increasingly prevalent due to technological advancements, have raised significant concerns regarding their potential biological effects on living organisms. While much attention has focused on human health, growing evidence suggests that EMFs can also affect invertebrates, which play vital ecological roles. This study investigates the biochemical and cell death biomarker responses to EMF exposure for 24 h or 72 h in Parasteatoda tepidariorum. The focus is placed on the 10 MHz frequency, which is relevant to environmental exposure scenarios. Biochemical biomarkers include heat shock proteins (HSP70) and the percentage of apoptotic and living cells in individuals at their embryonic, young and adult stages. Results indicate that exposure to EMFs can induce measurable stress responses at the biochemical level, with variations depending on developmental stage and protective structures. Embryos outside of the egg sac exhibited significantly elevated levels of HSP70 and apoptosis markers compared to those within the sac, suggesting a partial

protective effect of the cocoons. Furthermore, differences in biomarker sensitivity were observed across all the developmental stages and increased with prolonged exposure. These findings contribute to the understanding of EMF-induced biological effects in invertebrates and support the use of P. tepidariorum as a model species for environmental electromagnetic pollution.

Excerpts

The experimental setup for electromagnetic field (EMF) exposure included a pair of parallel copper plates (10 cm × 10 cm) separated by a distance of 10 cm and connected to a sinusoidal signal generator (Funktionsgenerator 250350—Frederiksen Scientific, Olgod, Denmark), providing a frequency of 10 MHz. The electromagnetic field strength was monitored using a broadband field meter (Tenmars TM-196, Taipei, Taiwan). Samples were placed precisely in the central part of the experimental setup (Figure 9).

Given the dimensions of the setup, the field between the plates was in the near-field regime. The dominant component of the field in our conditions is the electric field, which was directly measured and was within the range of 4.264–5.045 V/m. Measurements were performed at multiple positions between the plates to verify the spatial distribution and approximate uniformity of the generated field.

Background magnetic field levels were monitored prior to exposure using a low-frequency range meter (Tenmars TM-191, Taipei, Taiwan), and ranged from approximately 0.12 µT. These values refer to low-frequency environmental background, mainly associated with power-frequency fields (50 Hz), and are not directly comparable with the high-frequency electromagnetic field generated in the present experimental setup. Additionally, the background field was measured by means of the Tenmars TM-196 m. These values for the electric component were equal to 0.2–0.5 V/m, which are typical for indoor RF background (WiFi/GSM).

Open access: https://www.mdpi.com/1422-0067/27/9/4088

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**A Study on Biological Effects of Terahertz Radiations for 6G Communications**

Niranjan SP, Phani R, Attel HB, Baligar J. A Study on Biological Effects of Terahertz Radiations for 6G Communications. *2026 2nd International Conference on Computing for Sustainability and Intelligent Future (COMP-SIF)*, Bengaluru, India, 2026, pp. 1-5, doi: 10.1109/COMP-SIF69752.2026.11481943.

Abstract

The advent of sixth-generation (6 G) wireless communication systems, operating within the terahertz (THz) frequency spectrum (0.1−10THz), heralds a new frontier in ultra- high-speed data transmission and energy-efficient connectivity. This review critically examines the biological effects of THz radiation, focusing on cellular and molecular responses that include DNA damage, chromosomal instability, epigenetic modifications, mitochondrial dysfunction, and altered gene expression profiles. Experimental evidence from neural and stem cell models demonstrates that THz exposure can induce oxidative stress, apoptosis, and changes in cell proliferation, highlighting potential health risks associated with prolonged exposure. Concurrently, THz radiation's capacity to modulate membrane permeability and gene regulation opens promising biomedical applications in diagnostics and regenerative therapies. The paper also addresses the challenges of integrating THz antennas into wearable devices, emphasizing the need for designs that minimize human tissue absorption while maintaining performance. As 6 G technologies

advance toward widespread adoption, this review underscores the imperative for interdisciplinary research to establish robust safety standards and harness the full potential of THz radiation in both communication and medical fields.

Excerpt

Evidence from preliminary studies points to changes at the cellular and molecular levels, with implications for systems such as neural and reproductive health. These concerns emphasize that the progress of wireless technology must go hand in hand with thorough safety assessments, ensuring that the benefits of 6G are realized without compromising human well-being.

https://ieeexplore.ieee.org/document/11481943

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**Effect of three different frequencies of micro-magnetic stimulation on the neuronal electrical activity of the hippocampal CA1 neurons in mice**

Zheng Y, Wang M, Dong L, Tian C, Qi D, Chen Y. Effect of three different frequencies of micro-magnetic stimulation on the neuronal electrical activity of the hippocampal CA1 neurons in mice. Neuroscience. 2025 Apr 6;571:96-107. doi: 10.1016/j.neuroscience.2025.02.057.

Abstract

Frequency is essential in regulating neuroelectric activity using magnetic fields. Current reports focus on 100 Hz or less. Studying other relatively high magnetic stimulation frequencies is necessary to reveal the influence of magnetic stimulation frequency parameters on electrical activity.This paper examined the pyramidal neurons in the CA1 region of the hippocampus of C57 mice. A custom-built micro-magnetic stimulation (μMS) device with sub-millimeter dimensions was utilized. Three magnetic field frequencies of 15 Hz, 3 kHz, and 70 kHz were chosen at a magnetic field strength of 1 mT. Precision-targeted magnetic stimulation of CA3 area neurons upstream of CA1 by whole-cell membrane clamp method. The effects of three various magnetic stimulation frequencies on the action potential (AP), sodium channel current ($I_{Na}$), and transient outward potassium channel current ($I_A$) of neurons in the hippocampal CA1 area were investigated. 15 Hz inhibited the excitability of pyramidal neurons within the CA1 area; 3 kHz had a facilitating effect, while the 70 kHz magnetic stimulation had a more pronounced facilitating effect. Magnetic field stimulation at 15 Hz decreased neuronal excitability, whereas magnetic field stimulation at 3 and 70 kHz increased neuronal excitability.

https://pubmed.ncbi.nlm.nih.gov/40032037/

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**Impact of extremely low frequency electromagnetic fields exposure on sleep quality and mental health in a Tunisian power plant: a cross-sectional study**

Kacem I, Jammeli I, Sridi C, Gaddour A, Makhloufi M, Aloui A, Chouchane A, Maalel OE, Kahloul M, Mrizak N. Impact of extremely low frequency electromagnetic fields exposure on sleep quality and mental health in a Tunisian power plant: a cross-sectional study. Front Psychiatry. 2026 Apr 24;17:1755918. doi: 10.3389/fpsyt.2026.1755918.

Abstract

Introduction: Extremely low-frequency electromagnetic fields (ELF-EMFs) are ubiquitous in our daily life. They may have an impact not only on physical health but also on mental health.

Objectives: To assess the impact of occupational exposure to the ELF-EMFs on sleep quality, depression, anxiety and stress among workers at the Tunisian Electricity and Gas Company (TEGC).

Methods: This was a cross-sectional study. The study population included two groups: an exposed group (EG), consisting of power plant employees, and a non-exposed group (NEG), consisting of administrative workers. Exposure to ELF-EMFs was assessed via spot measurements using a magnetometer. Sleep quality, depression, anxiety and stress were assessed by the French versions of the Pittsburgh Sleep Quality Index (PSQI) and the Depression, Anxiety and Stress Scale (DASS-21).

Results: Seventy-seven participants in the EG and 88 participants in the NEG were included in the study. The median value of the ELF-EMFs was 5.86 µT at the power plant [min 0.1, max 40.34 µT]. According to the PSQI global score, 64.9% of the EG had poor sleep quality versus 29.5% of the NEG. Depression was registered in 24.7% of EG and in 3.4% of NEG. Anxiety was noted in 23.4% of the EG and in none of the NEG. Stress was found in 46.8% of the EG and none of the NEG. After multivariate analysis, ELF-EMF exposure was significantly associated with poor sleep quality and depression.

Conclusion: The present study revealed that ELF-EMFs can affect sleep and mental health. Further studies are needed to explain the mechanism involved.

Open access: https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2026.1755918/full

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**Determination of Ground Clearance for EHV 400 kV Overhead Power Lines Based on Electromagnetic Field Limits**

Bendík J, Cenký M, Eleschová Ž. Determination of Ground Clearance for EHV 400 kV Overhead Power Lines Based on Electromagnetic Field Limits. *Electricity*. 2026; 7(2):39. doi: 10.3390/electricity7020039

Abstract

The planning and design of Extra-High Voltage (EHV) overhead power lines require strict adherence to electromagnetic field exposure limits to ensure public safety. This paper presents a comprehensive analysis of the minimum ground clearance required for standard 400 kV transmission towers to comply with international safety guidelines. A review of legislative frameworks across 37 countries indicates a widespread consensus on limiting values of 5 kV/m for the electric field and 100 µT for magnetic flux density. Using analytical methods, the electric and magnetic fields were calculated for four common tower geometries (Cat, Portal, Danube, and Barrel) under varying ground clearances and phase configurations. The results demonstrate that the magnetic flux density is not a limiting factor, as it remains well below safety thresholds even at standard technical clearances. Conversely, the electric field intensity proves to be the critical design constraint, often requiring clearances significantly higher than those dictated by insulation coordination. The study identifies that optimizing the phase sequence

in double-circuit towers can reduce the required ground clearance by up to 28%, offering a cost-effective mitigation strategy. These findings provide power line designers with essential decision-making data for the preliminary design phase, enabling the optimization of tower geometry and phase arrangement without the need for computationally intensive simulations.

Conclusions

This study provides a systematic evaluation of the ground clearance requirements for 400 kV overhead power lines based on electromagnetic field limitations. The review of international regulatory frameworks reveals that the majority of European nations and surveyed countries align with the standard exposure limits of 5 kV/m for the electric field and 100 µT for the magnetic flux density. This legislative uniformity underscores the broad applicability of the presented results across the continental power grid.

The numerical analysis confirms that for EHV transmission lines, the electric field intensity E is the governing design constraint. In every simulated scenario, the magnetic flux density B remained significantly below the 100 µT threshold, even at the minimum technical clearance of 8 m. Therefore, safety assessments and mitigation efforts must prioritize the electric field, which often necessitates tower heights exceeding standard mechanical requirements.

Crucially, this research highlights the impact of phase sequence position optimization as a primary mitigation technique. For double-circuit configurations, selecting the optimal phase arrangement can lower the required ground clearance by several meters—most notably in the Barrel tower configuration—without incurring additional construction costs.

The data presented in this paper serves as a vital tool for power line designers. By integrating these findings into the preliminary design phase, engineers can determine the optimal tower geometry and phase sequence early in the project lifecycle. This proactive approach prevents the need for costly iterative modifications or complex custom simulations later in the process, ensuring both regulatory compliance and economic efficiency in the development of 400 kV transmission infrastructure.

Open access: https://www.mdpi.com/2673-4826/7/2/39

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**A Cumulative Exposure Assessment Method for Low-Frequency Magnetic Field for Electric Vehicles Based on Peak Detection**

Zhao S, Wang R, Fu J, Cui X, Cui P, She H. A Cumulative Exposure Assessment Method for Low-Frequency Magnetic Field for Electric Vehicles Based on Peak Detection. 2026 IEEE 8th International Conference on Communications, Information System and Computer Engineering (CISCE), Guangzhou, China, 2026, pp. 538-542, doi: 10.1109/CISCE69494.2026.11504622.

Abstract

This paper investigates the assessment method for low-frequency magnetic filed based on peak detection for electric vehicles. When applying the GB 8702 criterion to 20 actual EV measurements using full-frequency-point accumulation, the compliance rate was 0%, indicating overly conservative exposure assessment. This paper establishes an assessment model comprising threshold screening and peak

detection. This approach elevates the compliance rate and yields a logically physical interpretation. Furthermore, it conducts an in-depth analysis of the significance of varying thresholds and peak detection, thereby providing a more scientifically grounded engineering methodology for the electromagnetic field safety assessment of electric vehicles.

Excerpt

The weighted method was employed to reflect the average contribution of each operational state. Under the 1% threshold with weighting, no vehicles passed (zero pass rate) regardless of whether the threshold limit or peak detection filtering was applied, indicating that all vehicles failed to meet the requirements under this stringent criterion.

At the 5% weighted threshold, 10 vehicles passed based on the threshold limit, while the application of peak detection increased this number to 14. This represents an improvement of 5 and 7 vehicles, respectively, compared to the direct superposition method at the 5% threshold. Similarly, at the 10% weighted threshold, 14 vehicles passed using the threshold limit, which increased to 18 when peak detection was applied. Thus, there is a gain of 5 and 8 vehicles over the direct superposition results.

These results suggest that the 1% threshold is overly stringent, as neither peak detection nor the weighted method can effectively improve the pass rate. However, under the 5% and 10% thresholds, peak detection significantly enhances the pass rate, and the weighted method proves to be more lenient than direct superposition.

It is worth noting that all 20 selected vehicles have already passed the GB/T 37130 standard. Therefore, subsequent engineering adjustments regarding the frequency-domain accumulation scheme can be benchmarked against these results.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11504622&isnumber=11504452

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**Higher Daytime Light Exposure Predicts Lower Risk of Gastrointestinal Cancer Incidence and Mortality**

Mei X, Wang W, Zheng N, et al., Higher Daytime Light Exposure Predicts Lower Risk of Gastrointestinal Cancer Incidence and Mortality. International Journal of Cancer (2026): 1–10, https://doi.org/10.1002/ijc.70517.

Abstract

Daytime light exposure is essential for health, primarily by synchronizing tissue and cellular-level clocks with the external light/dark cycle. Insufficient exposure may disrupt circadian alignment and contribute to adverse outcomes, including cancer. Given the high prevalence of gastrointestinal cancer, we conducted a prospective cohort study of 89,069 participants with objectively measured daytime light intensity and duration. Cox proportional hazards models were used to evaluate associations with gastrointestinal cancer incidence and mortality. Over a median follow-up of 8.8 years (804,111 person-years), 1692 gastrointestinal cancer cases were recorded, of which 891 were fatal. Higher mean levels of daytime light (≥ 1916 lux between 7:30–20:30, based on the 80% cut-off) were associated with lower risk of gastrointestinal cancer incidence (Hazard Ratio [HR]: 0.87, 95% confidence interval [CI]: 0.76–

0.99, $p = 0.04$) and mortality (HR = 0.76, 95% CI: 0.63–0.93, $p = 0.008$), particularly for pancreatic cancer incidence (HR = 0.58, 95% CI: 0.40–0.85, $p = 0.005$) and mortality (HR = 0.47, 95% CI: 0.30–0.73, $p = 0.001$). Daytime light exposure ≥ 2.4 h (≥ 5000 lux between 7:30 and 20:30, which is often used as a chronotherapeutic threshold) was associated with a lower risk of pancreatic cancer incidence and mortality. Predictive ability of daytime light metrics exceeded that of sleep quality, diet, depression, and alcohol consumption. Higher daytime light exposure was associated with lower risks of gastrointestinal cancer incidence and mortality, especially for pancreatic cancer, indicating a potential protective effect that warrants further investigation in prevention and prognostic contexts.

https://www.deepdyve.com/lp/wiley/higher-daytime-light-exposure-predicts-lower-risk-of-gastrointestinal-MeywYXCGES

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**A systematic review of the health effects of occupational exposure to ultraviolet radiation**

Rocha R, Guedes J, Santos J *et al.* A systematic review of the health effects of occupational exposure to ultraviolet radiation. *Discov Public Health* **23**, 488 (2026). doi: 10.1186/s12982-026-01745-0.

Abstract

Introduction  Given the increasing duration and intensity of occupational exposure to solar ultraviolet radiation (UVR), outdoor workers are particularly vulnerable to its adverse effects. This systematic review aimed to identify the health outcomes associated with occupational exposure to solar UVR, considering both negative and positive effects, and examining related factors such as occupational groups involved, sun protection practices, and study limitations.

Methods  A systematic search was conducted in Scopus, Web of Science, and PubMed databases on 19 November 2024. Eligible studies were peer-reviewed, published in English between 2019 and 2024, and involved human participants occupationally exposed to solar UVR. The risk of bias was assessed using the Joanna Briggs Institute (JBI) Checklist for Qualitative Research. Data were synthesized descriptively.

Results  A total of 16 studies involving 12,268 participants met the inclusion criteria. The most frequently reported adverse health effects included skin cancer, cataracts, and photoaging. On the other hand, moderate solar UVR exposure was associated with a reduced risk of colon and prostate cancers. Sun protection practices varied considerably among studies. Common limitations included methodological heterogeneity and potential publication bias.

Conclusion  This review highlights the substantial health risks, and some potential benefits associated with occupational exposure to solar UVR. The findings support the urgent need for improved sun protection policies in occupational settings and call for more robust, quantitative research to better inform risk assessment and prevention strategies.

Open access: https://link.springer.com/article/10.1186/s12982-026-01745-0

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**Ultraviolet radiation exposure and melanoma risk among over 2 million Ontario workers**

O'Sullivan DE, Eros FR, DeBono NL, *et al.* Ultraviolet radiation exposure and melanoma risk among over 2 million Ontario workers. *Sci Rep* (2026). doi: 10.1038/s41598-026-48477-4.

Abstract

This study aimed to examine the association between occupational sun exposure and melanoma risk among a large cohort of 2.4 million workers. These workers were identified through accepted compensation claims, which were linked to cancer records to identify melanoma diagnoses from 1983 to 2019 in Ontario, Canada. An existing job exposure matrix, SUNJEM, was used to estimate occupational solar ultraviolet radiation (UVR) exposure as low-intermittent (intermittent/partly shaded exposure), moderate (2 to < 6 h/day), or high (≥6 h/day). The association between occupational solar UVR and melanoma risk was assessed using Cox proportional hazard regression models, with age as the timescale and adjustment for sex and birth cohort. A total of 8,170 incident melanoma cases were identified among workers. Both the low-intermittent (HR = 1.26; 95%CI = 1.17–1.38) and high exposure groups (HR = 1.13; 95%CI = 1.01–1.26) had higher rates of melanoma than indoor workers. The low-intermittent exposure group had elevated melanoma rates on the arms and trunk (body), while the high exposure group had an elevated rate on the head and trunk. High risk occupation groups included truck drivers and farmers. Findings support an association between low-intermittent and high occupational solar UVR exposures and melanoma risk. Sun protection measures should focus on at-risk occupational groups.

Open access: https://www.nature.com/articles/s41598-026-48477-4

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**Broad presence of ferromagnetism in bees and relationship to phylogeny, natural history, and sociality**

Russo L, Allen C, Jorgensen CS, Quigley L, Buchanan CC, Winklhofer M, Brady SG, Packer L, Murray A, Gilbert DA. Broad presence of ferromagnetism in bees and relationship to phylogeny, natural history, and sociality. Sci Adv. 2026 Apr 17;12(16):eaed7391. doi: 10.1126/sciadv.aed7391.

Abstract

Scientists have long been fascinated by magnetoreception, the innate capacity of many animals to sense and use Earth's magnetic field for navigation. In eusocial insects like honey bees, magnetoreception has been linked to communication and foraging. However, little is known about magnetoreception's phylogenetic patterns and relationship to species traits and natural history. Here, we demonstrate that putative magnetoreception based on ferromagnetic particles is widespread across a diversity of bee species (74 of 96 species tested), with no phylogenetic signal. We also detected such putative magnetoreception in non-bee outgroups, suggesting that this magnetic capacity predates the evolution of the Anthophila. Although magnetic signals were found across a diversity of life history traits, the strength of the magnetic signal varied within and between species and increased with body size and social behavior.

Open access: https://www.science.org/doi/10.1126/sciadv.aed7391

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**Magnetic disc enhances resilience and over-winter survival of honeybees (*Apis mellifera*)**

Havas M. Magnetic disc enhances resilience and over-winter survival of honeybees (*Apis mellifera*). Electromagn Biol Med. 2026 Apr 16:1-10. doi: 10.1080/15368378.2026.2644215.

Abstract

Honeybee losses continue to threaten ecological and agricultural stability worldwide. This field study evaluated whether a static neodymium magnetic disc placed beneath beehives could enhance colony resilience and overwinter survival. Two commercial apiaries (≈60 hives total) under identical management in Ontario, Canada, were monitored in late summer 2023, spring 2024 and after a mid-season partial crossover in August 2024. One yard received magnetic discs, while the second served as control. Treated hives (i.e. with magnets) compared with the control hives exhibited significantly higher overwinter survival, stronger spring populations, better hygiene and fewer queen replacements than controls ($p < 0.001$). After discs were added to the control yard, colony performance improved within 8 weeks, reaching parity with the initially treated hives. Static magnetic arrays positioned beneath hives appear to enhance colony health and stability, possibly through modulation of bioelectromagnetic or redox processes known to influence cellular energy metabolism. Although magnetic modulation of bioenergetic and redox processes is hypothesized, direct electrical or biochemical measurements were not performed and should be prioritized in future studies. This approach provides a simple, low-cost intervention to improve apicultural outcomes and pollinator resilience. Future studies could investigate the effectiveness of these magnets in areas with known environmental stressors.

https://pubmed.ncbi.nlm.nih.gov/41988747/

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**Exposure limits to radiofrequency EMF do not account for cancer risk or reproductive toxicity assessed from data in experimental animals**

Melnick RL, Moskowitz JM, International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF). Exposure limits to radiofrequency EMF do not account for cancer risk or reproductive toxicity assessed from data in experimental animals. Environ Health. 2026 Mar 14. doi: 10.1186/s12940-026-01288-6.

Abstract

Background  Recent WHO-commissioned systematic reviews have concluded with “high certainty” that exposure to radiofrequency electromagnetic fields (RF-EMF) increases cancer risk and reduces male fertility in experimental animals.

Methods  We performed benchmark dose (BMD) analyses on experimental cancer data to estimate exposure levels associated with cancer risk of 1 × 10–5 (1 in 100,000). Due to the lack of an established non-linear mode of action for RF-EMF-induced tumor responses, we utilized linear low-dose extrapolation from 1% BMD values. In addition, we applied traditional uncertainty factors to the reported linear potency value of 0.03 per W/kg for male reproductive toxicity to derive health-protective exposure limits.

Results  The derived dose per hour (expressed as the specific absorption rate, SAR) at 1 × 10–5 cancer

risk ranges from about 0.8 to 5 mW/kg. It should be noted that cancer risk increases with increasing time of exposure to RF-EMF. For protection of male fertility due to exposure to RF-EMF, the estimated SAR exposure limit was 3.3 to 10 mW/kg. These health protective whole-body exposure values are significantly lower than the current whole-body exposure limit value of 0.08 W/kg (80 mW/kg) established by ICNIRP and the FCC for the general public.

Conclusions  For the general public, current regulatory limits to RF-EMF are 15- to 900-fold higher than our estimates of exposure levels associated with cancer risk of 1 × 10–5 (depending on the duration of daily exposure), and 8- to 24-fold higher than levels that are protective of male reproductive health. Thus, we strongly recommend an independent re-evaluation of RF-EMF exposure limits, integrating scientific data accumulated over the past 30 years and applying rigorous health-protective methodologies.

Open access: https://link.springer.com/article/10.1186/s12940-026-01288-6

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**Systemic effects of radiofrequency electromagnetic fields (review). Spleen, excretory system, skin, bone system**

Khorseva NI, Grigoriev PE. Systemic effects of radiofrequency electromagnetic fields (review). Spleen, excretory system, skin, bone system. Health Risk Analysis.2025. doi: 10.21668/health.risk/2025.3.18.eng

Abstract

Currently, isolated publications appear to report the results of experimental and monitoring studies that provide solid evidence of the spleen, excretory system, skin and skeletal system being sensitive to effects produced by radio frequency electromagnetic fields (RF EMF) in a wide frequency range (from 900 MHz to 2.45 GHz). Since health and normal functioning of these organs and systems are the most important conditions for vital activity of the body, systematization of the available data determines the relevance of this review.

Analysis of the available results obtained by experimental studies has showed that numerous histopathological changes are registered in the spleen (for example, in the white pulp), excretory system (in the kidneys as degeneration of glomeruli and vessels, vacuolization of tubules, fibrosis, etc.; in the bladder as cell apoptosis, etc.), and skeletal system (decreased bone density) upon repeated exposure to RF EMF of various frequency ranges.

A special place belongs to studies with their focus on RF EMF effects in the 5G range on the skin, which is currently a new critical organ of its impact. The studies have reported acceleration of skin aging, pigmentation disorders, mitochondrial stress in fibroblasts and keratinocytes.

Negative changes in the spleen were recorded in studies that applied electrophotonic visualization during short-term exposure to RF EMF on adolescents.

Epidemiological studies indicate that the duration of conversations using a cell phone increases the risk of kidney disease and decreased bone density, detected in active mobile communication users, especially when they carry a gadget in trouser pockets.

The obtained results are relevant and have practical significance for children and adolescents who are currently active users of cellular communications.

Summarizing the available data on the negative impact of RF EMF not only on the nervous system, but also on other systems of the body, we can state its systemic effects.

In this regard, as noted in a number of foreign studies, there is a need to revise the previously adopted FCC and ICNIRP limits for the impact of RF EMF on the human body. The expert society should concentrate its future efforts on developing updated safe RF EMF limits and probable future revision of sanitary rules and norms in accordance with new identified health risks primarily for children and adolescents as a population group, which is the most susceptible to any environmental exposure.

We believe that guidelines should be developed for implementing relevant culture for safe use of up-to-date gadgets for children and adolescents including predominant use of wire-based hands-free kits (not Bluetooth), speakerphones, as well as messengers used for subsequent exchange of text and multimedia messages, and not carrying a gadget 'on oneself' (in shirt or trousers pockets). This will allow a significant reduction in negative effects produced by RF EMF, in particular, by mobile phones / smartphones, on the growing generations' health

Open access: https://doi.org/10.21668/health.risk/2025.3.18.eng

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**Wireless sensitivity and co-morbidities: A prevalence study in Australia, Canada, and the United States**

McCredden JE, McLean L, Steinemann A. Wireless sensitivity and co-morbidities: A prevalence study in Australia, Canada, and the United States. Next Research. Volume 8, 2026, doi: 10.1016/j.nexres.2026.101577.

Abstract

Wireless radiation—such as from cell phones, Wi-Fi, smart meters, laptops, and cell towers—is pervasive in society. Wireless sensitivity is the condition of adverse health effects from exposure to wireless radiation. This study investigates the prevalence of wireless sensitivity, and the medical diagnosis of electromagnetic hypersensitivity (EHS), in the general population of three countries: the United States (US), Australia (AU), and Canada (CA). It also investigates the prevalence of wireless sensitivity/EHS with co-morbid conditions: chemical sensitivity/multiple chemical sensitivities (MCS), asthma/asthma-related conditions (ARCs), autism/autism spectrum disorders (ASDs), and fragrance sensitivity. Nationally representative population-based data were collected in February 2022 (US, AU) and May 2022 (CA) through online surveys of adults [n=3,475 (1,271; 1,104; 1,100) US, AU, CA, respectively]. The study found that, across the general population, 12.6% reported wireless sensitivity (12.8%, 17.4%, 7.5%), 10.0% reported medically diagnosed electromagnetic hypersensitivity (EHS) (10.1%, 14.9%, 5.0%), and 14.0% reported either or both (14.3%, 18.9%, 8.7%). Among all gender and age categories, males ages 25 to 34 reported the highest prevalence proportionally. In addition, among those with wireless sensitivity/EHS, 80.6% also reported chemical sensitivity/MCS, 73.2% reported asthma/ARCs, 53.8% reported autism/ASDs, and 84.8% reported fragrance sensitivity. Given these results, across the three countries, over 26 million adults would experience health problems from

wireless radiation. Results underscore the need for further research on ways to prevent and reduce exposures and associated adverse effects.

Excerpts

Nationally representative cross-sectional population surveys of adults (ages 18–65) were conducted in the US, AU, and CA. Population samples (n=1,271; 1,104; 1,100; respectively) were statistically matched to age, gender, and region for the general population (confidence limit = 95%, margin of error = 3%, for each country)....

Participants were randomly recruited from large web-based panels, provided by Survey Sampling International/Dynata (SSI/D). Participant recruitment followed a three-stage process: first, participants were randomly selected from SSI/D panels and invited to take an on-line survey; second, participants were combined with others into SSI/D's sampling platform and responded to randomly selected profiling questions; and third, prospective participants were then randomly assigned to a survey. Participants were recruited for the survey until the final sample was statistically representative of the general population for gender, age, and region. Informed consent was obtained. Completion rates were 89% (US), 96% (AU), and 91% (CA), and all responses were anonymous. (See the ESM, "Survey Methodology," "Questionnaire," "STROBE Flow Diagram," and "SSI/Dynata Methodologies.")....

The survey instrument employed the following questions to assess prevalence:

*Wireless sensitivity*: "Do you consider yourself allergic or unusually sensitive to wireless radiation, such as from cell phones, Wi-Fi, smart meters, laptops, and other types of wireless technologies and devices?"

*Medically diagnosed EHS* (electromagnetic [hyper]sensitivity): "Has a doctor or health care professional ever told you that you have electromagnetic sensitivity?"

Conclusions

National population surveys in the United States, Australia, and Canada showed that 12.6% (12.8%, 17.4%, 7.5%) of adults reported wireless sensitivity, affecting an estimated 26.7 million adults across the three countries. In addition, 10.0% of adults reported receiving a medical diagnosis of EHS, and 14.0% reported having wireless sensitivity/EHS. Vulnerable individuals with other health conditions—such as chemical sensitivity, asthma, autism, and fragrance sensitivity—are proportionally even more affected. Among all gender and age groups, the relatively most affected by wireless sensitivity was males ages 25-34. Results accentuate the need for further research on specific sources and associated health effects; disease mechanisms underlying wireless sensitivity; and ways to prevent and reduce exposures (such as through alternative means to access the internet) and improve public health.

Given that wireless radiation affects an estimated one in seven adults, the race to implement new wireless technologies under the rubric of “sustainability” needs parallel consideration of possible effects on the environment, social equity, and economics. Reducing exposures to wireless radiation can improve outcomes for sustainability. Environmentally, reducing exposures may lessen potential harm to human health and environmental systems. Socially, reducing exposures may lower barriers to access and participation and productivity in wireless-dependent workplaces, services, and public spaces.

Economically, reducing exposures may decrease costs associated with lost workforce participation and increased healthcare needs.

https://www.sciencedirect.com/science/article/pii/S3050475926002745

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**Is occupational exposure to radiofrequency electromagnetic fields associated with glioma risk? An Australian population-based family case-control study**

My note: The paper's discussion section indicates that in addition to several strengths, the study had several major weaknesses including inadequate statistical power to detect small or moderate effects.

Mate R, Benke G, Loughran SP, Abramson MJ, Vjadic C, Turner M, Turuban M, Cardis E, Karipidis K. Is occupational exposure to radiofrequency electromagnetic fields associated with glioma risk? An Australian population-based family case-control study. BMJ Open. 2026 Mar 12;16(3):e107281. doi: 10.1136/bmjopen-2025-107281.

Abstract

Objectives: This study investigated occupational exposure to radiofrequency electromagnetic fields (RF EMF) using two job-exposure matrices (JEMs) and risk of glioma.

Design: Population-based family case-control study.

Setting: Cases were recruited from participating hospitals in the Australian states of New South Wales, Queensland, Tasmania, Western Australia and Victoria between January 2013 and November 2017.

Participants: The study population consisted of 467 cases of glioma and 367 family controls recruited for the Australian Genomics and Clinical Outcomes of Glioma case-control study between 2013 and 2017. Participants completed questionnaires on demographic and other information, including a detailed occupational history.

Exposures: Exposure to RF EMF was estimated using both the multicountry case-control study INTEROCC JEM and the Canadian JEM (CANJEM).

Primary outcome measures: ORs and 95% CIs were calculated from logistic regression models adjusted for relatedness between cases and controls, sex, age, ethnicity, education level, smoking status and alcohol consumption.

Results: There was no statistically significant positive association overall for risk of glioma when applying either JEM. For the highest compared with the lowest quartile of lifetime exposure, results using the INTEROCC JEM showed an OR of 0.74 (95% CI 0.47 to 1.15) for electric fields and 0.92 (95% CI 0.58 to 1.45) for magnetic fields, while the CANJEM showed an OR of 0.85 (95% CI 0.54 to 1.32). We also did not observe associations when applying different assumptions regarding latency or time windows or with glioma grade.

Conclusion: Overall, this study found no evidence of an association between occupational RF EMF exposure and glioma. Future research should focus on refining occupational RF EMF exposure assessment.

Open access: https://bmjopen.bmj.com/content/16/3/e107281.long

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**Cancer incidence in telecommunication and broadcasting workers in the United Kingdom: Preliminary analysis of the National Register of RF Workers**

My note: This is a preliminary study as a diagnosis of cancer may require 30 years of followup.

Litchfield I. Cancer incidence in telecommunication and broadcasting workers in the United Kingdom: Preliminary analysis of the National Register of RF Workers. International Journal of Hygiene and Environmental Health, Volume 274, 2026. doi: 10.1016/j.ijheh.2026.114785.

Abstract

Objectives There is a broadly acknowledged need for more robust research exploring the potential health effects of occupational radiofrequency radiation (RF) exposure. The National Register of RF Workers is a long-standing database consisting of workers that typically work outside and are occupationally exposed to RF in the telecommunication and broadcast industries in the United Kingdom. This work describes the initial preliminary analysis of the cohort comparing cancer incidence at multiple sites with that observed in the general population.

Methods Cancer registration (incidence) details from NHS Digital were used and standardised registration rates (SRR) calculated as the ratio of observed to expected numbers of registrations expressed as a percentage. In calculating P-values and confidence intervals, it was assumed that registrations occurred following a Poisson distribution. All significance tests were two-tailed.

Results The cohort comprised 1777 employees (1744 males and 33 females) Compared with national rates, all cancers combined are slightly below expectation (Observed 39, SRR 93). The only statistically significant finding is for an excess of skin cancer (excluding melanoma) (Observed 25, SRR 177, 95% CI 117 to 258, $P < 0.01$).

Conclusions Amongst legitimate concerns over the health effects of long-term occupational exposure to RF in the telecommunication and broadcast sector it is important not to overlook the significant hazard of exposure to ultraviolet radiation in a workforce that predominantly works outside. There are several ways organisations might mitigate this impact including amending working hours during the summer months and culturally tailored education on the importance of individual preventative measures.

Open access: https://www.sciencedirect.com/science/article/pii/S1438463926000453

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**Radiofrequency exposure to LTE signal does not alter cancer-related endpoints in human neuroblastoma cell model either alone, or co-exposed to menadione or Wi-Fi signal**

Allocca M, Scarfì MR, Romeo S, Sannino A, Peluso V, Zeni O. Radiofrequency exposure to LTE signal does not alter cancer-related endpoints in human neuroblastoma cell model either alone, or co-exposed to menadione or Wi-Fi signal. Environmental Research, 2026. doi: 10.1016/j.envres.2026.124292.

Abstract

Despite the long-term evolution (LTE) signal, also known as fourth generation (4G) technology, is the most employed and widely deployed system for telecommunications, only a few in vitro studies are devoted to assessing the biological effects related to exposure to LTE alone and in combination with other agents. To the best of our knowledge, the effect of simultaneous exposure to 4G LTE with other frequencies/signals has not been evaluated in any of these studies. In the present study we investigated the non-thermal carcinogenic effect of LTE signal under a co-exposure realistic scenario. Human neuroblastoma cells (SH-SY5Y) were exposed for three hours to 1950 MHz LTE signal, either alone or in combination with the chemical agent menadione. Moreover, the effect of simultaneous exposure to 1950 MHz, 4G LTE signal and 2450 MHz Wireless-Fidelity (Wi-Fi) signal was also evaluated to account for possible effects due to the co-existence of these frequencies/signals. A waveguide-based exposure system, well characterized from dosimetric and experimental point of view, was used, and two specific absorption rate values, 0.3 and 1.25 W/kg, were tested in all cases. Cancer-related endpoints such as reactive oxygen species formation, apoptosis, and cell cycle progression were assessed in flow cytometry assays. In our experimental conditions, neither LTE exposure alone nor LTE and menadione co-exposure or multiple LTE and Wi-Fi exposure influenced the investigated cellular parameters in SH-SY5Y cells.

Highlights

- Exposure to electromagnetic fields occurs from different wireless technologies
- Co-exposures to electromagnetic fields and chemicals represent a real-life scenario
- Well controlled and characterized radiofrequency exposure conditions
- Effects of 4G and Wi-Fi/Menadione co-exposures were tested in neuroblastoma cells
- No effects of co-exposures were detected on cancer related endpoints

https://www.sciencedirect.com/science/article/pii/S0013935126006225

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**Near-field and far-field exposures to radiofrequency electromagnetic fields and cancer risks in humans: a protocol for an umbrella review of epidemiological studies**

Ziegler JL, Lagorio S, Mattsson MO, Zeni O, Bolte J, Ledent M, Velghe M, Stam R, Rijs K, Deltour I, Dolatkhah R, Wollschläger D, Petroulakis N, Ortolano LC, Baaken D. Near-field and far-field exposures to radiofrequency electromagnetic fields and cancer risks in humans: a protocol for an umbrella review of epidemiological studies. Syst Rev. 2026 Mar 12. doi: 10.1186/s13643-026-03142-9.

Abstract

Background: Exposure to radiofrequency electromagnetic fields (RF-EMF; frequencies 100 kHz to 300 GHz) is ubiquitous. As the use of RF-EMF has grown steadily since the 1950s due to advances in telecommunications and other technologies, concerns about potential health effects have persisted. The World Health Organization (WHO) identified key areas of concern, with cancer being most frequently rated as critical. To synthesize evidence on the association between RF-EMF exposure and neoplastic diseases, we will carry out two separate umbrella reviews to account for different RF-EMF exposure conditions: one will focus on near-field exposure and the other on far-field exposure. Both umbrella reviews will include RF-EMF exposure in living and occupational settings.

Methods: Systematic reviews and meta-analyses of human observational studies on RF-EMF and cancer were searched in MEDLINE, Web of Science Core Collection, EMF-Portal, and Epistemonikos databases. Eligibility criteria will follow the PECOS (Population, Exposure, Comparator, Outcome, Study type) scheme. Eligibility and quality of the identified articles will be evaluated by two reviewers independently. The tools AMSTAR 2 (A MeaSurement Tool to Assess Systematic Reviews) and ROBIS (Risk of Bias in Systematic Reviews) will be used to systematically assess methodological quality and risk of bias. Data will be extracted and summarized in a qualitative synthesis using standardized forms and presented in text and tables.

Discussion: These umbrella reviews aim to offer a comprehensive overview of the topic by including systematic reviews and meta-analyses that studied cancer-related health effects of near-field and far-field RF-EMF exposure. In addition, a risk of bias rating will be performed to assess the quality of existing systematic reviews and meta-analyses in the field.

Systematic review registration: PROSPERO CRD42024529007.

Open access: https://link.springer.com/article/10.1186/s13643-026-03142-9

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**Belenki et al. criticizes WHO animal cancer systematic review (SR) by Mevissen et al. and conducts own meta-analysis (MA); Mevissen et al. defends their SR and criticizes Belenki et al. MA**

Belenki D, Baaken D, Meyer F, Kuhne J. Commentary on the systematic review of radiofrequency field exposure and animal cancer by Mevissen et al. (2025) – Revisiting the evidence and a quantitative perspective. Environment International. 2026,doi: 10.1016/j.envint.2026.110154.

Abstract

The systematic review by Mevissen et al. (2025, Environment International) evaluated the evidence on the carcinogenicity of radiofrequency electromagnetic fields (RF-EMF) in laboratory animals and concluded with a high certainty of evidence (CoE) that exposure to RF-EMF increases the risk of malignant glioma and malignant schwannoma in the brain and heart, respectively. Deviating from their pre-published systematic review protocol, the authors did not perform meta-analyses. Instead, they based their assessment on whether or not statistically significant increases in tumour rates were observed in the included studies. One positive finding was deemed sufficient to conclude an adverse effect of RF-EMF exposure in a specific organ, thereby setting the target of the CoE rating for that organ. Here, we question this approach because it does not consider all the available evidence, and highlight

further methodologically inconsistent decisions, while laying out a quantitative alternative based on the protocol and common guidelines for systematic reviews. Re-assessing the eligible long-term carcinogenicity experiments, we consider important studies to be sufficiently similar to be combined in a meta-analysis (MA). We calculate odds ratios as the effect measure and perform MA as well as dose–response MA. Rating the results using GRADE and OHAT guidance, we downgrade the CoE for imprecision due to the very wide confidence intervals of the pooled odds ratios, and upgrade the CoE for malignant heart schwannomas because of a positive exposure–response association, concluding moderate and low CoE for carcinogenicity of RF-EMF exposures in the heart and brain, respectively. In summary, our quantitative assessment of the evidence results in lower CoE conclusions than those of Mevissen et al.

Highlights

- Revisiting and scrutinising the systematic review by Mevissen et al. (2025).
- Relevant chronic bioassays on radiofrequency and cancer combinable in meta-analyses.
- Odds ratio-based (dose–response) meta-analyses for quantitative results synthesis.
- Moderate certainty of evidence for increased risk of malignant heart tumours.
- Low certainty of evidence for increased risk of malignant brain tumours.

Open access: https://www.sciencedirect.com/science/article/pii/S0160412026001121

Supplementary Files: https://ars.els-cdn.com/content/image/1-s2.0-S0160412026001121-mmc1.pdf

https://ars.els-cdn.com/content/image/1-s2.0-S0160412026001121-mmc2.pdf

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**Rationale for a narrative approach in assessing RF-EMF in animal cancer studies**

Mevissen M, Ducray A, Ward JM, Kopp-Schneider A, Wood AW, Rivero TM, Straif K. Rationale for a narrative approach in assessing RF-EMF in animal cancer studies. Environment International. 2026. doi: 10.1016/j.envint.2026.110153.

No abstract

Excerpts

1. Systematic review methodology for animal cancer bioassays
1.1. Meta-analysis versus narrative analysis for the RF-EMF animal cancer studies?

Belenki et al. stated that we deviated from the protocol in not conducting a meta-analysis. Our published protocol clearly states the conditions when a meta-analysis would be performed (Mevissen et al., 2022). None of the study collections satisfied the necessary criteria, we acted in concordance with the protocol and refrained from conducting meta-analyses. The use of meta-analysis was deemed unsuitable primarily due to methodological and biological variations among the animal models, including differences in species, genetically modified organisms, feeding practices, and caging protocols.

Belenki et al. performed a meta-analysis using different species and strains. There are many known

examples where a difference in species and even the strain within a species is very important for the outcome, e.g., atrazine and others. For example, atrazine has been classified by the IARC as probably carcinogenic in humans with the evidence from the animal studies being sufficient (Cattley et al., 2025)....

While acknowledging the strain differences (SD or F344) in studies that examined the brain, they combined them anyway in their analysis with the argument that these strains are widely used in carcinogenicity studies. This is not a reasonable argument for combining divergent studies. The example above clearly shows that this can lead to results that are mistaken. For this reason, it is biologically appropriate to view a negative finding in one species/strain/sex as not outweighing a positive result in a different species/strain/sex, and results from experiments across different sexes/species/strains should be pooled only with great caution. This principle is explicitly stated in many of the guidelines referenced previously and was clearly delineated in our published study protocol.....

Additionally, there were discrepancies in exposure characteristics (such as far-field versus near-field and modulation) and experimental parameters (including the timing, duration, and type of exposure system). The reasons for not employing meta-analyses, such as heterogeneity and biological inappropriateness, are also detailed in our systematic review. Tests for statistical heterogeneity (particularly when only few studies are included in a meta-analysis) cannot address biological differences. Belenki et al. acknowledged that the exposure characteristics differed, and different strains of rats were tested. Regardless, they relied on “common” guidance that is not suitable for evidence synthesis and certainty of evidence for long-term cancer experiments (LTCE). While we performed an SR on all cancer studies and sites available, Belenki et al. limited their meta-analysis only to the two cancer sites, brain and heart, where our SR concluded on high CoE, indicating their focus on challenging our positive findings. They also considered the study design using different strains and sexes as similar and did not consider them being biologically heterogenous. Based on this procedure, they downgraded the evidence twice regarding wide confidence intervals. We strongly disagree with the choices they made in defining a data set for the meta-analysis as it contradicts basic principles in toxicology, and in particular in animal cancer bioassays. The statement by Belenki et al. that a meta-analysis should not be conducted over different strains and sexes are contradictory to what was done and clearly show their lack of understanding of the toxicological literature. A negative finding in one species, strain, or sex does not necessarily undermine a positive result observed in another, as biological consistency supports evaluating such differences without automatic downweighing. Combining data across these variables requires careful, judicious consideration to avoid overgeneralization. This principle aligns explicitly with guidelines referenced previously and the published study protocol (https://ntp.niehs.nih.gov/research/assessments/noncancer/riskbias).

Finally, there are shortcomings when using odds ratio/relative risk (OR/RR) as the effect estimate for a meta-analysis. Different background rates of targeted tumours between species, strains and sexes can create false evaluations, especially in the case of rare tumors. More specifically, the choice of RR effect estimates (here ORs) should not be based on model convenience but guided by the appropriate effect estimate by study design, here risk, rate or hazard ratio – not OR. Collapsing multiple exposure groups into a single exposure group, essentially introduces serious non-differential exposure misclassification with a likely bias towards the null and is incompatible with guidelines for the design of LTCE.

1.2. Risk of bias

Our risk of bias (RoB) assessment was rigorous....

1.3. Data extraction and trend tests

1.3.1. Deviation from inclusion

Fig. 11A. Brain-related carcinogenicity of malignant neoplasms derived from glial cells − Exposure Array – of chronic bioassays. The dashed lines separate species and sex. For additional details see interactive graphic in HAWC (Anderson et al. 2004; Falcioni et al. 2018; La Regina et al. 2003; National Toxicology Program 2018a; b). Data not shown for studies where data were only presented in figures or described qualitatively.

Fig. 11B. Brain-related carcinogenicity of malignant neoplasms derived from glial cells − Effect Size – of chronic bioassays. The dashed lines separate species and sex. This is a thumbnail image of an interactive graphic in HAWC. Data not shown for studies where data were only presented in figures or described qualitatively.

1.4. Use of historical controls in animal cancer studies

2. Consistency across studies

The authors have incorrectly portrayed our review as failing to account for the totality of the evidence. A central element of our approach to assessing consistency across studies was to explicitly evaluate potential reasons for divergent results (e.g., species, strain, sex, life stage at exposure and assessment; exposure or treatment duration, level, or timing in relation to the outcome; and key methodological features such as route of administration and outcome assessment methods). We observed heterogeneity in study design that could plausibly account for the inconsistent findings.

3. Downgrading and upgrading

4. Considering the confidence of the evidence

5. Precision and imprecision

6. The NTP study – Assessment of scientific rigor

7. Conclusions

Drawing conclusions from flawed MAs that pool incompatible studies is inappropriate, and using such results to inform risk assessment or decision-making is misleading. In fact, two independent positive results for different target organs typically provide evidence for strict regulation as a carcinogen. The concerns raised by Belenki et al. highlight specific shortcomings in their application of toxicological

principles, particularly regarding hazard identification and the use of modern approaches in experimental carcinogenesis. Considering their analyses, the outcome only differs because of the downgrading (2 times) done by them. The methodology used in our evaluation of the data has been applied appropriately.

https://www.sciencedirect.com/science/article/pii/S016041202600111X

Supplementary data: https://ars.els-cdn.com/content/image/1-s2.0-S016041202600111X-mmc1.docx

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**Brain Accumulation of Airborne Magnetite Nanoparticles under Earphone/Smartphone-Embedded Magnetic Fields Triggers Neurotoxicity**

Zhang W, Deng S, Guo H, Hao S, Ji N, Xu W, Yang X, Liu Q, Jiang G. Brain Accumulation of Airborne Magnetite Nanoparticles under Earphone/Smartphone-Embedded Magnetic Fields Triggers Neurotoxicity. *ACS Nano.* doi: 10.1021/acsnano.5c22066.

Abstract

Magnetism is an important property of nanomaterials. Natural, incidental, and engineered magnetic nanoparticles are ubiquitous in nature and human activities. As an air pollutant, magnetite nanoparticles (MNPs) can enter the human body and even the brain, posing serious health concerns. However, unlike other physicochemical properties such as size, shape, or surface chemistry, the influence of magnetism on nanoparticle biodistribution and toxicity remains unclear. The manifestation of nanoparticle magnetism requires exposure to magnetic fields, which are ubiquitous in daily life, such as those from mobile phones and earphones. Here, we used six-to eight-week-old C57BL/6J mice coexposed to airborne MNPs and earphone/smartphone-embedded magnetism (EEM) to investigate the impact of nanomaterial magnetism on the *in vivo* fate and neurotoxicity of inhaled nanoparticles. Co-exposure significantly impaired cognitive performance, as evidenced by reduced target quadrant entries and increased escape latency in the Morris water maze ($p < 0.01$). EEM increased brain accumulation of inhaled MNPs by approximately 5-fold compared to non-EEM controls. Transcriptomics, immunohistochemistry, metallomics, and reactome profiling, revealed neurodegeneration-related molecular alterations enriched in the Mitogen-Activated Protein Kinase (MAPK) and guanosine triphosphatase-associated signaling pathways. Compared to exposure to non-EEM, or nonmagnetic engineered iron oxide nanoparticles or magnetism-reduced fine particulate matter ($PM_{2.5}$), the magnetism-mediated toxicity mechanism induced more severe behavioral damage in mice. Our findings reveal the link between nanomaterial magnetism and toxicity, discovering that exogenous nanoparticles can act as a direct medium *in vivo* for the health impacts of magnetic field exposure, and provide novel insights into the health impacts of magnetic field exposure and air pollution.

Conclusions

Our results demonstrate that static magnetic fields produced by mobile phones and earphones can enhance the accumulation of airborne MNPs in the mouse brain, which is associated with neurological impairments. This provides *in vivo* evidence supporting a mechanistic link between nanoparticle magnetism and toxicity. The EEM-induced accumulation of MNPs in the brain, combined with multiomic alterations, may activate MAPK pathways through interactions with small GTPases, (50) contributing to

neurotoxicity by reducing neuroplasticity and disrupting gene expression in the hippocampus. These results establish biological plausibility for magnetically enhanced neurotoxicity and identify an exogenous physical mediator for nanoparticle–brain interactions. While our work mimics aspects of magnetic exposure from mobile phones and earphones, the present model represents an acute/subacute exposure in young mice and does not establish disease causality or long-term health effects in humans. Further chronic exposure and epidemiological studies are needed to determine the relevance of these mechanisms to real-world exposure scenarios.

https://pubs.acs.org/doi/10.1021/acsnano.5c22066

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**Electromagnetic Exposure Assessment of 5G Mobile Phones: SAR and Thermal Distribution in a Multi-Layer Human Head Model**

My note: Another "5G paper" that did not assess 5G exposure.

Chen D, Zhang B. Electromagnetic Exposure Assessment of 5G Mobile Phones: SAR and Thermal Distribution in a Multi-Layer Human Head Model. *Sensors*. 2026; 26(5):1468. doi: 10.3390/s26051468.

Abstract

The rapid deployment of 5G technology has raised public concern regarding the potential health effects of electromagnetic radiation from mobile devices. This study systematically evaluates the specific absorption rate (SAR) and temperature distribution in a multi-layer spherical head model exposed to near-field radiation from a 5G mobile phone antenna. A planar inverted-F antenna (PIFA) covering the 3.5 GHz band was integrated into a smartphone model, and simulations were performed in COMSOL Multiphysics 6.3 under input powers of 21 dBm and 24 dBm at varying antenna–head distances. The results show that the peak SAR in the brain layer remained at 0.034 W/kg and 0.065 W/kg for the two power levels, both well below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) safety limit of 2 W/kg. The highest SAR occurred in the scalp layer, decreasing gradually through the skull and brain tissues. After 30 min of exposure, the maximum brain temperature reached only 37.223 °C, far lower than the thermal damage threshold. Increasing the antenna–head distance from 5 mm to 30 mm reduced SAR by up to 50.2%, while temperature variations remained negligible (≤0.18%). These findings demonstrate that under typical usage conditions, 5G mobile phone radiation complies with international safety standards and poses no significant thermal risk, thereby contributing to a deeper understanding of bio-electromagnetic interactions and supporting ongoing wireless-communication safety assessments.

3.5. Limitations and Considerations for Realistic Exposure Assessment

The exposure metrics presented in this work are derived under the assumption of a continuous-wave source, which serves as a standardized and reproducible benchmark. It is important to contextualize these findings within the framework of actual 5G New Radio (NR) transmissions. Commercial 5G systems employ complex modulated waveforms, primarily Orthogonal Frequency-Division Multiplexing (OFDM), characterized by a high Peak-to-Average Power Ratio (PAPR) and a non-constant envelope. This results in significant temporal variations in the instantaneous radiated power. While the time-averaged SAR is expected to correlate with results from a CW analysis of equivalent average power, the transient peak

field strengths associated with OFDM symbols could influence localized, short-term energy deposition patterns and related transient thermal responses in tissue. These dynamics represent an additional layer of complexity beyond the scope of the present steady-state model. Therefore, future investigations aiming for the highest fidelity in exposure assessment should incorporate detailed temporal models of specific 5G NR modulation schemes, resource allocation patterns, and traffic bursts to evaluate their potential effects on peak spatial and temporal exposure metrics.

## 4. Conclusions

This study designed a smartphone-integrated antenna model capable of operating across multiple communication bands, including GSM-850/900, DCS-1800, PCS-1900, UMTS-2000, WiMAX-2300, LTE-2300/2500, and the 5G-representative frequency of 3.5 GHz. The specific absorption rate (SAR) distributions in the scalp, skull, and brain layers of a human head model were systematically evaluated under near-field exposure at 3500 MHz with input powers of 21 dBm and 24 dBm, at a separation distance of 5 mm. The results indicate that the SAR in the brain layer at 24 dBm was approximately twice that at 21 dBm. In both cases, the highest SAR occurred in the scalp layer, yet all values remained well below the ICNIRP safety limit of 2 W/kg. Moreover, the maximum SAR observed in the brain layer corresponded to the peak surface temperature in the same region; however, this temperature increase remained within a physiologically negligible range and poses no risk of thermal injury.

Further analysis revealed that after 10 min of exposure, the temperature rise in the scalp layer became lower than that in the brain layer. Following 30 min of radiation, the temperature variation across the head model progressively stabilized, showing only minimal changes compared to the 10-min mark. In terms of distance dependence, when the antenna–head distance increased from 5 mm to 10 mm (in 1 mm steps), the decrease in SAR across all tissue layers was relatively gradual. A more pronounced reduction up to 50.2% was observed when the distance was extended from 10 mm to 30 mm (in 5 mm steps). In contrast, the corresponding temperature changes across tissues were markedly less sensitive to distance, with a maximum decrease of only 0.18% over the same range.

In conclusion, this study employs a canonical multi-layer spherical head model to perform a systematic, parametric analysis of electromagnetic exposure from a 5G mobile phone antenna at 3.5 GHz. The results provide clear quantitative trends regarding the dependence of SAR and temperature rise on key variables such as input power and antenna-to-head distance. It is important to interpret these findings as illustrative of fundamental biophysical interactions under controlled conditions, rather While the simplified geometry of our head model dictates that the absolute SAR and temperature values are scenario-specific, the key relationships and patterns we identify are robust and physically meaningful. These patterns offer crucial insights for safety-by-design principles in antenna development and help contextualize the rationale behind standardized compliance testing. Moving forward, extending this parametric approach to diverse anatomical models and higher 5G frequency bands will be essential for building a comprehensive, evidence-based understanding of human exposure in next-generation wireless networks.

Furthermore, the evolution toward advanced antenna systems, such as those employing beamforming and massive MIMO, opens a promising frontier for proactive exposure control. in the future, our work will explore the paradigm of “Exposure-Aware Beamforming.” This would involve developing intelligent algorithms that leverage real-time sensor or channel data to infer device-body orientation and

dynamically steer beams away from the user, thereby integrating safety as an active optimization goal within the communication system itself.

Open access: https://www.mdpi.com/1424-8220/26/5/1468

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**Biological effects of 5G-modulated 700 MHz RF-EMF exposure on neuronal and glial cell models under isothermal conditions**

Puginier E, Leclercq L, Poulletier de Gannes F, *et al.* Biological effects of 5G-modulated 700 MHz RF-EMF exposure on neuronal and glial cell models under isothermal conditions. *Sci Rep* **16**, 10767 (2026). doi: 10.1038/s41598-026-43960-4.

Abstract

Whether radiofrequency electromagnetic fields (RF-EMF) at wireless telecommunication frequencies can alter brain physiology remains a matter of debate. The 700 MHz band, recently allocated for 4G and early 5G deployment, is increasingly prevalent in the environment, yet its biological effects are poorly documented. Here, we investigated the impact of 700 MHz 5G-modulated RF-EMF exposure on two complementary central nervous system cell models: primary rat cortical astrocytes and human SH-SY5Y neuroblastoma cells. Cells were exposed in transverse electromagnetic (TEM) cells at specific absorption rates (SAR) of 0.08 W/kg and 4 W/kg, for 1 h or 24 h, and analyzed immediately or after a 24 h recovery period. Multiparametric flow cytometry quantified mitochondrial reactive oxygen species (ROS), cell viability, and apoptosis stratified as early and late, together with astrocytes' proliferation. Across all exposure conditions, no statistically significant differences were detected compared to sham controls, while positive controls with hydrogen peroxide elicited significant increases in ROS and apoptosis, validating assay sensitivity. These results demonstrate that, under strictly controlled iso-thermal conditions, 5G-modulated 700 MHz RF-EMF exposure does not induce measurable oxidative stress, apoptosis, or proliferative alterations in astrocytic and neuronal models. Our findings provide evidence supporting the absence of acute or subacute biological effects in vitro at isothermal exposure levels up to 4 W/kg, thereby reinforcing the scientific basis for current exposure guidelines.

Open access: https://www.nature.com/articles/s41598-026-43960-4#Abs1

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**The neuroprotective role of coenzyme Q10 against endoplasmic reticulum stress in the olfactory bulb caused by 5G electromagnetic field exposure**

My note: Another "5G paper" that did not assess 5G exposure.

Yilmaz H, Tumkaya L, Mercantepe T, Gül F, Karakas S. The neuroprotective role of coenzyme Q10 against endoplasmic reticulum stress in the olfactory bulb caused by 5 G electromagnetic field exposure. Tissue Cell. 2026 Mar 30;101:103510. doi: 10.1016/j.tice.2026.103510.

Abstract

The widespread use of 5 G mobile communication technology has raised the possibility of neurosensory effects arising from exposure to electromagnetic fields (EMF). This study investigated the effects of EMF

exposure in the 5 G FR1 band on the olfactory bulb and the potential protective role of coenzyme Q10 (CoQ10). Male Sprague-Dawley rats were randomly divided into three groups. Group 1 (Control) received only saline via oral gavage. Group 2 (EMF) was exposed to EMF in the 5 G FR1 band for 2 h per day (09:00-11:00) and received oral saline. Group 3 (EMF + CoQ10) underwent the same EMF exposure and additionally received 10 mg/kg CoQ10 dissolved in corn oil at 2 mg/kg orally for 30 days. At the end of the experiment, olfactory bulb tissue samples were collected from all animals. Tissue sections were stained with hematoxylin-eosin (H&E) and evaluated histopathologically. Endoplasmic reticulum (ER) stress levels were analyzed by immunohistochemical methods based on GRP78 and CHOP expression. Oxidative stress parameters, malondialdehyde (MDA) and glutathione (GSH) levels, were measured in the tissue (mg/g) using biochemical methods. In the EMF group, prominent histopathological changes such as widespread glial cell abnormalities, inflammation, necrotic neurons with pyknotic nuclei, and neuronal degeneration were observed in the olfactory bulb tissue. In this group, the expressions of GRP78 and CHOP, which are markers of ER stress, and MDA levels, which are indicators of oxidative stress, were significantly increased compared to the control group, while GSH levels were decreased. In contrast, in the EMF + CoQ10 group, these adverse changes were significantly reduced, histopathological damage was significantly decreased, GRP78 and CHOP expression levels were reduced, MDA levels showed a downward trend, and GSH levels increased significantly, approaching those of the control group ($p < 0.05$). It was demonstrated that EMF exposure in the 5 G FR1 band causes ER stress and oxidative damage in the olfactory bulb tissue, while CoQ10 may play a protective role by reducing these harmful effects.

https://pubmed.ncbi.nlm.nih.gov/41934922/

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**Determining the Impact of Nonionizing Electromagnetic Waves on Human Pregnancy and Teratogenicity: Protocol for Systematic Review and Meta-Analysis**

Armalina D, Susilaningsih N, Sutanto H, Sunarno S. Determining the Impact of Nonionizing Electromagnetic Waves on Human Pregnancy and Teratogenicity: Protocol for Systematic Review and Meta-Analysis. JMIR Res Protoc. 2026 Mar 30;15:e86479. doi: 10.2196/86479.

Abstract

Background: The widespread use of mobile devices has markedly increased global exposure to nonionizing electromagnetic waves (EMWs). Emerging evidence indicates potential biological effects of EMW exposure in susceptible populations, particularly pregnant women; however, findings remain inconsistent.

Objective: This protocol delineates a systematic review aimed at synthesizing and critically evaluating the teratogenic and pregnancy-related effects of nonionizing EMW exposure in pregnant women.

Methods: This protocol adheres to the PRISMA-P (Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols) 2020 guidelines and has been registered with the International Prospective Register of Systematic Reviews (PROSPERO; CRD42023475665). A comprehensive literature search will be conducted in PubMed/MEDLINE, Scopus, Web of Science, Embase, ScienceDirect, SpringerLink, Wiley Online Library, and Google Scholar, with supplementary searches of the World Health Organization

International Clinical Trials Registry Platform and ClinicalTrials.gov. Eligible studies will include pregnant women exposed to nonionizing EMWs from mobile phones and related wireless devices. The primary outcomes will be pregnancy complications and fetal anomalies, with secondary outcomes assessed as previously reported. Study selection, data extraction, and risk of bias assessment will be performed independently by 2 reviewers. Where appropriate, a random-effects meta-analysis will be conducted.

Results: Funding for this study was secured in March 2026. The literature search and study screening are planned for April to July 2026, with data extraction, risk of bias assessment, and synthesis expected to be completed by September 2026. The final results are anticipated to be submitted for publication in late 2026.

Conclusions: This systematic review is expected to provide consolidated evidence on the potential teratogenic and pregnancy-related effects of nonionizing EMW exposure, thereby supporting future research and evidence-based recommendations for public health.

Conclusion

This protocol provides a structured and reproducible framework for systematically synthesizing evidence of nonionizing EMW exposure during pregnancy. By applying rigorous methodological standards and transparent quality assessments, the forthcoming review aims to clarify the current state of evidence while explicitly acknowledging its limitations. The conclusions will be framed cautiously, reflecting the strength and consistency of the available data and are intended to support responsible scientific interpretation and future research rather than draw definitive clinical or causal inferences.

This study was supported by the Endowment Fund for Education (LPDP), Indonesia.

Open access: https://www.researchprotocols.org/2026/1/e86479

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**Evaluation of RF-EMF Exposure in 5G FR1 Band Using IEC 62232 Assessment Methodologies**

Suka D, Solmonte N, Ruttner M, Pasquino N, Djuric N. Evaluation of RF-EMF Exposure in 5G FR1 Band Using IEC 62232 Assessment Methodologies. *2025 IEEE International Workshop on Metrology for Green Technologies, Renewable Energy and Ecological Sustainability (MetroGREENST)*, Giardini Naxos (Messina), Italy, 2025, pp. 169-174, doi: 10.1109/MetroGREENST67435.2025.11428924.

Abstract

This study examines human exposure to electro-magnetic fields (EMFs) in modern mobile networks, focusing on 5G systems in the Frequency Range 1 (FR1). The complexity introduced by technologies like Active Antenna Systems (AAS) has increased the need for accurate and efficient exposure assessment methods. While existing standards such as IEC 62232 and IEC TR 62669 offer structured procedures, this work also explores a new approach using NARDA SignalShark spectrogram data. A comparison is made between traditional extrapolation methods, including those in Sections B.8.5 and Annex E of IEC 62232, and novel technique, with an emphasis on evaluating its practical use and consistency of results.

Conclusion

This study compared established and novel methods for assessing EMF exposure from 5G base stations operating in the FR 1 band. Traditional extrapolation approaches face challenges due to complex beamforming, antenna patterns, and network traffic variability. The spectrogram-based measurement technique using the NARDA SignalShark proved robust and practical, providing reliable maximum exposure estimates without requiring operator or antenna data input. Across diverse measurement points, this method showed consistent results and simplified the extrapolation process by eliminating dependence on correction factors like F extBeam. Simulated traffic-based measurements tended to underestimate exposure under real-world conditions, highlighting the importance of realistic traffic scenarios during assessments. Manual validation indicated minor discrepancies with automatic spectrogram evaluations, suggesting scope for further algorithm refinement. Overall, the findings validate spectrogram-based measurements as a valuable tool for accurate and efficient EMF exposure evaluation and strongly support their integration into future IEC standards.

https://ieeexplore.ieee.org/document/11428924

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**Model Variability in Assessment of Human Exposure to Radiofrequency Fields**

A. Hirata et al. Model Variability in Assessment of Human Exposure to Radiofrequency Fields. IEEE Journal of Microwaves, 6(2): 502-518, March 2026, doi: 10.1109/JMW.2025.3628902.

Abstract

The recent advances in computational dosimetry for electromagnetics and thermodynamics are reviewed to assess human exposure to electromagnetic fields in the MHz-to-terahertz range. This review emphasizes model variability in computational dosimetry. Apart from computational electromagnetic methods and their usage, the developments in anatomical phantoms and tissue dielectric properties characterization are also surveyed. In addition, the rationale for dosimetric quantities prescribed in international exposure guidelines, such as the specific absorption rate (SAR) and absorbed power density, is revisited in relation to their correlation with local and core temperature rises in various tissues and populations. A heating factor, which is defined as a steady-state temperature rise per SAR, for the brain, eye lens, skin, and body core is evaluated to estimate heating resulting from exposure to electromagnetic fields. The transition of a physical quantity in the guidelines at 6 GHz, from SAR to the absorbed power density, is discussed along with the optimal spatial averaging volume and areas. Computational evaluations of product compliance, 5G devices, and wireless power transfer systems are also reviewed. This review aims to synthesize the current knowledge, identify key sources of computational model variability and uncertainty, and outline further research needs for setting exposure guidelines and compliance assessment.

Summary

This review highlights the mechanism by which variability across anatomical, thermophysiological, and numerical human models affects the prediction of temperature rise in computational dosimetry. Computational dosimetry plays a crucial role in defining the physical quantities used in the guidelines and setting the limit. The conceptual framework is schematically illustrated in Fig. 1, highlighting that

SAR variability is largely driven by anatomical scaling, whereas temperature rise is predominantly governed by thermophysiological parameters. To complement this, the key quantitative findings are summarized in Table 2.

Model variability and computational uncertainty in SAR showed consistent patterns across studies. For $psSAR_{10g}$ under local exposure, children and adults exhibit broadly similar values, although anatomical factors, such as head size, can yield higher localized absorption in children. Intermodel analyses indicated variability on the order of ∼30%, with rare extreme cases up to a threefold difference. For WBASAR, smaller and child models generally show 40%–60% higher values than adults, whereas additional variability arises from body shape, modeling method, and tissue properties (10%–30%), with polarization and incidence angle occasionally producing variations of up to ∼60%. Computational uncertainty, which arises from discretization, boundary conditions, and algorithmic implementation, is typically small; however, additional errors of ±10%–20% may occur if the parameters are not properly controlled.

The model variability in the temperature rise showed a different pattern compared with the SAR. For the brain and eye, heating factors per $psSAR_{10g}$ remained consistently below ∼0.12–0.19 °C · kg/W, corresponding to <0.1 °C–0.2 °C rises under guideline limits, with limited differences between adults and children. In the skin, variability is mainly due to tissue thickness and microstructure, generally accounting for 10%–20%, whereas pulse exposures highlight the importance of transient surface heating. Core temperature rise is smaller in children and higher in fetuses and the elderly; however, in occupational scenarios, environmental and clothing factors outweigh EMF-induced heating. Furthermore, vascular models, which explicitly represent major blood vessels, have demonstrated additional influence on local temperature distributions, particularly near large arteries and in deep brain regions, although their contribution is generally secondary compared to bulk blood perfusion [174], [175].

Overall, unlike SAR, where anatomical scaling and body size are the dominant sources of variability, temperature rise is more sensitive to thermal and physiological parameters, such as blood perfusion and thermoregulatory responses. While further investigations into these aspects are warranted, with several challenges already identified by international standardization bodies [10], [176], the variability observed to date remains within the margins covered by the reduction factors in ICNIRP and IEEE guidelines, supporting both the robustness of current limits and their value for future refinement. Further research is essential, particularly in view of emerging applications such as 6G.

Open access:
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11269783&isnumber=11455229

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**Physiological Responses of Plants to 2.45 Ghz Non-Ionizing Electromagnetic Radiation**

Meenu L, Aiswarya S, Menon UKA, Menon SK. Physiological Responses of Plants to 2.45 Ghz Non-Ionizing Electromagnetic Radiation. *2025 IEEE Microwaves, Antennas, and Propagation Conference (MAPCON)*, Kochi, India, 2025, pp. 1-4, doi: 10.1109/MAPCON65020.2025.11426735.

Abstract

This research investigates the effects of 2.45 GHz electromagnetic radiation(EMR) exposure on the germination process of high-quality pea seeds, while simultaneously assessing the influence of the same on plant growth hormones. The germinating seeds are observed in a controlled environment over a 7-day period and subjected to varying intensities of electromagnetic radiation exposure along with monitoring of all the influences from the external environment. The experimental findings reveal that the germinating seeds exposed to electromagnetic radiation from the router exhibited growth retardation ranging from 21.5 % to 57.0 % depending upon the intensity and duration of electromagnetic radiation exposure. The study could act as a proof of concept to an extent in proving that the long term exposure of EMR can inhibit at least the plant growth hormones. These findings highlight the need for a more profound understanding of the environmental consequences of electromagnetic radiation and its intricate relationship with plant growth hormones. This research could also act as scientific evidence proving the ill effects of electromagnetic radiation towards living beings.

Excerpt

Pea (Mung bean) seed is taken as the test sample and is placed under the EM source. The Linksys E4200A router is used as the electromagnetic source in a controlled environment. It is characterised by simultaneous dual frequency operation at 2.45 GHz and 5 GHz with 2×3 on 2.45 GHz and 3×3 on 5 GHz MIMO mode. It helps the router to transmit multiple signals for a period of time to improve its communication system. The existence of 6 internal antennas in the router, all operating at 2.45 GHz have the gain of 3.6 dBi [21]. So the amount of EMR that exists in the controlled environment is higher. Over the entire period of the experimentation, 5 GHz frequency is disabled. The operation of Linksys E4200A router is enabled at 2.45 GHz frequency band.

Conclusion

This research investigates the relationship between electromagnetic radiation (EMR) exposure from a router and its effects on plant growth. By placing high-quality pea seeds at varying distances from the EM source and closely monitoring their germination over a week. The presence of EMR influences plant growth hormones, impacting the germination and growth of pea seeds. The average growth rates of seeds exposed to EMR were notably lower compared to the group without the influence of EMR, showcasing the direct effect of EMR on plant growth hormone activity. This provides scientific evidence on the influence of EMR on the plant physiological factors. Future research should expand the scope by conducting dose-response analyses to determine EMR thresholds, investigate molecular mechanisms at the genetic and biochemical levels, and extend observation periods to assess long-term effects on plant growth. The investigations are required to extend and evaluate the physiological responses of plants under EMR exposure across a broad spectrum of frequencies including the advanced 5G FR1 and FR2 bands to better understand their potential impacts on plant growth, metabolism, and hormonal activity. Additionally, studies should explore variations in plant species responses, conduct field studies to understand real-world implications, and develop mitigation strategies to minimize adverse effects of EMR. Collaborative efforts with policymakers and public awareness campaigns are crucial to establishing guidelines and educating communities about the environmental impacts of EMR.

https://ieeexplore.ieee.org/document/11426735

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**Safety Assessment of Sunroof Status on Radio Frequency Electromagnetic Exposure Levels for Drivers in Vehicle-to-Vehicle Communication**

Song Y, Lu M. Safety Assessment of Sunroof Status on Radio Frequency Electromagnetic Exposure Levels for Drivers in Vehicle-to-Vehicle Communication. Health Physics ():10.1097/HP.0000000000002145, March 23, 2026. | DOI: 10.1097/HP.0000000000002145.

Abstract

With the widespread application of vehicle-to-vehicle (V2V) communication technology, sunroofs have enhanced user experience while introducing novel electromagnetic exposure scenarios that may pose health risks to drivers. This study employs COMSOL Multiphysics to simulate three sunroof scenarios (no sunroof, sunroof closed, and sunroof open) to assess human exposure levels. The computational models incorporate a full-scale vehicle, a V2V antenna, and an anatomical human model. The whole-body averaged specific absorption rate (SARwb) and SAR averaged over 10g tissues ($SAR_{10g}$) in the central nervous system (CNS) are assessed against the International Commission on Non-Ionizing Radiation Protection (ICNIRP) public exposure limits. The results indicate that the sunroof open condition (worst-case exposure scenario) significantly increases SAR deposition, with SARwb reaching 0.318 mW $kg^{-1}$ (0.396% of the ICNIRP limit of 0.08 W $kg^{-1}$). This value represents a 1.45 times and 4.68 times increase compared to the sunroof closed and no sunroof conditions, respectively. In the worst-case exposure scenario, the superficial skin tissue exhibits the maximum $SAR_{10g}$ (72.39 mW $kg^{-1}$), representing a 29.30% increase compared to the sunroof closed state (55.99 mW $kg^{-1}$) and corresponding to only 3.62% of the ICNIRP limit (2 W $kg^{-1}$). Simultaneously, CNS tissues exhibit significant increases in $SAR_{10g}$ values, with grey matter displaying the most pronounced elevation (9.58 times), exceeding that of white matter (9.08 times) and thalamus (8.99 times). All results remain below the ICNIRP limits, confirming that V2V communication systems pose no health risks to drivers and provide a basis for occupant protection in connected vehicles.

Conclusion

This study employs COMSOL Multiphysics-based FEM modeling to quantitatively evaluate, for the first time, the impact of sunroof configurations (no sunroof, sunroof closed, and sunroof open) on the driver's RF electromagnetic exposure levels in V2V communication scenarios. The analysis focuses particularly on the CNS tissues.

The results show that different sunroof configurations lead to significant changes in the peak and spatial distribution of whole body-induced SAR and the $SAR_{10g}$ in CNS tissues. An open sunroof alters the electromagnetic field distribution inside the vehicle cabin. This results in greater energy deposition in the driver's whole body and CNS tissues than in configurations with a closed sunroof or no sunroof. It also shifts the locations of peak energy deposition due to changes in the propagation of electromagnetic waves into the cabin.

Nevertheless, it is important to note that, despite these variations, all computed SAR values, including both SARwb and $SAR_{10g}$, remain fully compliant with the ICNIRP public exposure limits. Therefore, under the investigated operational parameters, the RF-EMF exposure from the vehicle-mounted V2V communication system is not expected to pose a health risk to drivers.

This work emphasizes the significant influence of sunroof configurations on electromagnetic exposure levels during V2V communication. The observed variations in sunroof states result in a redistribution of SARwb and $SAR_{10g}$. These findings provide valuable insights for optimizing electromagnetic safety in vehicle design. In long-term safety evaluations, it is particularly important to consider exposure risk to the head region, especially to CNS tissues.

https://journals-lww-com.libproxy.berkeley.edu/health-physics/fulltext/9900/safety_assessment_of_sunroof_status_on_radio.343.aspx

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**Radiofrequency radiation-induced changes in Leydig cell function**

Jangid, P., Rai, U., Sevak, J.K. *et al.* Radiofrequency radiation-induced changes in Leydig cell function. *Sci Rep* (2026). doi: 10.1038/s41598-026-39244-6.

Abstract

Radiofrequency radiation, emitted from commonly used wireless communication devices, has been implicated in disrupting cellular homeostasis; however, its effects on testicular somatic cells such as Leydig cells remain poorly understood. To address this, the present study investigated the frequency- and time-specific effects of RFR on cellular morphology, proliferation, and cell cycle dynamics in TM3 Leydig cells. Cells were exposed to mobile phone radiation and radiofrequency signals at 1800 MHz and 2450 MHz for 15–120 min under non-thermal conditions. Following exposure, morphological alterations were examined using Giemsa staining, while proliferation and cell cycle progression were evaluated by BrdU-ELISA and PI-based flow cytometry. BrdU assays showed a progressive reduction in DNA synthesis across conditions, indicating suppressed proliferative activity. Consistently, cell cycle analysis revealed accumulation of cells in G1 phase with a corresponding decline in S-phase population at longer durations, suggesting checkpoint activation. These changes were supported by morphological alterations such as cell rounding, loss of adherence, and membrane blebbing, features associated with stress-induced antiproliferative responses. Overall, these findings indicate that RFR disrupts cellular morphology, DNA synthesis, and cell cycle progression in a frequency- and time-dependent manner, highlighting Leydig cell vulnerability to prolonged exposure and potential implications for male reproductive health.

Open access: https://www.nature.com/articles/s41598-026-39244-6

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**Cellular redox disruption and apoptosis: Differential effects of RFR frequencies on Leydig cells**

Jangid P, Rai U, Sevak TK, Singh S, Singh R. Cellular redox disruption and apoptosis: Differential effects of RFR frequencies on Leydig cells. Toxicology and Applied Pharmacology, 2026. doi: 10.1016/j.taap.2026.117807.

Abstract

Radiofrequency radiation (RFR), widely emitted from modern wireless devices, has raised questions regarding its possible impact on male reproductive health. In this comparative study, we examined the redox and apoptotic responses of TM3 Leydig cells following exposure to mobile phone radiation, as well as 2450 MHz, and 1800 MHz frequencies for 15, 30, 45, 60, 90 & 120 min, and redox imbalance was assessed by quantifying nitric oxide (NO) and intracellular superoxide (SO) levels. Apoptotic cell percentages were evaluated by dual labeling with Annexin V-FITC/PI using flow cytometry. Mobile phone and 2450 MHz exposures induced biphasic alterations in NO levels, while 1800 MHz exposure resulted in a sustained reduction in NO. SO levels increased progressively in a time- and frequency-specific manner. Apoptotic analysis revealed early apoptotic activation in mobile and 2450 MHz groups, whereas 1800 MHz exposure led to delayed but sustained late-stage apoptosis. These findings demonstrate that RFR triggers redox imbalance and apoptosis in TM3 cells, with effects varying by frequency and exposure duration. This comparative analysis underscores the biological risks of chronic low-intensity RFR exposure and highlights the growing concerns about RFR-associated testicular stress and its implications for male reproductive toxicity.

Highlights

- TM3 cells exposed to RFR showed frequency-specific redox imbalance.
- Mobile and 2450 MHz exposures induced biphasic nitric oxide alterations.
- Superoxide levels increased progressively with RFR exposure.
- Annexin V-FITC/PI staining revealed frequency-dependent apoptotic changes.
- Short term RFR exposure may impair testicular function and redox homeostasis.

https://www.sciencedirect.com/science/article/pii/S0041008X26001031

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**Comparison of Static & Oscillating Magnetic Field Effects on Gram-Negative & Gram-Positive Bacteria via Oxidative Stress and DNA Fragmentation**

Baş H, Çavuş HK, Morley N, Şahingöz R. Relative Comparison of the Static Magnetic Field and Oscillating Magnetic Field Effects on Gram-Negative and Gram-Positive Bacteria via Evaluating Oxidative Stress and DNA Fragmentation. Bioelectromagnetics. 2026 Mar;47(3):e70050. doi: 10.1002/bem.

Abstract

The effects of static magnetic field (SMF) and oscillating magnetic field (OMF) on oxidative stress responses and DNA fragmentation were investigated in Staphylococcus aureus and Escherichia coli. Bacterial cultures were exposed to magnetic field intensities ranging from 2 to 16 mT at 50 Hz for 8 h. Exposure to both SMF and OMF caused intensity-dependent decreases in optical density, indicating growth inhibition. In parallel, nitric oxide and superoxide anion radical levels, as well as the activities of catalase and superoxide dismutase, increased significantly in a field-strength-dependent manner. Glutathione disulfide levels were enhanced while reduced glutathione values decreased, reflecting a redox imbalance. Moreover, malondialdehyde and DNA fragmentation levels were markedly elevated, confirming oxidative and genotoxic stress. Comparative analysis revealed that E. coli exhibited more pronounced responses than S. aureus, with significant effects emerging above approximately 6-8 mT for

OMF and 8-10 mT for SMF exposure. Overall, these findings demonstrate that both OMF and SMF can induce oxidative stress and DNA damage in bacterial cells, with OMF producing stronger effects. The results highlight the differential susceptibility of Gram-positive and Gram-negative bacteria to electromagnetic exposure and suggest potential implications for non-antibiotic antimicrobial strategies based on magnetic fields.

https://pubmed.ncbi.nlm.nih.gov/41852117/

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**Electric field strengths & current densities induced inside the body due to Electronic Article Surveillance system antennas compared to ICNIRP's exposure limits**

Schneeweiss P, Hirtl R, Jhala T, Ueberbacher R, Cecil S, Becker C, Boemmels I, Altekoester C, Schmid G. Electric field strengths and current densities induced inside the body due to exposure to Electronic Article Surveillance (EAS) system antennas compared to ICNIRP's exposure limits. J Radiol Prot. 2026 Mar 20. doi: 10.1088/1361-6498/ae553b.

Abstract

Personal exposure to magnetic fields emitted by electronic article surveillance (EAS) systems was systematically assessed based on measurements of a representative sample of 19 different EAS devices. This sample included the two major EAS technologies currently on the market: acoustomagnetic (AM) and radio frequency (RF) systems. In addition to these measurements, numerical computations of the current densities and electric field strengths induced in body tissues were carried out for one representative AM-EAS device and several body models (adult male, adult female, child female, and a hand model) and reasonably foreseeable worst-case exposure scenarios using a real-valued magneto quasi-static solver, based on the Scalar Potential Finite Element (SPFE) method. The obtained measurement and computational results were compared to the different sets of exposure limits defined by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) in 1998 and 2010. Our results demonstrated that current RF-EAS technology, which typically operates in the 8.2 MHz frequency range, does not conflict with the exposure limits, even under adverse exposure conditions. However, AM-EAS systems, which typically operate at 58 kHz, may lead to induced current densities in the central nervous system and induced electric field strengths in the peripheral nervous systems of adults and children that exceed the basic restrictions for the general public (up to a factor of 22.5 for the adult female bending in front of the antenna) and even for occupational exposure (up to a factor of 4.5 for the same scenario) according to the ICNIRP 1998 and 2010 guidelines under reasonably foreseeable exposure conditions, which are not covered by the assessment procedures defined in the present version of the applicable standard IEC EN 62369-1. Therefore, radiation protection and market regulatory authorities should have a close look and check presently installed and future AM-EAS technology with respect to their compliance to exposure limits.

Open access: https://iopscience.iop.org/article/10.1088/1361-6498/ae553b

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**Magnetic resonance control of spin-correlated radical pair dynamics in vivo**

Burd SC, Bagheri N, Condon AF, Ingaramo M, Mondal S, Dowlatshahi DP, Summers JA, Mukherjee S, York AG, Wakatsuki S, Boxer SG, Kasevich M. Magnetic resonance control of spin-correlated radical pair dynamics in vivo. Nature. 2026 Mar 18. doi: 10.1038/s41586-026-10282-4.

Abstract

Magnetic fields can influence reactions involving spin-correlated radical pairs (SCRPs)[1,2]. This provides a mechanism by which both static and time-varying magnetic fields can affect living systems at the biomolecular level[3]. However, an engineered SCRP system conferring magnetic sensitivity to a non-native biochemical process in a multicellular organism has not yet been demonstrated. Here we demonstrate control of SCRP dynamics using magnetic resonance in a live transgenic animal. We show that the emission of various red fluorescent proteins (RFPs), in the presence of a flavin cofactor, can be modified by a combination of static and radiofrequency magnetic fields applied near the electron spin resonance frequency. This effect was measured at room temperature both in vitro and in the nematode Caenorhabditis elegans, genetically modified to express the RFP mScarlet[4]. These observations suggest that the magnetic field effects measured in RFP-flavin systems[5] are due to quantum-correlated radical pairs with a coherence time larger than 4 ns. Our experiments demonstrate that radiofrequency magnetic fields can influence dynamics of reactions involving SCRPs in vivo, potentially enabling new methods for remotely controlling biomolecular processes, such as gene expression, and suggest broader potential for quantum tools in biology.

https://pubmed.ncbi.nlm.nih.gov/41851455/

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**Oxidative DNA damage and necrotic cell death in differentiated SH-SY5Y cells induced by continuous extremely low-frequency magnetic field exposure**

Aydemir M, Kurt MŞ, Daş ASB, Arslan ME, Arslan E, Türkez H. Oxidative DNA damage and necrotic cell death in differentiated SH-SY5Y cells induced by continuous extremely low-frequency magnetic field exposure. Environ Toxicol Pharmacol. 2026 Mar 30;124:105011. doi: 10.1016/j.etap.2026.105011.

Abstract

Extremely low-frequency (ELF) magnetic fields generated by power-line sources are ubiquitous, yet their long-term effects on neuronal cells remain unclear. We investigated whether continuous exposure (72 - 96 h) to a 60 Hz ELF magnetic field induces oxidative DNA damage and alters cell death pathways in differentiated SH-SY5Y human neuroblastoma cells. Neuron-like cells generated by retinoic acid and brain-derived neurotrophic factor were exposed to 1-3 mT ELF magnetic fields for 96 h, with sham-exposed cells as controls. Chromosomal integrity (Hoechst 33258 staining), apoptosis/necrosis (Annexin V-FITC/propidium iodide flow cytometry), oxidative DNA damage (apurinic/apyrimidinic site analysis), and redox balance (total oxidant and total antioxidant status) were assessed. ELF magnetic field exposure caused intensity dependent nuclear abnormalities, increased oxidative DNA lesions, early oxidative imbalance, and a predominance of necrotic over apoptotic cell death. These findings indicate that continuous low-intensity ELF magnetic field exposure disrupts redox homeostasis and compromises genomic stability in differentiated neuronal cells.

https://pubmed.ncbi.nlm.nih.gov/41921635/

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**Magnetosensation - the unsolved mystery**

Lam BYK, Malkemper EP. Magnetosensation - the unsolved mystery. Physiol Rev. 2026 Mar 28. doi: 10.1152/physrev.00032.2025.

Abstract

Magnetosensation, or the magnetic sense, is the ability of organisms to detect the Earth's magnetic field. Behavioral evidence supporting magnetosensation emerged in the latter half of the 20th century, and it is now recognized as widespread across the animal kingdom. Yet, the mechanisms underlying this sense remain poorly understood, with three main hypotheses proposed: magnetite-based detection, radical pair reactions in photosensitive molecules, and electromagnetic induction. This review provides a concise overview of current knowledge on magnetosensation, emphasizing behavioral evidence, sensory mechanisms, and the neural processing of magnetic information. We also discuss findings on magnetosensitivity in humans, highlighting evidence that suggests humans may retain a residual unconscious magnetic sense. We argue that understanding the mystery of magnetosensation has broad implications: it can yield insight into poorly understood biological and health effects of magnetic fields, inform the emerging field of magnetogenetics for remote control of cellular activity, and guide the protection of ecosystems dependent on magnetosensitive species.

Conclusion and central open questions

Magnetosensation remains one of the most intriguing mysteries in sensory biology. From bacteria to vertebrates, compelling evidence shows that organisms utilize the EMF for orientation and navigation, yet the underlying receptor mechanisms and neural circuits remain a mystery. Despite decades of work on behavior, mechanisms, and neural pathways, no unifying explanation has emerged. Central open questions include:

1. Is cryptochrome a primary magnetic sensor?
2. Can (human) type II cryptochromes mediate magnetosensation?

3. What is the molecular transduction cascade between the primary effector molecule and the neuronal response?
4. What is the temporal and spatial precision of the magnetic sense?
5. Do terrestrial animals employ a mechanism based on electromagnetic induction?
6. Does a vertebrate produce biogenic magnetite?

Progress will depend on integrating modern genetic, molecular, and neurophysiological approaches with rigorous behavioral testing. A deeper understanding of the magnetic sense will not only resolve a long-standing enigma in biology but may also inform applied fields such as magnetogenetics, environmental health, and navigation technology.

https://pubmed.ncbi.nlm.nih.gov/41902539/

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**Comparison of effects of blue light, red light and radio waves on Caenorhabditis elegans and Gerbera jamesonii petals**

Kline AW, Beattie CS, Shenk AK, Spicher SI, Bloss TA, Tipton L, Walker MT, Vallier LG, Schmidt KL, Scarel G. A phenomenological comparison of the effects of blue light, red light and radio waves on the escape speed of Caenorhabditis elegans and the rate of closure of Gerbera jamesonii petals. PLoS One. 2026 Apr 1;21(4):e0343498. doi: 10.1371/journal.pone.0343498.

Abstract

Objective: Great interest surrounds understanding the effects of radio waves on biological organisms, including humans, animals and plants. Several prior studies, however, showed contradictory results. We hypothesized that the problem lay in the lack of a method for evaluating the energy transferred from radio waves, or electromagnetic waves in general, to biological organisms. Therefore, we proposed to measure the transferred energy with the classic electromagnetic wave energy, i.e., the product of the intensity and the inverse of the frequency of the waves.

Methods: To test this hypothesis, we exposed two simple light-sensitive biological organisms, Caenorhabditis elegans (C. elegans) and Gerbera jamesonii (G. jamesonii), to radio waves, red light, blue light and white light. We selected frequency and intensity such that each type of electromagnetic wave could transfer a similar amount of energy to the biological organisms. We then observed the kinematic and postural response of C. elegans, and the rate of closure of G. jamesonii's petals to assess whether similar effects would be detected when the energy at different frequencies is similar.

Conclusions: In both C. elegans and G. jamesonii, we found that radio waves trigger effects like those generated by light with similar energy. This outcome provides support to our hypothesis. We therefore infer that electromagnetic wave intensity needs to be considered when estimating possible harm linked to the exposure of biological organisms to radio waves or, in general, electromagnetic waves. Moreover, the successful ability of radio waves in biological organisms to produce effects like those produced by blue light, together with their long penetration depth in tissues, stimulates the investigation of radio waves as a substitute for blue light in a non-invasive version of optogenetics.

Conclusions

We observed that C. elegans nematodes responded to radio waves by increasing their forward speed in a manner that resembles the response to blue light. We also observed that G. jamesonii petals close their petals at a rate slightly lower than that under solar white light and higher than that under blue and red light. We thus inferred that the classic electromagnetic wave energy given as the product between intensity and inverse of the frequency described the amount of energy transferred from electromagnetic waves to biological organisms. We showed that the classic electromagnetic wave energy established a criterion to select the wave intensity once the amount of energy to be transferred on a biological organism was specified. We noted that, in transferring the same amount of energy, radio waves required a significantly lower intensity than light. Further studies based on these results could lead to the development of radio-genetics as a non-invasive alternative to optogenetics in the diagnosis and treatment of neurological pathologies.

Open access: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0343498

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**Orientation-dependent effects of a 1 mT static magnetic field on HT22 neural cell proliferation**

Pirbhai M, Wagner N, Ferguson C, Belden C, Estevez AY. Orientation-dependent effects of a 1 mT static magnetic field on HT22 neural cell proliferation. Electromagn Biol Med. 2026 Apr 5:1-7. doi: 10.1080/15368378.2026.2652926.

Abstract

This study examines how the vertical orientation of a moderate-intensity static magnetic field (1 mT) influences the proliferation of HT22 mouse hippocampal cells. Static magnetic fields (SMFs) offer potential for biomedical applications due to their ability to influence cellular processes in a non-invasive manner. However, their effects on neural cell proliferation remain poorly understood, particularly with respect to magnetic field orientation. Cells were exposed to SMFs in two orientations: downward and upward. SMF exposure was associated with significantly higher proliferation relative to both incubator and sham controls, with the downward orientation producing the most consistent increase. This trend was observed across multiple experimental conditions, including exposure duration and antibiotic use. Ion substitution experiments further showed that replacing extracellular $K^+$ with $Cs^+$ attenuated the orientation-dependent response, suggesting that ion conductance may contribute to SMF sensitivity. These findings emphasize the importance of magnetic field orientation in low-intensity SMF studies and indicate that directional exposure can modulate neural cell proliferation under well-controlled conditions.

Plain language summary

Cells are influenced not only by chemical signals, but also by physical cues in their environment. They can sense and respond to factors such as light, temperature, and even electric fields. However, whether cells can respond to a static magnetic field, a field that remains constant in strength and direction, has been less clear. In this study, we explored how hippocampal neuronal cells respond to repeated exposure to a moderate static magnetic field. We measured how these cells grew over time and examined whether the direction of the magnetic field mattered, comparing fields oriented upward versus downward. We also varied how long the cells were exposed each day and tested multiple culture conditions to ensure that any observed effects were not due to changes in nutrients. Across all conditions, we observed a consistent pattern: cells exposed to a downward-oriented magnetic field showed greater growth than cells exposed to other conditions. To better understand what might be driving this response, we altered the ionic environment surrounding the cells. Specifically, we replaced potassium with cesium, known to block certain potassium channels that help regulate how ions move across the cell membrane. When potassium conductance was disrupted in this way, the growth enhancement associated with the downward magnetic field disappeared, suggesting that potassium movement plays an important role in the cellular response. These findings may help inform future research exploring non-invasive physical cues in regenerative medicine and neural repair, which are central to wound healing, neural regeneration, and recovery after injury.

https://pubmed.ncbi.nlm.nih.gov/41936130/

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**The WHO-Commissioned Systematic Reviews on Health Effects of Microwave and RF Radiation [Health Matters]**

Lin JC. The WHO-Commissioned Systematic Reviews on Health Effects of Microwave and RF Radiation [Health Matters]. *IEEE Microwave Magazine*, 27(3): 14-17, March 2026, doi: 10.1109/MMM.2025.3637921.

No abstract

Excerpts

The peer-reviewed assessment concluded that the body of evidence reviewed is inadequate to either support or refute the safety of the ICNIRP exposure guidelines.

The unsubtle message, in attempts to prop up the ICNIRP position that cellular mobile phone RF radiation and radiation from other wireless communication devices does not pose a health risk, can hardly be mistaken.

The scientific credibility of the World Health Organization (WHO)-commissioned series of systematic reviews (SRs) and meta-analyses (MAs) on the health effects of exposure to microwave and RF radiation is challenged by the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF) in a recent Environmental Health journal article [1]. The article concluded that the SRs and MAs on the health effects of RF exposure cannot be used as proof of safety of cellular mobile phones and other wireless communication devices because of the serious methodological faults and deficiencies in conducting the reviews and MAs. This situation places WHO in an awkward position in partnering with the International Commission on Nonionizing Radiation Protection (ICNIRP) in their attempts to reassure the public on the effectiveness and safety of the ICNIRP RF exposure guidelines [26]. RF and microwave radiation are ubiquitous in modern society. They enable cellular mobile and wireless communication systems and devices to transmit and receive texts, conversations, pictures, news, and entertainment programs. RF-radiating devices and systems are found in homes, offices, schools, playgrounds, theaters, stores, factory floors, automobiles, public transport systems, sports arenas, stadiums, recreational parks and facilities, and public spaces. They are located indoors and outdoors, on persons, and practically everywhere....

The last article in the series of WHO-commissioned SRs reviewed the effects of RF exposure on cancer in experimental animals [16]. This SR was the only WHO-commissioned SR that did not include an MA; the authors deemed it inappropriate because of methodological differences among the studies, including differences in experimental parameters, exposure characteristics, and different biological models. It included all 52 reported studies with 20 chronic bioassays. The SR included all reported studies to minimize the risk of bias concerns. The certainty of the evidence for an increased risk in gliomas was judged as high. Also, in three chronic bioassays, statistically significant increases in malignant schwannomas were demonstrated as high in the heart of male rats. While this conclusion is in opposition to the interpretations of the ICNIRP, it is consistent with the findings of the National Institutes of Health National Toxicology Program [23], [24] and the Ramazzini Institute [25] and is in support of the earlier WHO [International Agency for Research on Cancer (IARC)] conclusion [22]. Almost

immediately after the earlier batch of WHO-commissioned SRs was published, evaluations of the quality of those SRs and MAs and the relevance of their conclusions on biological effects and human safety began to appear in scientific publications [17], [18], [19], [20]. The criticisms encountered by those WHO-commissioned SRs and MAs were serious and severe, including calls for retraction....

The recent ICBE-EMF article [1] critically evaluated the 12 WHO-commissioned SRs on the health effects of RF radiation and identified significant flaws and weaknesses that undermine the SRs' conclusions regarding RF exposure safety. The ICBE-EMF article listed many examples that illustrate the failings in the WHO SRs' selection of publications. The extensive involvement of present and past members of the ICNIRP raises serious concerns. All of the WHO-commissioned SRs had at least one ICNIRP member as authors, and some had several members. Across multiple SRs, there are issues in the inclusion and exclusion criteria that often led to the exclusion of relevant, well-conducted studies, while flawed studies were given disproportionate weight, thereby undermining the reliability of the evidence assessments.

Simply put, MAs are inappropriate for the WHO SRs. MAs are generally intended to combine quantitative results from multiple studies to estimate overall effects, but their usefulness depends on methodological consistency, low between-study heterogeneity, sufficient statistical power, and statistical independence of the effect sizes. However, as discussed in the ICBE-EMF article, those criteria were mostly unmet in the WHO SRs on RF health effects.

Almost all of the MAs included in the 11 WHO SRs had methodological weaknesses that compromised the interpretability of results because of the relatively few primary studies available for each MA and/or high between-study heterogeneity. High levels of heterogeneity across primary studies result in MAs that are unreliable and that risk producing biased pooled results because of the excessive influence of just one or two larger studies.

There are many aspects of both SRs and MAs that, despite the use of widely recommended tools, such as the OHAT Risk of Bias scale [27] and the GRADE scheme for assessing strength of evidence [28], involve inherently subjective decisions. Such subjectivity can lead to significant variation across the reviews, even when the same primary studies are being assessed. The potential for subjectivity requires clear-cut independence of the reviews' coauthors from all influences that might lead to bias—conditions that were clearly not met in the WHO-commissioned SRs.

In summary, the ICBE-EMF evaluation of the SRs exposes major problems with at least 10 or 11 of them. In addition to the scientific quality of the less-than-balanced reviews, they appear to be biased with a strong conviction of nothing but heat to worry about with RF and microwave radiation, in apparent support of the ICNIRP guidelines [26].

The ICBE-EMF article showed that the MAs in the SRs suffered from relatively few primary studies available for each MA (some due to excessive subgrouping), exclusion of relevant studies, weaknesses in many of the included primary studies, high between-study heterogeneity, and/or the lack of a basis for analyzing complex processes, such as those involved in cognitive functions.

Simply put, the criticisms and challenges encountered by those WHO SRs, aside from the most recent one, are serious and severe, including calls for retraction. In addition to the scientific quality of the less-than-balanced reviews, the unsubtle message, in attempts to prop up the ICNIRP position that cellular mobile phone RF radiation and radiation from other wireless communication devices does not pose a health risk, can hardly be mistaken. The systematic reviews displayed unequivocal but misguided bias for the ICNIRP RF exposure guidelines for human safety, with faulty scientific analysis and justification.

In the words according to *Microwave News* [29], "WHO gets a 'Failing' grade on RF systematic reviews: faulted for bad analysis and ICNIRP bias."

https://ieeexplore.ieee.org/document/11372512

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**The need to rethink the everyday electromagnetic environment**

Isaac A. Jamieson. Chapter 10 - The need to rethink the everyday electromagnetic environment. (Ed.) Jan Martel. Recent Advances in Bioelectromagnetism and Subtle Energies. Academic Press. 2026. Pages 335-368. doi: 10.1016/B978-0-443-33018-6.00010-5.

Abstract

The potential biological effects of everyday electromagnetic environments, and the electromagnetic pollution that can often be present within them, present a critical yet dramatically under-considered risk factor in public health, technological innovation, and everyday life. Even low-intensity EMF exposures, below current regulatory limits, can have biological effects. While cancer and electromagnetic hypersensitivity (EHS) receive the most attention with regard to these, a broader range of health issues that substantially contribute to economic burdens has also been linked with EMF exposures. It is proposed that individuals, businesses and industries can substantially benefit from proactively addressing EMF risks. Encouragingly, not all EMF exposures are harmful. This provides opportunities to optimize electromagnetic environments and technologies to better support health, wellness and productivity. Bioelectromagnetic design, in particular, offers the potential for innovation, creating environments that are safer, more inclusive, and aligned with emerging guidelines that prioritize health and well-being. By applying the precautionary principle and embracing proactive biologically informed innovation, industries can better future-proof their operations and play a meaningful role in shaping healthier, more sustainable everyday environments.

Conclusion

A huge opportunity exists to rethink the everyday electromagnetic environments and technologies most people are exposed to and create more bio-friendly versions of them. Doing so can help reduce risk, drive innovation, and grow the wellness economy. This is especially true for wellness real estate, the fastest-growing sector of the global wellness industry.

With regard to EMF exposure standards and guidelines, even relatively low intensity exposures below permitted exposure levels can have biological effects. While the greatest degree of publicity related to exposures is given to cancer risk and EHS being associated with environmental exposures, numerous

other health conditions are indicated as being negatively affected and create high levels of financial burden. Such evidence provides strong reason to create healthier electromagnetic environments and technologies.

Another reason for addressing such issues is that many regulations and guidelines related to EMF exposures are getting stricter, so proactively addressing this trend can help future-proof industries. This type of approach can further open-up opportunities for innovation for those observing market trends and who seek to create “multiple layers of benefit” solutions.

The insurance industry’s perspective on EMF risks provides further evidence of why developing solutions is of paramount importance. The need to effectively address this issue is further highlighted from the documentation of the wide range of health effects associated with EMF exposures, and the costs that these can create to national economies.

Those findings provide strong evidence for the need to apply the precautionary principle with regard to electromagnetic pollution and the need to see how such issues can be better addressed. In particular, it is suggested that proactive precautionary approaches can be adopted by members of the wireless and tech industries enabling them to reframe themselves as future-compliant and future-oriented, which will increase their attractiveness to investors and help them make greater inroads into the global wellness economy through creating more bioelectromagnetically friendly technologies. The health industry also stands to be able to expand its mission through helping develop more bioelectromagnetically friendly environments.

Such approaches will allow EHS accessibility requirements, which a growing body of authorities are taking ever more seriously, to be more easily addressed while creating extra value and reducing risk to other members of society who may also be negatively affected by electromagnetic pollution.

Calls for more bio-friendly environmental exposures are likely to increase as consumer education on these issues increases. The trend for building certification initiatives that reward proactive measures that positively impact health and wellbeing is in line with this and can already be coupled with existing initiatives to improve environmental conditions and incorporate new innovations as they arise through multidisciplinary interventions.

Fortuitously, not all exposures to electromagnetic phenomena are harmful, and some types of artificially created EMF exposures (when used correctly) benefit both health and productivity. There are, in addition, technological breakthroughs that allow increased technical efficiency while reducing exposures to electromagnetic pollution. This is particularly heartening and suggests that in addition to the low EMF tactic often advocated to address electromagnetic pollution issues a more proactive approach can be taken to help biologically optimize the bioelectromagnetic characteristics of environments, sometimes beyond what nature itself can even achieve. Bioelectromagnetic design can drive innovation, reduce risk, and take the design and operation of technologies and environments to a whole new level, creating potential “Win/Win” solutions for all stakeholders that are kind to people, planet, and profit.

https://www.sciencedirect.com/science/article/pii/B9780443330186000105

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**Prevalence of self-reported sensitivities to various environmental factors in Germany, Sweden, and Finland based on multiple classification criteria**

Köteles F, Witthöft M, Bräscher AK, Bailer J, Nordin S. Prevalence of self-reported sensitivities to various environmental factors in Germany, Sweden, and Finland based on multiple classification criteria. J Psychosom Res. 2026 Feb;201:112495. doi: 10.1016/j.jpsychores.2025.112495.

Abstract

Objective: Our knowledge on the prevalence of self-reported sensitivities to environmental factors is poor. The lack of accepted criteria/assessment makes findings of different studies difficult to compare; the way of assessment might play a role in the reported prevalence rates. The present study aimed to report the prevalence rates of five environmental sensitivities for the German general population, to compare three of them with Swedish and Finnish data, and to demonstrate the impact of strictness of criterion on the results.

Methods: Data from a German (n = 2515), a Swedish (n = 3253) and a Finnish (n = 1467) population-based survey was used. Sentitivities were rated on ordinal scales in all samples.

Results: In the German sample, about 25 % of participants reported mild reactions to sounds, chemicals, and buildings, and about 10 % to electromagnetic fields (EMFs) and wind turbines, with a similar pattern for strong reactions, but with proportions of 1-2 %. Data from the Nordic countries show consistent similarities between these two countries, with prevalences exceeding 34 % for mild reactions to chemicals and sounds and about 5 % to EMFs, with a similar pattern for strong reactions, but with proportions of 1-8 %. Prevalence of sensitivity to EMFs was higher, whereas prevalence of sensitivity to chemicals and sounds was lower in Germany. Classification criteria significantly impacted the reported prevalence rates.

Conclusion: Various environmental sensitivities affect a considerable proportion of the general populations of the three countries. To improve comparability, self-report assessment of sensitivities should be based on at least an ordinal scale instead of the widely used yes-or-no question.

Excerpt

The current study has both strengths and limitations. It represents the most comprehensive epidemiological assessment of environmental sensitivities in Europe, including samples being population-based and of large sizes that enhance representativeness to the general populations in these countries. Another strength is the study of five major types of environmental sensitivity, providing broad understanding, and enabling direct comparison between them. Yet another strength is the use of two, rather than typically one, level of strictness of criterion for assessment of prevalence of sensitivities. However, an obvious limitation is the different questions and response alternatives used for the German vs Swedish/Finnish samples; most importantly, symptoms are explicitly mentioned in the German survey, whereas the Swedish/Finnish questions referred to sensitivity. This calls for caution when comparing results from the German and Nordic countries. Another limitation is the relatively low

response rate that may result in selection bias, and thus impacting on representativeness. Furthermore, the sampling method used for the Swedish and Finnish samples was the same, but different from that of the German sample, making comparison between these countries more difficult. Also, the different time points for assessment in the included countries might also limit the comparability. Finally, sensitivity was assessed via self-reports thus does not necessarily reflect confirmed environmental health effects.

Open access: https://www.sciencedirect.com/science/article/pii/S0022399925004593?via%3Dihub

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**Electromagnetic Exposure Assessment of 5G Mobile Phones: SAR and Thermal Distribution in a Multi-Layer Human Head Model**

My note: Another "5G" study that uses a continuous wave signal at 3.5 GHz and not 5G modulation. To its credit, this paper reports this limitation in its limitations section (see below)

Chen D, Zhang B. Electromagnetic Exposure Assessment of 5G Mobile Phones: SAR and Thermal Distribution in a Multi-Layer Human Head Model. *Sensors*. 2026; 26(5):1468. doi: 10.3390/s26051468.

Abstract

The rapid deployment of 5G technology has raised public concern regarding the potential health effects of electromagnetic radiation from mobile devices. This study systematically evaluates the specific absorption rate (SAR) and temperature distribution in a multi-layer spherical head model exposed to near-field radiation from a 5G mobile phone antenna. A planar inverted-F antenna (PIFA) covering the 3.5 GHz band was integrated into a smartphone model, and simulations were performed in COMSOL Multiphysics 6.3 under input powers of 21 dBm and 24 dBm at varying antenna–head distances. The results show that the peak SAR in the brain layer remained at 0.034 W/kg and 0.065 W/kg for the two power levels, both well below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) safety limit of 2 W/kg. The highest SAR occurred in the scalp layer, decreasing gradually through the skull and brain tissues. After 30 min of exposure, the maximum brain temperature reached only 37.223 °C, far lower than the thermal damage threshold. Increasing the antenna–head distance from 5 mm to 30 mm reduced SAR by up to 50.2%, while temperature variations remained negligible (≤0.18%). These findings demonstrate that under typical usage conditions, 5G mobile phone radiation complies with international safety standards and poses no significant thermal risk, thereby contributing to a deeper understanding of bio-electromagnetic interactions and supporting ongoing wireless-communication safety assessments.

Limitations and Considerations for Realistic Exposure Assessment

The exposure metrics presented in this work are derived under the assumption of a continuous-wave source, which serves as a standardized and reproducible benchmark. It is important to contextualize these findings within the framework of actual 5G New Radio (NR) transmissions. Commercial 5G systems employ complex modulated waveforms, primarily Orthogonal Frequency-Division Multiplexing (OFDM), characterized by a high Peak-to-Average Power Ratio (PAPR) and a non-constant envelope. This results in significant temporal variations in the instantaneous radiated power. While the time-averaged SAR is expected to correlate with results from a CW analysis of equivalent average power, the transient peak field strengths associated with OFDM symbols could influence localized, short-term energy deposition

patterns and related transient thermal responses in tissue. These dynamics represent an additional layer of complexity beyond the scope of the present steady-state model. Therefore, future investigations aiming for the highest fidelity in exposure assessment should incorporate detailed temporal models of specific 5G NR modulation schemes, resource allocation patterns, and traffic bursts to evaluate their potential effects on peak spatial and temporal exposure metrics.

## Conclusions

This study designed a smartphone-integrated antenna model capable of operating across multiple communication bands, including GSM-850/900, DCS-1800, PCS-1900, UMTS-2000, WiMAX-2300, LTE-2300/2500, and the 5G-representative frequency of 3.5 GHz. The specific absorption rate (SAR) distributions in the scalp, skull, and brain layers of a human head model were systematically evaluated under near-field exposure at 3500 MHz with input powers of 21 dBm and 24 dBm, at a separation distance of 5 mm. The results indicate that the SAR in the brain layer at 24 dBm was approximately twice that at 21 dBm. In both cases, the highest SAR occurred in the scalp layer, yet all values remained well below the ICNIRP safety limit of 2 W/kg. Moreover, the maximum SAR observed in the brain layer corresponded to the peak surface temperature in the same region; however, this temperature increase remained within a physiologically negligible range and poses no risk of thermal injury.

Further analysis revealed that after 10 min of exposure, the temperature rise in the scalp layer became lower than that in the brain layer. Following 30 min of radiation, the temperature variation across the head model progressively stabilized, showing only minimal changes compared to the 10-min mark. In terms of distance dependence, when the antenna–head distance increased from 5 mm to 10 mm (in 1 mm steps), the decrease in SAR across all tissue layers was relatively gradual. A more pronounced reduction up to 50.2% was observed when the distance was extended from 10 mm to 30 mm (in 5 mm steps). In contrast, the corresponding temperature changes across tissues were markedly less sensitive to distance, with a maximum decrease of only 0.18% over the same range.

In conclusion, this study employs a canonical multi-layer spherical head model to perform a systematic, parametric analysis of electromagnetic exposure from a 5G mobile phone antenna at 3.5 GHz. The results provide clear quantitative trends regarding the dependence of SAR and temperature rise on key variables such as input power and antenna-to-head distance. It is important to interpret these findings as illustrative of fundamental biophysical interactions under controlled conditions, rather While the simplified geometry of our head model dictates that the absolute SAR and temperature values are scenario-specific, the key relationships and patterns we identify are robust and physically meaningful. These patterns offer crucial insights for safety-by-design principles in antenna development and help contextualize the rationale behind standardized compliance testing. Moving forward, extending this parametric approach to diverse anatomical models and higher 5G frequency bands will be essential for building a comprehensive, evidence-based understanding of human exposure in next-generation wireless networks.

Furthermore, the evolution toward advanced antenna systems, such as those employing beamforming and massive MIMO, opens a promising frontier for proactive exposure control. In the future, our work will explore the paradigm of “Exposure-Aware Beamforming.” This would involve developing intelligent algorithms that leverage real-time sensor or channel data to infer device-body orientation and dynamically steer beams away from the user, thereby integrating safety as an active optimization goal within the communication system itself.

Open access: https://www.mdpi.com/1424-8220/26/5/1468

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**SAR and Temperature Rise in Human Tissues Under 5G Electromagnetic Wave Exposure: A Numerical Study**

Amit Verma A, Kumar V, Singh AR. SAR and Temperature Rise in Human Tissues Under 5G Electromagnetic Wave Exposure: A Numerical Study. Indian Journal of Pure & Applied Physics. 64(3). 2026. doi: 10.56042/ijpap.v64i3.22289.

Abstract

The rollout of fifth-generation (5G) wireless networks is driving the pervasive exposure to high-frequency electromagnetic fields, in the range (28–60 GHz), to a new scale. These are faster in carrying out data, but possible thermogenic effects on human tissue have raised concerns. This study aims to investigate the numerical modelling of channel-specific absorption rate and associated temperature increase in the human organs for 5G exposure based on Maxwell's equations. Simulations were performed at different frequencies (28, 38, and 60 GHz) and exposure durations (6 and 20 min) in the visual part (skin and subcutaneous fat) and in/on the structures of the human head (eyes, brain, skull, ear canal, thyroid, wrist, chest). Results suggest that the SAR increases with frequency and has a maximum value in superficial tissues, whereas the temperature rise is strongly associated with both SAR and exposure time. The most sensitive tissues are the cornea, ear canal, which show temperature increases larger than 3 °C at 60 GHz for long exposure, even if SAR values stay under internationally accepted safety levels. The results indicate that 5G EMW Waves at frequencies are of negligible risk to deep tissues despite a small elevation in temperature due to resonant absorption within the skin, with localized heating of the skin surface becoming of concern given ultra-close proximity exposure of long duration to devices operating at or near 5 G frequencies. The research highlights the need to incorporate thermal safety evaluations into existing exposure standards and proposes more looking into the long-term biological impacts of prolonged exposure to 5G.

Open access: https://or.niscpr.res.in/index.php/IJPAP/article/view/22289

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**When biology meets polarity: Toward a unified framework for sex-dependent responses to magnetic polarity in living systems**

Nelson I. When biology meets polarity: Toward a unified framework for sex-dependent responses to magnetic polarity in living systems. Electromagn Biol Med. 2026 Jan 31:1-15. doi: 10.1080/15368378.2026.2621660.

Abstract

The human body emits a bioelectromagnetic field primarily generated by the electrical activity of the heart, with additional contributions from the brain, muscles, and peripheral nerves. These endogenous

fields are not isolated and can be modulated by external electromagnetic and magnetic influences. Current evidence suggests that the main mechanisms underlying such interactions include modulation of ion channels, radical pair dynamics, and ion cyclotron resonance. Several studies report sex-specific differences in responses to magnetic exposure. The main factors implicated in these differences include heart orientation and position, heart mass, tissue conductivity, hormonal modulation, autonomic balance, and cortical field organization. Beyond sex, consistent findings demonstrate that biological effects depend not only on field intensity and frequency but also on polarity (north/south), and direction (vector angle). These parameters are often overlooked or unreported in published works. Some observations even suggest a direct relationship between polarity and sex, with divergent physiological and behavioral outcomes. Recognizing these interactions is crucial to refining models of magnetoreception, resolving inconsistencies, and advancing therapeutic applications of electromagnetic fields. This review integrates evidence from magnetobiology and sex-based physiology to propose that hormonal and structural dimorphism may modulate biological responses to magnetic field. Potential mechanisms involving ion-channel modulation, magnetite orientation, and radical-pair dynamics are outlined and experimental paradigms to test these interactions are proposed. Together, these insights establish a framework for studying sex-dependent magnetic sensitivity in living systems.

Plain language summary

Our bodies naturally produce a bioelectromagnetic field. The heart is the strongest source, but other organs and tissues also contribute. These fields can be influenced by external magnetic or electromagnetic forces, such as those produced by magnets or induction coils. The way living systems respond to these fields depends on many factors. Those are not just signal amplitude and frequency, but also polarity (north/south), and direction (vector angle). There is also evidence that responses may vary according to sex. In fact, multiple studies show that magnetic and electromagnetic exposure can affect sleep, stress responses, and hormone levels differently in males and females. Similar effects have been observed in animals, plants, and even cell cultures. It is supposed that differences in heart size and position, body composition, hormone levels, and nervous system activity can all influence the way the body generates and interacts with electromagnetic fields. Some findings even suggest that magnetic polarity may interact with biological sex in a dependent manner, for instance, one polarity may stimulate men while inhibiting women, and vice versa. These insights help explain why studies on magnetic exposure sometimes report inconsistent results. Ignoring sex differences or magnetic field characterizing variables can lead to confusion and slow progress in this field. By considering these factors, researchers may improve our understanding how magnetic fields interact with living organisms. Notably, this knowledge could open the door to new and more effective medical treatments using magnetic and electromagnetic fields.

https://pubmed.ncbi.nlm.nih.gov/41618935/

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**Effects of exposure to nearby mobile phone base stations and mobile phone usage on human blood parameters**

Laldinpuii, Sailo L, Weller S, Varte CL, Tochhawng L, Bandara P, McCredden JE, Zothansiama. Effects of exposure to nearby mobile phone base stations and mobile phone usage on human blood parameters. Electromagn Biol Med. 2026 Feb 6:1-20. doi: 10.1080/15368378.2026.2623473.

Abstract

The present study investigates the impact of RF-EMF (900 and 1800 MHz) emissions from mobile phone base stations (MPBS) as well as from mobile phone usage on the hematological parameters and stress markers of exposed individuals. Members of MPBS highly exposed (*N* = 50) and a reference group (*N* = 51) were tested using a complete blood count and two stress markers, amylase and cortisol. Different effects were found for different blood parameters, based on various combinations of exposure type, demographics, and lifestyle behaviors. Subsequent stepwise regression analysis revealed that exposure from MPBS contributed significantly to TLC, while various combinations of gender, age and power density contributed significantly to differential and absolute basophil counts and absolute monocyte counts. MPBS exposures contributed to absolute monocytes similar to smoking. Furthermore, hours of daily mobile phone exposure together with age contributed significantly to absolute and differential basophil counts and absolute lymphocyte counts. Of concern, almost a quarter of those with high MPBS exposures had basophil counts above the clinical reference limits, while over half of those with heavy daily mobile phone use (4 to 6 hours) had lymphocyte counts above the limits, and most were under 30 years old. While smoking and age contributed to amylase levels, no exposure variables contributed to amylase or cortisol levels. Altogether, there is an indication that RF-EMF from mobile phones and MPBS together with age and gender can differentially impact leucocytes, indicating biological stress and potentially affecting health. These results suggest the necessity for increasing awareness regarding adverse effects of RF-EMF exposures.

Plain language summary

This study aimed to test whether people who live closer to mobile phone towers (MPBS) and those with greater mobile phones' use show any changes in their red and white blood cells, or to their stress hormones. Two groups of volunteers were recruited, a reference group of those living more than 300 m away, and a highly exposed group, living less than 60 m away from the closest MPBS. Blood samples were taken from both groups and analyzed. The strength of the radiofrequency signal from the MPBS in participants’ homes was measured, and mobile phone use, lifestyle factors, and demographics that could affect the blood parameters were also recorded. Results showed that different white blood cells were affected by different combinations of gender, age, smoking, many hours of daily mobile phone use and high exposures from MPBS. Concerning effects on lymphocytes were found in a large group of residents under 30 years old with high daily mobile phone use (4 to 6 hours). These results indicate human biological systems are under stress from both mobile phone use and local mobile phone tower exposures, leading to potential health effects. Placement and signal strength from MPBS, and guidance regarding daily mobile phone use need to be informed by these results.

Excerpts

The study was conducted in 2022 and 2023 in Aizawl city (23.8789° N and 92.8976° E). Ten mobile phone base stations erected in densely populated areas of the city and operating in two frequency ranges of 900 MHz and 1800 MHz were measured....

Around each mobile base station, a minimum of two people were sampled. Participants were recruited via door knocking of all houses around the towers, mostly in the evenings during both weekdays and weekends....

The highly exposed group comprised 50 individuals over 18 years in good health and living within a 60-meter radius of a MPBS. Similarly, the reference group consisted of 51 individuals in good health who resided at least 300 meters away from any MPBS, matched to the highly exposed group in terms of gender and age. Participants were selected so as to ensure that the majority of their exposure came consistently from the local MPBS and not from work exposures, in the following ways. Participants who were included in the highly exposed group as well as about half of the reference group were those who stayed at home during the day due to being home-makers or unemployed. Furthermore, participants who were included in the reference group (i.e. living more than 300 m from the MPBS) were screened to ensure that they were not being highly exposed at work (i.e., that any MPBS near to their workplace was also more than 300 m away). Selection also ensured that there were no electric transformers, high voltage electrical power lines, radio transmitters, or television transmitters within 500 m of any of the participant's homes, so as to minimize any effects from these potentially confounding factors. summarizes the characteristics of the ten MPBS....

Measurements for radio-frequency power density emitted by the base stations were taken in 50 houses, in the living room of each participant. A HF-60105V4 spectrum analyzer (Germany) was used for all RF measurements. Measurements were taken by a trained physicist competent in the use of the spectrum analyzer, who determined the average power density for the frequencies that were present (which was necessary because there is no official Indian government register for the region that describes tower placement and frequencies). Frequencies of 900 MHz and 1800 MHz were determined to be present in most residences, due to several towers being close by. The maximum recorded power density was 7.22 $mW/m^2$ (1.65 V/m) near base station number 5 (see ). The safety limits for public exposure from mobile phone base stations are set to 0.45 $W/m^2$ (450 $mW/m^2$; 13 V/m) for 900 MHz and 0.90 $W/m^2$ (900 $mW/m^2$; 18.4 V/m) for 1800 MHz frequency as prescribed by the Department of Telecommunications, Ministry of Communications, Government of India, New Delhi guidelines (DoT Citation2013). The distance from each residence to the nearby MPBS was determined using a digital laser tape measure (Bosch, GLM)....

https://pubmed.ncbi.nlm.nih.gov/41645932/

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**A Decision Support System for Managing Health Symptoms of Living Near Mobile Phone Base Stations**

Parsaei H, Faraz M, Mortazavi SMJ. A Decision Support System for Managing Health Symptoms of Living Near Mobile Phone Base Stations. J Biomed Phys Eng. 2026 Feb 1;16(1):47-56. doi: 10.31661/jbpe.v0i0.2310-1667.

Abstract

Background: The rapid increase in the number of Mobile Phone Base Stations (MPBS) has raised global concerns about the potential adverse health effects of exposure to Radiofrequency Electromagnetic Fields (RF-EMF). The application of machine learning techniques can enable healthcare professionals and

policymakers to proactively address concerns surrounding RF-EMF exposure near MPBS.

Objective: The current study aimed to investigate the potential of machine learning models for the prediction of health symptoms associated with RF-EMF exposure in individuals residing near MPBS.

Material and methods: This analytical study utilized Support Vector Machine (SVM) and Random Forest (RF) algorithms, incorporating 11 predictors related to participants' living conditions. A total of 699 adults participated in the study, and model performance was assessed using sensitivity, specificity, accuracy, and the Area Under Curve (AUC).

Results: The SVM-based model demonstrated strong performance, with accuracies of 85.3%, 82%, 84%, 82.4%, and 65.1% for headache, sleep disturbance, dizziness, vertigo, and fatigue, respectively. The corresponding AUC values were 0.99, 0.98, 0.920, 0.89, and 0.81. Compared to the RF model and a previously developed model, the SVM-based model exhibited higher sensitivity, particularly for fatigue, with sensitivities of 70.0%, 83.4%, 85.3%, 73.0%, and 69.0% for these five health symptoms. Particularly for predicting fatigue, sensitivity and AUC were significantly improved (70% vs. 8% and 11.1% for SVM, Multilayer Perceptron Neural Network (MLPNN), and RF, respectively, and 0.81 vs. 0.62 and 0.64, for SVM, MLPNN, and RF, respectively).

Conclusion: Machine learning methods, specifically SVM, hold promise in effectively managing health symptoms in individuals residing near or planning to settle in the vicinity of MPBS.

Conclusion

The current study highlights that addressing the impact of microwave radiation on the human nervous system, and cognitive functions necessitates the consideration of multiple factors, such as environmental exposure to mobile phone base stations and individual health conditions. By harnessing the power of AI, healthcare providers can better understand and predict the health risks associated with EMF exposure, leading to delivering targeted interventions and supporting affected individuals. In this study, an SVM classifier was successfully implemented to predict five subjective health symptoms, surpassing the performance of a previously developed MLPNN-based model. The findings of this research underscore the potential of AI-based models in assisting healthcare professionals, including physicians, in effectively managing symptoms associated with EMF exposure in individuals living near mobile phone base stations. Future work should include additional variables, statistical analyses, and longer follow-up periods.

https://jbpe.sums.ac.ir/article_49803.html

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**The Possibility of Concentrating Microwave Radiation at Certain Points of the Endothelium of Blood Vessels**

Sachkov IN. The Possibility of Concentrating Microwave Radiation at Certain Points of the Endothelium of Blood Vessels. Am J Biomed Sci & Res. 2026 30(1). doi: 10.34297/AJBSR.2026.30.003884.

Abstract

Purpose: The main purpose of the study is to show that the connective tissue forming the inner surfaces of blood vessels can be a concentrator of an electric field.

Material and Methods: Previously, when studying the effects of electromagnetic fields and radiation on the human body, only thermal processes were taken into account. In this case, the calculated SAR method and the experimental method of tissue equivalent phantom dummies were used, as a rule. Also, their implementation assumed, as a rule, that the absorbing medium is single-phase. This did not take into account the effects associated with the fact that biological tissue is a mixture of components whose dielectric permittivity differs tenfold, and the particle sizes of the phase components, as a rule, do not exceed one millimeter. The article presents the results of using a computer model that makes it possible to analyze the uneven distribution of the electric field in blood vessels. Computational experiments were performed using the author's computer program based on the finite element method.

The structure of the tissue containing blood capillaries was imitated by matrix systems containing cylindrical inclusions, the sections of which were characterized by round and rectangular shapes. Computer experiments have been carried out to calculate patterns of spatial distributions of electric field strength. The values of the dielectric constant of the matrix and inclusions, the relative sizes and relative positions of the inclusions varied. The processes were considered stationary and axisymmetric.

Results: It was found that blood vessels can focus the external electric field of microwave radiation on some points of their internal surfaces. The de- gree of concentration is characterized by the parameter k = E/E0, which is equal to the ratio of local tension to the average for the tissue. A significant anisotropy of the concentration effect was found. If the microwave radiation is directed perpendicular to the axis of the cylindrical vessel, the field strengths inside the capillary and in the surrounding tissue are close to each other, there is no concentration effect. If the external field is directed perpendicular to the capillary axis, there is a significant (tens of times) concentration of tension in the connective tissue surrounding the vessel. It was found that the most significant concentration (k>40) occurs in the areas of vascular branching.

Conclusion: 1). The obtained results can be used in the analysis of the results of the pathological effects of electromagnetic waves on the human body. 2). Attention is drawn to the fact that the endothelium, which performs a number of important physiological functions, falls into the area of concentration of electric field strength. It is suggested that the effect of an electric field on the endothelium can create both carcinogenic and physio- logical effects due to physico-chemical processes initiated by an electric field characterized by high intensity values. 3) It must be borne in mind that the electrical component of the electromagnetic wave fluctuates in time and direction. Therefore, the action under discussion is carried out locally,

Open access: https://biomedgrid.com/pdf/AJBSR.MS.ID.003884.pdf

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**Effect of high-frequency radiofrequency (6 GHz) electromagnetic radiation on oxidative stress and kidney morphology**

Emre M, Karamazi Y, Emre T, Varan NE, Toyran T, Yücebilgiç G. Effect of high-frequency radiofrequency (6 GHz) electromagnetic radiation on oxidative stress and kidney morphology. Toxicol Ind Health. 2026 Feb 17:7482337261422845. doi: 10.1177/07482337261422845.

Abstract

This study aimed to investigate the effects of high-frequency (6 GHz) radiofrequency electromagnetic radiation (RF-EMR) exposure on oxidative stress markers and kidney morphology. Our study was designed with 3 groups, each containing 10 animals. These groups were: control, sham, and RF-EMR exposed group. No treatment was applied to the control group; the sham group was housed in the same room under the same conditions and for equal periods of time, except that the generator was turned off. The RF-EMR exposed group was exposed to 6 GHz RF-EMR emitted from the signal generator for 4 hours per day for 6 weeks. At the end of the experimental period, intracardiac blood was collected from animals and plasma oxidant (MDA), antioxidant (SOD, CAT and GSH) and cortisol markers were analyzed. After, the rats in all groups were sacrificed and kidney tissues were removed. Hematoxylin and eosin staining methods were applied histopathologically. Blood-plasma GSH, CAT, SOD and MDA levels (excluding cortisol) were lower in the RF-EMR exposed group compared to the control and sham groups ($p < .001$). No significant difference was observed in plasma levels GSH, CAT, SOD, MDA and cortisol activities between control and sham groups. In addition, we reported that the histological characteristics of kidney tissue were affected by RF-EMR. The results of our study indicated that 6 GHz RF-EMR can function as an environmental stress factor and can modulate oxidative stress in blood plasma and cause morphological changes in kidney tissue.

Highlights

• Histopathological and biochemical analyses were conducted to evaluate the effects of high-frequency (6 GHz) RF-EMR exposure on oxidative stress markers and kidney morphology in rats.

• Blood-plasma GSH, CAT, SOD, and MDA levels were lower in the RF-EMR exposed group compared with the control and sham groups. No significant difference was observed in plasma GSH, CAT, SOD, and MDA activities between control and sham groups. A partial but not significant increase in cortisol levels was observed in the RF-EMR exposed group compared to the control and sham groups. In addition, we found that the histological characteristics of kidney tissue were affected by RF-EMR.

• According to our findings, 6 GHz RF-EMR can function as an environmental stress factor and can modulate oxidative stress in blood plasma and cause morphological changes in kidney tissue.

Excerpts

We used a fixed-output frequency RF signal generator operating at 6 GHz to apply RF-EMR (Set Electronic, Co. model:FR6GX-2W, Sakarya, Turkey). The radiofrequency radiation (RFR) emitted power could be adjusted from 0 to 2 Watts. The modulation was in Continuous Wave (CW) format, and the specific model we used was FR6GX-2W....

The rats in the experimental group were continuously exposed to the far-field range of an antenna at 6 GHz with an electric field of 6.3 V/m, a magnetic field of 16.3 mA/m, and an RFR power density of 11.80 $\mu W/cm^2$. The antenna-rat distance in the vertical position was 30 cm. Due to movement, the antenna-rat distance varied between 7 and 10 cm during exposure. The exposure apparatus was heated

by running it for 20 minutes to equilibrate the RF generator before RF exposure. The RF-EMR-exposed group was exposed to 6 GHz RF-EMR emitted from the signal generator for 4 hours per day for 6 weeks....

https://journals.sagepub.com/doi/10.1177/07482337261422845

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**Effects of industrial, scientific, and medical (ISM) band frequency 2.45 GHz on membrane integrity and oxidative stress of human skin bacteria**

Tomar AK, Jha N, Priyadarshini E, Gautam R, Nirala JP, Rajamani P. Effects of industrial, scientific, and medical (ISM) band frequency 2.45 GHz on membrane integrity and oxidative stress of human skin bacteria. Int J Radiat Biol. 2026 Feb 26:1-15. doi: 10.1080/09553002.2026.2636305. Epub ahead of print. PMID: 41747184.

Abstract

Purpose: To investigate the effects of 2.45 GHz radiofrequency radiation (RFR) on oxidative stress and membrane integrity of human skin bacteria.

Materials and methods: Cultures of Staphylococcus epidermidis, Micrococcus luteus, and Enterobacter cloacae were exposed to 2.45 GHz RFR. Oxidative stress was assessed by quantifying hydroxyl (•OH) and superoxide ($O_2^{\bullet-}$) radicals and total intracellular ROS (DCFH2-DA assay). Lipid peroxidation (MDA levels) and protein carbonyl content were measured as oxidative damage markers. Membrane integrity was examined by SEM and TEM imaging and by evaluating protein and carbohydrate leakage. All experiments were performed with at least three independent biological replicates.

Results: RFR-exposed bacteria exhibited a marked increase in ROS generation compared to sham and control groups. Total intracellular ROS, hydroxyl radicals, and superoxide radicals were significantly elevated (~ 2 fold), indicating strong oxidative stress induction. This biochemical stress correlated with structural alterations: SEM and TEM revealed disrupted cell membranes and cytoplasmic disorganization. Functionally, exposed bacteria showed enhanced membrane permeability, evidenced by substantial leakage of proteins and carbohydrates into the extracellular environment. Furthermore, oxidative damage was confirmed biochemically, with significantly elevated malondialdehyde (MDA >1.5 fold) levels reflecting lipid peroxidation, and increased protein carbonyl (>2 fold) content indicating oxidative modification of proteins. These effects were consistent across all three bacterial species, although E. cloacae demonstrated more pronounced damages. Collectively, these findings highlight a clear link between RFR-induced ROS overproduction, oxidative macromolecular damage, and compromised cellular integrity.

Conclusions: Exposure to 2.45 GHz RFR induces oxidative stress, membrane disruption, and macromolecular leakage in skin-associated bacteria, suggesting possible risks to skin microbiome stability under high-RFR environments.

https://pubmed.ncbi.nlm.nih.gov/41747184/

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**Electric Field Emissions from Laptop Computers: A Quantitative Study of User Exposure During Charging and Non-Charging Operations**

Udekwe CN, Akin-Ponnle AE, Arosoye H, Ponnle AA. Electric Field Emissions from Laptop Computers: A Quantitative Study of User Exposure During Charging and Non-Charging Operations. 2025 IEEE International Microwave and Antenna Symposium (IMAS), Nairobi, Kenya, 2025, pp. 1-6, doi: 10.1109/IMAS66694.2025.11387396.

Abstract

This paper evaluates electric field (EF) emissions from commonly used HP laptops under realistic operational conditions, with an emphasis on charging states and user proximity in relation to international exposure limits. Five HP laptop models were tested using the TriField TF2 EMF meter, with measurements recorded at fixed distances ranging from 0 to 25 cm under two power conditions (charging and noncharging) and three usage modes (airplane, browsing, and video playback). A total of 30 test scenarios were analyzed. EF intensity was plotted and fitted to theoretical decay models namely inverse-square and exponential functions-with goodness of fit assessed via R2 and RMSE metrics. Results show that EF emissions decrease with distance, generally following exponential attenuation. Charging consistently resulted in higher EF values, with several models reaching or exceeding the TF2's upper detection limit of 1000 V/m at 0−2 cm, whereas noncharging emissions remained below 20 V/m across all modes. Among the laptop tested, the EliteBook Folio 9480m exhibited the highest emissions, attributed to its compact design and legacy power architecture. Curve fitting demonstrated strong model alignment, particularly under browsing mode (R2≥0.99). While all observed values fall within ICNIRP and IEEE C95.1 public exposure guidelines, the elevated emissions during charging raise ergonomic concerns for close-contact users. The study recommends maintaining a minimum distance of 20−25 cm during laptop charging to mitigate near-field EF exposure. These findings contribute to EMF safety discourse and support the development of informed usage practices and shielding-conscious device designs.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11387396&isnumber=11387094

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**Correction: Loughran et al. Radiofrequency Electromagnetic Field Exposure and the Resting EEG: Exploring the Thermal Mechanism Hypothesis**

Loughran SP, Verrender A, Dalecki A, Burdon CA, Tagami K, Park J, Taylor NAS, Croft RJ. Correction: Loughran et al. Radiofrequency Electromagnetic Field Exposure and the Resting EEG: Exploring the Thermal Mechanism Hypothesis. Int. J. Environ. Res. Public Health 2019, 16, 1505. International Journal of Environmental Research and Public Health. 2026; 23(2):157. doi: 10.3390/ijerph23020157

No abstract

Open access: https://www.mdpi.com/1660-4601/23/2/157

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**Long-term residential magnetic field exposure and neurodegenerative disease mortality: An 18-year nationwide cohort study in Switzerland**

My note: Due to measurement error, this study likely underestimates the risk of long term magnetic field exposure on deaths due to neurodegenerative disease. Moreover, the study seriously underestimates the incidence of Alzheimer's disease as this disease is significantly underreported on death certificates. Only about one-third to one-half of actual Alzheimer's cases are recorded as the underlying cause of death. Thus, for every death officially attributed to Alzheimer's, there are likely 2 to 3 deaths where the disease was the true underlying cause but was omitted from the death certificate.

Sandoval-Diez N, Loizeau N, Huss A, Röösli M, Vienneau D. Long-term residential magnetic field exposure and neurodegenerative disease mortality: An 18-year nationwide cohort study in Switzerland. Environment International. Volume 208, 2026.doi: 10.1016/j.envint.2026.110145.

Abstract

Background  Epidemiological evidence on the association between extremely low-frequency magnetic fields (ELF-MF) exposure and neurodegenerative diseases (NDD) remains inconsistent. Few population-based studies using exposure from high-voltage power lines (HVPL) have found mixed findings, and none have yet considered exposure from railway lines.

Methods  We followed 3,555,064 adults from the Swiss National Cohort (2001–2018), contributing 55.4 million person-years. Long-term ELF-MF exposure from HVPL (50 Hz) and railway lines (16.7 Hz) was modelled using validated proximity models and updated over four intervals (2001–2005, 2006–2010, 2011–2015, 2016–2018). Long-term ELF-MF exposure was calculated as a time-weighted average exposure over 10-year windows preceding each interval. Cox proportional hazards models estimated hazard ratios (HRs) for mortality from Alzheimer’s disease (AD), other types of dementia (OTD), amyotrophic lateral sclerosis (ALS), Parkinson’s disease (PD), and multiple sclerosis (MS), adjusting for sociodemographic and environmental co-exposures.

Results  During follow-up, 146,655 NDD deaths occurred. Less than 1% of the population was exposed to long-term ELF-MF ≥ 0.3 μT [3 milligauss] from HVPL and 2.4% from railway lines. HVPL exposure was positively associated with mortality from AD (HR per 1 μT increase in exposure = 1.54; 95% CI: 1.23–1.92) and OTD (HR = 1.31; 95% CI: 1.13–1.52). Associations for railway exposure were weaker and attenuated after adjusting for environmental co-exposures. No associations were observed for ALS, PD, or MS.

Conclusions  Long-term ELF-MF exposure was associated with higher dementia mortality risk in the general population, but not with ALS, PD, or MS. Causal inference remains limited by the absence of established biological mechanisms.

Highlights

• Exposure to high voltage power lines was associated to dementia mortality.
• If causal, 1.01% of Alzheimer's disease cases could be attributed to HVPL exposure.
• Associations for railway ELF-MF with dementia mortality were less consistent.
• Other neurodegenerative diseases were not related to ELF-MF exposure.

Open access: https://www.sciencedirect.com/science/article/pii/S0160412026001030

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**The combined effect of cadmium and 50 Hz magnetic fields exposure at occupational levels on DNA damage in human fetal lung fibroblasts**

Wei X, Zhao H, Zhang J, Sun C. The combined effect of cadmium and 50 Hz magnetic fields exposure at occupational levels on DNA damage in human fetal lung fibroblasts. Ecotoxicol Environ Saf. 2026 Feb 10;311:119861. doi: 10.1016/j.ecoenv.2026.119861.

Abstract

In occupational environments with a high risk of cadmium (Cd) exposure, such as electroplating plants, workers are concurrently exposed to power frequency magnetic fields (MFs). However, health implications of combined exposure to these agents remain poorly understood. In this study, we examined both short-term (24 h) and long-term (4 weeks) exposure to Cd at an occupational exposure relative concentration (100 nM) and 0.4 mT, 50 Hz MFs on DNA damage, apoptosis, and cell viability in human fetal lung fibroblasts (WI-38). We found that co-exposure to Cd and 50 Hz MFs have no significant impact on these endpoints. Additionally, we evaluated short-term exposure to high-dose Cd (10 μM) combined with 50 Hz MFs, as well as long-term exposure to 50 Hz MFs in cells pre-treated with 10 μM Cd for 24 h. Consistently, no significant effects of combined exposure were observed. In conclusion, at occupational relevant exposure levels, co-exposure to Cd and 50 Hz MFs does not appear to induce synergistic adverse effect on DNA integrity, apoptotic activity, or cell viability in WI-38 cells.

https://pubmed.ncbi.nlm.nih.gov/41671955/

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**Quality of life and physical activity levels of musculoskeletal disorders in workers exposed to high and low frequency magnetic fields: A comparative study**

Çankaya M, Cingöz HT. Quality of life and physical activity levels of musculoskeletal disorders in workers exposed to high and low frequency magnetic fields: A comparative study. Work. 2026 Feb 9:10519815251414411. doi: 10.1177/10519815251414411.

Abstract

Background  The increased use of electronic devices and technological advances has led to greater exposure to electromagnetic fields (EMF) in various occupational environments.ObjectivesThe study's objective was to assess the effect of work-related musculoskeletal disorders (WMSD) on the quality of life and physical activity levels of individuals exposed to high-frequency magnetic fields.

Methods  The mean age of one hundred and twenty EMF exposed workers was 37.44 ± 9.16 years. The following were assessed: musculoskeletal symptoms in the last 12 months (using the Extended Nordic

Musculoskeletal Questionnaire Version (ENMQ) and the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), working posture (Ovako Working Posture Analysis System (OWAS), physical activity level (International Physical Activity Questionnaire Short Form (IPAQ-Sf), and quality of life (World Health Organization Quality of Life Scale (WHOQOL-Bref).

Results  The highest prevalence rate of ENMQ in the last 12 months was 77.5% (n = 31) in the low back region and 50% (n = 20) in the shoulder region in those exposed to high-grade magnetic fields. The mean scores of WHOQOL-Bref were given for those exposed to high and low magnetic fields and those not exposed to magnetic fields (M ± SD: 63.51 ± 8.35; 73.27 ± 9.37; 76.43 ± 8.43, respectively).

Conclusion  The prevalence of WMSD in workers was found to be highest in the low back, shoulder, and hand region in HF-MF workers. LF-MF group, the highest concentration was found to be highest in the neck region. Prevalence rates have been reported for different body sites, with the highest prevalence rates observed in the group exposed to HF-MF. Quality of life was found to be lower in the group exposed to HF-MF.

Conclusions

Prevalence of WMSD in EMF workers was found to be highest in the lumbar and shoulder regions in HF-MF workers, and in the neck region in the LF-MF group. The quality of life of the HF-MF group was lower than that of each of the other groups. In addition, there was a relationship between the prevalence of MSD in the last 12 months, and quality of life in the knee region in the HF-MF group and in the neck region in the LF-MF group. It was determined that the physical activity results of the HF-MF group were higher than the other groups. In addition, it was found that there was no significant relationship between the prevalence of MSD in the last 12 months and physical activity level among the three groups. Workers exposed to HF-MF have higher rates of WMSD than other groups. WMSD can be reduced by improving working conditions and reducing activities that require bending during the day. It can also be prevented by reducing exposure to HF-MF. There are very few studies on exposure to high magnetic fields in literature. In addition, although the negative aspects of exposure to high magnetic fields are known, there is not enough information about the specific effects. New research could focus on this issue.

https://pubmed.ncbi.nlm.nih.gov/41664461/

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**Non-thermal acceleration of DNA base pairing by sub-terahertz irradiation**

Yamamoto J, Tokunaga Y, Takeuchi K, Imashimizu M. Non-thermal acceleration of DNA base pairing by sub-terahertz irradiation. J Chem Phys. 2026 Feb 14;164(6):065102. doi: 10.1063/5.0298033.

Abstract

We report a non-thermal mechanism by which sub-terahertz (sub-THz) radiation accelerates DNA base pairing in aqueous environments. By using a randomized 40-mer DNA pool as a model system, we investigated the effects of 0.1 THz continuous-wave irradiation on rehydration-coupled structural reorganization. UV absorption spectroscopy revealed a selective enhancement of the G:C base pairing-associated spectral component under this irradiation, in contrast to conductive heating, which suppressed this component. Fluorescence correlation spectroscopy using a base-pair-sensitive dye

further demonstrated that 0.1 THz irradiation increased the population of base-paired DNA molecules, while heating induced the opposite effect. These findings indicate that sub-THz waves promote nucleobase-specific hydrogen bonding, potentially by altering non-specific base-stacking interactions, in a manner inconsistent with thermal activation. This study provides mechanistic insight into the physical basis of sub-THz radiation-mediated modulation of nucleic acid structure and dynamics, with implications for the noninvasive manipulation of biomolecular processes.

Conclusions

This work demonstrates that sub-THz irradiation can non-thermally accelerate specific DNA bp formation in aqueous solution under non-equilibrium hydration conditions. Our findings suggest a promising strategy for the gentle modulation of DNA base-pairing-mediated molecular processes under physiological conditions.

https://pubmed.ncbi.nlm.nih.gov/41665454/

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**Electromagnetic fields from submarine power cables: A 35 Year synthesis of effects on aquatic biota**

James E, Ghodsi M, Alex T. Ford AT. Electromagnetic fields from submarine power cables: A 35 Year synthesis of effects on aquatic biota. Marine Environmental Research. Volume 216, 2026. doi: 10.1016/j.marenvres.2026.107916.

Abstract

Submarine power cables (SPCs) associated with offshore renewable energy developments emit electromagnetic fields (EMFs) that can influence aquatic biota. Although research on this topic has increased, a comprehensive, systematic synthesis of observed effects across taxa and life stages, and biological contexts has been lacking. Following PRISMA 2020 guidelines (PROSPERO ID: 1138188), we systematically reviewed peer-reviewed and grey literature published between 1990 and 2024. Of 1637 records screened, 67 eligible field and laboratory studies were included. Significant behavioural and physiological responses to EMF exposure were reported in 66% of studies, with early life stages (embryos, larvae, juveniles) and magnetosensitive taxa, particularly fishes and crustaceans being most frequently affected. Effects occurred even at environmentally relevant intensities (<250 μT). Laboratory experiments more frequently detected effects than field studies, which were generally fewer, shorter in duration, and methodologically heterogeneous. Sensitivity heatmaps identified developmental stages and freshwater species as particularly sensitive, with notable taxonomic disparities. EMFs from SPCs can elicit ecologically relevant responses in aquatic biota, particularly during sensitive developmental windows and in magnetically responsive taxa. Emerging evidence further indicates that sex specific responses represent an important and previously under recognised dimension of EMF sensitivity. However, major uncertainties persist regarding chronic, population and ecosystem level impacts. Future research should prioritise standardisation of exposure characterisation and reporting, routine inclusion of sex and life stage as biological variables and coordinated laboratory to field validation. Integrating EMF considerations into marine spatial planning, environmental regulation, and biodiversity conservation frameworks will be essential to support proportionate ecological risk assessment and management of offshore renewable energy infrastructure.

Excerpt

One of the most important patterns is the disproportionate sensitivity of early developmental stages across taxa. Heatmap analysis of laboratory data (Fig. 4) revealed that embryos and larvae of fish, crustaceans, polychaetes, and echinoderms exhibited consistently higher rates of EMF related effects compared with juveniles and adults. For example, 93% of early-stage fish studies reported significant impacts, compared with 73% of juveniles and 53% of adults. Crustaceans showed a similar pattern, with 100% sensitivity in early stages but only 41% in adults. By contrast, molluscs and other invertebrates showed comparatively low responsiveness, particularly at adult stages.

Open access: https://www.sciencedirect.com/science/article/pii/S0141113626000851

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**Electric Field Reduction in Overhead Transmission Lines Right-of-Way Using Sine Cosine Optimization Algorithm**

Guerrero LFI, Barrera MAR, Giral-Ramírez DA, Olaya HFI. Electric Field Reduction in Overhead Transmission Lines Right-of-Way Using Sine Cosine Optimization Algorithm. Results in Engineering, 2026. doi: 10.1016/j.rineng.2026.109588.

Abstract

Population growth and the expansion of electrical infrastructure have intensified concerns regarding exposure to low-frequency electric fields, due to their potential effects on human health, including cardiac disorders and childhood leukemia—as well as on the environment. Considering the existing scientific uncertainty, this paper proposes a strategy to reduce the electric field generated by overhead transmission lines using the Sine–Cosine Algorithm (SCA). The methodology comprises five stages: (i) system configuration, (ii) geometric definition, (iii) SCA adaptation, (iv) validation strategies, and (v) mathematical formulation of the electric field. Two case studies are analyzed: single- and double-circuit configurations in right-of-way areas. The performance of the SCA is benchmarked against the Particle Swarm Optimization (PSO) and Ant Lion Optimizer (ALO) algorithms, as well as the phase-sequence permutation technique. The results demonstrate that SCA-based optimization achieves a significant reduction in electric field intensity relative to the original configurations, exhibiting competitive and consistent performance compared with the other evaluated techniques. This proposal therefore constitutes a technically viable tool for mitigating impacts in right-of-way areas, in accordance with the precautionary principle.

Highlight

- Reducing the electric field generated by overhead transmission lines is challenging, given that prolonged exposure can affect both humans and the environment.
- The implementation of SCA to minimize the electric field produced by overhead transmission lines stands out for its optimization efficiency and its ability to generate stable and consistent solutions.

- The precautionary principle is particularly relevant when dealing with electric fields generated by overhead transmission lines. Requires acting prudently: conducting studies, establishing controls, and adopting measures to mitigate potential risks.

Open access: https://www.sciencedirect.com/science/article/pii/S2590123026006286

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**The sun-earth-health connection: a short review of potential mechanisms and implications**

Maghrabi AH, Maghrabi MA. The sun-earth-health connection: a short review of potential mechanisms and implications. Int J Biometeorol. 2026 Feb 14;70(2):61. doi: 10.1007/s00484-026-03134-3.

Abstract

Heliobiology explores the influence of solar and geomagnetic activity on human health. This short review synthesises evidence linking solar flares, coronal mass ejections, and geomagnetic storms to cardiovascular events, autonomic dysregulation, circadian disruption, and possible neurological effects. Proposed mechanisms include melatonin suppression, cryptochrome magnetoreception, and voltage-gated calcium-channel modulation. Recent studies further support associations between geomagnetic disturbances and endothelial activation, systemic inflammation, and elevated cardiovascular mortality. The most reproducible effects involve acute cardiovascular and autonomic responses during major geomagnetic storms, whereas neurological, psychological, and infectious-disease associations remain preliminary. For clinicians, geomagnetic disturbances represent a novel environmental risk factor for vulnerable patients; for space scientists, they have direct implications for astronaut safety. Causal pathways are not yet established. Interdisciplinary collaboration is essential to refine predictive models and develop mitigation strategies for both terrestrial and extraterrestrial populations.

Excerpt

In summary, while temporal correlations are consistent across multiple outcomes and geographic regions, the absence of large, prospective, individual-level studies with rigorous confounding control means that most reported associations currently reflect correlation rather than proven causation. Future research must prioritise standardised, satellite-derived exposure metrics and multi-centre prospective designs to advance the evidence base beyond Level 3–4.

Future directions and conclusions

This review consolidates evidence that solar activity and geomagnetic disturbances influence human health across cardiovascular, autonomic, circadian, neurological, psychological, and immunological domains. The most reproducible associations involve acute cardiovascular events and autonomic dysregulation during major geomagnetic storms, whereas neurological, psychological, and infectious-disease links remain preliminary. By integrating heliobiology, solar-terrestrial physics, and clinical research, the work establishes space weather as an under-recognised environmental determinant of health with direct relevance for public health policy, clinical practice, and human spaceflight.

https://pubmed.ncbi.nlm.nih.gov/41689632/

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**A hybrid compass mechanism combining radical pairs and magnetite crystals**

Hore PJ. A hybrid compass mechanism combining radical pairs and magnetite crystals. Proc Natl Acad Sci U S A. 2026 Feb 24;123(8):e2524093123. doi: 10.1073/pnas.2524093123.

Abstract

That night-migratory songbirds have a magnetic compass sense is undisputed. The nature of the sensor, however, is far from certain. The two leading hypotheses are organic radical pairs in cryptochrome flavoproteins and crystals of inorganic magnetic minerals such as magnetite. Here, we propose a magnetoreception mechanism that combines radical pair chemistry with magnetite nanoparticles. Instead of directly detecting the tiny dependence of a radical pair reaction on the direction of the Earth's (~50 µT) magnetic field, this hybrid sensor uses a magnetic particle to amplify the Earth's field. Directional information is thereby encoded in the response of nearby radical pairs to the intensity of a much stronger (~5 mT) magnetic field. The result is a magnetoreceptor with potentially 10 to 100-fold greater sensitivity than afforded by radical pairs alone.

Open access: https://pubmed.ncbi.nlm.nih.gov/41712640/

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**[Determination of exposure to electromagnetic fields from electric mobility]**

Schmid G, Hirtl R, Schneeweiß P, Kainz J, Kubocz M, Drießen S, Vogt M, Kalb L, Silvestro M. Bestimmung von Expositionen gegenüber elektromagnetischen Feldern der Elektromobilität: Vorhaben 3620S82473. Federal Office for Radiation Protection (BfS). 2025. Ressortforschungsberichte zum Strahlenschutz, BfS-RESFOR-252/25: 1-142 {In German)

Abstract

This report summarizes the results of extensive systematic measurements and numerical calculations with respect to the exposure of persons to magnetic fields during the charging of passenger vehicles with electric drive systems. Both areas inside and outside the vehicles, in the immediate vicinity of the vehicles and of the charging infrastructure were considered.

After a comprehensive literature review and the optimization and development of suitable measurement methods, systematic measurements were carried out at a selection of charging points and purely electrically powered passenger vehicles (BEV). The selection of vehicles and charging points was made in such a way that the current technologies and charging processes are recorded as representatively as possible. Regarding conductive (cable-based) charging, all common charging modes were tested, i.e. AC charging at 230 V (mode 2), AC charging at 400 V (mode 3 at 11 kW wallbox and 22 kW charging station), as well as DC charging at two different fast-charging stations (mode 4 at 300 kW and 350 kW stations). When selecting the vehicle, care was taken to ensure that the range of possible charging capacities of modern BEV was as wide as possible. Due to its lack of widespread use, inductive (wireless) charging could only be examined at a pilot installation for charging taxi vehicles.

Measurements during conductive charging were carried out for different vehicle-to-charging- point combinations and different battery charge states (< 10 % and > 95 %) were considered for both

conductive and inductive charging. For situations in which the measurement results led to exposure values above the reference values recommended by ICNIRP in 1998 and 2010, additional numerical calculations with anatomical body models were carried out and the results were compared with the respective basic restrictions.

The measurement and calculation results showed that for the investigated charging technologies in typical exposure scenarios corresponding to common behavior, no exceedances of basic restrictions for the general public according to the ICNIRP 1998 and 2010 recommendations are to be expected. This finding is also consistent with the literature available to date.

However, local exceedances of reference values for the general public are possible with both, conductive and inductive charging in normally accessible areas. In the case of conductive charging, these local exceedances of reference values were caused by transient processes with comparatively high peak values of magnetic flux density in the initiation phase of the charging process. During the stationary conductive charging process, no exceedances of the reference values were detected in the usual occupied area. The utilization of the reference values is typically in the lower single-digit percentage range and below. Particularly with DC charging, the utilization of the reference values typically remains well below 1 %. Only directly at the charging cable or at the charging plug, magnetic flux densities during AC charging were observed that were slightly above the reference values, even during stationary charging, but not during DC charging.

Based on the current ICNIRP evaluation paradigm, DC charging turned out to be less relevant in terms of radiation protection (lower exposure indices) than AC charging.

In the case of the inductive charging system investigated, the maximum magnetic field immissions inside and in the immediate vicinity outside the vehicle are determined by the stationary charging process, no relevant transients when switching the 85 kHz energy transmission on and off could be observed. Only at the driver's seat of the examined vehicle transients in the initial phase were observed, which, evaluated according to the ICNIRP recommendations, led to somewhat larger exposure indices in the foot area than the immissions during stationary charging. In the typically occupied area inside the examined vehicle, the measured magnetic field immissions locally reached the mid-double-digit percentage range of the reference level for the general public according to ICNIRP 1998.

Outside the vehicle, along the vehicle perimeter at street level, local exceedances of 5 to 6 times the reference level for the general public according to ICNIRP 1998 occurred but quickly decreased with increasing height above street level, thus no exceedances from approx. 50 cm above street level could be observed.

When comparing conductive and inductive charging systems from a radiation protection point of view, the measurements and calculations carried out indicate that conductive AC charging is more relevant from a radiation protection point of view with regard to short-term exposure peaks and inductive charging with regard to long-term average exposure.

With regard to the exposure of persons with electronic implants, the measurements carried out for the

charging systems examined also do not provide any indications of electromagnetic interference with the implants.

Open access: https://doris.bfs.de/jspui/bitstream/urn:nbn:de:0221-2025112157059/3/BfS-RESFOR-252-25.pdf

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**U.S. policy on wireless technologies and public health protection: regulatory gaps and proposed reforms**

Scarato T. U.S. policy on wireless technologies and public health protection: regulatory gaps and proposed reforms. Front. Public Health, 18 December 2025. Volume 13. doi: 10.3389/fpubh.2025.1677583.

Abstract

The current U.S. regulatory framework governing non-ionizing radiofrequency radiation (RFR) used in all wireless technology is outdated and lacks adequate protection, oversight, and enforcement. The U.S. Federal Communications Commission (FCC) was given regulatory jurisdiction by the U.S. Congress in 1996 over RFR exposure standards setting even though FCC has no in-house expertise regarding health or environmental effects from RFR. FCC is a licensing/engineering entity that relies on other government agencies for guidance on ambient exposures and devices. However, all relevant civilian public health and environmental agencies have been defunded from non-ionizing radiation research activities and oversight. Thus, current regulations have remained unchanged since 1996. Human exposure limits are designed to protect against short-term high-intensity effects, not today's long-term chronic low-intensity exposures. Scientific evidence indicates that children's thinner skulls, unique physiology, and more conductive tissues result in significantly higher RFR absorption rates deeper into critical brain regions, which are still in development and thus more sensitive to environmental insults. However, current policies offer no safeguards for children/pregnancy or vulnerable populations. Growing research also indicates risks to wildlife, especially pollinators. In 2021, a U.S. federal court mandated that the FCC show proper review of growing scientific evidence, after a cursory FCC re-approval of limits in 2019, but FCC has yet to respond. This paper explores regulatory infrastructure deficiencies, including the absence of monitoring/oversight, premarket safety testing, post-market surveillance, emissions compliance/ enforcement, occupational safety, and wildlife protection. Compliance tests for cell phones do not reflect real-world consumer use and can therefore camouflage exposures that exceed even FCC's outdated limits. Other countries enforce stricter limits, robust monitoring, transparency measures, and compliance programs with additional policies to protect children. Also discussed is the chronic revolving door between FCC leadership and the wireless industry, resulting in a state of regulatory capture. Policy recommendations for common-sense reforms are made for reinvigorating independent research, developing science-based safety limits, ensuring pre- and post-market surveillance, and improving oversight/enforcement, as well as implementing risk mitigation to reduce exposures to children, vulnerable groups, and wildlife.

Discussion and conclusion

What has emerged from this review is a profound failure of governance, with the U.S. as an exemplar of regulatory gaps. While wireless technologies are rapidly advancing to 5G and beyond, U.S. regulatory oversight has failed to keep pace. The current regulatory framework governing wireless technology in the U.S. is outdated, fragmented, and heavily influenced by industry. Assumptions that federal safety limits are current and science-based are inaccurate, as today's guidelines are based on decades-old research, obsolete/incomplete test methods, and a landscape marked by a near-total absence of civilian research, oversight, and enforcement activity (10). Given the ubiquity of wireless in modern workplaces, the lack of a comprehensive occupational RFR/EMF program, exposure research, and medical surveillance represents a serious gap. This issue should command newfound attention.

The existing research paralysis has led to significant regulatory deflection and abdication. Local and state officials defer to federal agencies. Federal agencies defer to one another. Yet, there has not been an evaluation of all the scientific evidence regarding the health effects of wireless technologies despite major technological changes and an ever-growing body of science. Agencies that policymakers expect to have studied the issue simply have not done so.

The result is that U.S. regulations exist without an up-to-date review. Exposure limits are based only on protecting short-term exposures, ignoring the realities of today's long-term cumulative exposure and complex modulations and signaling characteristics reported as important variables. Nothing has changed since 2002, when the EPA wrote that "…federal health and safety agencies have not yet developed policies concerning possible risk from long-term, non-thermal exposures" (321).

To rectify the current situation, government oversight must balance industry power. A strong regulatory framework must be built that rests on transparency and robust evidence-based evaluation, free of industry influence. Prevention is the cornerstone of public health, and the U.S. needs to move toward a risk mitigation approach.

Advancing regulatory reforms is not just a matter of good governance but an ethical imperative. The consequences of ignoring the growing science on non-thermal impacts could be severe, not only for irreversible health impacts, but also for economic impacts, worker productivity, educational outcomes, and environmental damage. The U.S. should take a leadership role in technology safety by putting children, vulnerable groups, and environmental protection at the center of our decision-making process.

Open access:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1677583/full

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**The Systems of Radiological Protection for Ionizing and Non-Ionizing Radiation**

Dumit S, Clement C, O'Hagan J, Croft R, Rühm W, Magnússon SM, van Deventer E, Higley KA. The Systems of Radiological Protection for Ionizing and Non-Ionizing Radiation. Health Phys. 2026 Feb 1;130(2):145-149. doi: 10.1097/HP.0000000000002109.

Abstract

This paper summarizes the presentations and panel discussion held at Plenary Session 1 of the 16th IRPA International Congress/69th Health Physics Society Annual Meeting, in Orlando, FL, in July 2024. Plenary Session 1 discussed the basics of the systems of radiological protection (RP) for ionizing radiation (IR) and non-ionizing radiation (NIR) and included five presentations and a panel discussion. Rodney Croft, Chair of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), delivered the first presentation. Croft introduced the System of RP for NIR and provided an overview of ICNIRP's coverage and current areas of work. Werner Rühm, Chair of the International Commission on Radiological Protection (ICRP), delivered the second presentation. He gave an overview of the System of RP for IR and covered the key principles of justification, optimization, and dose limitation, including the current plans of ICRP toward the envisaged revision of the System of RP. The third speaker, Sigurður Magnús Magnússon, from the International Radiation Protection Association (IRPA), provided the perspective of the RP professionals on the development of the Systems of RP for IR and NIR. Emilie van Deventer, from the World Health Organization (WHO), presented WHO's views of both Systems of RP and discussed the relevant current activities of WHO with regard to IR and NIR. Kathryn Higley, President of the National Council on Radiation Protection and Measurements (NCRP), delivered the final presentation. Higley outlined the history of NCRP, the differences between ICRP and NCRP, and discussed the role of the NCRP in the System of RP, including NCRP's role to analyze mechanisms of interaction of NIR with biological systems, including humans. The session concluded with a fruitful panel discussion, where the audience had the opportunity to ask the five invited speakers questions.

Outcome and Emerging Issues

The main outcome of Plenary Session 1 was a better understanding of the Systems of RP for IR and NIR. Participants learned about:

- ICNIRP's coverage and current areas of work;
- ICRP's current plans toward the envisaged revision of the System of RP for IR;
- IRPA's perspective of the RP professionals on the development of the Systems of RP for IR and NIR;
- WHO's views of both Systems of RP and current activities of WHO with regards to IR and NIR; and
- NCRP's role in the System of RP, including its role to analyze mechanisms of interaction of NIR with biological systems, including humans.

The session concluded with a fruitful panel discussion, where these five invited speakers had the opportunity to answer the audience's questions. Emerging issues discussed during the Plenary Session include:

- No international framework for NIR radiation protection has yet been developed like that for IR;
- Rapidly evolving applications using new NIR technologies are emerging that produce a variety of exposure situations for the public, workers, and patients. Punctual regulations at international and national levels for certain applications, for parts of the photon energy spectrum, and only for certain populations are problematic; and

- The system of RP for IR is mature, multi-faceted, and currently being revised, while the system of RP for NIR could be further strengthened by considerations beyond science.

Open access: https://journals.lww.com/health-physics/fulltext/2026/02000/the_systems_of_radiological_protection_for.2.aspx

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**Towards a Planetary Health Impact Assessment Framework: Exploring Expert Knowledge & Artificial Intelligence for RF-EMF Exposure Case-Study**

Stefanopoulou M, Sonnenschein TS, de Gannes FP, Scheider S, Vermeulen R, Röösli M, Huss A. Towards a Planetary Health Impact Assessment Framework: Exploring Expert Knowledge and Artificial Intelligence for a RF-EMF Exposure Case-Study. Bioelectromagnetics. 2025 Dec;46(8):e70038. doi: 10.1002/bem.70038.

Abstract

While recent WHO systematic reviews have comprehensively assessed the direct health effects of radiofrequency electromagnetic field (RF-EMF) exposure, its potential indirect impacts on human health via ecosystem disruption remain unstudied. Therefore, we propose a Planetary Health Impact Assessment (PHIA) approach, which incorporates both direct and ecologically mediated pathways. Developing the underlying framework requires a method for organizing and visualizing complex, interdisciplinary knowledge. This study explores an approach for constructing a PHIA framework in the form of knowledge graphs (KGs). Using RF-EMF exposure from mobile telecommunication technologies as a case study, we developed an expert-based KG in collaboration with 12 specialists. We further evaluated the potential of an artificial intelligence (AI)-based tool, incorporating Natural Language Processing (NLP) and Deep Learning, to extract relevant information from scientific literature and generate KGs to explore ways to enhance the expert-based approach. Experts developed and visualized jointly the hypothesized pathways linking RF-EMF exposure to direct health effects on organisms and indirect effects on human health through ecological consequences. The AI tool quickly processed large volumes of literature and visualized it into KGs with varied structures but required extensive expert validation due to limitations in precision and context sensitivity. The expert-based KG can serve as organizer of the available knowledge and as a first step in PHIA development. While AI tools offer potential for exploratory analysis, they currently require substantial human oversight and cannot replace expert judgment. The resulting KGs also identified possible gaps in the scientific literature.

Excerpts

We identified 97 publications on the potential effects of RF-EMF on humans and various organisms and 13 reviews on potential ecological consequences and their effects on human health related to insects, birds, and plants. After automated extraction and cleaning, we compiled a table of 4215 unique instances that reported or hypothesized associations between RF-EMF and direct health effects and 232 unique instances on potential indirect effects (Table ST8)....

Figure 4 visualizes the extracted information representing hypothesized pathways for direct effects,

specifically effects on population, species diversity, pollinators community/colony health, and general pollinators health, linked to ecological consequences due to ecosystem service disruptions. These were subsequently connected to indirect effects on humans.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70038

Supplementary material:

https://onlinelibrary.wiley.com/action/downloadSupplement?doi=10.1002%2Fbem.70038&file=bem70038-sup-0001-Supplementary_material_revised.docx

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**Adverse Effects of Electromagnetic Fields on The Central Nervous System: A Review**

Karapinar BO, Altuntas E, Gul T, Tokpinar A, Degermenci M, Bas O. Adverse Effects of Electromagnetic Fields on The Central Nervous System: A Review. ODU Med J. 2025;12(3):158-69.

Abstract

With the rapid advancement of technology in recent years, exposure to electromagnetic fields (EMFs) has become an integral part of daily life. Electromagnetic fields emitted by both natural and artificial sources have attracted increasing attention, particularly due to their potential biological effects on the central nervous system (CNS). Current literature suggests that EMF exposure may be associated with increased blood–brain barrier permeability, oxidative stress, altered neurotransmitter levels, impaired learning and memory processes, neurodevelopmental alterations, and potential neurodegenerative outcomes. Furthermore, conflicting findings have been reported regarding the relationship between radiofrequency EMFs and extremely low-frequency EMFs and the development of brain tumors, and the World Health Organization has classified radiofrequency EMFs as “possibly carcinogenic to humans.” It is further emphasized that critical developmental stages, such as childhood and the prenatal period, are particularly susceptible to EMF-related effects. While some findings indicate potential therapeutic applications of EMFs, the majority highlight adverse neurological outcomes. Given the widespread prevalence of EMF exposure in modern society, long-term, standardized, and multifaceted studies are required to elucidate the underlying mechanisms and clarify their effects on the CNS.

Conclusion

In summary, accumulating evidence suggests that EMF exposure exerts a wide range of biological effects on the central nervous system (CNS). These include oxidative stress, blood-brain barrier disruption, altered neurotransmitter regulation, cognitive decline, and potential carcinogenicity. While some studies indicate possible neuroprotective or therapeutic roles particularly in the context of neurodegenerative disorders most findings highlight adverse consequences, especially in vulnerable populations such as children and during critical developmental stages.

Given the ubiquity of EMFs in modern environments and the inconsistencies across current findings, further standardized, long-term, and mechanistic studies are essential. Such investigations are vital for clarifying potential neurological risks and for guiding evidence-based public health policies and preventive strategies aimed at mitigating the possible hazards of EMF exposure.

Open access: https://dergipark.org.tr/en/download/article-file/5360399

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**Exploring the Potential Observations Between Geomagnetic Activity and Cardiovascular Events: A Scoping Review**

Belenko J, Cancel G, Mayrovitz HN. Exploring the Potential Observations Between Geomagnetic Activity and Cardiovascular Events: A Scoping Review. Cureus. 2025 Dec 22;17(12):e99851. doi: 10.7759/cureus.99851.

Abstract

Cardiovascular disease (CVD) is the leading cause of death globally, with a growing impact worldwide, yet the role of environmental exposures such as geomagnetic activity (GMA) is unclear. In recent years, environmental factors such as air pollution, extreme temperatures, and natural disasters have been recognized as triggers for cardiovascular events, prompting interest in other environmental influences. Geomagnetic activity (GMA), defined as fluctuations in Earth's magnetic field driven by solar energy and charged particles, remains understudied due to challenges in its integration into epidemiologic research. This scoping review aimed to map the existing evidence on reported associations between geomagnetic activity and cardiovascular outcomes. A systematic literature search of PubMed, Web of Science, Excerpta Medica Database (EMBASE), and Cumulative Index to Nursing and Allied Health Literature (CINAHL) identified 1,718 articles published between 1964 and 2023. After removal of 147 duplicates and screening against predefined eligibility criteria, 36 studies were included in the final review. These studies examined adult populations, measured geomagnetic activity or related space-weather exposures (geomagnetic storms, solar proton events, high-speed solar wind, cosmic ray intensity, and Schumann resonances), and reported cardiovascular outcomes such as myocardial infarction, acute coronary syndrome, stroke, or mortality.

The majority of studies (n = 28) reported significant correlations, while eight found no effect. The incidence of myocardial infarction and acute coronary syndrome increased during geomagnetic storms, solar proton events, and high-speed solar wind, with greater susceptibility observed in individuals with diabetes, metabolic syndrome, or prior cardiovascular disease. The risk of stroke increased with storm intensity, up to 52% during severe events, particularly among young adults. Low geomagnetic activity combined with high cosmic ray activity was consistently associated with increased myocardial infarction incidence and mortality, while more active solar conditions appeared protective.

Overall, evidence suggests that geomagnetic and cosmic variability may coincide with cardiovascular risk; however, findings remain inconsistent, and many studies rely on ecological designs with uncontrolled factors that limit interpretation. Given that evidence is still emerging, these observations remain preliminary. Standardized prospective studies are necessary to determine underlying mechanisms and assess whether space weather monitoring could benefit cardiovascular risk prediction and public health preparedness.

Open access: https://pmc.ncbi.nlm.nih.gov/articles/PMC12822803/

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**Doxorubicin-induced cardiotoxicity under 28 GHz 5G-band electromagnetic radiation in rats: Insights into the mitigative role of vitamin C**

Rahimi A, Rafati A, Mortazavi SMJ, Edalat F, Jooyan N, Naseh M, Keshavarz S, Jahromi HM, Nabizadeh A, Dastghaib S, Karbalaei N. Doxorubicin-induced cardiotoxicity under 28 GHz 5G-band electromagnetic radiation in rats: Insights into the mitigative role of vitamin C. Toxicol Appl Pharmacol. 2026 Feb;507:117703. doi: 10.1016/j.taap.2025.117703.

Abstract

Doxorubicin (DOX), an effective anthracycline chemotherapeutic agent, induces cardiotoxicity through oxidative stress, mitochondrial dysfunction, and activation of apoptotic pathways. As millimeter-wave frequencies used in fifth-generation (5G) communication systems continue to expand, experimental data on potential biological interactions under clinically relevant conditions remain limited. This study investigated whether short-term 28-GHz electromagnetic radiation (EMR) modifies the cardiac response to DOX and evaluated the potential protective role of vitamin C. Thirty male Sprague–Dawley rats were assigned to five groups (n = 6): Sham, DOX, DOX + Vit C, DOX + 5G, and DOX + 5G + Vit C. DOX (15 mg/kg intraperitoneally, six injections) induced cardiotoxicity, while vitamin C (250 mg/kg orally) was administered daily for 14 days. EMR exposure consisted of three 10-min cycles per day at 28 GHz for 14 days. Cardiac injury was assessed using electrocardiography, serum cTnI, oxidative markers (MDA, GSH, SOD, CAT), apoptotic and inflammatory gene expression (BAX, CASP3, BCL-2, TNF-α), and design-based stereology. DOX induced significant functional, biochemical, molecular, and structural alterations. Co-exposure to 28-GHz EMR amplified reductions in CAT ($p < 0.001$), and enhanced pro-apoptotic BAX gene expression ($p < 0.0001$), accompanied by QT interval prolongation ($p < 0.05$). Vitamin C provided partial protection across these endpoints. Under the specific short-term pre-clinical conditions tested, these findings indicate that 28-GHz EMR can modulate the severity of DOX-induced cardiotoxicity, while vitamin C confers modest attenuation. Further long-term and clinical studies are needed to clarify mechanisms and refine translational relevance.

Excerpts

Animals were subjected to 28 GHz radiation in three 10-min cycles per day for 14 consecutive days. The radiation was generated by a Vector Signal Generator (Keysight E8267D, USA) connected to a Narda V637 horn antenna, which emitted linearly polarized continuous-wave (CW) radiation with a maximum radiated power of 21 dBm. The antenna was positioned 18 cm above the animal enclosures to provide uniform field distribution. Throughout the exposure protocol, animals had ad libitum access to food and water and were able to move freely within their assigned compartments. Dosimetry was conducted in CST Microwave Studio. A simplified semi-oval rat phantom was modeled, and spatial distribution of absorbed energy was calculated. Under maximum output conditions, the peak local SAR in the exposed region reached 7.62 $W \cdot kg^{-1}$....

Conclusion

This study shows that, under the specific short-term conditions, 28-GHz millimeter-wave exposure amplified several indices of doxorubicin-induced cardiac injury, whereas vitamin C provided only partial attenuation. These findings indicate a measurable interaction within this controlled co-exposure model. By incorporating millimeter-wave exposure into a cardiotoxicity model, this work bridges the disciplines

of bioelectromagnetics and cardiooncology, suggesting a possible redox-mediated interaction between environmental and pharmacological stressors. The conclusions of this work are restricted to a preclinical, short-duration experiment conducted in male rats without long-term follow-up. Accordingly, any implications for human health remain preliminary and hypothesis-generating. Further mechanistic and longitudinal studies are required to determine whether similar interactions may occur under clinically relevant exposure conditions.

https://pubmed.ncbi.nlm.nih.gov/41478317/

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**Increasing Incidence of Thyroid Cancer and Use of Smart Phones [Health Matters]**

Lin JC. Increasing Incidence of Thyroid Cancer and Use of Smart Phones [Health Matters]. *IEEE Microwave Magazine*, 27(1):14-16, Jan. 2026, doi: 10.1109/MMM.2025.3613612.

No abstract

Open access: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11329092

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**Measurement of Outdoor Micro-Environmental Radio Frequency Electromagnetic Field Exposure Levels in Daily Life Using a Portable Measurement Device**

Ikuyo M, Taki M, Onishi T. (2026). Measurement of Outdoor Micro-Environmental Radio Frequency Electromagnetic Field Exposure Levels in Daily Life Using a Portable Measurement Device. Electron Comm Jpn.. https://doi.org/10.1002/ecj.70015

Abstract

Our research project aims to clarify actual human exposure levels to radio frequency electromagnetic field (RF-EMF) in daily life, as well as investigate risk communication methods using the RF-EMF exposure levels. In this project, we conducted to measure the micro-environmental RF-EMF exposure levels across surrounding different environments which are major railway station areas, shopping streets, residential areas, public parks in urban and suburban areas because of acquiring the detailed data supporting an understanding of the micro-environmental personal RF-EMF exposure levels in Japan. Additionally, in order to evaluate a measurement method using a portable measuring device, we conducted measurements by traversing a designated route way and back. The results showed that RF-EMF exposure levels in urban areas were significantly higher than those in suburban areas. Among the surrounding environments, the major railway station areas had the highest RF-EMF exposure levels, followed by the shopping streets, the residential areas, and the parks. Furthermore, the micro-environmental RF-EMF exposure levels by the way-and-back measurement showed no significant difference between them. The results of these measurements confirm that outdoor mobile measurements using a portable measurement device are effective for assessing micro-environmental RF-EMF exposure levels during daily activities.

Excerpts

The portable measurement device used in this study is ExpoM-RF4 (Fields at Work, Swiss). This measurement device is equipped with a triaxial isotropic antenna and can record the effective values (average time: approx. 50 ms) of E-field strength in multiple arbitrarily set bands over a long period of time at regular intervals. However, the detailed structure of the antenna is not clear. In addition, when the device is carried close to the human body, an underestimation may occur due to the human body shielding. This issue was explored in the previous studies [6, 10-12]. The frequency range supported by the device is 50 MHz to 6 GHz. The center frequency and bandpass filter bandwidth (35, 75, 100 MHz) are preset; the measurement begins as the device is turned on, and the effective values of E-field strength of each band are automatically recorded into the built-in memory. In this study, 29 frequency bands were set to cover 23 bands, including those used in mobile phone systems, FM broadcasting, terrestrial digital television broadcasting, and wireless LANs. The upper measurement limit was set to 20 V/m, and the recording interval was set to 10 s; the GPS function was enabled. The set frequency bands are listed in Table A1.....

Conclusion

In this study, the measurements were conducted while walking with a portable measurement device around major railway stations as well as in shopping streets, residential areas, and public parks in urban and suburban areas. The measurements were carried out by the authors themselves on predetermined routes of about 15–20 min on foot one way. RF-EMF levels in all environments were higher in urban areas as compared to the suburbs. In addition, the RF-EMF levels were the highest around major railway stations, followed by shopping streets, residential areas, and public parks. These results suggested a positive proportional relationship between RF-EMF levels and population density or floating population statistics. The results of this study, acquired by people carrying measurement devices, proved consistent with previous spot measurements and car-mounted measurements.

Although the influence of human body shielding [10, 12] is supposed to depend on the relative positions of the measurement device and radio wave source, there and back, the measurement of continuous micro-environmental exposures of individuals can be measured with the portable measurement device used in this study, at least in environments with little bias in the radio wave arrival direction. However, it should be noted that the data of this study include the effects of human body shielding and so forth. Moreover, the results of this study are limited, and further measurement and analysis are needed to explore RF-EMF levels in various indoor and outdoor micro-environments depending on the lifestyles.

https://onlinelibrary.wiley.com/doi/10.1002/ecj.70015

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**On exposure–response interpretation and evidence synthesis in low-intensity RF-EMF research**

Belyaev I, Dasdag S. On exposure–response interpretation and evidence synthesis in low-intensity RF-EMF research. Environment International, Volume 208, 2026, doi: 10.1016/j.envint.2026.110075.

No abstract

Excerpt

We read with interest the recent exchange in Environment International concerning the systematic review by Mevissen et al. on radiofrequency electromagnetic fields (RF-EMF) and cancer in experimental animals, the critique by Karipidis et al., and the subsequent response by Mevissen et al. (Mevissen, 2025, Karipidis, 2025). This exchange reflects an important methodological discussion on how evidence from animal cancer bioassays should be analysed and interpreted for carcinogenic hazard identification, particularly with respect to evidence synthesis, statistical inference, and exposure relevance.

Open access: https://www.sciencedirect.com/science/article/pii/S0160412026000334

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**The International Collaborative Animal Study of Mobile Phone Radiofrequency Radiation Carcinogenicity and Genotoxicity**

My note: Due to methodologic differences, this study is not a replication of the NTP study; moreover, the Japanese and Korean studies are underpowered.

Imaida K, Kawabe M, Wang J, Yokohira M, Imai N, Han K-H, Kim Y-B, Jeon SB, Kim HY, Ahn YH.The International Collaborative Animal Study of Mobile Phone Radiofrequency Radiation Carcinogenicity and Genotoxicity: The Japanese Study. Toxicol Sci. 2026. 1/13/26. https://doi.org/10.1093/toxsci/kfag002.

Abstract

The potential carcinogenic and genotoxic effects of radiofrequency electromagnetic fields, particularly those emitted by mobile communication systems, have raised public health concerns. A previous study by the U.S. National Toxicology Program suggested increased incidences of gliomas and cardiac schwannomas in rats exposed to high levels of RF radiation. To evaluate these findings, an international collaborative study was initiated between Japan and Korea.

Male Hsd:Sprague Dawley® SD® rats were exposed to 900 MHz CDMA-modulated RF-EMFs at a whole-body specific absorption rate of 4 W/kg for 18 hours and 20 minutes daily over two years. The study included a 28-day preliminary toxicity study, genotoxicity assays (alkaline comet and micronucleus tests), and a two-year carcinogenicity assessment. All procedures followed OECD guidelines and Good Laboratory Practice. No statistically significant increases in the incidences of neoplastic or non-neoplastic lesions were found in any major organ, including the brain, heart, and adrenal glands. Genotoxicity assays revealed no evidence of DNA damage or chromosomal aberrations in RF-exposed rats. A higher survival rate in the RF-exposed group, likely due to lower body weight and food consumption, was observed.

This study performed in Japan, jointly planned and executed by Japan and Korea, provides strong evidence that long-term exposure to 900 MHz RF-EMFs did not produce reproducible carcinogenic or genotoxic effects in male rats. Combined with data from the Korean counterpart study, these results are expected to contribute to future international assessments of the carcinogenic potential of electromagnetic radiation.

Open access:

https://academic.oup.com/toxsci/advance-article/doi/10.1093/toxsci/kfag002/8423504?searchresult=1

Supplementary data: https://academic.oup.com/toxsci/advance-article/doi/10.1093/toxsci/kfag002/8423504?searchresult=1&login=false#supplementary-data

**The International Collaborative Animal Study of The Carcinogenicity and Genotoxicity of Mobile Phone Radiofrequency Radiation: The Korean Study**

Kim HS, Han KH, Kim YB, Jeon SB, Lee AK, Moon JI, Choi HD, Imaida K, Yokohira M, Kawabe M, Imai N, Wang J, Ahn YH. The International Collaborative Animal Study of The Carcinogenicity and Genotoxicity of Mobile Phone Radiofrequency Radiation: The Korean Study. Toxicol Sci. 2026 Jan 16:kfag001. doi: 10.1093/toxsci/kfag001.

Abstract

A chronic bioassay investigating radiofrequency (RF) carcinogenicity, intentionally designed to be conducted simultaneously in Korea and Japan, using the same research protocol and experimental environment. The study aimed to assess the potential carcinogenicity of Code Division Multiple Access (CDMA)-modulated 900 MHz RF signals at a whole-body specific absorption rate (SAR) of 4 W/kg, which is the reference level of the international human safety guideline, and to verify the key findings from the National Toxicology Program (NTP) study at that SAR level. Two reverberation chamber systems were used for RF exposures, and the same study protocols were followed. Male Harlan Sprague-Dawley (Hsd: Sprague Dawley® SD®) rats were randomly assigned to cage-control, sham-exposed, or RF-exposed groups. The exposure started on gestational day 5 and lasted for 18 hours and 20 minutes each day, with 10-minute on/off cycles. The project included a 28-day toxicity study, a 2-year carcinogenicity study, and a 14-week genotoxicity test. Histopathological evaluations were conducted in a partially blinded manner. The results were independently analyzed and submitted separately based on each country's research findings. In the Korean study, no statistically significant changes in tumor incidence or survival rates were observed. No significant RF-related effects were detected in the heart, brain, or adrenal glands. No changes in body temperature. Genotoxicity tests showed no evidence of DNA damage or mutation. In conclusion, the Korean part found that long-term exposure to CDMA-modulated 900 MHz RF was neither carcinogenic nor genotoxic at a SAR of 4 W/kg in male rats.

Open access:

https://academic.oup.com/toxsci/advance-article/doi/10.1093/toxsci/kfag001/8428133?login=false

Supplementary file: Not available at this time.

**An International Collaborative Animal Study of the Carcinogenicity of Mobile Phone Radiofrequency Radiation: Considerations for Preparation of a Global Project**

Ahn YH, Imaida K, Kim YB, Han KH, Pack JK, Kim N, Jeon SB, Lee AK, Choi HD, Wang J, Kawabe M, Kim HS. An International Collaborative Animal Study of the Carcinogenicity of Mobile Phone Radiofrequency Radiation: Considerations for Preparation of a Global Project. Bioelectromagnetics. 2022 May;43(4):218-224. doi: 10.1002/bem.22407.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.224071

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**Ameliorative Role of Coenzyme Q10 in RF Radiation-Associated Testicular and Oxidative Impairments in a 3.5-GHz Exposure Model**

Bektas H, Yildirim S, Cakir S, Dogu S, Altindag F. Ameliorative Role of Coenzyme Q10 in RF Radiation-Associated Testicular and Oxidative Impairments in a 3.5-GHz Exposure Model. Bioelectromagnetics. 2026 Jan;47(1):e70043. doi: 10.1002/bem.70043.

Abstract

This study investigated the biological effects of GSM-modulated 3.5 GHz radiofrequency (RF) electromagnetic field exposure on male reproductive function and evaluated the potential protective role of Coenzyme Q10 (CoQ10). Twenty-eight adult male Wistar rats were allocated into four groups: Control, RF, CoQ10, and RF + CoQ10. Animals were exposed to RF for 2 h/day over 30 days, while CoQ10 was administered intraperitoneally at 10 mg/kg/day. Hormonal (testosterone, LH, FSH), biochemical (MDA, GSH, TAS, TOS), and histopathological assessments were performed. Specific absorption rate (SAR) simulations estimated a whole-body SAR of 0.16995 W/kg and a testis-specific SAR of 0.02669 W/kg. RF exposure significantly reduced testosterone, LH, and FSH levels, increased MDA and TOS concentrations, and induced degenerative changes in testicular histology. CoQ10 treatment partially ameliorated these alterations by restoring testosterone and TAS levels and reducing tissue damage. These results indicate that even low-SAR GSM-modulated 3.5 GHz RF exposure may negatively impact male reproductive health, and CoQ10 supplementation may confer partial protective effects. Because the exposure consisted of a GSM-modulated waveform, the results cannot be extrapolated to FR1 5G NR signals used in real communication systems. Further studies are needed to clarify mechanisms and assess biological relevance under real-world exposure conditions.

Summary

• GSM-modulated 3.5 GHz RF exposure induces hormonal suppression, oxidative stress, and testicular tissue damage in male rats, despite low SAR levels.
• Coenzyme Q10 supplementation partially restores testosterone levels, antioxidant balance, and histological integrity in RF-exposed testicular tissue.
• This study provides one of the first integrative assessments of GSM-modulated 3.5 GHz RF exposure on reproductive health, combining SAR simulation, biochemical, hormonal, and histopathological analyses.

Conclusions

This experimental study demonstrates that exposure to 3.5 GHz RF disrupts hormonal balance, induces oxidative stress, and causes microscopic histopathological damage in the testicular tissue of male rats. The biological effects observed, despite low SAR levels, indicate that RF may have meaningful impacts on the reproductive system. CoQ10 supplementation conferred partial protective effects, particularly in preserving testosterone levels, reducing oxidative burden, and maintaining seminiferous tubule integrity. These findings underscore the importance of developing personal protection strategies against electro-magnetic exposure and suggest that antioxidant agents such as CoQ10 may hold therapeutic potential in this context. Future clinical and translational research will be essential to further elucidate the biological consequences of electromagnetic field exposure and to inform effective public health

strategies aimed at reducing associated risks. However, because the exposure waveform was GSM-modulated, these results should not be interpreted as 5G NR–specific biological effects.

https://pubmed.ncbi.nlm.nih.gov/41578890/

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**Neurotoxic effects of 3.5 GHz GSM-like RF exposure on cultured DRG neurons: a mechanistic insight into oxidative and apoptotic pathways**

Bektas H, Seker A, Ustun R, Dogu S. Neurotoxic effects of 3.5 GHz GSM-like RF exposure on cultured DRG neurons: a mechanistic insight into oxidative and apoptotic pathways. Int J Radiat Biol. 2026 Jan 21:1-14. doi: 10.1080/09553002.2026.2617592.

Abstract

Purpose: This study investigated whether strictly non-thermal, GSM-like 3.5 GHz radiofrequency electromagnetic fields (RF-EMF)-overlapping in frequency with bands used by 5 G networks but not employing a 5 G NR waveform-disrupt redox homeostasis and activate apoptotic signaling in peripheral sensory neurons.

Materials and methods: Primary mouse dorsal root ganglion (DRG) cultures were exposed in a GTEM-based setup to pulsed 3.5 GHz RF-EMF (217 Hz, ∼12.5% duty) for 1-24 h at 37 °C with <0.1 °C temperature difference between groups. Dosimetry confirmed non-thermal exposure with localized peaks consistent with IEEE/IEC guidance. Cell viability, reactive oxygen species (ROS), mitochondrial-apoptotic markers (Bax, Bcl-2, cytochrome c, caspase-3), and p75^NTR were quantified by blinded confocal analysis.

Results: RF-EMF caused a significant, time-dependent reduction in viability with robust ROS elevations; increased Bax and caspase-3; decreased Bcl-2; and cytochrome c release, with maximal effects at 12-24 h. p75^NTR upregulation indicated maladaptive neurotrophin signaling.

Conclusions: Under non-thermal conditions, 3.5 GHz RF-EMF perturbs redox balance and triggers mitochondria-dependent apoptosis in DRG neurons, highlighting peripheral neuronal vulnerability to mid-band exposures. These findings provide a mechanistic link between RF exposure and oxidative/apoptotic pathways and warrant in vivo studies assessing long-term and interventional outcomes.

Highlights

- Non-thermal 3.5 GHz RF-EMF elevates ROS and triggers mitochondrial apoptosis in DRG neurons.
- Precise dosimetry: SAR_total 171 mW/kg; 1-g 270 mW/kg; peak 1149 mW/kg with ΔT < 0.1 °C.
- Molecular signature: Bax↑, caspase-3↑, cytochrome-c↑, Bcl-2↓, p75^NTR↑.
- Relevance to mid-band exposures overlapping 3–4 GHz allocations (waveform ≠ full 5 G).

https://pubmed.ncbi.nlm.nih.gov/41562640/

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**Effects of wireless local area network exposure on testicular morphology and VEGF levels**

Çakmak E, Bilgici B, Engiz BK, *et al.* Effects of wireless local area network exposure on testicular morphology and VEGF levels. *Sci Rep* (2026). https://doi.org/10.1038/s41598-026-37323-2.

Abstract

This study investigated the effects of exposure to a 2.45 GHz electromagnetic field (EMF) on rat testicular tissue, focusing on histological alterations and the potential activation of the HIF1A-VEGF pathway. Twenty-four adult male albino Wistar rats were divided into a control group ($n$ = 12) with no EMF exposure and an experimental group ($n$ = 12) exposed to 2.45 GHz microwave radiation (3 V/m, SAR 0.00208 W/kg) for one hour daily over 60 days. Following the exposure period, testicular tissues were analyzed for histopathological changes, VEGFA and HIF1A gene expression levels, and VEGFA protein concentration. In rat testicular tissue, while VEGFA gene expression ($p < 0.05$) and protein levels ($p < 0.001$) increased in the EMF group, no significant change was detected in HIF1A gene expression levels in the EMF group compared to the control group. Histological examination revealed a significant reduction in seminiferous tubule diameter ($p < 0.001$), epithelial thickness ($p < 0.001$), tubule density ($p < 0.001$), and Sertoli cell count ($p = 0.0098$) in the EMF-exposed group. It may be concluded that EMF at 2.45 GHz increases HIF1A-independent VEGF levels, and EMF exposure may cause testicular damage by increasing VEGF gene expression levels.

Excerpt

Application of the electromagnetic field  In this study, a monopole antenna Microwave system (2004X-RF, Everest Co., Adapazarı, Turkey) was used to generate the 2.45 GHz frequency generated by WLAN systems. The microwave system is capable of emitting continuous or discrete waves at 2.45 GHz, with 0-1 W of output power and 217 Hz modulation.

Open access: https://www.nature.com/articles/s41598-026-37323-2

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**5G RF-EMFs Mitigate UV-Induced Genotoxic Stress Through Redox Balance and p38 Pathway Regulation in Skin Cells**

Kim JH, Jin H, Jang KM, Lee JE, Na S, Jeon S, Choi HD, Moon JI, Kim N, Lim KM, Kim HR, Lee YS. 5G RF-EMFs Mitigate UV-Induced Genotoxic Stress Through Redox Balance and p38 Pathway Regulation in Skin Cells. Antioxidants (Basel). 2026 Jan 19;15(1):127. doi: 10.3390/antiox15010127.

Abstract

The biological effects of radiofrequency electromagnetic fields (RF-EMFs) remain an unresolved scientific issue with important societal relevance, particularly in the context of the global deployment of fifth-generation (5G) wireless technologies. The skin is continuously exposed to both RF-EMFs and ultraviolet (UV) radiation, a well-established inducer of oxidative stress and DNA damage, making it a relevant model for assessing combined environmental exposures. In this study, we investigated whether post-exposure to 5G RF-EMFs (3.5 and 28 GHz) modulates ultraviolet A (UVA)-induced genotoxic stress in human keratinocytes (HaCaT) and murine melanoma (B16) cells. Post-UV RF-EMF exposure

significantly reduced DNA damage markers, including phosphorylated histone H2AX (γH2AX) foci formation (by approximately 30-50%) and comet tail moments (by 60-80%), and suppressed intracellular reactive oxygen species (ROS) accumulation (by 56-93%). These effects were accompanied by selective attenuation of p38 mitogen-activated protein kinase (MAPK) phosphorylation (reduced by 55-85%). The magnitude of molecular protection was comparable to that observed with N-acetylcysteine treatment or pharmacological inhibition of p38 MAPK. In contrast, RF-EMF exposure did not reverse UV-induced reductions in cell viability or alterations in cell cycle distribution, indicating that its protective effects are confined to early molecular stress-response pathways rather than downstream survival outcomes. Together, these findings demonstrate that 5G RF-EMFs can facilitate recovery from UVA-induced molecular damage via redox-sensitive and p38-dependent mechanisms, providing mechanistic insight into the interaction between modern telecommunication frequencies and UV-induced skin stress.

Open access: https://www.mdpi.com/2076-3921/15/1/127

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**Exposure to hexavalent chromium and 1800 MHz electromagnetic radiation can synergistically induce intracellular DNA damage in mouse embryonic fibroblasts**

Zhu Y, Zhu L, Lan Y, Sun C, Chen G. Exposure to hexavalent chromium and 1800 MHz electromagnetic radiation can synergistically induce intracellular DNA damage in mouse embryonic fibroblasts. Biochem Biophys Res Commun. 2026 Jan 28;804:153360. doi: 10.1016/j.bbrc.2026.153360.

Abstract

Radiofrequency electromagnetic fields (RF-EMF) are widely present in the modern environment and have been classified by the International Agency for Research on Cancer as possibly carcinogenic to humans (Group 2B). However, their potential role as co-carcinogens remains unclear. The present study aimed to evaluate whether 1800 MHz RF-EMF exposure can modulate chemically induced DNA damage. Mouse embryonic fibroblasts (MEF) were exposed to RF-EMF alone or in combination with hydrogen peroxide ($H_2O_2$), 4-nitroquinoline-1-oxide (4NQO), cadmium ($Cd^{2+}$), or hexavalent chromium [Cr(VI)]. RF-EMF exposure was performed using a waveguide system under standardized, non-thermal conditions, and DNA damage was assessed using the alkaline comet assay. RF-EMF exposure alone did not induce detectable DNA damage, nor did it significantly enhance DNA damage caused by $H_2O_2$, 4NQO, or $Cd^{2+}$. In contrast, co-exposure to RF-EMF and Cr(VI) resulted in a significant synergistic increase in DNA damage in MEF cells. These findings suggest that RF-EMF may selectively exacerbate Cr(VI)-induced genotoxicity, highlighting the need for further investigation into the underlying co-toxic mechanisms.

https://pubmed.ncbi.nlm.nih.gov/41619510/

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**Human cells response to electromagnetic waves of radio and microwave frequencies**

Souchelnytskyi S. Human cells response to electromagnetic waves of radio and microwave frequencies. Ukr Biochem J. 2025; 97(6): 5-22. doi: 10.15407/ubj97.06.005.

Human cells both generate and absorb electromagnetic waves (EMW), but information about sensing and responding to EMW at different Hz frequencies is still fragmentary. The reported impact of radio

(RF) and microwave (MW) frequencies is variable, from harmful to human health to applications promising for novel diagnostics and treatment of diseases, e.g., cancer. The review highlights both recent achievements in elucidation of molecular mechanisms of RF and MW effects and a direction for their successful practical application in humans.

Open access: http://ukrbiochemjournal.org/2025/12/human-cells-response-to-electromagnetic-waves-of-radio-and-microwave-frequencies.html

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**Is It Time to Reconsider Chronic Electromagnetic Field Exposure as a Possible Risk Factor in Oral Cancer?**

Nitya K, Hema Shree K. Is It Time to Reconsider Chronic Electromagnetic Field Exposure as a Possible Risk Factor in Oral Cancer? Journal of Stomatology Oral and Maxillofacial Surgery, 2025, doi:10.1016/j.jormas.2025.102703.

Abstract

Introduction  Oral squamous cell carcinoma (OSCC) is a major global health burden, traditionally associated with tobacco, alcohol, and betel quid. In recent years, however, cases have emerged among individuals without these classic risk factors. Chronic exposure to electromagnetic fields (EMFs) from mobile phones and wireless devices has been classified as possibly carcinogenic, yet its potential role in oral carcinogenesis has not been systematically studied.

Technical Note  This article highlights the biological plausibility that prolonged, localized EMF exposure may contribute to DNA damage, oxidative stress, and epigenetic modifications in oral epithelial tissues. Evidence from pilot cytogenetic studies, in vitro models, and limited epidemiological data observed increased micronucleus frequency and altered cellular stress responses in buccal mucosal cells of long-term mobile phone users. While direct causal data in OSCC remain absent, these findings suggest that EMFs could act alone or in synergy with established carcinogens.

Discussion  The technical note underscores the urgent need for in vitro, in vivo, and epidemiological studies to evaluate whether chronic EMF exposure contributes to oral carcinogenesis. Recognizing this hypothesis is not alarmist but rather a call for rigorous and unbiased investigation. If validated, such evidence could inform preventive guidelines and public health policy for emerging exposures.

https://www.sciencedirect.com/science/article/pii/S2468785525004884

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**Prevalence of self-reported sensitivities to various environmental factors in Germany, Sweden, and Finland based on multiple classification criteria**

Köteles F, Witthöft M, Bräscher AK, Bailer J, Nordin S. Prevalence of self-reported sensitivities to various environmental factors in Germany, Sweden, and Finland based on multiple classification criteria. J Psychosom Res. 2025 Dec 10;201:112495. doi: 10.1016/j.jpsychores.2025.112495.

Abstract

Objective: Our knowledge on the prevalence of self-reported sensitivities to environmental factors is poor. The lack of accepted criteria/assessment makes findings of different studies difficult to compare; the way of assessment might play a role in the reported prevalence rates. The present study aimed to report the prevalence rates of five environmental sensitivities for the German general population, to compare three of them with Swedish and Finnish data, and to demonstrate the impact of strictness of criterion on the results.

Methods: Data from a German (n = 2515), a Swedish (n = 3253) and a Finnish (n = 1467) population-based survey was used. Sentitivities were rated on ordinal scales in all samples.

Results: In the German sample, about 25 % of participants reported mild reactions to sounds, chemicals, and buildings, and about 10 % to electromagnetic fields (EMFs) and wind turbines, with a similar pattern for strong reactions, but with proportions of 1-2 %. Data from the Nordic countries show consistent similarities between these two countries, with prevalences exceeding 34 % for mild reactions to chemicals and sounds and about 5 % to EMFs, with a similar pattern for strong reactions, but with proportions of 1-8 %. Prevalence of sensitivity to EMFs was higher, whereas prevalence of sensitivity to chemicals and sounds was lower in Germany. Classification criteria significantly impacted the reported prevalence rates.

Conclusion: Various environmental sensitivities affect a considerable proportion of the general populations of the three countries. To improve comparability, self-report assessment of sensitivities should be based on at least an ordinal scale instead of the widely used yes-or-no question.

Excerpts

For sensitivity to EMFs, 10.9% of the population is affected to some extent, including those with a strong impact (0.8%). These values are in concert with the estimated values in previous reports (7.2–10.3 %) from Germany [20,21].

Open access: https://www.sciencedirect.com/science/article/pii/S0022399925004593?via%3Dihub

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**Radio Frequency Exposure in Military Contexts: A Narrative Review of Thermal Effects and Safety Considerations**

Risling M, Günther, M. Radio Frequency Exposure in Military Contexts: A Narrative Review of Thermal Effects and Safety Considerations. Military Medicine. 2025. doi: 10.1093/milmed/usaf613.

Radiofrequency (RF) exposure has been extensively studied for potential health risks. Unlike ionizing radiation, RF fields primarily cause thermal health effects, the only established mechanism of biological harm. Regulatory bodies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE), set limits to prevent excessive heating. This review examines the relationship between RF exposure, heat generation, and physiological responses, with relevance to civilian and military safety.A narrative review of peer-reviewed literature, regulatory reports, and experimental studies was conducted using PubMed, IEEE Xplore, Google Scholar and Scopus. Emphasis was placed on Specific Absorption Rate (SAR) and Cumulative Equivalent Minutes

at 43 °C (CEM43). Studies on thermal effects and exposure scenarios were prioritized; speculative non-thermal mechanisms were excluded.Thermal effects depend on frequency, tissue composition, and environmental conditions. Whole-body SAR limits (≤4 W/kg) generally prevent core temperature increases, but localized heating remains a concern. CEM43 provides a temperature-based metric but is difficult to apply in transient exposures. Penetration depth across NATO frequency bands shows variability because of differences in tissue models and measurement methods. This variability is clinically relevant, as localized heating of the skin, eye, or superficial nerves may occur even when whole-body exposure is within limits.Current guidelines prevent systemic overheating but may not fully address localized risks. Combining SAR and CEM43 with refined penetration depth data could improve risk assessment. Future work should refine dose–response thresholds and methods for detecting and modeling localized heating, especially under military conditions where thermoregulation may be impaired.

Conclusions

Current RF safety guidelines, primarily based on SAR limits, effectively prevent excessive heat accumulation in the body, but localized heating remains a key concern, particularly in environments where thermoregulation is compromised. Although the body dissipates heat efficiently through perfusion and sweating, tissue-specific heating thresholds vary, and prolonged or intense exposure can create hotspots with potential for thermal damage. Metrics like CEM43 offer a temperature-based assessment of risk, but further refinement is needed for real-world applications. Future research should focus on integrating SAR and thermal dose models to better predict heat-related risks, especially high-stress operational settings.

Open access: https://doi.org/10.1093/milmed/usaf613

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**RF-EMF Risk Perception & Trust in Radiation Protection Authorities: Comparative Study on Precautionary Information in Germany & Greece**

Eggeling-Böcker M, Karabetsos E, Christopoulou M, Link SC, Abacioglu F, Boehmert C. RF-EMF Risk Perception and Trust in Radiation Protection Authorities: A Comparative Study on Precautionary Information in Germany and Greece. Bioelectromagnetics. 2026 Jan;47(1):e70042. doi: 10.1002/bem.70042.

Abstract

This study investigates how different types of precautionary information affect risk perception and trust in national radiation protection authorities regarding radio-frequency electromagnetic fields (RF-EMF) from mobile communications, with a specific focus on 5G networks. A total of 2169 participants (1040 in Germany, 1129 in Greece) were randomly assigned to one of three conditions: (1) basic information, (2) simple precautionary information regarding possibilities to reduce personal RF-EMF exposure while using a mobile phone, and (3) conceptual precautionary information, including an explanation distinguishing "precaution" from "prevention" (1 × 3 factorial design). Contrary to the expectation that simple precautionary messages lead to higher risk perception and lower trust compared to basic messages, this was only the case for general conditional risk perception assuming that no precautions are taken, but not for affective risk perception, trust, or general conditional risk perception assuming

that precautions are taken. Notably, providing a more elaborate explanation of the precaution/ prevention distinction did not decrease risk perception or increase trust compared to giving simple precautionary information only, and even increased risk perception compared to basic information. This suggests limited benefit in emphasizing this conceptual nuance of precaution. Considering other variables, precautionary information increased feelings of self-efficacy and perception of message consistency. The findings reveal significant country differences: Greek participants reported higher perceived risks and lower trust than German participants. Gender differences also emerged, with women expressing higher risk perception and less trust than men. In contrast to the previous literature, the results suggest that precautionary information concerning personal mobile phone use can be communicated without leading to higher public concern about RF-EMF exposure from mobile communications. However, we found some evidence that adding conceptual explanations to precautionary information leads to higher risk perception. The results also show that considering sociocultural and individual differences in risk communication can be relevant. Possible explanations for the findings and implications for risk communicators are discussed.

Summary

- The study investigated risk perception and trust in authorities regarding RF-EMF from mobile communication, particularly 5G NR networks.
- Precautionary information did mostly not lead to higher risk perception or lower trust, but increased feeling of self-efficacy. Unexpectedly, adding conceptual information intended to explain the precautionary approach actually increased risk perception.
- Greek (compared to German) and female (compared to male) participants reported higher RF-EMF risk perception and lower trust in authorities.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70042

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**Massive assessment of exposure to 5G electromagnetic fields in France: a 5-year synthesis**

Jawad O, Conil E, Sefsouf L, *et al.* Massive assessment of exposure to 5G electromagnetic fields in France: a 5-year synthesis. *Ann. Telecommun.* (2026). https://doi.org/10.1007/s12243-025-01142-9

Abstract

This paper presents the results of a large-scale measurement campaign to assess the impact of 5G deployment on exposure levels in mainland France. The campaign consists of more than 24,000 measurements taken on the ground in direct view of 5G antennas between 2020 and 2024, subdivided into seven phases, in order to closely monitor changes in exposure. The measurements consist of accredited measurements following the ANFR protocol and exploratory measurements designed to emulate steerable-beam loading in the 3.5 GHz band. The paper also introduces a metric quantifying the rate of 5G usage. Results show that, at 5G 3500 MHz sites, the broadband exposure level increased by 0.12 V/m on average over the 5-year period, while the 3500 MHz band contribution increased by 0.34 V/m on average, reflecting the progressive adoption of 5G. Despite this increase, the 3500 MHz band remained a secondary contributor, accounting for only 10% of the main contributors in 2024, far behind historical 800/900 MHz bands. Exploratory measurements reveal that exposure during a 1 GB download

is, on average, four times higher than in idle mode, with a median 5G 3500 MHz usage rate of 17% and a mean of 26%. In the other 5G bands, exposure increased more moderately: +0.15 V/m in the 2100 MHz band and +0.14 V/m in the 700 MHz band, where pre-existing 4G signals already dominated. This unique long-term dataset provides the most extensive 5G exposure assessment published to date under real deployment conditions, quantifying the gradual contribution of 5G to overall exposure.

https://link.springer.com/article/10.1007/s12243-025-01142-9

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**Effects of paternal 5G RFR exposure on health of male offspring mice**

Zhaowen Z, Ling G, Guiqiang Z, Jiajin L, Tongzhou Q, Jiangyi L, Jing L, Fuli W, Guirong D. Effects of paternal 5G RFR exposure on health of male offspring mice. Reproductive Toxicology, 2025. doi: 10.1016/j.reprotox.2025.109139.

Abstract

With the widespread application of 5G communication technology, the potential health risks of radiofrequency radiation (RFR) have been paid much attention. Prior studies have demonstrated that the testes are highly sensitive to RFR, and notably, paternal epigenetic modifications can be transmitted to offspring, impacting their reproductive and neurobehavioral phenotypes. To investigate the intergenerational effects of paternal exposure to 5G RFR on male offspring health, 7-8-week-old male C57BL/6 mice were randomly divided into Sham group and 4.9GHz RFR group (16 mice per group). The mice in 4.9GHz RFR group were exposed to 4.9GHz RFR for 1h/d over 42 consecutive days. Male offspring derived from exposed males and unexposed females were raised to adulthood. Anxiety and depression-like behaviors, learning and memory capabilities, sperm quality, and fertility in male offspring were assessed. Paternal testicular LRGUK gene (sperm motility-related) methylation, mRNA, and protein expression were detected. The results showed that paternal 5G RFR exposure induced anxiety-like behaviors and impaired sperm quality in F1 males, potentially associated with RFR-induced hypermethylation of paternal LRGUK gene and subsequent down regulation of its expression in offspring testes. No significant effects were observed on depression-like behaviors, cognitive performance, or fertility across F1-F2 generations. These findings indicated that paternal 5G RFR exposure induced intergenerational adverse effects on F1 males, potentially mediated by germ cell epigenetic modifications.

https://www.sciencedirect.com/science/article/pii/S0890623825003107

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**DNA Damage Analysis in Blood Tissue & Physiopathological Evaluation of the Effect of Quercetin on Kidney Tissue in 2600 MHz EMF Exposure**

Karaman IP, Coskun O, Senol N, Aslankoc R, Comlekci S. DNA Damage Analysis by Comet Assay Method in Blood Tissue and Physiopathological Evaluation of the Effect of Quercetin on Kidney Tissue in 2600 MHz Electromagnetic Field Exposure. Altern Ther Health Med. 2025 Dec 16:AT7599.

Abstract

Background: Electrical devices around us are sources of electromagnetic fields (EMF). The EMR induces the formation of free radicals, leading to oxidative damage in various tissues, with the kidney being highly sensitive to oxidative damage.

Aim: This study aimed to evaluate the physiopathological effects of 2600 MHz EMF on the kidney tissue of rats and DNA damage in blood tissue. Quercetin (Qu) was administered as an antioxidant to reduce these effects.

Methods: Male Wistar-Albino rats were divided into four groups, with each containing 8 rats. Group 1 (control group), Group 2 (sham group), Group 3 (EMF group), and Group 4 (EMF + Qu). From the animals sacrificed on the end of the 30th day, kidney tissues were taken for physiopathological examination. Additionally, blood samples were collected for DNA damage analysis by the Comet assay method.

Results: Histopathological examination of the kidney tissue revealed tubular dilatation damage at a low level in all groups. The immunohistochemical evaluation gave similar results in all groups. There was no significant change in malondialdehyde, catalase, and superoxide dismutase levels. Additionally, in the EMF group, DNA damage was observed in the lymphocytes (P = .007, <.05).

Conclusion: It was rationalized that 2600 MHz EMF exposure did not cause any significant damage to the kidney tissue. However, it caused remarkable DNA damage in blood tissue.

https://pubmed.ncbi.nlm.nih.gov/41411134/

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**The effects of acute and chronic exposure of 3G UMTS 2100 MHz radiofrequency radiation on rat mismatch negativity**

Er H, Hidisoglu E, Deniz Kantar D, Acun AD, Akkoyunlu G, Sukru Ozen S, Yargicoglu P. The effects of acute and chronic exposure of 2100 MHz radiofrequency radiation on rat mismatch negativity. Journal of Radiation Research and Applied Sciences. 19(1), 2026, doi: 10.1016/j.jrras.2025.102126.

Abstract

Cell phones operate by emitting radiofrequency radiation (RFR), a form of electromagnetic radiation (EMR). Consequently, ongoing researches target to determine whether it poses potential risks to human health. One of these risks is related with brain and auditory system. This study aims to examine the impact of acute and chronic exposure to 2100 MHz radiofrequency radiation on mismatch negativity (MMN) in rats. In this study, we established 1-week (RFR1) and 10-week (RFR10) RFR groups from rats, which were subjected to 2100 MHz RFR exposure. Cage control groups (CC1, CC10) and sham groups (S1, S10) that were not subjected to RFR for equivalent durations were also established. Following auditory event-related potential (AERP) recordings, MMN waves were computed and analyzed. Additionally, brain samples were collected and biochemical and histological analyses were performed. The RFR1 group exhibited a reduction in AMPAR GluR2 subunit protein levels relative to the CC1 and S1 groups, although GFAP protein levels increased. Conversely, the opposite was observed in the chronic groups. Edema of astrocytic endfeet, mitochondrial damage, and lysosomal vesicles were identified in the RFR1 group. The MMN amplitude was found to be reduced in the RFR1 group relative to the CC1

group. The RFR1 group exhibited a reduction in delta and theta power relative to the S1/CC1 groups. Alpha coherence diminished in the RFR1 group relative to the S1 group, however it augmented in the RFR10 group compared to the S10 group. The assessment of event-related potentials indicated that 2100 MHz RFR led to a decrease in MMN amplitude, power spectrum, and coherence values in the RFR1 group relative to the S1 and CC1 groups, but an increase was observed in the RFR10 group compared to the S10 group. Consequently, in the acute period, 2100 MHz RFR may have adverse effects on auditory sensory memory.

Excerpts

A radiofrequency (RF) generator producing 2100 MHz RFR (2100 MHz UMTS Simulator; Everest Corp., Adapazari, Turkey) was utilized to simulate exposure to the Universal Mobile Telecommunications System (UMTS). At 10 cm from the antenna, the electric-field strength over the rat's head was 35.2 V/m for 2100 MHz while the generator was in "signal on" mode. The mean whole-body SAR value and the SAR value in the brain were determined to be 128 mW/kg and 0.27 W/kg, respectively. SAR computations were executed via the Finite Difference Time Domain technique (LeBlanc & D&Post, 2000)....

The evaluation of the event-related potentials revealed that 2100 MHz RFR resulted in a reduction in MMN amplitude, power spectrum, and coherence values in the RFR1 group when compared to the S1 and CC1 groups and an elevation in the RFR10 group compared to the S10 group. Given that there was no significant difference in terms of lipid peroxidation in the acute groups, the lower MMN response and GluR2 expression in the RFR1 group cannot be explained by the effect of lipid peroxidation. However, these changes may be due to increased GFAP expression in the RFR1 group. It is possible that the increased GFAP expression in the RFR1 group may have led to a decrease in AMPAR expression, thus resulting in an inadequate function of NMDAR. Conversely, the elevated MMN response and GluR2 expression observed in the RFR10 group may be associated with a reduction in GFAP expression, given that no notable discrepancy was identified between the chronic groups with regard to lipid peroxidation. The reduction in GFAP expression observed in the RFR10 group may have resulted in an increase in AMPAR expression, which in turn has led to the physiological functioning of NMDAR. It was hypothesized that these findings may be attributed to alterations in astrocyte function, which are vital for maintaining normal brain activity, due to astrogliosis. Furthermore, the mitigating responses detected in the RFR10 group could indicate the time-dependent recruitment of additional endogenous protective mechanisms against RFR exposure. Along with all these findings, our study has certain limitations, including the lack of behavioral correlations in rats and the potential stress effects resulting from confinement in plexiglass tubes.

In conclusion, the effect and mechanism of 2100 MHz RFR on MMN was investigated in our study, which determined that RFR may affect sensory memory. Given the vital role of NMDAR in the formation of MMN, the status of NMDA and AMPA receptors was attempted to be explained by GFAP expression. However, further studies are needed for a more detailed understanding of the potential implications for sensory memory and to assess human health relevance.

Open access: https://www.sciencedirect.com/science/article/pii/S1687850725008386

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**Alpha-Lipoic Acid Preserves Testicular Integrity Under 2.45 GHz Electromagnetic Radiation by Restoring Redox and Inflammatory Balance**

Cakir T, Keskin S, Yildizhan K, Bayir MH, Altindag F, Karaman E. Alpha-Lipoic Acid Preserves Testicular Integrity Under 2.45 GHz Electromagnetic Radiation by Restoring Redox and Inflammatory Balance. Biomedicines. 2025; 13(12):3089. doi: 10.3390/biomedicines13123089

Abstract

Background/Objective: Electromagnetic radiation (EMR) from wireless technologies has raised concerns about male reproductive health. We aimed to evaluate the protective role of alpha-lipoic acid (ALA), a potent antioxidant, against testicular alterations induced by 2.45 GHz EMR.

Methods: Twenty-eight adult male rats were randomly divided into four groups: control, EMR, ALA, and ALA+EMR. Animals in the EMR and ALA+EMR groups were exposed to EMR for 2 h/day for 1 month. Testicular tissues were examined histologically, stereologically, and immunohistochemically, while serum samples were analysed biochemically.

Results: EMR exposure caused marked structural damage, including disruption of seminiferous tubule architecture, increased collagen deposition, and expansion of tubular and interstitial volumes. These pathological changes were primarily prevented in the ALA+EMR group. Immunohistochemical analyses revealed increased IL-6 and TNF-α expression following EMR exposure, whereas ALA supplementation significantly reduced these inflammatory markers and restored AR, ZO-1, and ZO-2 expression. Biochemically, EMR reduced antioxidant enzyme activities (SOD, GSH, GPx) and elevated MDA levels, indicating oxidative stress; these parameters were reversed by ALA treatment.

Conclusions: Collectively, our findings demonstrate that 2.45 GHz EMR induces oxidative stress, inflammation, and testicular injury, while ALA provides significant protection. These results highlight the therapeutic potential of ALA as a protective agent against EMR-related reproductive toxicity and infertility risk.

Excerpts

The distance between the antenna and the cage centre was fixed at 39 cm, resulting in an estimated power density of ~0.6 mW/cm$^2$ at the animal location. The whole-body specific absorption rate (SAR) was calculated using standard dosimetric equations (SAR = $\sigma E^2/\rho$), yielding an estimated SAR of 0.00588 W/g. These values fall within the reported range for low-level 2.45 GHz experimental exposures in rodent studies, thereby enabling appropriate comparison with previously published EMR research....

At 2.45 GHz exposure ($\lambda \approx 12.24$ cm), the antenna-to-cage distance of 39 cm ensured far-field conditions. Local SAR values were calculated using electric field strengths (E) measured at nine predetermined points on the cage floor. Power density was derived as $S = E^2/Z_0$, and SAR was computed using SAR = $\sigma E^2/(2\rho)$, with tissue conductivity ($\sigma = 1.7$ S/m) and density ($\rho = 1040$ kg/m$^3$) adopted for muscle-equivalent tissue. The mean local SAR across the nine measurement points was 0.00588 W/kg (SD = 0.00153 W/kg; range: 0.00425–0.00890 W/kg). Since the duty cycle was 1.0, the time-averaged

SAR remained identical. Using conservative whole-body absorption parameters (η_abs = 0.5, A_proj = 35 $cm^2$), the whole-body SAR was estimated to fall within the 0.000134–0.000223 W/kg range.

Open access: https://www.mdpi.com/2227-9059/13/12/3089

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**Exposure to 5G-NR electromagnetic fields affects larval development of Aedes aegypti mosquito**

De Borre E, De Massia C, Boone MN, Müller P, Thielens A. Exposure to 5G-NR electromagnetic fields affects larval development of Aedes aegypti mosquito. Sci Rep. 2025 Dec 25. doi: 10.1038/s41598-025-32816-y.

Abstract

Telecommunication networks, including 5G New Radio (5G-NR), emit these fields and consequently expose many insects. To quantify the potential effect of RF-EMF exposure on insects, a study was designed examining the development of the Aedes aegypti mosquito, a major vector of dengue and other pathogens, as model organism exposed to RF-EMFs at 3.6 GHz. A custom exposure setup, a reverberation chamber, was designed, built, and characterized. Numerical simulations made it possible to calculate doses received by the larvae during the exposure. Larvae were reared on two feeding regimes, differing in nutritional value, and exposed for 5 days. At an RF exposure level of 46.2 V/m and absorbed power of 1.2 [Formula: see text]W, a slower development occurred, especially for weakened larvae. At an RF exposure level of 182.6 V/m and 18.7 [Formula: see text]W absorbed power, dielectric heating changed development timing and adult size.

Excerpt

The two exposure levels resulted in different effects on the insect. For the lower exposure level, no difference in wing length was found. However, a slower development occurred after exposure for 5 days of larvae fed with diluted milk to weaken them. The stronger larvae fed with Tetramin seemed not affected by the low exposure and the nutritional diet led to a faster development. At the higher exposure level, dielectric heating was observed and wing length measurements indicated smaller adults as a result of the thermal effect. The effect on development duration at this exposure level was stronger than the effect on development duration that was observed at lower exposure levels and an accelerated development was detected. Mortality and wing length asymmetry were unaffected by RF-EMF exposure.

We consider it highly likely that aquatic immature invertebrates do not encounter these RF-EMF levels that might induce developmental effects in nature. On the other hand, our study does demonstrate that it is possible to induce delayed development and dielectric heating causing thermal effects with power absorptions that can occur in terrestrial and aerial insects. To the best of our knowledge, this is the most extensive study of RF-EMF effects on insect development including dosimetry, exposure setup development and calibration, experimental biology, and statistical analysis. These results are very important because they can establish a basis for thresholds and a dose-response relationship for developmental effects of RF-EMF exposure in insects.

Open access: https://www.nature.com/articles/s41598-025-32816-y

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**Intercomparisons of computed epithelial/absorbed power density & temperature rise in anatomical human face models under localized exposures at 10 & 30 GHz**

Li K, Kodera S, Poljak D, Prokop A, Diao Y, Zhang S, Yao M, Li C, Wu T, Liebig T, Simon W, Škiljo M, Hirata A. Intercomparisons of computed epithelial/absorbed power density and temperature rise in anatomical human face models under localized exposures at 10 GHz and 30 GHz. Phys Med Biol. 2025 Dec 15. doi: 10.1088/1361-6560/ae2ce1. Epub ahead of print. PMID: 41397352.

Abstract

Objective: Epithelial/absorbed power density (EPD/APD) was recently introduced in the latest revision of international exposure guidelines as a dosimetric quantity associated with body surface temperature rise. To provide insight into their relationship, the intercomparison was organized by the IEEE Standards Coordinating Committee 95 Subcommittee 6 Working Group 5 and carried out by an international task force comprising eight governmental, academic, and industrial research institutions.

Approach: EPD/APD was evaluated for exposure from the antenna in proximity to human face models. Two high-resolution anatomical face models were used for comparison, which were extracted from anatomical whole-body models with refined resolution to ensure computational accuracy at 10 GHz and 30 GHz. The participants were encouraged to use consistent computational conditions as much as possible, such as the human model, antenna type and position, and frequency, without limitations on the averaging method of the EPD/APD, computational methods, and software for electromagnetic and thermal calculations.

Main results: Our results suggest that when appropriate averaging methods are applied, spatially averaged APD and temperature rise in realistic human face models are statistically correlated.

Significance: The analysis also revealed that the power absorption focality caused by antenna type had a more pronounced impact on variability than differences in the averaging method or anatomical modeling.

Conclusions

In previous intercomparison studies conducted under IEEE ICES TC95/SC6 WG6, the sAPD was computed using both planar and curved models, and deviations due to averaging methods were found to be relatively small compared with variations from exposure sources. In this study, a similar statistical analysis was conducted using data from eight groups based on two realistic human face models. Despite methodological differences, the overall deviation remained relatively small, and when appropriate averaging was applied, sAPD and ΔT showed a statistically significant correlation. The results further demonstrated that variability caused by antenna type was considerably larger than that due to anatomical model selection or averaging scheme. This highlights antenna configuration as the dominant factor influencing intercomparison outcomes. The findings from our intercomparison will help inform standard evaluation procedures and support the development of measurement equipment for compliance assessments in millimetre-wave bands. Furthermore, these results strengthen the scientific

basis for international exposure guidelines, particularly the application of reduction factors to ensure robust protection across populations.

https://pubmed.ncbi.nlm.nih.gov/41397352/

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**Development and Testing of a Novel Whole-body Exposure System for Investigative Studies of Radiofrequency Radiation in Rodents (NIEHS)**

Wyde ME, Capstick M, Hall SM, Hooth MJ, Kuster N, Ladbury JM, Roberts GK, Shipkowski KA, Shockley KS, Smith-Roe SL, Stout MD, Walker NJ. 2025. Development and testing of a novel whole-body exposure system for investigative studies of radiofrequency radiation in rodents. Research Triangle Park, NC: National Institute of Environmental Health Sciences. [https://doi.org/10.22427/NIEHS-RFR]

Executive Summary

The predominant source of human exposure to radiofrequency radiation (RFR) occurs through the use of cell phone handsets. Previous toxicology studies on RFR, conducted in support of the National Toxicology Program (NTP) by researchers at the National Institute of Environmental Health Sciences (NIEHS), found exposure-related effects on body temperature and DNA damage. The studies reported herein were conducted by NIEHS researchers in the Division of Translational Toxicology to better understand the biological mechanisms that produced tumor development and DNA damage in exposed rodents. These studies were not conducted as part of the NTP.

The goals of the current research were to design, construct, and use a small-scale RFR exposure system to conduct toxicological research in rats and mice. One of the primary specific objectives of this research was to test and use new, experimental methods to collect physiological data from animals in real time during RFR exposures, including assessment of body temperature and use of videos for clinical observations. Previously, such data collections were not feasible without cessation of RFR exposure.

A new RFR exposure system based on the technical parameters of the system used in the previous NTP toxicology and carcinogenesis studies was developed for small-scale investigative studies with fewer animals. The system was designed with enhanced capabilities and more flexibility, including the ability to generate additional radiofrequency (RF) signals with frequencies and modulations used in more current wireless communication technologies. After development and installation, the system was rigorously tested and independently verified before animal studies were conducted. Following completion of the mouse study, several system modifications were required before the rat studies could be conducted. These system modifications required significant technical expertise and sometimes took several months to resolve successfully.

A series of 5-day studies was conducted in male or female Sprague Dawley (Hsd:Sprague Dawley® SD®) rats or B6C3F1/N mice to evaluate the effect of exposure to the same Code Division Multiple Access (CDMA)- or Global System for Mobile Communications (GSM)-modulated RF signals used in the previous NTP studies. Video from the cameras in the exposure chambers demonstrated no visible response in either rats or mice at the first time the exposure system was activated, at subsequent system on/off transitions, or during the periods of exposure. Exposure to RFR for 5 days did not induce DNA damage in brain cells (frontal cortex, hippocampus, and cerebellum), or in liver, heart, or blood cells of rats and

mice, as measured using the comet assay. These investigative studies of RFR exposure were technically challenging to conduct and, unfortunately, measurement by two different methods did not yield data useful for assessing body temperature during exposure.

Despite a number of difficulties (i.e., engineering requirements, system modifications, measurement of body temperature during exposure), this small-scale RFR exposure system presents a prototype for investigative toxicological studies by researchers interested in conducting experimental RFR studies in rodent models. High-quality studies to understand the effects of RFR exposure on biological responses are needed given the widespread human exposure to RFR associated with cell phone use. The aim of this report is to share knowledge and facilitate advancement in research methodologies for investigating the potential health effects of RFR.

Open access report: https://www.niehs.nih.gov/sites/default/files/2025-08/cellphonerfr_long_508.pdf

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**When biology meets polarity: Toward a unified framework for sex-dependent responses to magnetic polarity in living systems**

Nelson I. When biology meets polarity: Toward a unified framework for sex-dependent responses to magnetic polarity in living systems. Electromagn Biol Med. 2026 Jan 31:1-15. doi: 10.1080/15368378.2026.2621660.

Abstract

The human body emits a bioelectromagnetic field primarily generated by the electrical activity of the heart, with additional contributions from the brain, muscles, and peripheral nerves. These endogenous fields are not isolated and can be modulated by external electromagnetic and magnetic influences. Current evidence suggests that the main mechanisms underlying such interactions include modulation of ion channels, radical pair dynamics, and ion cyclotron resonance. Several studies report sex-specific differences in responses to magnetic exposure. The main factors implicated in these differences include heart orientation and position, heart mass, tissue conductivity, hormonal modulation, autonomic balance, and cortical field organization. Beyond sex, consistent findings demonstrate that biological effects depend not only on field intensity and frequency but also on polarity (north/south), and direction (vector angle). These parameters are often overlooked or unreported in published works. Some observations even suggest a direct relationship between polarity and sex, with divergent physiological and behavioral outcomes. Recognizing these interactions is crucial to refining models of magnetoreception, resolving inconsistencies, and advancing therapeutic applications of electromagnetic fields. This review integrates evidence from magnetobiology and sex-based physiology to propose that hormonal and structural dimorphism may modulate biological responses to magnetic field. Potential mechanisms involving ion-channel modulation, magnetite orientation, and radical-pair dynamics are outlined and experimental paradigms to test these interactions are proposed. Together, these insights establish a framework for studying sex-dependent magnetic sensitivity in living systems.

https://pubmed.ncbi.nlm.nih.gov/41618935/

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**The effects of electrical stimulation on neurons and glia of the central nervous system**

Devlin J, Gilbert RJ. The effects of electrical stimulation on neurons and glia of the central nervous system. J Neural Eng. 2025 Dec 19. doi: 10.1088/1741-2552/ae2f9c.

Abstract

This review paper focuses on how both direct current (DC) stimulation and alternating current (AC) stimulation affects the central nervous system's (CNS) cells and its potential as a neurotherapeutic. Furthermore, addressing the promise of combinatorial approaches that utilize other treatments alongside electrical stimulation (ES) and how ES has shaped clinical approaches as a new rehabilitation treatment.

Approach: Authors conducted this review to bridge the gap between basic research and clinical translation; 124 manuscripts were identified through Google Scholar for insights into ES effects on neurons and glia in both in vitro and in vivo models.

Main Results: The review summarizes findings from DC and AC stimulation paradigms applied to in vitro or in vivo preclinical models and summarizes the promise of ES when applied clinically. Generally, DC stimulation promotes axonal extension towards the cathode, while axons retract at the anode, limiting regeneration. AC stimulation alternates electrode polarity, enabling axonal extension in both directions. The intensity and duration of ES significantly affects the extent of neurite outgrowth. For astrocytes and microglia, ES-whether AC or DC-downregulates pro-inflammatory cytokine production and upregulates anti-inflammatory cytokine production, promoting A2 or M2 reactive states conducive to regeneration, respectively. Regarding oligodendrocyte precursor cells (OPCs), both DC and AC stimulation enhance OPC differentiation into oligodendrocytes, increasing myelin content and supporting axonal myelination. ES, when combined with stem cell treatments, drug delivery approaches, or with electroactive biomaterials, facilitate greater efficacy of these approaches. Clinically, short-single sessions of ES have shown long-term improvement. More specifically, preliminary efforts have been implemented to restore gait, hand tremors, and speech in spinal cord injuries, Parkinson's Disease, and stroke patients, respectively.

Significance: ES is an evolving neurotherapeutic strategy for CNS related disease or injuries. Understanding how ES modulates neurons and glia is critical for optimizing its application in the clinic.

https://pubmed.ncbi.nlm.nih.gov/41418406/

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**The Effect of High-Voltage Power Lines on Magnetic Orientation of Domestic Dogs**

Iakovenko NS, Benediktová K, Adámková J, Hart V, Brinkeová H, Ježek M, Kušta T, Hanzal V, Nováková P, Burda H. The Effect of High-Voltage Power Lines on Magnetic Orientation of Domestic Dogs. Animals (Basel). 2025 Dec 8;15(24):3534. doi: 10.3390/ani15243534.

Abstract

Domestic dogs can sense the geomagnetic field (GMF), spontaneously aligning their bodies along its axis, altering the alignment's pattern during geomagnetic disturbances. Whether anthropogenic magnetic fields (MF) from high-voltage power lines (PL) influence this behavior remains unclear. We investigated the effects of alternating MF generated by PL on spontaneous magnetic alignment in 36 dogs. Behavior

was recorded under north-south (NS) and east-west (EW) oriented PL and compared with control conditions lacking anthropogenic MF. Each dog's mean alignment angle relative to magnetic north was calculated from >50 measurements per condition, and Grand Means (GMs) were derived. Under control geomagnetically calm conditions, alignment was bimodal (GM = 23°/203°), while geomagnetic storms caused significant shifts and increased angular dispersion. Under NS-oriented PL, alignment remained bimodal (GM = 5°/185°), but under EW-oriented PL it became trimodal (Likelihood ratio test for multimodality: nodes = 3, $p = 0.042$; GM = 103°/283°). These differences were statistically significant (LME for linearized angles: $p < 0.001$ for control vs. NS PL and control vs. EW PL). Our results demonstrate that dogs maintain directional alignment under PL exposure, with orientation patterns corresponding to the direction of both MF and PL, which suggests a potentially complex impact involving non-magnetic cues.

Simple Summary

Domestic dogs have been reported to sense the Earth's magnetic field, aligning their bodies along its axis and altering this alignment during geomagnetic disturbances. Building on previous findings in cattle and deer, we tested whether high-voltage power lines disrupt directional alignment in dogs, presumably by interfering with a magnetoreceptive system tuned to the geomagnetic field. Contrary to our expectations, dogs still exhibited axial alignment under the power lines. However, both the direction and pattern of their alignment shifted markedly directly under the power line wires. Our results suggest that, rather than simple disruption, power lines may induce a complex interplay of magnetic and non-magnetic cues modulating dogs' orientation behavior.

Open access: https://www.mdpi.com/2076-2615/15/24/3534

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**Biological responses to 30 mT static magnetic field in young and 36-month-old rats**

Jovanović M, Ille M, Vuković A, Milovanovich ID, Mitić D, De Luka SR. Biological responses to 30 mT static magnetic field in young and 36-month-old rats. Electromagn Biol Med. 2026 Jan 19:1-9. doi: 10.1080/15368378.2026.2617536.

Abstract

This study aimed to investigate the effects of subchronic exposure to a 30 mT static magnetic field (SMF) on hematological parameters, spleen and tibia cellularity in 36-month-old and young rats. A total of 27 rats were divided into four groups (Young, Young SMF, Old, Old SMF) and two groups were exposed to SMF for 10 weeks. After exposure period, blood counts, neutrophil-to-lymphocyte ratio (NLR, an index of systemic inflammation), platelet-to-lymphocyte ratio (PLR, a platelet-based inflammatory marker) and cellularity of immune-related organs were analyzed. SMF exposure reduced lymphocyte counts and increased NLR in both age groups, while PLR increased only in young rats. In 36-month-old rats, SMF significantly reduced platelet counts, whereas this effect was not observed in young animals. SMF exposure also enhanced tibial and splenic cellularity in both groups but exerted opposite effects on the proportions of lymphocytes and erythrocytes depending on age. These findings suggest age-dependent immune modulation by SMF. In young animals, SMF likely promoted a proinflammatory shift, reflected by elevated NLR and PLR. In contrast, in 36-month-old rats, SMF may act as a nonspecific physiological stressor, potentially triggering the General Adaptation Syndrome (three-stage stress response), leading

to corticosterone-mediated immunosuppression and cell redistribution. To our knowledge, this is the first study demonstrating age-dependent differential modulation of NLR and PLR by subchronic SMF exposure, linking proinflammatory shifts in youth with stress-related immunosuppression in aging. Overall, age appears to be a critical factor in determining the biological responses to SMF, underscoring the need for age-specific evaluation of SMF exposure.

Plain Language Summary

This study examined how a 30 mT static magnetic field affects blood and immune cells in very old and young rats over 10 weeks. The old rats were about 36 months old, roughly equal to 80 human years. All animals were treated humanely following animal welfare rules. Blood, bone marrow and spleen samples were taken under deep anesthesia to avoid pain, and animals were euthanized humanely at the end. We measured blood cells and calculated two important markers: NLR (neutrophil-to-lymphocyte ratio) and PLR (platelet-to-lymphocyte ratio). In 36-month-old rats, the magnetic field lowered platelets, which may reduce the risk of blood clots. It also reduced lymphocytes and increased NLR in both young and 36-month-old rats. PLR increased only in young rats, suggesting a higher clot risk and more inflammation in young animals compared to old ones. The magnetic field also increased bone marrow cellularity in old rats, which may improve blood flow and nourish bones better. Overall, the magnetic field impacts the immune system differently by age. In young rats, it causes more inflammation and possibly higher clot risk. In 36-month-old rats, it acts like mild stress, triggering hormones that reduce excessive immune activity, lowering inflammaging and clot risk. These findings show that age is very important when studying how magnetic fields affect living beings. Future research and medical uses of magnetic fields should consider the age of the person or animal involved.

https://pubmed.ncbi.nlm.nih.gov/41550064/

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**Inhibition of mitochondrial NADH:ubiquinone oxidoreductase by spinning oscillating magnetic fields causes toxicity in cancer cells**

Hambarde S, Pandey A, Baskin DS, Helekar SA. Inhibition of mitochondrial NADH:ubiquinone oxidoreductase by spinning oscillating magnetic fields causes toxicity in cancer cells. FEBS Lett. 2026 Jan 9. doi: 10.1002/1873-3468.70271.

Abstract

A newly developed noninvasive Oncomagnetic device (OMD) causes selective cytotoxicity in glioblastoma and diffuse intrinsic pontine glioma cells, providing a novel, non-toxic approach to anticancer therapy. Here, we report results in cultured glioma cells and in a syngeneic mouse model indicating that the immediate intracellular target mechanism of action of the spinning oscillating magnetic field (sOMF) produced by this device is reactive oxygen species-dependent persistent inhibition of mitochondrial complex I. Steps downstream of this mechanism involve the production of oxidative stress, DNA damage, G1 phase cell cycle arrest, and caspase-dependent apoptosis. We also show that sOMF does not produce these effects in normal human astrocytes and astroglial cells. These data provide a rationale for safe clinical use of OMD.

https://pubmed.ncbi.nlm.nih.gov/41510612/

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**Electric and Magnetic Field Technologies in Agriculture: Plant Responses, Experimental Limitations, and Future Directions**

Zhang Y, Baldos O, Kim J, Yuan X, Ahmad A, Li QX, Idol T, Nguyen H. Electric and Magnetic Field Technologies in Agriculture: Plant Responses, Experimental Limitations, and Future Directions*/ ACS Agricultural Science & Technology. doi*: 10.1021/acsagscitech.5c00865

Abstract

All living organisms on Earth are naturally exposed to planetary electromagnetic fields, which interact with biological processes in various ways. In agriculture, applications typically employ these fields separately through distinct technologies and methodologies. Electric and magnetic fields are inherently linked, as each can generate the other when the fields are dynamic. Despite growing research interest in both fields, no review has systematically described their effectiveness and mechanisms of plant growth and development. This Review provides a theoretical, technological, and practical comparison of electric and magnetic field effects on plant systems and proposes a model clarifying the mechanistic convergence of both fields. Four predominant mechanisms have been suggested: (a) changes in membrane permeability, (b) reactive oxygen species production and antioxidant response, (c) improvements in ion absorption and transport, and (d) DNA alterations and gene expression patterns. Applications of both fields can extend beyond simple seed treatment to various applications for real-world crop production.

https://doi.org/10.1021/acsagscitech.5c00865

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**Flora and fauna: how nonhuman species interact with natural and man-made EMF at ecosystem levels and public policy recommendations**

Levitt BB, Lai HC, Manville III AM, Scarato T. Flora and fauna: how nonhuman species interact with natural and man-made EMF at ecosystem levels and public policy recommendations. Front. Public Health, 18 November 2025. Volume 13. 2025. doi:10.3389/fpubh.2025.1693873.

Abstract

In the last 60 years, there has been a steady increase in ambient exposures from nonionizing electromagnetic fields (EMF) between 0 and 300 GHz, primarily in the radiofrequency (RF) ranges between 30 kHz and 3 GHz. Each technology has introduced a layer of exposures with different transmission characteristics into the environment, creating what is today a broad scope of complex chronic, low-intensity, ambient exposures known to be biologically active in human and nonhuman species alike. The next generation of broadband technology employs a wide span of simultaneous frequency exposures for pervasive civilian use with signaling characteristics heretofore never deployed. Fifth and sixth generation (5G, 6G) networks utilize significantly higher areas of the electromagnetic spectrum >3.5 GHz unlike previous wireless technologies. The scale at which this EMF deployment unfolded has now reached documented proportions that simply do not exist in nature, creating 24/7

exposures to a novel energetic form of air pollution. While there are extensive local variations in exposure intensities, e.g., rural versus urban environments with proximity to transmission sources being the controlling variable, the advent of significantly increased satellites in low earth orbits, disseminating radiofrequency EMF (RF-EMF) toward Earth in broad radiation patterns, has now all but erased such demographic distinctions. Nowhere on Earth today is completely RF-EMF free. Nonhuman species are highly sensitive to the Earth's geomagnetic fields which are used for orientation, migration, mating, food finding, territorial defense, and all of life's activities. Compared to human abilities, myriad species have evolved an exceptionally sensitive physical array of electro/magneto-receptors with which to perceive environmental EMF often at, or very near, natural geomagnetic fields. Today's exposures are capable, even at very low intensities, of disrupting critical fauna/flora functions. Any existing exposure standards are strictly for humans. Discussed are nonhuman unique physiologies and potential resonant matches at ambient levels today. Policy recommendations for wildlife protection includes discussion of "airspace as habitat," adherence to existing laws, and mitigation that could include frequency re-allocation, redesign of hardware and network engineering, and societies moving away from certain competitive economic models, as well as EMF-free zones during migration and breeding seasons where possible.

Open access: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1693873/full

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**Causal relationship between duration of mobile phone use and risk of aneurysmal subarachnoid hemorrhage: A 2-sample Mendelian randomization analysis**

Gao W, Jiang X, Lin Q, Ye L, Huang X, Xiong Y, Guo X, Zheng H, Ke C, Hu W, Zheng F. Causal relationship between duration of mobile phone use and risk of aneurysmal subarachnoid hemorrhage: A 2-sample Mendelian randomization analysis. Medicine (Baltimore). 2025 Nov 21;104(47):e46053. doi: 10.1097/MD.0000000000046053.

Abstract

This study investigates whether the duration of mobile phone use (DMPU) is causally associated with the risk of aneurysmal subarachnoid hemorrhage (aSAH). We pooled data from publicly available genome-wide association studies. DMPU was assessed in European populations (n = 456972), and genome-wide association studies data on patients with aSAH were obtained from the Common Metabolic Disease Knowledge Portal (total n = 337159; cases = 7480; controls = 329679). Inverse-variance weighted was applied as the primary Mendelian randomization (MR) method, and 2-sample MR analyses with sensitivity tests were performed. Twenty-three single nucleotide polymorphisms reaching genome-wide significance were selected as instrumental variables for DMPU. Inverse-variance weighted analysis suggested a causal relationship between excessive DMPU and increased risk of aSAH (odds ratio [OR] = 2.20; 95% confidence interval: 1.26-3.83; P = .006). MR-Egger regression indicated that directional pleiotropy was unlikely to bias the results (OR = 12.93; 95% confidence interval:1.15-145.31; P = .051). The weighted median method supported the causal relationship between excessive DMPU and increased risk of aSAH (OR = 2.48; 95% Cl: 1.17-5.24; P = .018). The Cochrane Q test and funnel plot showed no heterogeneity or asymmetry, confirming the robustness of the findings. This study provides evidence supporting a causal relationship between DMPU and aSAH. Excessive mobile phone use may increase the risk of aSAH, with important implications for clinical practice, public health, and policy

Plain language summary

This study explored whether using mobile phones for long periods is linked to a higher risk of aneurysmal subarachnoid hemorrhage (aSAH), a type of brain bleed. Researchers analyzed genetic data from large European studies and found that excessive mobile phone use might indeed increase the risk of aSAH. They used Mendelian randomization, a method that helps determine causal relationships, and found consistent results across different analyses. The findings suggest that heavy mobile phone use could be a risk factor for aSAH, which has significant implications for healthcare practices and public health policies.

Key Points

• This study uses MR methods to examine a potential causal association between the DMPU and aneurysmal subarachnoid hemorrhage risk using genome-wide association study datasets.

• Our study demonstrates that excessive DMPU may be causally associated with an increased aneurysmal subarachnoid hemorrhage risk. We believe that our study makes a significant contribution to the literature because we are the first to use 2-sample MR methods to reduce the bias associated with observational studies and to identify causal relationships.

• We believe that this paper will be of interest to the readership of your journal because our data provides the evidence required to develop clinical and public health policies and provides rationale for longitudinal and experimental studies investigating the mechanisms behind the causality.

Open access: https://journals.lww.com/md-journal/fulltext/2025/11210/causal_relationship_between_duration_of_mobile.40.aspx

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**Personal radio use and risk of cancers among police officers in Great Britain: Results from the airwave health monitoring study**

Di Gravio C, Elliott P, Muller DC. Personal radio use and risk of cancers among police officers in Great Britain: Results from the airwave health monitoring study. Int J Cancer. 2025 Nov 18. doi: 10.1002/ijc.70255.

Abstract

Exposure to radiofrequency electromagnetic fields (RF-EMF) from mobile phones and other wireless devices has been classified as possibly carcinogenic to humans. With data from 48,457 police officers and staff enrolled in the Airwave Health Monitoring Study, we investigated associations between personal radio use and the risk of developing cancer using Cox proportional hazard regressions. Personal radio use and duration of use were derived by combining objective data on call duration provided by the Home Office and participants' self-reported data via gradient boosting methods. Across a median follow-up time of 11 years, there were 1502 incident cancer cases of which 146 were cancers of the head, neck and central nervous system (CNS). There was no association between personal radio use, all cancers (hazard ratio [HR] = 0.96, 95% confidence interval [CI]: 0.79, 1.15) and head, neck, and CNS cancers (HR = 0.74, 95% CI: 0.39, 1.38). Doubling minutes of call duration via personal radio use was not associated with increased hazard of developing all cancers (HR = 1.00, 95% CI: 0.96, 1.04) or head, neck and CNS

cancers (HR = 1.09, 95% CI: 0.97, 1.22). Results were similar when considering exposure to RF-EMF via mobile phone use as well as when restricting the analyses to police officers only.

What's New?

Terrestrial trunked radio (TETRA) is the standard digital communication system used by police and other emergency services in Great Britain. During active use, TETRA emits radiofrequency electromagnetic fields, which are potentially carcinogenic in humans. Here, using data on objective call duration, the authors examined cancer risk from personal radio use among police forces across Great Britain. No significant association was detected between radio use, call duration, and cancer risk.

Excerpts

There was no association between personal radio use and the risk of developing cancer. Compared to participants who did not use a personal radio, users had 4% (HR: 0.96, 95% CI: 0.80, 1.16), 26% (HR: 0.74, 95% CI: 0.39, 1.38) and 17% (HR: 0.83, 95% CI: 0.29, 2.40) lower hazard of developing all cancers, head, neck and CNS cancers, and brain cancer and meningeal tumours respectively. Overall, monthly call duration in the year before recruitment was not associated with cancer risk; however, results in Table 2 suggest a potential—although not statistically significant—9% higher risk of developing head, neck and CNS cancers (HR: 1.09, 95% CI: 0.97, 1.22) when doubling minutes of monthly call duration. There was no evidence of a non-linear association between call duration and cancer risk (Figure 2 and Table S3). Compared to participants with an average of 8.15 minutes of monthly call duration (equivalent to the observed median call duration), those in the 90th percentile (averaging 92.8 minutes per month) had a 9% higher risk of developing all cancers (HR: 1.09, 95% CI: 0.92, 1.51), a 40% (HR: 1.40, 95% CI: 0.85, 2.23) higher risk of developing head, neck and CNS cancers and a 4% (HR: 1.04, 95% CI: 0.45, 2.39) higher risk of developing brain cancers and meningeal tumours. In contrast, participants who did not use a personal radio (i.e., those in the 25th percentile or lower with zero minutes of call duration) had an 18% (HR: 1.18, 95% CI: 0.82, 1.51) higher risk of all cancers, a 15% (HR: 0.85, 95% CI: 0.38, 1.92) lower risk of head, neck and CNS cancers, and a 41% (HR: 0.59, 95% CI: 0.14, 2.45) lower risk of brain cancers and meningeal tumours. There was no evidence that the frequency of personal radio use without an earpiece/microphone modified the association between call duration and risk of cancer (Table S4). Results were similar when we restricted our sample only to police officers who were cancer-free at recruitment (N = 31,263). There were no discernible associations between mobile phone use and cancer risk (Table S5)....

In conclusion, we found no evidence of an association between TETRA use and risk of cancer. Whilst the results from the linear and non-linear models cannot exclude a modestly greater risk with higher TETRA usage, the wide confidence intervals are consistent with both substantially increased and substantially decreased risks, and thus a definite conclusion cannot be reached. Longer follow-up time would give us the opportunity to accrue more cancer cases, increase precision of estimated risks, ease the interpretation of the results, and analyse whether specific groups of participants have higher risk of developing cancer.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/ijc.70255

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**Radiofrequency radiation from mobile phones and the risk of breast cancer: A multicenter case–control study with an additional suspected comparison group**

Tahmasebi S; Mortazavi SMJ, Pourghayoomi M; Sheikhzadeh P; Welsh JS et al.. Radiofrequency radiation from mobile phones and the risk of breast cancer: A multicenter case–control study with an additional suspected comparison group. Journal of Research in Medical Sciences 30(1):63, November 2025. | DOI: 10.4103/jrms.jrms_679_25

Abstract

Background: The rapid global increase in mobile phone use has raised concerns about the potential long-term health effects of radiofrequency electromagnetic fields. While most studies have focused on brain tumors, evidence regarding breast cancer remains limited. The objective of the study is to examine the association between mobile phone use and breast cancer risk among women in Iran.

Materials and Methods: In this multicenter case–control study, 226 women were recruited from diagnostic, mammography, and radiotherapy centers across Iran and classified as controls (no history of breast cancer, n = 97), suspected cases (advised to undergo mammography due to breast-related complaints or physician recommendation, n = 52), and confirmed cases (histologically verified invasive breast cancer, n = 77). Structured questionnaires collected demographic, reproductive, lifestyle, and environmental data, including mobile phone call duration, screen time, and phone placement. Associations were analyzed using multinomial logistic regression, adjusting sequentially for demographic, reproductive, environmental, and lifestyle variables.

Results: In fully adjusted models, women reporting more than 60 min of daily mobile phone conversations had higher odds of confirmed breast cancer (odds ratio [OR] = 3.49, 95% confidence interval [CI]: 1.02–11.97) and suspected status (OR = 10.84, 95% CI: 2.29–51.41) compared with those using phones <10 min daily. Longer screen time (>4 h/day), later age at menarche, lower education level, and exposure to environmental pollutants were also associated with increased odds.

Conclusion: Prolonged mobile phone use was associated with higher odds of breast cancer, but this does not imply causation. Given self-reported exposures and potential residual confounding, findings should be interpreted cautiously. Larger prospective studies with objective exposure assessment are warranted.

https://journals.lww.com/jrms/fulltext/2025/11290/radiofrequency_radiation_from_mobile_phones_and.63.aspx

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**No Measurable Impact of Acute 26 GHz 5G Exposure on Salivary Stress Markers in Healthy Adults**

Michelant L, Hugueville L, Lévêque P, Selmaoui B. No Measurable Impact of Acute 26 GHz 5G Exposure on Salivary Stress Markers in Healthy Adults. Environ Res. 2025 Nov 27:123439. doi: 10.1016/j.envres.2025.123439.

Abstract

The rapid deployment of fifth generation (5G) wireless networks has raised concerns about potential health effects associated with exposure to novel radiofrequency electromagnetic field (RF) frequencies, particularly the 26 GHz band which represents a new exposure scenario for the general population with limited prior use in telecommunications. However, evidence regarding the acute biological impact of these exposures remains limited and inconclusive. This study aimed to assess whether short-term exposure (26.5 minutes) of healthy adults to 5G RF at 26 GHz, at levels representative of real-world environmental conditions, affects salivary cortisol and alpha-amylase, two established biomarkers of stress and autonomic nervous system activity. Thirty-one participants completed a triple-blind, randomized protocol with electroencephalography recordings. A subset of sixteen participants from this group also participated in an exploratory protocol with cognitive testing and higher temporal sampling resolution (5minute intervals). Saliva samples were collected before, during, and after exposure in both protocols. RF exposure was delivered via a horn antenna at 2 V/m (head) and 1 V/m (torso), in line with upper-range environmental measurements. Statistical analyses revealed no significant differences in salivary cortisol or alpha-amylase concentrations between real and sham exposures. Descriptive examination of the exploratory cognitive protocol, with higher temporal sampling resolution, showed consistent temporal stability of both biomarkers in both conditions. These findings suggest that acute 5G RF exposure at 26 GHz, under controlled and realistic conditions, does not elicit measurable changes in stress biomarkers. Further research is warranted to evaluate the effects of repeated or long-term exposures and to investigate potential impacts in vulnerable populations.

Highlights

- A 26.5 min 5G exposure at 26 GHz had no effect on salivary cortisol levels.
- No changes were observed in alpha-amylase levels in healthy adult participants.
- The study design allowed rigorous control of potential confounding variables.
- Findings suggest absence of acute stress effects from 26 GHz 5G exposure.
- Further research is needed on long-term effects and on different populations.

https://pubmed.ncbi.nlm.nih.gov/41317834/

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**Definition and Validation of an Exposure Measurement Method for a Typical Load of a Base Station**

Schiffarth AM, Ta TJ, Bornkessel C, Schilling LM, Hein M, Heberling D. Definition and Validation of an Exposure Measurement Method for a Typical Load of a Base Station. Bioelectromagnetics. 2025 Dec;46(8):e70029. doi: 10.1002/bem.70029.

Abstract

In the context of risk communication in mobile radio, a discussion has emerged whether exposure at common load of a base station should be presented in addition to the theoretical maximum, especially with 5G massive-MIMO. However, a reproducible measurement method for instantaneous exposure independent of the utilization of the cell has yet to be developed. To fill this gap, 10 mobile phone use

cases were identified, the corresponding data rates were measured and categorized into low (20 Mbps), medium (200 Mbps), and high (600 Mbps) data rates to generate a typical base station load. A measurement method was developed, using iPerf on a user equipment to generate the data rates at a measurement point, while a channel power measurement is used to determine the exposure of all mobile radio services installed. The method was validated at four base stations, considering various factors such as reproducibility in relation to the number of users in the cell, averaging time, and application buffering. The results show the reliability of the method across different times of day and base station loads and that averaging over 30 sweeps provides reproducible exposure results. Consequently, this study presents a validated approach for measuring typical instantaneous exposure in real-world mobile network conditions.

Excerpt

A comparison between the instantaneous exposure of an actual application and the instantaneous exposure, when the corresponding constant data rate is provoked using iPerf, revealed that, overall, in only 5 out of the 48 cases examined, a higher deviation than the expanded uncertainty was observed in the comparison of the 5G exposures. Regarding the total exposure, a deviation of more than 3 dB was determined in only two of these cases. It thus follows that maintaining a constant data rate in iPerf is equivalent in terms of instantaneous exposure compared to typical usage scenarios, regardless of whether user data is buffered or not.

In summary, the studies presented here demonstrate the feasibility of measuring an instantaneous exposure at a typical base station load using the measurement method outlined, and subsequently outputting it for risk communication, in addition to the maximum possible exposure at each measurement point.

In the future, the integration of this measurement method for typical load conditions into the IEC 62232:2022 standard (International Electrotechnical Commission [IEC] 2022) could be discussed, as a method for deriving typical loads is already proposed there. In its present version, it mentions in-situ measurements taken during regular network operation over a longer period of time without provoking a load condition. Additionally, exposure under a typical load condition is to be determined while streaming a video, livestreaming, or downloading a 1 GB data file. A consistent, reproducible measurement method by provoking a data rate over a relatively short period would be a useful addition.

Open access: https://pmc.ncbi.nlm.nih.gov/articles/PMC12579388/

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**Evidence on RF-EMF and cancer in animals misjudged: methodological and analytical flaws in the Mevissen et al. systematic review**

Karipidis K, Sean Hewson S, Mate R, Bhatt C, Henderson S, Peyman A, Loughran S. Evidence on RF-EMF and cancer in animals misjudged: methodological and analytical flaws in the Mevissen et al. systematic review. Environment International, 2025, doi: 10.1016/j.envint.2025.109961.

No abstract

Open access: https://www.sciencedirect.com/science/article/pii/S0160412025007123

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Methodologically solid and analytically rigorous: the evaluations of our systematic review on RF-EMF and animal cancer are reliable

Mevissen M, Ducray A, Ward JM, Kopp-Schneider A, Rivero TM, Straif K. Methodologically solid and analytically rigorous: the evaluations of our systematic review on RF-EMF and animal cancer are reliable. Environment International, 2025, doi: 10.1016/j.envint.2025.109962.

No abstract.

Open access: https://www.sciencedirect.com/science/article/pii/S0160412025007135

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**NTP Lite: The Japan–Korea Collaborative RF Exposure Toxicity Project [Health Matters]**

Lin JC. NTP Lite: The Japan–Korea Collaborative RF Exposure Toxicity Project [Health Matters]. IEEE Microwave Magazine, vol. 26, no. 12, pp. 16-17, Dec. 2025, doi: 10.1109/MMM.2025.3605069.

No abstract

The U.S. National Toxicology Program (NTP) reported findings of clear evidence that lifelong exposure to low-level RF radiation caused cancers in laboratory rats in 2018 [1]. It showed that RF radiation used for wireless telecommunication devices and systems was the cause for the observation of two cancers—gliomas in the brain and schwannoma inside the heart of male rats. The reported temperature rise induced by RF exposure in the animal's body did not exceed 1 °C at the highest exposure [specific absorption rate (SAR) = 6 W/kg]. Shortly thereafter, in the same year, the findings were confirmed by a Ramazzini Institute study from Italy [2]. Since then, a follow-up project had commenced in late 2020 through a formal collaboration between Japan and Korea. The two-year animal exposure phase was completed in December 2022 [3], [4]. At this moment, the final report for "NTP Lite" is already two years late and the earliest prospect of completing it is at least another year away [5].

The closely coordinated but independently conducted project involves laboratories from two different countries. The project employed the same custom-designed RF exposure system reverberation chamber (RC)— and applied the same study protocol, with Sprague-Dawley rats from the same breeder. The experimental animals were not restrained in order to avoid the commonly known stress factor from such practices that could potentially confound the results. An important performance feature for an RC is uniformity of the electric field or power density distribution. In this case, the distribution was evaluated at 900 MHz using 150 measurement points both in an empty and a loaded chamber.

Nevertheless, the coordinated projects are not distinctive either as a confirmation or replication of the NTP rat study. It is a scaled-down version with a single exposure level at a whole-body SAR of 4 W/kg, instead of the NTP's SARs ranging from 1.5, 3.0, to 6.0 W/kg. An SAR of 4 W/kg is lower than 6 W/kg. Given that an SAR of 4 W/kg is the basic restriction in the currently promulgated ICNIRP guidelines [7] and IEEE-ICES standards [8] for safe exposure, perhaps, it represents a subtle attempt to reaffirm the status quo for the current exposure limits. It is noteworthy that, if so, even in the event of a negative result of no cancer from the collaborative project, it would not be in any position to challenge the

impact of NTP evidence of gliomas and schwannomas at 6 W/kg. An SAR of 4 W/kg is one-third lower than 6 W/kg. That's a very thin margin for safety given the vagaries of biological variabilities and uncertainties of microwave power density or SAR measurements in practice.

The International Agency for Research on Cancer (IARC) has been waiting for the project results before embarking on an update of its assessment of RF–cancer risks. While the wait may seem prudent, in effect, the December 2025 17 outcome of the narrow scope of NTP-Lite would likely have limited influence on the IARC's deliberations on the carcinogenicity of RF exposure. Simply put, the outcome of the Japan–Korea NTP-Lite project is unlikely to dissolve the NTP cancer findings of clear evidence for RF exposure in laboratory rats. On the contrary, it is conceivable that a positive result for RF carcinogenesis would oblige IARC to elevate its cancer risk classification from its current "possibly cancer causing" to the next level of "probably cancer causing," or to directly to its highest level of classification as a "carcinogen" for RF exposure. In any case, the NTP- Lite RF rat cancer project has been hit by several delays. The project's data evaluation has been in progress for more than two years since the completion of the RF-exposure phase of the project. It is obviously behind schedule. Indications are that the histopathological and genotoxicity examinations are currently underway. However, publication of the study results is not expected any time soon.

Complications revealed by available reports [6], [7] from the experiments include RF-exposed rats in Japan had significantly different body mass and food consumptions than control animals, however, without any specific details. Also, the Korean part of the collaborative research disclosed the accidental death of four of the RF-exposed rats. The reason for the four deaths was not released. The rats died in the RF–chamber, on two separate days, about three months into the exposure. Note that reports on the carcinogenicity of cellphone RF radiation have been controversial [10], [11]. Many of the reported studies are limited and imperfect and have encountered skepticism. The investigations are multidisciplinary in nature. It is often complicated and can be subtle to appreciate the important features, facts, or theories from another discipline. Many of the older studies employed RF exposure systems and measurement instrumentations that did not allow or were unable to ascertain the specific and relevant local expo- sure conditions of the animal subjects.

A recent systematic review of the effects of RF exposure on cancer in experimental animals [12] included all 52 reported studies employing 20 chronic bioassays to minimize the possibility of selection bias. Elevations in incidence or risk of two tumor types were identified in the systematic review. Specifically, an increase in glial cell-derived brain cancer (glioma) was observed in two life-long bioassays in male rats. The certainty of the evidence for an increased risk in glioma was judged as high. Also, in three chronic bioassays, statistically significant increases in malignant schwannomas were demonstrated as high in the heart of male rats. While this conclusion is in opposition to the interpretations of ICNIRP [7] and IEEE-ICES [8], it is consistent with the laboratory animal findings of NIH-NTP [1], Falcioni et al. [2], and Brooks et al. [13].

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**Acoustic Pressures in the Head From Pulsed Microwaves: Can They Explain "Anomalous" Health Incidents? (Havana syndrome)**

Foster LR, Diao Y, Chou C. -K. Acoustic Pressures in the Head From Pulsed Microwaves: Can They Explain "Anomalous" Health Incidents? IEEE Microwave Magazine. 2025. doi: 10.1109/MMM.2025.3624334.

Abstract

The microwave auditory effect—referring to "clicks" or "buzzing" sensations that a person experiences when their head is exposed to pulsed microwave energy such as emitted by radar transmitters—has been known since the 1960s. Formerly a threshold hearing phenomenon, the effect has gained renewed interest due to the advent of high-powered microwave sources in recent decades. Over the past decade, some experts and expert panels have implicated the effect as a cause of "anomalous health incidents," often but not exclusively to U.S. Government employees stationed in unfriendly countries. Can the microwave auditory effect explain such events?

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11251469&isnumber=11122301

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**Millimeter-wave high frequency 5G (26 GHz) electromagnetic fields do not modulate human brain electrical activity**

Michelant L, Baz T, Carrie A, Hugueville L, Lévêque P, Selmaoui B. Millimeter-wave high frequency 5G (26 GHz) electromagnetic fields do not modulate human brain electrical activity. Environ Res. 2025 Nov 18:123349. doi: 10.1016/j.envres.2025.123349.

Abstract

The deployment of 5G networks utilizing millimeter-wave frequencies such as 26 GHz has raised concerns about potential neurophysiological effects. However, no controlled studies have investigated the impact of 26 GHz exposure on human brain electrical activity. We conducted a randomized, triple-blind crossover study in 31 healthy young adults (18 men, 14 women, mean age 26.1 ± 5.2 years). Participants underwent two sessions (real and sham exposure) separated by one week, with 26.5-minute exposure to 26 GHz electromagnetic fields at 2 V/m. EEG activity was recorded before, during, and after exposure. Power spectral density was computed for delta (1-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), and beta (12-35 Hz) frequency bands. Statistical analysis employed mixed-effects models with baseline correction, examining exposure effects across temporal phases and electrode clusters. No significant modulation of EEG frequency bands was observed during eyes-closed conditions following 26 GHz exposure. Mixed-effects modeling revealed no significant main effects or interactions for exposure conditions across all frequency bands and electrode clusters. This first controlled investigation of 26 GHz 5G effects on human EEG activity found no detectable alterations in brain electrical activity under regulatory-compliant exposure conditions. These findings contribute important preliminary safety data

for 5G millimeter-wave technology deployment, though further research across diverse populations and exposure scenarios remains warranted.

https://pubmed.ncbi.nlm.nih.gov/41265672/

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**Assessment of Electromagnetic Field Exposure from Multiple Sources Simultaneously in the High-Frequency Range Based on Safety Standards**

Chutchavong V, Aroonmitr P. Assessment of Electromagnetic Field Exposure from Multiple Sources Simultaneously in the High-Frequency Range Based on Safety Standards. 2025 SICE Festival with Annual Conference (SICE FES), Chiang Mai, Thailand, 2025, pp. 1234-1238, doi: 10.23919/SICEFES67750.2025.11236585.

Abstract

This study presents a method for evaluating electromagnetic field (EMF) exposure from multiple sources operating simultaneously across a wide range of frequencies, based on the guidelines defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in its 2020 publication. The proposed approach adopts the normalized exposure ratio, which combines the exposure values from all relevant sources and frequency bands. A key issue addressed in this study is the lack of standardized measurement methods for absorbed power density (Sab) in high frequency bands above 10 GHz, despite the existence of defined exposure limits. A comparison reveals that the difference between the limits for Sab and incident power density (Sinc) for the general public is relatively small when compared to the gap between the general public and occupational exposure limits. Therefore, the use of Sinc is proposed as a temporary surrogate for Sab in frequency ranges where direct measurement is not yet feasible. This approach enables comprehensive exposure assessment from multiple sources under both near-field and far-field conditions. It also serves as a practical alternative while Sab measurement techniques for high-frequency applications such as 5G, WiGig, and next-generation wireless technologies are still under development.

Conclusion

This study proposed a method for evaluating human exposure to EMFs from multiple sources operating simultaneously across various frequency ranges. The assessment was based on the normalized exposure ratio concept defined by ICNIRP 2020, which considers cumulative exposure across all applicable sources and frequency bands. A key challenge addressed in this work was the lack of standardized measurement methods for Sab in high-frequency ranges above 10 GHz, despite the availability of established exposure limits.

To overcome this limitation, the author proposed the use of Sinc as a temporary substitute for Sab in frequency ranges where direct Sab measurement is not feasible. A new combined equation, referred to as (3), was developed by integrating the evaluation principles of (1) and (2). This approach enables practical and comprehensive assessment of simultaneous exposure from multiple RF sources in both near-field and far-field scenarios.

The approach proposed in this study can be applied as a supporting tool for designing safety measures or as a supplementary criterion in verifying the compliance of radiocommunication equipment operating in environments with multiple EMF sources. This is especially relevant for emerging high-frequency wireless systems such as 5G networks and short-range communication devices. However, (3) should be further validated through simulations or experimental measurements to confirm its accuracy and applicability in real-world scenarios, particularly when standardized methods for measuring Sab in high-frequency bands become available in the future.

Future research should focus on the development and standardization of Sab measurement techniques at frequencies above 10 GHz. Additionally, extensive experimental validation under various realistic environmental conditions will further strengthen the applicability and reliability of the proposed methodology.

https://ieeexplore.ieee.org/document/11236585

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**Analysis of Actual Transmitted Power from Hundreds of 5G FR2 Radio Base Stations over One Month in Urban Areas in Japan**

Ishioka R, Iyama T, Higashiyama J, Hada F, Suzuki Y, Suyama S. Analysis of Actual Transmitted Power from Hundreds of FR2 Radio Base Stations over One Month in Urban Areas in Japan. *Electronics*. 2025; 14(23):4676. https://doi.org/10.3390/electronics14234676

Abstract

This study analyzes the actual transmitted power from 5G beamforming radio base stations (BF-RBSs) to clarify the effectiveness and issues of an actual maximum approach specified in the International Electrotechnical Commission 62232:2025. The actual maximum approach is a new compliance assessment method for electromagnetic field exposure levels from BF-RBSs based on time-averaged transmitted power. In this study, the actual maximum transmitted power every 5 or 30 min from more than 400 BF-RBSs using millimeter waves in urban areas in Japan was collected using a network management system over a period of one month. For each BF-RBS, normalized actual transmitted power was derived as the ratio of actual to configured maximum transmitted power. As a result of this measurement, the maximum value of normalized actual transmitted power was approximately −3 dB when the number of sets of user equipment (UEs) in the BF-RBS was less than two with high data traffic. Moreover, statistical analysis results of the measurement data shows that the actual maximum approach may underestimate the electromagnetic field exposure levels from a BF-RBS with three or fewer UEs when the actual transmitted power of the BF-RBSs is not monitored and controlled to maintain a level below the threshold.

Conclusions

This study analyzed network data obtained from more than 400 BF-RBSs using millimeter waves in urban areas in Japan via a network management system for a month. As a result of the network-based measurement, we found that all the actual transmitted powers for each BF-RBS were below the configured maximum transmitted power. In particular, the maximum value of the normalized actual

transmitted power averaged for 30 min was less than −8 dB. Therefore, when the average time of compliance assessment for RBSs exceeds 30 min, the actual maximum approach is effective in avoiding overestimation using the conventional compliance assessment. In contrast, the maximum value of the normalized actual transmitted power averaged for 5 min was approximately −3 dB when the number of UEs was less than three. In this situation, the power reduction factor for beamforming technologies defined in the IEC 62232:2025 standard is approximately 0.19. Since this power reduction factor did not consider the influence of adjacent beams, future studies should address the calculation of FPR considering the impact of sidelobes from adjacent beams for the compliance assessment of an RBS installation. Regarding the issues of the actual maximum approach, the theoretical statistical analysis of the network data using multinomial distribution showed that the actual maximum approach underestimates the EMF exposure levels from a BF-RBS with three or fewer UEs when the actual transmitted power of the BF-RBSs is not monitored and controlled to maintain a level below the threshold. The measurement results show the necessity of monitoring and controlling the actual transmitted power of BF-RBSs to avoid underestimating the EMF exposure levels.

Open access paper: https://www.mdpi.com/2079-9292/14/23/4676

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**Model Variability in Assessment of Human Exposure to Radiofrequency Fields**

Hirata *A, et al*. Model Variability in Assessment of Human Exposure to Radiofrequency Fields. *IEEE Journal of Microwaves*, doi: 10.1109/JMW.2025.3628902.

Abstract

The recent advances in computational dosimetry for electromagnetics and thermodynamics are reviewed to assess human exposure to electromagnetic fields in the MHz-to-terahertz range. This review emphasizes model variability in computational dosimetry. Apart from computational electromagnetic methods and their usage, the developments in anatomical phantoms and tissue dielectric properties characterization are also surveyed. In addition, the rationale for dosimetric quantities prescribed in international exposure guidelines, such as the specific absorption rate (SAR) and absorbed power density, is revisited in relation to their correlation with local and core temperature rises in various tissues and populations. A heating factor, which is defined as a steady-state temperature rise per SAR, for the brain, eye lens, skin, and body core is evaluated to estimate heating resulting from exposure to electromagnetic fields. The transition of a physical quantity in the guidelines at 6 GHz, from SAR to the absorbed power density, is discussed along with the optimal spatial averaging volume and areas. Computational evaluations of product compliance, 5G devices, and wireless power transfer systems are also reviewed. This review aims to synthesize the current knowledge, identify key sources of computational model variability and uncertainty, and outline further research needs for setting exposure guidelines and compliance assessment.

Summary

This review highlights the mechanism by which variability across anatomical, thermophysiological, and numerical human models affects the prediction of temperature rise in computational dosimetry. Computational dosimetry plays a crucial role in defining the physical quantities used in the guidelines and setting the limit. The conceptual framework is schematically illustrated in Fig. 1, highlighting that

SAR variability is largely driven by anatomical scaling, whereas temperature rise is predominantly governed by thermophysiological parameters. To complement this, the key quantitative findings are summarized in Table 2.

Model variability and computational uncertainty in SAR showed consistent patterns across studies. For psSAR10g under local exposure, children and adults exhibit broadly similar values, although anatomical factors, such as head size, can yield higher localized absorption in children. Intermodel analyses indicated variability on the order of ∼30%, with rare extreme cases up to a threefold difference. For WBASAR, smaller and child models generally show 40%–60% higher values than adults, whereas additional variability arises from body shape, modeling method, and tissue properties (10%– 30%), with polarization and incidence angle occasionally producing variations of up to ∼60%. Computational uncertainty, which arises from discretization, boundary conditions, and algorithmic implementation, is typically small; however, additional errors of ±10%–20% may occur if the parameters are not properly controlled.

The model variability in the temperature rise showed a different pattern compared with the SAR. For the brain and eye, heating factors per psSAR10g remained consistently be- low ∼0.12–0.19 °C · kg/W, corresponding to <0.1 °C–0.2 °C rises under guideline limits, with limited differences between adults and children. In the skin, variability is mainly due to tissue thickness and microstructure, generally accounting for 10%–20%, whereas pulse exposures highlight the importance of transient surface heating. Core temperature rise is smaller in children and higher in fetuses and the elderly; however, in occupational scenarios, environmental and clothing factors outweigh EMF-induced heating. Furthermore, vascular models, which explicitly represent major blood vessels, have demonstrated additional influence on local temperature dis- tributions, particularly near large arteries and in deep brain regions, although their contribution is generally secondary compared to bulk blood perfusion [174], [175].

Overall, unlike SAR, where anatomical scaling and body size are the dominant sources of variability, temperature rise is more sensitive to thermal and physiological parameters, such as blood perfusion and thermoregulatory responses. While further investigations into these aspects are warranted, with several challenges already identified by international stan- dardization bodies [10], [176], the variability observed to date remains within the margins covered by the reduction factors in ICNIRP and IEEE guidelines, supporting both the robust- ness of current limits and their value for future refinement. Further research is essential, particularly in view of emerging applications such as 6G.

Open access: https://ieeexplore.ieee.org/document/11269783

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**Prospective cohort study on non-specific symptoms, cognitive, behavioral, sleep and mental health in relation to electronic media use and transportation noise among adolescents (HERMES): study protocol**

Jaillian H, Sandoval-Diez N Waibl VJ, Schmutz M Trefalt S et al. Prospective cohort study on non-specific symptoms, cognitive, behavioral, sleep and mental health in relation to electronic media use and

transportation noise among adolescents (HERMES): study protocol [version 2; peer review: 2 approved with reservations]

This article is included in Horizon Europe gateway and Wireless Communications collection


## Abstract

Electronic media (eMedia) devices along with exposure to transportation noise are integral to the daily routines of adolescents. The concerns associated with excessive eMedia usage extend beyond sleep deprivation to include the heightened exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by these wireless devices. The aim of HERMES (Health Effects Related to Mobile PhonE Use in AdolescentS) study is to better understand biophysical and psychological pathways in relation to eMedia use, RF-EMF exposure and transportation noise that may affect cognitive, behavioral, sleep and mental health, as well as non-specific symptoms. Following two previous HERMES cohorts conducted between 2012 and 2015 we have initiated the third wave of HERMES study as a prospective cohort with intermediate (every four months) and one year follows-up. Eligible participants are adolescents attending 7th or 8th school grades in Northwest and Central Switzerland. Baseline examinations are a questionnaire on eMedia usage and selected health outcomes, as well as computerized cognitive tests. In addition, parents/guardians are asked to fill in a questionnaire about their child's health and potential eMedia use determinants. Far-field RF-EMF exposure and transportation noise at the place of residence and school are predicted based on a propagation model. Cumulative RF-EMF brain dose is calculated based on self-reported eMedia use, mobile phone operator data, and RF-EMF modelling. A follow-up visit is conducted one year later, and two interim questionnaires are sent to adolescents to be completed at home. Between baseline and 1-year follow-up, a subsample of 150 study participants is invited to collect personal RF-EMF measurements as well as sleep and physical activity data using accelerometers. This new recruitment wave of HERMES study provides a greater understanding of causal pathways between eMedia, RF-EMF, and transportation noise exposure and their effects on health outcomes, with relevant implications for both governmental health policy and lay people alike.



## Plain Language Summary

Use of electronic media (eMedia) devices such as mobile phones as well exposure to transportation noise are inseparable parts of adolescents' everyday life. The excessive use of eMedia can be of concern when it results in sleep deprivation, but also when it leads to an increase in exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by wireless devices. These exposures could potentially affect cognition, and mental health resulting in behavioral problems of adolescents.

This study is part of a large research effort within the project GOLIAT aiming to understand the relationship of eMedia use, RF EMF exposure, and transportation noise exposure with cognitive, behavioral, sleep and mental health, as well as non-specific symptoms of Swiss adolescents. In this research, we recruit adolescents in secondary school and use questionnaires, cognitive tests, measurement devices, and mobile applications to collect information regarding exposure and outcomes at two time points, at baseline and one year later.



https://open-research-europe.ec.europa.eu/articles/4-120/v2

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**The Impact of Mobile Phone Electromagnetic Waves on the Neurons and Blood Brain Barrier Integrity in the Chick Embryo**

Siddiqi N, Moin F, Al-Kindi M. The Impact of Mobile Phone Electromagnetic Waves on the Neurons and Blood Brain Barrier Integrity in the Chick Embryo. Biomed Pharmacol J 2024;17(3).

Abstract

The electromagnetic environment surrounding us has dramatically evolved over the past decade, with the proliferation of Wi-Fi, Bluetooth, and other wireless technologies becoming commonplace in our daily lives. Mobile phones emit non-ionizing low-frequency electromagnetic waves (EW). To examine the effects of EW on living cells, this study aims to explore the impact of cell phone EW on the developing brain of chick embryos. The fertilized eggs were allowed to develop under exposure to electromagnetic waves emitted by cell mobile. A cell phone was placed inside the incubator with 20 eggs and was called from outside on a precise schedule. The same number of fertilized eggs were placed in another incubator without a mobile phone and served as the control. Embryos were sacrificed on days 10 and 15, and the cerebral cortex and cerebellum were removed and sent for electron microscopy. In the control group, cerebral neurons appeared healthy, with a large, centrally placed nucleus, visible oligodendrocytes, and a less dense extracellular matrix. In contrast, neurons from the exposed group were smaller, fewer in number, with unclear nuclear margins, signs of shrinkage, and apoptosis and a dense extracellular matrix. In the cerebellum, the exposed group revealed a reduced number of Purkinje neurons and noticeable mitochondrial swelling. The blood-brain barrier remained intact in the control group but was compromised in the exposed group. We conclude that electromagnetic waves emitted by cell phones adversely affect the normal development of the brain in chick embryos.

Open access: https://biomedpharmajournal.org/vol17no3/the-impact-of-mobile-phone-electromagnetic-waves-on-the-neurons-and-blood-brain-barrier-integrity-in-the-chick-embryo/

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**Role of radio-frequency electromagnetic waves in causing oxidative stress**

Siddiqi N, Al Nazwani N. Role of radio-frequency electromagnetic waves in causing oxidative stress. In Eds: Faiza Alam, Rehana Rehman, Fundamental Principles of Oxidative Stress in Metabolism and Reproduction. Academic Press, 2024, Pages 77-91. doiL 10.1016/B978-0-443-18807-7.00005-3.

Abstract

The objective of this study was to study the effects of electromagnetic waves emitted by cell phones on the heart, liver, and brain in a developing chick embryo. Forty fertilized chick eggs were acquired. Twenty eggs were placed in the egg incubator with a mobile phone, which was given calls from outside while the other 20 eggs were not exposed to mobile. Embryos were sacrificed at days 10 and 15 of its development, heart, liver, and brain tissues were removed, and electron microscopy and heat shock protein 70 were done. Exposed groups showed elongated, dumbbell-shaped mitochondria in the hepatocytes, swollen mitochondria in the neurons, and damaged mitochondria and intercalated discs in the cardiomyocyte. HSP70 levels were increased in exposed groups in cardiomyocytes and hepatocytes

confirming oxidative stress by the cells. We conclude that electromagnetic waves damaged the mitochondria in the heart, liver, and neurons of the developing chick embryo.

Excerpt

For each experiment, 40 fertilized eggs were randomly divided into two groups: the control and the experimental group. One incubator was used carrying 20 eggs at a time: one wave of the exposed group experiment and one wave of the control group. Freshly fertilized chicken eggs were exposed to radiofrequency waves (RFW) emitted by a mobile phone during embryonic development and compared with the control eggs, which were not exposed to RFW. A popular mobile phone and service provider was selected with 1800 MHz frequency, power of 0.47 W/kg body, and SAR 1.10 W/kg (head). A TriField Meter, model 100XE was used to detect the strength of RFW of the mobile phone during the experiment (Fig. 5.1). *Experimental group*: 20 fertilized eggs were incubated in the incubator with the mobile phone in silent mode with the vibration mode disabled. The distance of all the eggs from the mobile phone was maintained within one wavelength (approximately 16.5 cm) of the emitting 1800 MHz frequency electromagnetic waves. The mobile phone was rung from another mobile phone for 5 min, 10 times daily with an exposure-free period in between the calls. No calls were made at night. The total daily exposure duration was 50 min in each 24 h starting from day 1. Ten eggs were sacrificed on day 10 (total exposure time 500 min) and 10 eggs at day 15 (total exposure time 750 min). For the control group, 20 eggs were placed in the incubator, and 10 eggs were sacrificed on days 10 and the other 10 eggs at day 15 of development.

Conclusion

It is apparent from this study that electromagnetic wave exposure has induced many changes to the hepatocytes, cardiomyocytes, and neurons of developing chick embryos, especially to the mitochondria and increase in the levels of HSP70. Hence, it is scientifically documented that these electromagnetic waves are causing stress to the living cells. Further studies should be carried out to fully understand the mechanism of apoptosis because of this mitochondrial damage when exposed to RFW.

https://www.sciencedirect.com/science/article/pii/B9780443188077000053

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**Behaviour and reproduction of Drosophila melanogaster exposed to 3.6 GHz radio-frequency electromagnetic fields**

De Boose P, Ribas FO, Bell D, Bouga M, De Borre E, Fröhlich J, Hatjina F, Huss A, Kalapouti A, Katsamenis OL, Blackwell L, Georgiadou P, Mohiud-Din A, Alshamrani E, Lasbleiz C, Stavrinides M, Thanou Z, Tsagkarakis A, Varnava A, Zahner M, Wijnen H, Thielens A. Behaviour and reproduction of Drosophila melanogaster exposed to 3.6 GHz radio-frequency electromagnetic fields. PLoS One. 2025 Dec 1;20(12):e0336228. doi: 10.1371/journal.pone.0336228.

Abstract

Insects are exposed to radio-frequency electromagnetic fields emitted by wireless telecommunication networks. A part of these fields will be absorbed by these insects. This absorption might have biological effects, depending on the amount of absorbed power. It is currently unknown at what level of absorption this might occur. To investigate this, we used RF dosimetry of adult Drosophila melanogaster

flies, which we combined with two assays studying the locomotor activity and fecundity of D. melanogaster exposed to electromagnetic fields at 3.6 GHz. To perform dosimetry, we created a 3D digital twin of an adult fly using micro-CT scans of a female D. melanogaster. We used this model in numerical EM simulations to estimate the absorbed power in the fly as a function of RF frequency in the far field of an antenna and during the two experimental assays at 3.6 GHz. In the behavioural experiments, no effects were found on the locomotor activity for a 5-day exposure to RF field values between 5.4 and 9 V/m, which correspond to 3.56 nW to 9.88 nW absorbed power. We also did not find any effects on fecundity, at an absorption level of 1.91 mW for 48h at 3.6 GHz. In our future work, we aim to investigate possible exposure effects at higher frequencies and exposures, and for immature stages.

Open access: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0336228

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**Mitigating Heat-Induced Sperm Damage and Testicular Tissue Abnormalities: The Protective Role of Radiofrequency Radiation from Wi-Fi Routers in Rodent Models**

Mahmoudi R, Karbalay-Doust S, Masoudi E, Jafari-Barmak M, Ghanbri A, Nikseresht M, Mortazavi SMJ, Mortazavi SA. Mitigating Heat-Induced Sperm Damage and Testicular Tissue Abnormalities: The Protective Role of Radiofrequency Radiation from Wi-Fi Routers in Rodent Models. J Biomed Phys Eng. 2025 Dec 1;15(6):555-566. doi: 10.31661/jbpe.v0i0.2405-1759.

Abstract

Background: Radiofrequency Electromagnetic Fields (RF-EMF) have raised concerns due to their potential adverse effects on reproductive health. However, emerging evidence indicates that exposure to low-level RF-EMF may induce adaptive responses, rendering cells or organisms more resilient to subsequent stressors.

Objective: To investigate whether exposure to 2.45 GHz Wi-Fi radiation could mitigate heat-induced damage in the reproductive system of male rats.

Material and methods: In this factorial experimental study, 32 adult male Wistar rats were divided into four groups: control, RF-EMF alone, heat stress alone, and RF-EMF combined with heat stress. Rats in the RF-EMF group were exposed to RF-EMF for 2 hours daily over 52 days, while those in the heat group experienced 10 minutes of heat stress per day over the same period. The 'RF-EMF + heat' group received both RF-EMF and heat exposure. After 52 days, the testes and sperm parameters were assessed.

Results: Animals exposed to 'RF-EMF + heat' combined with heat showed significant improvements in testis volume, tubular epithelium, interstitium, cell counts, sperm quality, and Leydig cells compared to those exposed to heat alone ($P<0.05$).

Conclusion: As far as we know, this is the first study to explore the potential protective effects of RF-EMF exposure against heat-induced structural abnormalities in the testes of male rats. Our findings suggest that RF-EMF exposure may mitigate heat-induced damage, possibly through the induction of adaptive responses. These results have implications for various fields, including reproductive biology, environmental health, and occupational safety, highlighting the need for further research to elucidate the underlying mechanisms.

Excerpt

A D-Link Wi-Fi router (D-Link, D-Link Corporation, Taiwan) was used in this study as the RF-EMF exposure source. This modem was exchanging data with a laptop computer that was in another room (at least 5 meters away from the Wi-Fi router) during the exposure period. The Wi-Fi router operated on power level of 1W and the Specific Absorption Rate at the distance of 30 cm in animals' head level, as reported in another publication by our team, was 0.091 W/kg [11]

Open access: https://jbpe.sums.ac.ir/article_50328_e8a7f3e8c74e93143def214e643cc851.pdf

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**Time-Dependence Effect of 2.45 GHz RF-EMR Exposure on Male Reproductive Hormones and LHCGR**

Jamaludin N, Ibrahim SF, Osman K, Syed Taha SMA, Hairulazam A, Vijay S, Farzana Zulkefli A, Mat Ros MF, Fathihah Jaffar FH. Time-Dependence Effect of 2.45 GHz RF-EMR Exposure on Male Reproductive Hormones and LHCGR. Journal of Pioneering Medical Sciences. 2025 Oct;14(10):43-51.

Abstract

As wireless technologies become increasingly integrated into daily life, concerns have grown regarding the biological effects of Radiofrequency Electromagnetic Radiation (RF-EMR), particularly its influence on the Luteinizing Hormone (LH)–LH receptor (LHCGR)-testosterone pathway within the Hypothalamic-Pituitary-Gonadal (HPG) axis. This study investigated the effects of 2.45 GHz Wi-Fi exposure on this pathway in male rats. A total of 24 male Sprague Dawley rats were divided into four groups (n = 6 per group) and exposed to Wi-Fi for 0 (control), 4, 8, or 24 hours daily for eight weeks. Serum LH and testosterone levels were measured by ELISA. LHCGR gene and protein expression were assessed using RT-qPCR and Western blot. All data were analyzed using ANOVA, except for serum testosterone levels which were analyzed using the Kruskal-Wallis test. No significant differences were found in systemic LH or testosterone levels between groups. However, LHCGR mRNA expression showed a significant time-dependent increase. LHCGR protein levels decreased with shorter exposure durations and showed partial improvement at 24 hours, though they remained significantly lower than controls. These findings suggest that although systemic hormonal levels remain stable, RF-EMR exposure may associated with molecular alterations in testicular tissue, including compensatory upregulation of LHCGR expression. The increased LHCGR gene expression, alongside the fluctuating protein levels, indicates an adaptive, but not fully restorative response in Leydig cells compared with non-exposed controls.

Open access: https://jpmsonline.com/article/time-dependence-effect-of-2-45-ghz-rf-emr-exposure-on-male-reproductive-hormones-and-lhcgr-906/

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**From adults to offspring: Wi-Fi RF-EMR exposure in adult zebrafish impairs reproduction and transgenerationally effects development and behavior of progeny**

Mehta J, Khira R, Fumakiya S, Sharma P, Punekar A, Jain C, Uggini GK. From adults to offspring: Wi-Fi RF-EMR exposure in adult zebrafish impairs reproduction and transgenerationally effects development and

behavior of progeny. Sci Total Environ. 2025 Dec 15;1008:180982. doi: 10.1016/j.scitotenv.2025.180982.

Abstract

The widespread presence of wireless communication technologies in modern human society is raising concerns about the biological effects of radiofrequency electromagnetic radiation (RF-EMR). In this study the impacts of Wi-Fi induced RF-EMR exposure in Danio rerio (zebrafish) were examined. Adult zebrafish were exposed to 4 h of RF-EMR daily from a 4G Wi-Fi router over a 30-day period. The exposed adult fish were bred under exposure free condition, on the 10th, 20th and 30th day of experiment. Fertilized embryos obtained from these breeding events were maintained under EMF-free conditions and were observed up to 10 dpf and analysed for developmental and neurobehavioral changes. After completion of the exposure on the 30th day, the adult male and female gonads were processed for histomorphological study. Histopathological analysis revealed significant testicular abnormalities, including seminiferous tubule disintegration, reduced spermatids, and abnormal lumina. Ovaries showed notable follicular degeneration and stromal disruption. Significant rates of mortality and gross morphological abnormalities like yolk sac edema, pericardial edema, curved axis and tail deformities were found in the progeny of exposed fish. Malformation rates increased significantly with longer adult exposure periods. Neurobehavioral tests on these larvae at 10 dpf showed anxiety-like behavior. The results indicated progressive decline in reproductive health of adults and increased adversities in the progeny. The study highlights long-term biological risks of widespread electromagnetic radiation exposure and calls for further research into potential transgenerational effects.

Highlights

Zebrafish were exposed to 4G Wi-Fi RF-EMR for 30 days, 4 h/day.
Fish were bred on 10th, 20th, and 30th day of exposure.
Exposure caused damage to gonadal histoarchitecture in both males and females.
The progeny of exposed adults showed severe developmental malformations and neurobehavioral alterations.
Study highlights progressive transgenerational effects of Wi-Fi RF-EMR that intensify with longer exposure.

https://pubmed.ncbi.nlm.nih.gov/41264945/

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**Modeling the interplay between myelin architecture and local electromagnetic fields**

Han J, Qin P, Zhu G, Wang R, Bai S, Wen J, Italiano M, Aplin F, Lovell NH, Tsai D, Wang H, Guo T. Modeling the interplay between myelin architecture and local electromagnetic fields. Annu Int Conf IEEE Eng Med Biol Soc. 2025 Jul;2025:1-4. doi: 10.1109/EMBC58623.2025.11253436.

Abstract

Myelin plays a vital role in the functioning of the nervous system and is highly susceptible to damage in neurodegenerative diseases. This study investigates how alterations in electromagnetic fields associated with myelin can reflect its integrity. To achieve this, we developed a 3D microstructure model using

finite element analysis and high-resolution imaging, enabling us to simulate electromagnetic field distributions. Unlike conventional models, our approach retains key microstructural details. Our findings demonstrate that the myelin microstructure significantly influences the distribution of electromagnetic fields, with variations in these fields potentially serving as indicators of myelin health. Furthermore, the analysis reveals that combining assessments of both electric and magnetic fields provides a more comprehensive understanding of myelin integrity.

Clinical Relevance-This work offers a non-invasive framework for tracking disease progression by analyzing electromagnetic signatures, thus providing new insights into the mechanisms underlying neurodegenerative diseases.

https://ieeexplore.ieee.org/document/11253436

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**Electrical oscillations in microtubules**

Mohsin M, Cantiello HF, Cantero MR*, Marucho M.* Electrical oscillations in microtubules. *Sci Rep* 15, 41106 (2025). doi: 10.1038/s41598-025-24920-w

Abstract

Environmental perturbations and local changes in cellular electric potential can stimulate cytoskeletal filaments to transmit ionic currents along their surface. Advanced models and accurate experiments may provide a molecular understanding of these processes and reveal their role in cell electrical activities. This article introduces a multi-scale electrokinetic model incorporating atomistic protein details and biological environments to characterize electrical impulses along microtubules. We consider that condensed ionic layers on microtubule surfaces form two coupled asymmetric nonlinear electrical transmission lines. The model accounts for tubulin-tubulin interactions, dissipation, and a nanopore coupling between inner and outer surfaces, enabling luminal currents, energy transfer, amplification, and oscillatory dynamics that resemble the experimentally observed transistor properties of microtubules. The approach has been used to analyze how different electrolyte conditions and voltage stimuli affect electrical impulses' shape, attenuation, oscillation, and propagation velocity along microtubules. Integrating transistor-like properties in the microtubules model has profound implications for intracellular communication and bioelectronic applications.

Conclusion

In summary, the combined theoretical and experimental evidence underscores the central role of nanopores in the electrical activity of MTs. Pharmacological inhibition by Taxol and $Gd^{3+}$ demonstrates that these pores are not passive structural defects but functional nanogates whose state determines the oscillatory and amplifying properties of the polymer. Their coupling to the surrounding ionic environment enables MTs to act as biological transistors, mediating nonlinear amplification and signal propagation at the nanoscale.

By situating these phenomena within the broader context of cell signaling, our findings extend the frontier of cytoskeletal biophysics, positioning MTs as active bioelectronic elements with potential relevance for cellular communication, neuronal dynamics, and emergent quantum–electrodynamic phenomena in biology. Rather than relying solely on diffusion-limited processes, cells could harness

frequency-specific oscillatory signals along cytoskeletal filaments to regulate local biochemical events, synchronize activity across compartments, and potentially contribute to higher-order integrative processes in excitable tissues such as the brain. This biological framing underscores the broader significance of our model, making it accessible not only to physicists and engineers but also to experimental biologists interested in cytoskeletal dynamics and cell communication.

Open access: https://www.nature.com/articles/s41598-025-24920-w

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**Role of visual and non-visual opsins in blue light–induced neurodegeneration in Drosophila melanogaster**

Piacenti-Silva M, de Mattos AS, Zaparoli HH, de Oliveira M, Morimoto J, Zilli Vieira CL. Role of visual and non-visual opsins in blue light–induced neurodegeneration in Drosophila melanogaster. Frontiers in Public Health. Volume 13. 2025. doi:10.3389/fpubh.2025.1644780

Abstract

Introduction  Light plays a key role in regulating circadian rhythms and downstream physiological and behavioural functions. However, excessive exposure to artificial blue light (450–500 nm) can disrupt sleep, metabolism and neural integrity. Visual opsins mediate light-dependent signalling, but organisms also express non-visual opsins whose roles in blue-light-induced neural stress are not well understood.

Methods  We used Drosophila melanogaster knockout lines lacking either visual rhodopsin 1 (Rh11) or non-visual rhodopsin 7 (Rh71), alongside wild-type (w1118) controls. Flies were continuously exposed to 488 nm blue light (1,320 lux; 1,120 µW·cm−2) from egg deposition until they were 20 days old. DNA damage (γ-H2Av immunostaining) and vacuole formation were quantified in brain regions associated with sensory processing and neurotransmission.

Results  Rh11 flies exhibited the highest levels of DNA damage and vacuolisation compared to the w1118 and Rh71 lines. These effects were most pronounced in neuropils linked to sensory integration and synaptic activity.

Discussion  Our findings demonstrate that the visual opsin Rh1 plays a predominant role in blue-light-induced DNA damage and neurodegeneration in the Drosophila central nervous system. This suggests that it is visual, rather than non-visual, opsins that mediate the neurotoxic effects of exposure to artificial light.

Open access: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1644780

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**Non-thermal biological effects of radiofrequency electromagnetic radiation: Mechanistic insights into male reproductive vulnerability in the era of ubiquitous exposure**

Jangid P, Rai U, Ahmed S, Singh S, Singh R. Non-thermal biological effects of radiofrequency electromagnetic radiation: Mechanistic insights into male reproductive vulnerability in the era of ubiquitous exposure. Reproductive Toxicology, Volume 138, 2025. doi:10.1016/j.reprotox.2025.109087.

Abstract

The rapid proliferation of wireless technologies has led to continuous, low-intensity exposure to radiofrequency electromagnetic radiation (RF-EMR) from devices such as mobile phones, Wi-Fi routers, and wearable electronics. Although RF-EMR is non-ionizing, a growing body of evidence indicates that chronic exposure can induce non-thermal biological effects with significant implications for male reproductive health. This review synthesizes current findings on the mechanistic pathways through which RF-EMR may impair fertility, focusing on oxidative stress, mitochondrial dysfunction, DNA damage, apoptosis, autophagy dysregulation, and hormonal disruption via hypothalamic-pituitary-gonadal (HPG) axis interference. Experimental and clinical studies consistently link RF-EMR exposure to reduced sperm count and motility, altered testicular architecture, blood-testis barrier compromise, and suppressed testosterone synthesis, often at specific absorption rates below current safety thresholds. These outcomes are underpinned by redox imbalance, mitochondrial collapse, and steroidogenic impairment, with emerging evidence for epigenetic and transgenerational effects. Existing regulatory frameworks, based largely on thermal safety limits, fail to address the complexity of real-world, multi-source, long-term exposures. The review highlights critical knowledge gaps, particularly regarding 5 G and millimeter-wave frequencies, and underscores the need for standardized research protocols, biologically relevant exposure metrics, and precautionary public health measures to mitigate reproductive risks in an increasingly wireless environment.

Highlights

- RF-EMR triggers oxidative stress in male reproductive cells.
- Leydig cell mitochondria are highly sensitive to RF exposure.
- RF-EMR impairs testosterone synthesis and steroidogenesis.
- Sperm quality declines after non-thermal RF-EMR exposure.
- ROS and autophagy mediate RF-EMR-induced cell damage.

Limitations of SAR-based regulatory paradigms

Regulatory bodies like the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Commission (FCC) still rely on SAR as the main safety benchmark for RF-EMR exposure [14], [74]. But SAR mainly reflects how much tissue heats up over short periods, it was originally designed to prevent thermal damage in lab settings [15]. While that works for avoiding immediate overheating, it doesn’t capture the kinds of long-term, non-thermal effects that research is now increasingly reporting. For example, oxidative stress, hormonal imbalances, mitochondrial dysfunction, and even DNA fragmentation have been observed at SAR levels still considered "safe" under current guidelines [4], [19]. These kinds of findings make it clear that we need to rethink how exposure is measured, especially for reproductive health, and move toward including more biologically relevant markers like oxidative stress indicators, endocrine changes, and genotoxic outcomes.

The need for a precautionary framework

A proactive, precautionary approach is essential to safeguard public health amid ongoing scientific uncertainty. The absence of acute thermal injury must not be equated with biological safety. Multiple expert groups have advocated for the inclusion of non-thermal biological endpoints, such as oxidative stress, hormonal disruption, and reproductive toxicity, into current safety standards [5], [17].

To align public health policy with emerging evidence, reforms should prioritize:

- Mandatory RF-EMR labeling on consumer electronics;
- Promotion of low-exposure practices (e.g., using speaker mode or wired headphones, maintaining device distance, limiting phone use in low-signal areas, etc.);
- Creation of low-EMF zones in schools, hospitals, and transport systems;
- Dedicated funding for longitudinal studies on fertility and epigenetic impacts;
- Regular RF exposure mapping and transparent public communication.

Incorporating these elements into policy will better reflect biological realities and ensure protection for high-risk populations. Without such action, regulatory frameworks may continue to underestimate the long-term reproductive risks of chronic low-intensity RF-EMR exposure.

Conclusion

With wireless technologies now embedded in almost every part of daily life, we're constantly exposed to low levels of RF-EMR, often without even realizing it. This kind of ongoing exposure has raised real concerns about biological effects that go well beyond just heating tissues. Studies using cell lines, animals, and even human subjects have pointed to consistent changes in things like redox balance, mitochondrial health, programmed cell death pathways, autophagy, and hormonal regulation, and these effects seem especially pronounced in the male reproductive system. These disturbances have been linked to reduced sperm quality, disrupted testicular architecture, and compromised fertility, with some studies pointing to potential impacts on future generations.

Existing safety standards, primarily based on thermal effects, do not capture the complexity of these non-thermal, long-term exposures. As technologies like 5 G introduce novel frequencies and modulations, there is a critical need for biologically relevant models, standardized endpoints, and human-focused cohort studies. A multidisciplinary approach integrating mechanistic research and policy updates is essential to ensure reproductive safety amid expanding RF-EMR exposure.

https://www.sciencedirect.com/science/article/pii/S0890623825002588

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**Radiofrequency radiation-induced gene expression**

Lai H, Levitt BB. Radiofrequency radiation-induced gene expression. Rev Environ Health. 2025 Oct 29. doi: 10.1515/reveh-2025-0104.

Abstract

Genes are differentially expressed in cells in response to changes in the internal or external environment. The response is generally an adaptive mechanism to the environmental challenge to restore cell functions to homeostasis. There are numerous studies reporting changes in gene expression in cells exposed to radiofrequency radiation (RFR), the type of energy emitted by wireless communication devices. The major genes affected are those involved in: repair of damaged proteins, response to stress, oxidative changes, apoptosis, DNA damage detection and repair, and changes in neural functions. Gene expression data supports the notion that RFR is a stressor that causes oxidative changes and DNA and protein damage in cells under different exposure conditions, in many biological systems. Changes in all these significant gene expression effects are supported by results of other biological studies of RFR exposure in the literature. They should be considered in the setting of RFR-exposure guidelines.

Excerpts

"Gene expressions are under feedback control in response to external challenges with numerous variables. RFR has a complex interaction with living organisms depending on various parameters of the field. With these considerations in mind, response oscillation and non-linear dose-response could occur. But gene expression is not expected under all exposure conditions and biological systems studied. Thus, inevitably, in some studies, no significant effects would be expected. There are studies that reported no significant effect of RFR on gene expression related to protein damage and removal, DNA, oxidative processes, stress, and brain functions (Table 7)."

"Forty gene expression effects (marked as low intensity (LI) in Tables 1–6) were observed at a SAR less than 0.4 W/kg. This is relevant to the effects of exposure to RFR in the environment. 0.4 W/kg is the dose rate assumed to be safe by international radiofrequency radiation guidelines (e.g., the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the International Electronics and Electrical Engineers (IEEE)). This is important to understand regarding the validity of those organization's high-intensity standards-setting models. (For readers who are interested in 'low-intensity' RFR effects, there are more than 200 studies that reported biological effects at SAR <0.4 W/kg [see the 'RFR-low-intensity studies' file in reference [1]]).

Lastly, one may wonder whether up-regulation of gene expression would lead to translation into functional proteins. Several RFR studies support increased translation (e.g., [33], [34], [35], [36]). It is an important complement to the gene-expression studies to look at translation levels of proteins as these are the functional units that promote/sustain both health and illness. Proteomic studies are an attractive next step in understanding the biological effects of RFR exposure. This was suggested more than a decade ago [37]. Changes in transcription and protein functions point to a need to investigate molecular signaling pathways after RFR exposure [38]. In addition, the data on gene-expression suggests two areas of mechanism research that are worth pursuing. The first area is the involvement of stress in RFR-induced biological effects. Involvements of 'cellular stress responses' and the hypothalamic-pituitary-adrenal axis and, particularly, effects on the limbic system should be further investigated [3]. The second area is the cellular oxidative processes. Particularly, the mechanism of induction of free radicals by RFR should be systematically studied. Present data indicates that low-frequency modulations in RFR may play a role [39]. It is, however, not known how much these low-frequency components contribute to the overall effect. Similar effects on gene expression have been reported after exposure to

extremely-low frequency electromagnetic fields (see ‘static and ELF EMF genetic effects’ file in reference [1])."

Open access: https://www.degruyterbrill.com/document/doi/10.1515/reveh-2025-0104/html

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**Electromagnetic fields and oxidative stress: The link to the development of cancer, neurological diseases, and behavioral disorders**

Leković Ž. Electromagnetic fields and oxidative stress: The link to the development of cancer, neurological diseases, and behavioral disorders. Electromagn Biol Med. 2025 Oct 21:1-25. doi: 10.1080/15368378.2025.2567872.

Abstract

Background: Epidemiological studies suggest an association between exposure to electromagnetic fields (EMFs) and an increased incidence of malignant, cardiovascular, and neurodegenerative diseases. This study aims to elucidate the fundamental principles and plausible mechanisms by which EMFs may influence physiological and pathological processes that lead to disease development.

Materials and methods: Published reports of oxidative stress, DNA damage, and disease risk related to EMF exposure were examined. The literature review provided the foundation for building a new conceptual model called the Electromagnetic Pathogenesis (EMP) model.

Mechanisms: The EMP model proposes an increase in the probability of electron tunneling through the mitochondrial electron transport chain as the primary pathophysiological mechanism triggered by non-ionizing EMFs. Induced electric fields and quantum tunneling may enhance electron leakage during mitochondrial respiration, which is a major source of free radicals.

Findings: There is a deep connection between quantum tunneling, entropy, and Heisenberg's principle. As a direct consequence of Heisenberg's principle, electron tunneling is essentially involved in free radical production and entropy generation in cells. Both normal aging and chronic diseases may be considered as the biologic manifestations of increasing entropy. Heisenberg's principle underlies normal aging and sets the limit to life expectancy.

Social implications: The human brain, particularly the structural and functional networks that support social communication, is highly vulnerable to oxidative stress associated with EMF exposure. Long-term exposure may negatively affect social and reproductive behaviors in both men and women, potentially contributing to a decline in fertility rates and the acceleration of population aging.

Concluding remarks

As a direct consequence of Heisenberg’s principle, quantum tunneling is essential for energy conversion in mitochondria and many physiological processes in cells, including the production of free radicals.

The external time-varying magnetic field brings energy into the biological system and transfers it to charged particles, especially electrons, via induced electric field (electromotive force). During exposure, the induced electric field increases the probability of electron tunneling through the mitochondrial ETC. This facilitates electron leakage during mitochondrial respiration, which is the major source of free radicals in cells.

The oxidative stress associated with man-made EMF exposures represents one of the primary mechanisms that can lead to disease development. Under oxidative stress conditions, excess superoxide releases iron from ferritin and iron-sulfur proteins and increases intracellular free iron. In addition, peroxynitrite, formed when nitric oxide reacts with the superoxide, can liberate iron from iron-sulfur proteins and copper from ceruloplasmin, which destroys an important part of the antioxidant defense – transition metal binding proteins. The elevation in free iron and copper and the ability of DNA to bind metal ions leads to damage by the site-specific Fenton-type reaction, which generates hydroxyl radicals immediately near the site of metal fixation in the DNA.

Autoxidation of dopamine is relatively slow under normal physiological conditions but is accelerated by free transition metals like iron and copper. Oxidative stress-induced dysfunction of the dopamine system has been implicated in different nervous system diseases and neuropsychiatric behavioral disorders, including autism, addiction, and depression.

Embryonic and fetal brain tissues are especially susceptible to peroxidative injury. Maternal oxidative stress may compromise fetal development, leading to congenital malformations or the pathogenesis of neurodevelopmental disorders. EMFs as an environmental factor have the potential to increase the rate of somatic mutations and incidence of brain disorders, including autism.

The human brain, particularly the structural and functional networks that support social communication, is highly vulnerable to oxidative stress associated with EMF exposure. Disturbance in social communication affects partnership, marital status, reproductive behavior, and ultimately childbearing. Oxidative stress can also initiate degenerative processes in other tissues and organs, which explains the association between social relationships, including marital status, and disease risk. At the population level, long-term EMF exposure can contribute to a decline in the total fertility rate and the acceleration of population aging.

In establishing a causal relationship between electromagnetic fields and associated diseases, the key and final step would be to reduce population exposure. The EMP model predicts that measures to reduce the level of electromagnetic fields in the environment based on the precautionary principle would lead to a decrease in the incidence of almost all diseases associated with oxidative stress, including malignant, cardiovascular, neurodevelopmental, and neurodegenerative diseases.

The EMP model indicates possible links between long-term EMF exposure, oxidative stress, brain disorders, and social and reproductive behavior, providing a solid foundation for future research.

https://pubmed.ncbi.nlm.nih.gov/41117390/

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**Transition Pathways Towards Electromagnetic Sustainability in the Built and Lived Environment**

Habash R, Baho GY. Transition Pathways Towards Electromagnetic Sustainability in the Built and Lived Environment. *Sustainability*. 2025; 17(22):10252. doi: 10.3390/su172210252

Abstract

Electromagnetic (EM) fields, as one of the basic forms of energy in the built and lived environment (BLE), present an environmental health challenge, yet they often remain an overlooked concern, particularly with the development of information and communication technologies (ICT) and energy systems. Although these fields are essential for the contemporary infrastructure, society needs to engage in a thorough discussion regarding their potential impact on health. In light of this, a commitment should be made to design and manage technologies and infrastructure that strive to lower EM pollution, while ensuring optimal functionality. Achieving this goal requires viable urban planning and sustainability strategies. The motivation of this study is to examine various instances to foster a deeper understanding of the EM in the BLE. It explores significant sources of exposure and major safety guidelines. A literature review and EM field audits in three locations within two cities in Canada and the UK have been provided to understand the trends and serve as a comparative sample. Key transition pathways towards EM sustainability have been proposed, including the establishment of observatory systems in urban locations, hygiene practices, risk governance, and an interplay between sustainability and technology.

Open access: https://www.mdpi.com/2071-1050/17/22/10252

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**Brain Tumor and Mobile Phone Risk Among Young People: Analysis of Japanese People Using the MOBI-Kids International Case-Control Study**

Kojimahara N, Kiyohara K, Sato Y, Wake K, Taki M, Castano-Vinyals G, Yamaguchi N, The Study Group of MOBI-Kids Japan. Brain Tumor and Mobile Phone Risk Among Young People: Analysis of Japanese People Using the MOBI-Kids International Case-Control Study. Bioelectromagnetics. 05 November 2025. doi: 10.1002/bem.70032.

Abstract

This study investigated the association between mobile phone use and brain tumors in young people aged 10–29 years, specifically within the Japanese population. Building upon the international MOBI-Kids study, this Japanese case-control study included 120 brain tumor patients and 360 controls treated in the Kanto area, broadening the age range and including all primary brain tumors, unlike the international study. The data were evaluated using unconditional logistic regression, both unadjusted and adjusted for age and sex, with respect to the duration and intensity of mobile phone use. The analysis accounted for differences in the output power of various mobile phone generations prevalent in Japan, particularly the high-output 2G PDC system. Despite this rigorous exposure modeling, the study found no increased risk of brain tumors associated with mobile phone use, even when factoring in the weighted power output. The findings align with other recent international studies that also report no causal association. While acknowledging limitations such as potential recall bias and a relatively small sample size for sub-analyses, the study's strengths include its expanded age range and a realistic assessment of Japanese mobile phone usage patterns. Due to the ever-changing exposure conditions

from wireless technology, further studies are needed to address their relation to young people's health.

Summary

Our study, focusing on young people in Japan, found no association between brain tumors and mobile phone use, based on a rigorous case-control design expanding the MOBI-Kids international case control study.

Analysis accounted for mobile phone generation differences, including Japan's high-output 2G PDC system with different phone types and power outputs.

https://onlinelibrary.wiley.com/doi/10.1002/bem.70032

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**The Influence of Mobile Technologies on the Quality of Sleep**

Slezáková Z, Baláž J, Wimmerová S, Valachovičová M. The Influence of Mobile Technologies on the Quality of Sleep. J Biomed Phys Eng. 2025 Oct 1;15(5):491-496. doi: 10.31661/jbpe.v0i0.2311-1685.

Abstract

The extensive usage of mobile phones across all age brackets, including children and teenagers, leads to significant exposure to Radiofrequency Electromagnetic Fields (RF-EMF). This exposure raises concerns about potential adverse effects on sleep. The current study aimed to explore the influence of mobile phone-emitted RF-EMFs on the duration and quality of sleep in a cohort of medical students. Participants alternated between sleeping with and without a mobile phone for two-week intervals, while their sleep patterns were monitored using smartwatches. The study results indicated no statistically significant disparities in sleep quality between sleeping with and without a mobile phone. However, exposure to radiofrequency electromagnetic fields had a notable impact on the minimum and average blood oxygen saturation levels.

Excerpt

During sleep, the deep sleep phase is considered crucial for physical recovery as it facilitates the release of growth hormones and regeneration of organs, muscles, and cells. In our study, we did not observe any statistically significant differences in the durations of wakefulness, REM sleep, light sleep, and deep sleep. However, we did find that RF EMF had a significant impact on minimum and average blood oxygen saturation levels. These findings emphasize the importance of conducting further comprehensive research in this area.

Open access: https://jbpe.sums.ac.ir/article_50575_eb6407c3fe71aef14e1f2dbc24bbcadb.pdf

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**Symptoms associated with environmental factors are positively related to sensory-processing sensitivity**

Reddington K, Witthöft M, Köteles F, Szemerszky R. Symptoms associated with environmental factors are positively related to sensory-processing sensitivity. J Psychosom Res. 2025 Oct 25;199:112425. doi: 10.1016/j.jpsychores.2025.112425.

Abstract

Objective: Symptoms associated with environmental factors (SAEFs) are conditions characterized by chronic somatic symptom distress and impaired everyday functioning. SAEFs are positively related to certain psychological characteristics, such as somatosensory amplification (SSA), worries about the negative health consequences of modern technologies (MHWs), and body awareness. It was proposed recently that SAEFs might also be associated with sensory-processing sensitivity (SPS), i.e., the trait-like perceived sensitivity to internal and external sensory information.

Methods: Participants of a cross-sectional survey (n = 491; $M_{age}$ = 34.7 yrs., $SD_{age}$ = 14.2 yrs.; 76.4 % women) completed questionnaires assessing four SAEFs (perceived sensitivity to chemicals, buildings, sounds, electromagnetic fields) with multiple questions, and somatic symptom distress, body awareness, SSA, MHWs, and SPS.

Results: Somatic symptoms distress, SSA, body awareness, and SPS were significantly positively related to all four SAEFs. A very strong association ($r = 0.73$, $p < .001$) between SSA and SPS was found.

Conclusion: SPS can be considered a newly described (although not independent) psychological concomitant of SAEFs. Understanding the background of the association between SSA and SPS can be helpful to better understand SAEFs.

https://pubmed.ncbi.nlm.nih.gov/41160934/

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**Effects of Simultaneous In-Vitro Exposure to 5G-Modulated 3.5 GHz and GSM-Modulated 1.8 GHz Radio-Frequency Electromagnetic Fields on Neuronal Network Electrical Activity and Cellular Stress in Skin Fibroblast Cells**

Hurtier A, Patrignoni L, Canovi A, Orlacchio R, Tjiou H, Gannes FP, Garenne A, Lévêque P, Arnaud-Cormos D, Lagroye I, Lewis N, Percherancier Y. Effects of Simultaneous In-Vitro Exposure to 5G-Modulated 3.5 GHz and GSM-Modulated 1.8 GHz Radio-Frequency Electromagnetic Fields on Neuronal Network Electrical Activity and Cellular Stress in Skin Fibroblast Cells. Bioelectromagnetics. 2025 Oct;46(7):e70026. doi: 10.1002/bem.70026.

Abstract

The widespread deployment of 5G wireless networks alongside existing GSM technologies has increased the need to assess potential biological effects of co-exposure to multiple radiofrequency electromagnetic fields (RF-EMF). This study evaluates the in-vitro impact of simultaneous exposure to 5G-modulated 3.5 GHz and GSM-modulated 1.8 GHz signals on neuronal electrical activity, mitochondrial reactive oxygen species (ROS) production, and cellular stress protein responses in neurons and skin fibroblasts. Primary cortical neurons and human immortalized skin fibroblasts were exposed to RF-EMF at specific absorption rates (SAR) of 1 or 4 W/kg for 15 min or 24 h, respectively. Neuronal activity was analyzed using multi-electrode arrays (MEAs), mitochondrial ROS production was

measured using MitoSOX Red, and stress protein activity was assessed using bioluminescence resonance energy transfer (BRET) assays targeting RAS, PML, and HSF1 proteins. The results indicate no significant effects on the mean bursting rate (MBR) or mean firing rate (MFR) of cortical neurons, consistent with previous findings at similar SAR levels. Mitochondrial ROS production in fibroblasts also remained unaffected by RF-EMF co-exposure. BRET assays detected minor variations in the basal activity of RAS and PML and in the maximal efficacy of PMA and $As_2O_3$ to activate these pathways. However, these effects were small, near the detection threshold, and showed no consistent pattern across different tests or chemical treatments. No change was observed in HSF1 basal activity or responsiveness to MG132. These findings suggest that co-exposure to 5G- and GSM-modulated RF-EMF at SAR levels up to 4 W/kg does not produce conclusive evidence of marked biological effects under the tested conditions. Observed variations, when present, are of low amplitude and likely to fall within the range of experimental variability.

Summary

- Co-exposure to 5G-modulated 3.5 GHz and GSM-modulated 1.8 GHz at a total SAR of 4 W/kg (15 min) did not alter spontaneous bursting or firing rates in cortical neuronal networks.
- Twenty four hours co-exposure to 5G-modulated 3.5 GHz and GSM-modulated 1.8 GHz at a total SAR of 1 or 4 W/kg did not change mitochondrial ROS levels in human skin fibroblasts.
- BRET assays in fibroblasts showed that 24 h co-exposure to 5G-modulated 3.5 GHz and GSM-modulated 1.8 GHz at a total SAR of 1 or 4 W/kg produced only small changes, with slight increases in basal RAS and PML activity and minor variations in their chemical responses, while HSF1 remained unaffected.

Excerpts

Knowing the widespread deployment of the 5G wireless network at 3.5 GHz alongside the Global System for Mobile Communications (GSM) at 1.8 GHz, this study aims to investigate in-vitro effects of simultaneous exposure to both signals at SAR levels up to 4 W/kg on neuronal electrical activity, as well as ROS production and stress protein responses in skin fibroblasts. At such carrier frequencies, the penetration depth into biological tissues is approximately 1 cm. As a result, the primary targets of interest are the skin cells and the central nervous system, particularly cortical neurons....

As illustrated in Figure 1, two exposure setups were used for 5G-modulated 3.5 GHz and GSM-modulated 1.8 GHz co-exposure depending on the cell model of interest. The setups were based on a cell culture incubator converted into a reverberation chamber exposure system (Figure 1A) for exposing skin fibroblasts, and an open transverse electromagnetic cell (TEM cell) containing a microelectrode array (MEA) placed in a classical cell culture incubator for neurons exposure (Figure 1B). The signal generation components were located outside incubators. For both exposure systems, the external signal unit was composed of two RF signal generators (SMBV100A, Rohde & Schwarz, Munich), a power combiner (Mini-circuits, ZB2PD-63-N+, NY, USA) combining 5G-modulated 3.5 GHz and GSM-modulated 1.8 GHz signals, a 25-dB gain amplifier (Mini-circuits, ZHL-4W-422+, NY, USA), a bidirectional coupler (Mini-circuits, ZGBDC30-372HP+, NY, USA), and a power meter (Keysight N1912A, USA) connected to two power sensors (Keysight N1921A, USA). The 3.5 GHz signal emitted by the radiofrequency generator is a real 5G NR signal (release 15, Digital Standards SMBVB-K444; Rohde & Schwarz) with FDD duplexing,

QPSK modulation and 100 MHz channel bandwidth. The signal is also characterized by the power level and the peak envelope power (PEP), for example, for a power level of -10 dBm the peak envelope power is 1.26 dBm.

https://pubmed.ncbi.nlm.nih.gov/41104878/

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**Male Reproductive and Cellular Damage After Prenatal 3.5 GHz Radiation Exposure: One-Year Postnatal Effects**

Dolanbay EG, Mert T, Bender GC, Bektas H, Uslu U, Fernandez-Rodriguez CE, Dasdag S. Male Reproductive and Cellular Damage After Prenatal 3.5 GHz Radiation Exposure: One-Year Postnatal Effects. 23 October 2025. doi: 10.1111/nyas.70116.

Abstract

This study investigates the long-term effects of prenatal exposure to 3.5 GHz radiofrequency radiation (RFR) on male reproductive health. Pregnant Wistar Hannover rats were divided into sham control, full-gestation exposure (3T RFR), and late-gestation exposure (2T RFR) groups (2 h/day). Male offspring were euthanized at 12 months for testicular analysis. In the 3T RFR group, seminiferous tubule diameter and epithelial height were significantly reduced compared to controls (adjusted $p = 0.03$ and $9.71 \times 10^{-8}$), along with lower Johnsen scores (adjusted $p = 0.022$). Abnormal sperm morphology increased significantly (adjusted $p = 0.036$). γ-H2AX immunostaining scores were elevated in the 2T and 3T groups (adjusted $p = 0.012$ and $6.36 \times 10^{-9}$). Beclin-1 expression was significantly higher in the 3T group versus sham and 2T groups (adjusted $p = 8.55 \times 10^{-4}$ and $4.51 \times 10^{-6}$). TUNEL-positive cell counts were significantly higher in both RFR groups than in sham (adjusted $p = 8.77 \times 10^{-18}$ for 3T, $6.42 \times 10^{-17}$ for 2T), as was the apoptosis index (adjusted $p = 8.77 \times 10^{-18}$ for 3T, $5.66 \times 10^{-17}$ for 2T). All $p$ values were Holm–Bonferroni corrected. These findings indicate that prenatal exposure to 3.5 GHz RFR results in persistent testicular damage, impaired spermatogenesis, and increased DNA damage, autophagy, and apoptosis in adult male rats.

Graphical Abstract

Despite the accumulated knowledge of its effects, the long-term consequences of prenatal radiofrequency radiation (RFR) exposure on male reproductive health remain underexplored. Widespread usage makes understanding the potential impact of RFR on molecular pathways crucial. Thus, the purpose of this study is to investigate whether the reproductive systems of male rats exposed to 3.5 GHz RFR exclusively in the prenatal period were affected in the first year after birth.

Excerpts

A GSM signal generator (model 3500 PM10, Everest Comp., Adapazarı, Turkey), which generates a radiofrequency waveform modulated in the 3.5 GHz GSM band, was utilized to expose rats to RFR resembling the frequency to that generated by mobile phones. The power output of the signal generator was kept at 1 W during the exposure period. The piece of the generator that functions as the antenna was designed to replicate that of a conventional mobile phone....

EMR 300 (NARDA, Pfullingen, Germany) was used to measure the electric fields. E field measurements were performed with an EMR 300 in the corners and at the center of the cages we used in our study, which are the same size as standard animal cages. E fields were measured as 24 V/m, 26 V/m, 26.3 V/m, and 27 V/m at the corners, while 28 V/m was measured at the center of the cage....

The SAR calculations were conducted using the IEEE/IEC 62704-1 standard to assess the distribution of SAR values. The psSAR for 1 g was 0.06622 mW/g, and for 10 g was 0.03825 mW/g....

Conclusion

This study involved monitoring the male offspring of pregnant rats exposed to 3.5 GHz RFR exclusively during the prenatal period, with no exposure to electromagnetic waves for a period of one year following birth. The most original aspect of this study is that young male rats were kept alive for 1 year without any RF radiation exposure except during the prenatal period, and at the end of this period, their reproductive systems were examined. The examinations conducted in the first year after birth showed that exposure to 3.5 GHz RFRs only during the prenatal period poses significant risks to male rat reproductive health. Another original aspect of the study is that the first of the pregnant groups was exposed to RFRs during the three trimesters and the other during the last two trimesters.

Histological changes, increased abnormal sperm morphology, DNA damage, increased autophagic activity, and increased apoptosis are among the observed effects. These findings revealed that the reproductive systems of male offspring exposed to RFRs exclusively during pregnancy were negatively affected, even though they were not exposed to any EMFs for a year after birth, and the observed effects were even more pronounced in the full trimester group. In summary, this study showed that exposure to radiofrequency radiation (RFR) during pregnancy may have a negative impact on the reproductive health of subsequent male generations. Therefore, further molecular and cellular studies are needed to improve our understanding of the relationship between prenatal exposure to 3.5 GHz radiofrequency radiation (RFR) and subsequent male reproductive toxicity, and the mechanisms involved. Future investigations should extend the experimental timeline by incorporating multiple postexposure time points (e.g., 1, 6, and 12 months) to allow for a more comprehensive evaluation of the long-term effects of prenatal RFR exposure on reproductive function. Additionally, detailed assessments of sperm parameters such as motility, as well as organ weights, were not included in the current study. These aspects represent limitations and are planned to be addressed in ongoing and future studies to provide a more comprehensive understanding of the systemic and functional consequences of prenatal RFR exposure. Finally, such research is crucial for developing evidence-based guidelines and implementing precautionary measures to safeguard reproductive health.

https://nyaspubs.onlinelibrary.wiley.com/doi/10.1111/nyas.70116

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**Synergistic Effects of 2600 MHz Radiofrequency Exposure and Indomethacin on Oxidative Stress and Gastric Mucosal Injury in Rats**

Oruç S, Aral BS, Eraslan E, *et al.* Synergistic Effects of 2600 MHz Radiofrequency Exposure and Indomethacin on Oxidative Stress and Gastric Mucosal Injury in Rats. *Bratisl. Med. J.* (2025). doi:

10.1007/s44411-025-00382-4.

Abstract

Background/Aim  With the widespread use of mobile technologies and NSAIDs, concerns have emerged regarding their potential combined impact on gastric health. This study investigated the synergistic effects of 2600 MHz RFF exposure and IND, a commonly used NSAID, on oxidative stress and gastric injury in rats.

Materials and Methods  Forty male Wistar albino rats were randomly assigned to five groups: control, sham, IND, RFF, and IND + RFF. Animals were exposed to 2600 MHz RFF (1 h/day, 5 days/week) for 15 days, and/or received IND (4 mg/kg) via intragastric gavage. Gastric tissues were evaluated biochemically for oxidative stress markers (TOS, OSI, MDA, GSSG), antioxidant parameters (TAC, SOD, CAT, GSH, GPx), histologically for tissue damage, and immunohistochemically for HSP70 expression and apoptosis.

Results  Single exposure to IND or RFF significantly elevated oxidative stress markers and decreased antioxidant levels in gastric tissues ($p < 0.001$). Combined IND + RFF exposure resulted in markedly greater gastric injury, with pronounced increases in HSP70 expression and apoptotic cell counts compared to single exposures ($p < 0.001$).

Conclusion  Co-exposure to 2600 MHz RFF and IND markedly intensified oxidative stress, apoptosis, and gastric mucosal injury in rats. These findings suggest that the combined exposure produces a synergistic detrimental effect, exacerbating gastric tissue damage beyond the impact of each factor alone.

link.springer.com/article/10.1007/s44411-025-00382-4

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**Effect of Electromagnetic Field on Oral Tissues: A Narrative Review**

Mallipattana V, Satelur KP, Shah MN, Thirugnana P, Ramnarayan BK.(2025). Effect of Electromagnetic Field on Oral Tissues: A Narrative Review. J Clin of Diagn Res. *19*(10), ZE01-ZE04. doi: 10.7860/JCDR/2025/79533/21893.

Abstract

An emerging pattern in clinical practice involves patients presenting with unexplained systemic and neurological symptoms despite normal diagnostic workups, with metallic or dissimilar-metal dental restorations being a recurring feature. The present narrative review explores potential links between Electromagnetic Field (EMF) exposure, dental materials and systemic health effects, with a particular focus on neurological manifestations. Drawing on principles from quantum biology and physics, the review examines unique clinical cases that defy conventional medical explanations yet may be interpreted through interactions between EMFs and metal restorations at the quantum level. These cases suggest that the human body may act as a biological interface where classical and quantum physical phenomena intersect. While the review emphasises evidence-based findings, it also presents quantum-level hypotheses—such as spin dynamics and Radical-Pair Mechanisms (RPM)—for

interdisciplinary consideration, underscoring the complexity of EMF-biological interactions and the need for further investigation.

Open access: https://www.jcdr.net/article_fulltext.asp?issn=0973-709x&year=2025&month=October&volume=19&issue=10&page=ZE01-ZE04&id=21893

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**Electromagnetic Field Stimulation Effects on Intrinsically Disordered Proteins and Their Role in Aging and Neurodegeneration**

Perez FP, Bandeira J, Morisaki J, Kanakri H, Rizkalla M. Electromagnetic Field Stimulation Effects on Intrinsically Disordered Proteins and Their Role in Aging and Neurodegeneration. J Biomed Sci Eng. 2025 Oct;18(10):408-438. doi: 10.4236/jbise.2025.1810030.

Abstract

There is increasing evidence from preclinical studies. There is growing evidence from preclinical studies in cell cultures and small organisms that exposure to Electromagnetic Fields (EMFs) produces beneficial biological effects. However, controversy persists due to the absence of a clearly defined mechanism. Classical physics, constrained by the non-ionizing nature of these exposures, cannot account for these effects, which do not involve the breaking of chemical bonds to induce conformational changes in proteins. Emerging studies suggest that these effects are mediated through quantum mechanical phenomena-specifically, quantum tunneling and particle-wave duality-acting on the water surrounding proteins at their interfaces. Furthermore, we present evidence of EMF-induced conformational changes in Intrinsically Disordered Proteins (IDPs), including beta-amyloid, tau, alpha-synuclein, and Heat Shock Factor 1 (HSF1). These findings offer a new framework for understanding EMF bioeffects and open promising avenues for research in biophysics and quantum biology. In this context, we address the challenge of reproducibility by examining how variables such as frequency, intensity, Specific Absorption Rate (SAR), and exposure time windows interact, along with how parameters like polarization, phase, pulse modulation, and scheduling influence outcomes. Experimental data identify specific RF frequencies and SAR levels that activate proteostasis and autophagy in cell cultures and small animal models, with potential applications in human treatments that remain consistent with safety thresholds established by regulatory agencies.

Open access: https://www.scirp.org/journal/paperinformation?paperid=146794

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**RF-EMF Exposure Assessment: Comparison of Measurements in Airports and Flights with and Without Wi-Fi Service**

Arribas E, Escobar I, Martinez-Plaza A, Rufo-Pérez M, Jimenez-Barco A, Paniagua-Sánchez JM, Marín P, Ramirez-Vazquez R. RF-EMF Exposure Assessment: Comparison of Measurements in Airports and Flights with and Without Wi-Fi Service. *Sensors*. 2025; 25(21):6710. doi: 10.3390/s25216710.

Abstract

This paper presents the results of personal exposure measurements to Radiofrequency Electromagnetic

Fields from 2.4 GHz and 5.85 GHz Wi-Fi frequency bands. Measurements were taken in several specific scenarios: within international airports terminals, during takeoff, inside airplanes while flying with and without onboard Wi-Fi service (including while actively using a Wi-Fi connection), and during landing. Data were recorded onboard four international flights (two-round trip flights), from Spain to Mexico, and from Spain to Belgium. Two personal exposimeters, EME SPY 140 and EME Spy Evolution, were used to collect intensity level measurements in each scenario. During the outbound, the mean exposure value inside the airplane flight was 93.9 µW/m2 in the 2.4 GHz Wi-Fi frequency band and 46.4 µW/m2 in the 5.85 GHz Wi-Fi band (Spain to Mexico), and 7.29 µW/m2 in the 2.4 GHz Wi-Fi band and 2.40 µW/m2 in the 5.85 GHz Wi-Fi band (Spain to Belgium). For the return flight, the average value was 26.7 µW/m2 in the 2.4 GHz Wi-Fi band and an average of 9.87 µW/m2 in the 5.85 GHz Wi-Fi band (Mexico to Spain), and 3.24 µW/m2 in the 2.4 GHz Wi-Fi band and 1.23 µW/m2 in the 5.85 GHz Wi-Fi band (Belgium to Spain). Personal exposure levels to RF-EMFs from the Wi-Fi frequency band inside an airplane, even at the airport, are very low and well below the reference levels established by the international guidelines (10 W/m2).

Open access: https://www.mdpi.com/1424-8220/25/21/6710

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**Exposure Variability Between 1- or 6-Minute and 30-Minute Averaging Time Lengths in Radiofrequency-Electromagnetic Field Exposure Monitoring**

Bhatt CR, Henderson S, Sanagou M, Loughran S. Exposure Variability Between 1- or 6-Minute and 30-Minute Averaging Time Lengths in Radiofrequency-Electromagnetic Field Exposure Monitoring. Bioelectromagnetics. 2025 Dec;46(8):e70030. doi: 10.1002/bem.70030.

Abstract

Different averaging time lengths (ATLs) are widely used in radiofrequency-electromagnetic field (RF-EMF) exposure monitoring. This study evaluated variability in RF-EMF exposure associated with the ATLs of 1- and 6-min normalised to 30-min data. For 15 frequency bands of interest, RF-EMF exposures were collected in contiguous 1-min blocks over 30 min at four sites (two outdoor and two indoor). Frequency-band and site-specific variability in exposure between the three ATLs was assessed. First, the variability in terms of relative deviation (in dB) between 1- or 6-min and 30-min were estimated. Second, the overall exposure variability (in $\mu W/m^2$) were compared between 1- or 6-min and 30-min blocks statistically using the quantile regression method. The overall exposure variability on ATL of 1-min or 6-min was considered different to 30-min if a majority of respective sub-pair comparisons across different percentiles ( $P_5$ , $P_{25}$ , $P_{50}$ , $P_{75}$ , $P_{95}$ ) were significantly different. The study largely showed that the exposure variability (i.e., relative deviation) of different ATLs was within +/− 3 dB. Further, the overall exposure variability between 1- or 6-min and 30-min ATLs showed inconsistent outcomes. Frequency bands of broadcast and most of the mobile services < 2 GHz demonstrated overall similar exposure variability for 1-min and 6-min ATLs.

https://onlinelibrary.wiley.com/doi/10.1002/bem.70030

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**Visualizing radiofrequency electromagnetic field exposure through Voronoi-based maps**

Arribas E, Ramirez-Vazquez R, Escobar I. Visualizing radiofrequency electromagnetic field exposure through Voronoi-based maps. Environ Sci Pollut Res Int. 2025 Nov 15. doi: 10.1007/s11356-025-37188-4.

Abstract

Measuring the exposure of radiofrequency electromagnetic fields in a city is a very laborious task. To simplify this process for a city of 200 thousand inhabitants, Voronoi diagrams were used. The city was divided into cells based on the Euclidean distance to a point on the map, and each cell was assigned the value of the electric field measured at that point using a personal exposimeter. The number of cells varied from five to 30 and, finally, one 100. The maps obtained are commented on, using a palette of four uniform colors for the cells, to facilitate their perception. The more cells are considered, the smaller the cells will be. A stabilization of the process is observed as the points within the city map increase. The colors represent the RMS (root mean square) electric field measured at each seed point, extended geometrically to its Voronoi cell for visualization purposes. The colors of the areas remain the same; and in some other areas, cells appear with slightly distinct colors, due to the addition of new measured points. Some cells change color due to these new measurements of the new points. In this study, the predominant color is green, which is the measured field at the seed point was 1.9 V/m RMS (while the maximum allowed by the ICNIRP guidelines is 61.4 V/m). There are three cells in the city with E values above 3.9 V/m, reaching the highest value of 11.4 V/m. The entire city is within the recommended maximum. The Voronoi diagram method is shown to be useful and interesting for the presentation of radiofrequency electromagnetic fields exposure measurements in a medium-sized city. The Voronoi cells do not contain information about the intracell spatial variation of the electric field; each polygon represents the RMS value measured at its generating point (seed), offering a discrete visualization of the spatial distribution of the measurements and illustrating how the electric field levels vary across the study area.

https://pubmed.ncbi.nlm.nih.gov/41239101/

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**Empowering the Serbian EMF RATEL System for Monitoring RF-EMF Through Drive Test**

Djuric N, Kavecan N, Otasevic V, Kljajic D, Djuric S. Empowering the Serbian EMF RATEL System for Monitoring RF-EMF Through Drive Test. *IEEE Access*, vol. 13, pp. 180918-180940, 2025, doi: 10.1109/ACCESS.2025.3618714.

Abstract

The Serbian EMF RATEL system has been monitoring radiofrequency (RF) electromagnetic fields (EMFs) since 2017. As one of five active European systems for continuous monitoring of RF-EMF, it has been able to provide insight into the long-term, temporal variability of the field, especially in areas with increased sensitivity to RF-EMF exposure. Although it has proven its benefits for the general public and the scientific community, the relatively small number of RF-EMF sensors installed at fixed locations reveals its weakness – the inability to cover larger urban areas and provide adequate information on the spatial distribution of the overall field. The distribution of sensors at scattered points is a consequence of the limited costs of system development, as well as the practical difficulties in obtaining an authorized permit to install sensors at a public or private location, which is crucial for the use of any large number

of sensors. Consequently, the EMF RATEL network has been upgraded to perform spatial field analysis by integrating the functionality of the drive test, for the first time among existing monitoring systems, developing it to a higher level and achieving progress in RF-EMF research by establishing a single EMF entity for observing both temporal and spatial changes of RF-EMF in the territory of interest. This paper presents some technical details of the integration of the drive test into EMF RATEL, as well as preliminary quantitative results of the corresponding drive test measurements to validate the approach. The aim of this paper is to encourage other, similar EMF monitoring systems to further develop the topic of RF-EMF observation.

Open access: https://ieeexplore.ieee.org/document/11195077

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**Thermal and SAR-Based Limits for Human Skin Exposed to Terahertz Radiation**

Elmaadawy S, Jornet JM. Thermal and SAR-Based Limits for Human Skin Exposed to Terahertz Radiation. *2025 International Telecommunications Conference (ITC-Egypt)*, Cairo, Egypt, 2025, pp. 388-393, doi: 10.1109/ITC-Egypt66095.2025.11186625.

Abstract

Terahertz technology holds strong potential for wireless communication and sensing and has become a growing focus of research in recent years. However, current safety guidelines for wireless communication do not fully address the entire terahertz spectrum, as they only cover the sub-terahertz band (100−300GHz). Establishing safe exposure limits is a necessary prerequisite for the practical deployment of terahertz systems. In this paper, a COMSOL Multiphysics model was developed to analyze the thermal impact of terahertz exposure on human skin and to determine the maximum permissible power limits across the frequency range from 0.1 THz to 5 THz. The current state of terahertz wireless communication technology was also explored by analyzing a representative system to assess present capabilities and exposure safety. The results indicate that the existing power levels defined for the sub-terahertz band may no longer be adequate, either for the sub-terahertz range itself or for the broader terahertz region evaluated in this study. This research lays the groundwork for safer terahertz technology standards, facilitating its broader use in wireless communication.

Conclusions

This study established the first comprehensive thermal and SAR safety analysis for human skin exposed to terahertz radiation across the 0.1−5THz spectrum. Our COMSOL Multiphysics ® simulations revealed that maintaining SAR below the 1.6 W/kg safety threshold requires power densities not exceeding 0.226 W/m2, which induced negligible temperature increases. Temporal SAR analysis demonstrated that even stricter limits may be necessary for prolonged exposures. Notably, while power densities up to 100 W/m2 produced minimal thermal effects (approximately 0.03 K), they generated SAR values that far exceeded safety standards. These findings directly informed safe operating parameters for emerging terahertz wireless communication systems. Our results demonstrated that current sub-THz safety standards could not be extrapolated to the broader THz spectrum, necessitating new exposure guidelines.

Our analysis was limited to the 0.1−5THz range and did not extend to frequencies up to 10 THz, where

additional thermal effects may emerge. Moreover, our model assumed uniform skin structure, whereas actual skin exhibits complex layered heterogeneity that could affect radiation absorption patterns.

Future work will incorporate experimental validation of these findings through phantom studies and extend the analysis to investigate potential long-term biological effects of terahertz radiation.

https://ieeexplore-ieee-org.libproxy.berkeley.edu/document/11186625

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**Prolonged 3.5 GHz and 24 GHz RF-EMF Exposure Alters Testicular Immune Balance, Apoptotic Gene Expression, and Sperm Function in Rats**

Syed Taha SMA, Jaffar FHF, Hairulazam A, Vijay S, Jamaludin N, Zulkifli AF, Mat Ros MF, Osman K, Zakaria Z, Mohd Bahar MAA, et al. Prolonged 3.5 GHz and 24 GHz RF-EMF Exposure Alters Testicular Immune Balance, Apoptotic Gene Expression, and Sperm Function in Rats. *Biomedicines*. 2025; 13(10):2471. https://doi.org/10.3390/biomedicines13102471

Abstract

Background/Objectives: The rapid rollout of 5G has renewed interest in potential reproductive effects of mid-band (3.5 GHz) and millimeter-wave (24 GHz) radiofrequency electromagnetic fields (RF-EMF). We examined frequency- and duration-dependent changes in testicular cytokines, apoptosis-related genes, and sperm quality in rats.

Methods: Male Sprague Dawley rats (n = 6 per group) were exposed for 60 days to 3.5 GHz or 24 GHz RF-EMF for 1 h/day or 7 h/day. The sham controls were housed identically. Testicular expressions of IL-10, IL-6, IL-1β, and TNF-α were quantified; Tp53, Bax, Bcl2, and Casp3 mRNA expressions were measured; and sperm concentration, viability, and motility were evaluated.

Results: IL-10 was significantly reduced in the 24 GHz group at both 1-h and 7-h exposure duration. At 7 h, TNF-α was also lower at 24 GHz. Casp3 expression was higher and Tp53 was lower at 3.5 GHz at 1-h exposure duration. Sperm concentration and viability were reduced after 24 GHz exposure at 7 h, while sperm motility was reduced after 3.5 GHz exposure at both durations.

Conclusions: Exposure to RF-EMF 3.5 GHz primarily impacts sperm motility via extrinsic pro-apoptotic pathways, while exposure to 24 GHz impacts sperm concentration and viability potentially through immune–apoptotic mechanisms, with all negative effects amplified by 7-h daily exposure.

Open access: https://www.mdpi.com/2227-9059/13/10/2471

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**The effect of Wi-Fi on elastic and collagen fibres in the blood vessel wall of the chorioallantoic membrane**

Holovská K, Andrašková S, Petrovová E, Molnár J, Vince T, Almášiová V. The effect of Wi-Fi on elastic and

collagen fibres in the blood vessel wall of the chorioallantoic membrane. Acta Vet. Brno 2025, 94: 137-144. doi: 10.2754/avb202594020137

In this study we observed the effect of Wi-Fi on various fibrous components that form the wall of large blood vessels in the chorioallantoic membrane (CAM) of the chicken embryo. Chicken embryos in the experimental groups (Wi-Fi) were continuously exposed (24 h per day) to Wi-Fi radiation at a frequency of 2.4 GHz and an average power density of 300 $\mu W/m^2$ for 9 and 14 embryonic days (ED). Subsequently, the CAM samples from the control (CO) and experimental (Wi-Fi) groups were histologically processed and evaluated. The samples stained with haematoxylin and eosin did not reveal any notable differences in the structure of large blood vessels between the CO and Wi-Fi groups. However, the use of special staining methods showed adverse effect of Wi-Fi on the fibrous elements within the blood vessel wall. The optical density (OD) of elastic fibres significantly decreased from 0.294 ± 0.025 (CO 9) to 0.197 ± 0.022 (Wi-Fi 9) at ED 9 and from 0.706 ± 0.028 (CO 14) to 0.271 ± 0.031 (Wi-Fi 14) at ED 14. On the other hand, at ED 9, the OD of collagen fibres exhibited a notable increase from 0.178 ± 0.023 (CO 9) to 0.334 ± 0.020 (Wi-Fi 9). However, at ED 14, there was a significant decline of collagen fibres from 0.418 ± 0.033 (CO 14) to 0.327 ± 0.031 (Wi-Fi 14). Our results support the hypothesis that Wi-Fi could affect the fibrous elements of the large vessel wall and may play a role in the development of different cardiovascular disorders.

Open access: https://actavet.vfu.cz/media/pdf/actavet_2025094020137.pdf

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**Investigating the Effects of Occupational Noise and Extremely Low-Frequency Electromagnetic Field Exposure on Oxidative Response in Power Plant Workers**

Jafarimanesh S, Ehsani H, Shaki F, Moosazadeh M, Samaei SE. Investigating the Effects of Occupational Noise and Extremely Low-Frequency Electromagnetic Field Exposure on Oxidative Response in Power Plant Workers. Bioelectromagnetics. 2025 Oct;46(7):e70027. doi: 10.1002/bem.70027.

Abstract

Occupational noise and extremely low-frequency electromagnetic fields (ELF-EMF) are common in power plants and represent important risk factors that may contribute to oxidative stress. This study examined how simultaneous exposure to these hazards affects oxidative stress biomarkers in workers under real-world conditions. Participants were assigned to one of four exposure groups: Control (C), Noise (N), ELF-EMF (E), or a combined Noise and ELF-EMF group (NE). Occupational noise and ELF-EMF exposures were measured according to ISO 9612 and IEEE Std C95.3.1, respectively. To assess oxidative stress, venous blood samples were collected from all participants, and plasma levels of malondialdehyde (MDA), glutathione (GSH), superoxide dismutase (SOD), and total antioxidant capacity (TAC) were analyzed using validated biochemical assays. The NE group showed the highest MDA levels, indicating elevated lipid peroxidation compared with controls ($p < 0.001$). GSH concentrations were lower in NE relative to controls ($p < 0.001$). SOD activity was significantly reduced in both the N and NE groups compared with the control group ($p < 0.005$). TAC was lowest in the NE group, showing a significant decrease compared with both the control and Noise-only groups ($p < 0.05$). While these findings suggest that concurrent exposure to noise and ELF-EMF can influence oxidative stress biomarkers, they do not

provide direct evidence to mandate specific workplace monitoring or interventions. Further studies are needed to clarify potential health risks and to guide evidence-based occupational safety measures.

Summary

- This study investigated oxidative stress biomarkers in power plant workers exposed to occupational noise, ELF-EMF, and their combined exposure.
- Concurrent exposure to noise and ELF-EMF was linked to a significant increase in the lipid peroxidation marker malondialdehyde compared with unexposed workers.
- Other oxidative stress markers, including glutathione, superoxide dismutase, and total antioxidant capacity, exhibited less consistent changes across the exposure groups.
- These findings indicate potential oxidative stress effects associated with combined occupational exposures, highlighting the need for further research.

https://pubmed.ncbi.nlm.nih.gov/41104887/

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**Measurement of Electromagnetic Fields Exposure to Humans from Electric Vehicles and Their Supply Equipment**

Murthy GPP, Varadarajan GS.Measurement of Electromagnetic Fields Exposure to Humans from Electric Vehicles and Their Supply Equipment.Measurement. Volume 258, Part D,2026, doi: 10.1016/j.measurement.2025.119378.

Abstract

Electric Vehicles (EVs) represent a progressive approach to fostering a healthy and sustainable transportation future on Earth. Intended for mitigating global warming by virtue of decarbonizing transportation sector. Besides being environmentally beneficial, electrification in transportation necessitates a study of non-ionizing Electromagnetic Fields (EMF). Despite extensive research, the health effects related to long-term exposure to EMF remain inconclusive. The main aim of this research is to share and disseminate measurement findings of EMF emission from EVs and their Electric Vehicle Supply Equipment (EVSE). The specification of the measuring instrument, methodology adhered to measurement, and observed results have been discussed. Measurements have been carried out at different EVs and EVSEs in and around Chennai city, up to 400 kHz frequency band. To analyze human exposures, Electric Field Intensity (E) and Magnetic Flux Density (B) have been measured in the vicinity of driver and passenger seats inside EVs during driving condition, furthermore fields near different positions of EVSEs during charging condition. The measured values have been compared with the ICNIRP and IEEE standard recommendations for human external body exposure level. In accordance with the findings, E & B inside EVs fall within the standard limit. The E in the vicinity of EVSE is under standard limit, but at certain places B is concurrently above general public exposure threshold (>200 μT). In addition, a preliminary computational analysis has been done using Finite Element Method (FEM). Simulated fields are then compared with measurement readings of AC charger, where the electric and magnetic field magnitudes are relatively higher. With an ever-increasing electrification of vehicle fleets,

knowledge of health impacts of long-term exposure to humans can be enhanced through more observational research.

Highlights

• Measurement of Electric Field Intensity (E) and Magnetic Flux Density (B) from EVs and EVSEs while driving and charging respectively.
•The measured values have been compared with the ICNIRP and IEEE standard recommendations for human external body exposure level.
• E and B inside EVs falls within the standard limit.
• The E in the vicinity of EVSEs is also under standard limits but B is concurrently above the standard exposure threshold at certain positions.
• FEM model of electric vehicle AC charging cable using COMSOL Multiphysics® software for EMF computational analysis has been done.
• The measurement results are compared with simulation outputs.
• From the findings, policy recommendations to mitigate EMF exposure from EVs and EVSEs in the context of global electric vehicle adoption are addressed.

https://www.sciencedirect.com/science/article/pii/S026322412502737X

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**A Cohort Study on Alzheimer's Disease in Relation to Residential Magnetic Fields From Indoor Transformer Stations**

Liimatainen A, Roivainen P, Juutilainen J, Höytö A, Naarala J. A Cohort Study on Alzheimer's Disease in Relation to Residential Magnetic Fields From Indoor Transformer Stations. Bioelectromagnetics. 2025 Dec;46(8):e70031. doi: 10.1002/bem.70031.

Abstract

Meta-analyses of epidemiological studies have suggested that Alzheimer's disease (AD) may be linked with exposure to extremely low frequency (ELF) magnetic fields (MF). This is the first study investigating the association of AD with exposure to residential ELF MFs from indoor transformer stations, using a study design that avoids shortcomings of previous studies. All cohort members had lived in buildings with indoor transformer stations. MF exposure was assessed based on the location of their apartment in relation to the transformer room. AD patients were identified from Drug Purchase Register and Drug Reimbursement Register. Out of the 155,562 individuals, 5652 (111,357 person-years of follow-up) living in apartments next to transformer stations were considered as exposed, while 115,772 (2,289,526 person-years of follow-up) individuals living on higher floors of the same buildings were considered as referents. Associations between MF exposure and AD were examined using Cox proportional hazard models. The hazard ratio (HR) was 1.02 (95% confidence interval: 0.85-1.22), indicating that the risk of AD is not associated with residential ELF MFs present in apartments next to transformer stations. The duration of residence did not essentially change the HR. The risk of AD was slightly but not statistically significantly higher (HR 1.22, 95% confidence interval: 0.94-1.57) for those whose residence started before the age of 50 years. The results did not support positive findings from previous studies that have reported a link between AD and occupational or residential MF exposure.

Summary

- The study included high residential extremely low frequency (ELF) magnetic field (MF) levels from indoor transformer stations and avoided many limitations of previous studies.
- Residential ELF MFs did not affect the risk of Alzheimer's disease (AD).
- Further studies should focus on investigating occupational ELF MF exposure and the potential effect of diurnal timing of MF on the risk of AD.

Conclusions

No evidence for an association between residential ELF MFs and AD was found in this study that involved relatively high exposure levels and avoided many limitations of previous studies addressing residential MF exposure. We recommend that, if any further studies on the possible link between ELF MF exposure and AD are conducted, they should focus on occupational MF exposure, trying to identify occupational groups exposed to particularly strong ELF MFs. Studies (including experimental studies) on the possible differences between night-time and day-time exposure might also be helpful.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70031

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**Effect of Increased Ionizing Radiation and Near-Null Magnetic Field on Electrical Signals of Plants**

Grinberg MA, Il'in NV, Nemtsova YA *et al.* Effect of Increased Ionizing Radiation and Near-Null Magnetic Field on Electrical Signals of Plants. *Radiophys Quantum El* (2025). https://doi.org/10.1007/s11141-025-10418-y.

Abstract

There is currently a significant gap in understanding the effects of astro- and geophysical factors such as ionizing and non-ionizing radiation, including electromagnetic fields, on living organisms. The effects caused by these factors are important for planning scenarios in which significant changes in the intensity of such factors can be expected both on the Earth and during space missions. There is a reason to believe that, of all the indicators of the functioning of living organisms, the signaling systems responsible for the perception, processing, and amplification of the incoming stimulus are the most sensitive. In this work, we have studied the effect of increased levels of ionizing radiation (β radiation, dose rate of 31.3 μGy/h) and hypomagnetic conditions (induced magnetic field 0–1.5 μT) on electrical signals of plants caused by an additional stimulus. To conduct the experiments, a setup based on triaxial Helmholtz rings was created, which permits one to set and maintain altered conditions of the electromagnetic environment with high accuracy. The work showed that an increased level of ionizing radiation strengthens, while the near-null level of magnetic field weakens electrical signals in plants. It is assumed that the mechanism of action of such factors is their effect on a single component of stress signaling, namely, concentration of reactive oxygen species. The observed effects open up a new way for studying the mechanisms of the influence of ionizing and non-ionizing radiation on the state of living organisms.

https://link.springer.com/article/10.1007/s11141-025-10418-y

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**Electromagnetic Interference in the Modern Era: Concerns, Trends, and Nanomaterial-Based Solutions**

Prekodravac Filipovic J, Milenkovic M, Kepic D, Dorontic S, Yasir M, Nardin B, Jovanovic S. Electromagnetic Interference in the Modern Era: Concerns, Trends, and Nanomaterial-Based Solutions. Nanomaterials (Basel). 2025 Oct 13;15(20):1558. doi: 10.3390/nano15201558.

Abstract

Electromagnetic interference (EMI) represents a growing challenge in the modern era, as electronic systems and wireless technologies become increasingly integrated into daily life. This review provides a comprehensive overview of EMI, beginning with its historical evolution over centuries, from early power transmission systems and industrial machinery to today's complex environment shaped by IoT, 5G, smart devices, and autonomous technologies. The diverse sources of EMI and their wide-ranging effects are examined, including disruptions in electrical and medical devices, ecological impacts on wildlife, and potential risks to human health. Beyond its technical and societal implications, the economic dimension of EMI is explored, highlighting the rapid expansion of the global shielding materials market and its forecasted growth driven by telecommunications, automotive, aerospace, and healthcare sectors. Preventative strategies against EMI are discussed, with particular emphasis on the role of advanced materials. Carbon-based nanomaterials-such as graphene, carbon nanotubes, and carbon foams-are presented as promising solutions owing to their exceptional conductivity, mechanical strength, tunable structure, and environmental sustainability. By uniting perspectives on EMI's origins, consequences, market dynamics, and mitigation strategies, this work underscores the urgent need for scalable, high-performance, and eco-friendly shielding approaches. Special attention is given to recent advances in carbon-based nanomaterials, which are poised to play a transformative role in ensuring the safety, reliability, and sustainability of future electronic technologies.

Open access: https://www.mdpi.com/2079-4991/15/20/1558

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**The WHO-commissioned systematic reviews on health effects of radiofrequency radiation provide no assurance of safety**

Melnick RL, Moskowitz JM, Héroux P, Mallery-Blythe E, McCredden JE, Herbert M, Hardell L, Phillips A, Belpoggi F, Frank JW, Scarato T, Kelley E, on behalf of the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF). The WHO-commissioned systematic reviews on health effects of radiofrequency radiation provide no assurance of safety. Environ Health 24, 70 (2025). https://doi.org/10.1186/s12940-025-01220-4.

Abstract

The World Health Organization (WHO) commissioned 12 systematic reviews (SR) and meta-analyses (MA) on health effects of exposure to radiofrequency electromagnetic fields (RF-EMF). The health outcomes selected for those reviews (cancer, electromagnetic hypersensitivity, cognitive impairment, birth outcomes, male fertility, oxidative stress, and heat-related effects) were based on a WHO-conducted international survey. The SR of the studies of cancer in laboratory animal studies was the only one that did not include a MA, because those authors considered it inappropriate due to methodological differences among the available studies, including differences in exposure

characteristics (carrier frequency, modulation, polarization), experimental parameters (hours/day of exposure, duration of exposure, exposure systems), and different biological models. MAs in all the other SRs suffered from relatively few primary studies available for each MA (sometimes due to excessive subgrouping), exclusion of relevant studies, weaknesses in many of the included primary studies, lack of a framework for analyzing complex processes such as those involved in cognitive functions, and/or high between-study heterogeneity. Due to serious methodological flaws and weaknesses in the conduct of the reviews and MAs on health effects of RF-EMF exposure, the WHO-commissioned SRs cannot be used as proof of safety of cell phones and other wireless communication devices. However, the animal cancer SR, which was rated as "high certainty of evidence" for heart schwannomas and "moderate certainty of evidence" for brain gliomas, provided quantitative information that could be used to set exposure limits based on reducing cancer risk. The multiple and significant dose-related adverse effects found in the SRs on male fertility and pregnancy and birth outcome should also serve as the basis for policy decisions to lower exposure limits and reduce human reproductive risks. The report of harmful effects (e.g., cancer, reproductive toxicity, etc.) at doses below the adverse health effect threshold claimed by ICNIRP demonstrates that current exposure limits to RF-EMF, which were established by applying arbitrary uncertainty factors to their putative adverse threshold dose, lack scientific credibility.

**Open access: https://ehjournal.biomedcentral.com/articles/10.1186/s12940-025-01220-4**

**Supplementary Material 1. "Examples of Working Group Authors' Ties to Industry"**

**Supplementary Material 2. "The Meta-Analyses in the WHO RF-EMF Systematic Reviews Yielded Unreliable Results"**

**https://www.saferemr.com/2022/10/international-commission-on-biological.html**

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**Review of the evidence on the influence of Wi-Fi 2.4 GHz radiation on oxidative stress and its possible relationship with Alzheimer's disease**

Laván D, Argüelles N, Lluncor A, Huaman D, Moyano J, Ubillus J, Peña M, Paredes M, Hernández I, Guerra A, De La Cruz-Vargas J, Cruz V. Review of the evidence on the influence of Wi-Fi 2.4 GHz radiation on oxidative stress and its possible relationship with Alzheimer's disease. Frontiers in Neurology. Volume 16, 2025. doi: 10.3389/fneur.2025.1616435.

Abstract

To date, there is no scientific consensus on whether wireless communication systems, such as 2.4 and 5 GHz Wi-Fi, play a crucial role in the development of Alzheimer's disease through oxidative stress. Although numerous studies have linked oxidative stress to exposure to electromagnetic radiation from wireless systems in various biological contexts, these studies have not established a direct connection to neurodegenerative diseases. Research on Alzheimer's disease and oxidative stress is an active field in neuroscience and medicine, as oxidative stress involves an imbalance between the production of free radicals and the antioxidant system's ability to neutralize them, leading to cellular and neuronal damage. It is essential to recognize that Alzheimer's disease is multifactorial, and its development generally results from a complex interaction of genetic, environmental, and lifestyle factors. The relationship between wireless systems such as Wi-Fi and oxidative stress, as well as its possible link to

Alzheimer's disease, continues to be the subject of research and debate in the scientific community. Although some studies have explored this possible association, the results have been mixed and inconclusive. While research on the health effects of wireless systems remains relevant, it is prudent not to consider this association as an established fact until solid and consistent scientific evidence is available. The study we present focuses on indirectly analyzing the relationship between genes that respond to oxidative stress upon exposure to Wi-Fi 2.4 GHz electromagnetic waves and genes associated with the development of Alzheimer's disease. Our results indicate that the modification of key genes involved in neurodegeneration, such as GSK3B and APOE, could be exacerbated by prolonged exposure to this radiation. It is essential for future research to explore this hypothesis to further clarify the potential risks associated with electromagnetic radiation and its impact on neuronal health and the progression of Alzheimer's disease.

Conclusion

In summary, exposure to 2.4 GHz electromagnetic fields emitted by Wi-Fi devices could have an indirect impact on the regulation of genes involved in Alzheimer's disease, particularly those related to oxidative stress and cellular homeostasis. Although a direct relationship has not been demonstrated, current findings suggest that the alteration of genes such as GSK3B and APOE, which are fundamental in neurodegeneration, could be exacerbated by chronic exposure to this radiation. Future research should address this hypothesis to provide a clearer understanding of the potential risks associated with electromagnetic radiation and its impact on neuronal health and the development of Alzheimer's disease.

Open access: https://www.frontiersin.org/journals/neurology/articles/10.3389/fneur.2025.1616435

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**Microwave and RF Exposure-Induced Molecular and Genetic Alterations**

Lin JC. Microwave and RF Exposure-Induced Molecular and Genetic Alterations [Health Matters]. *IEEE Microwave Magazine*, vol. 26, no. 11, pp. 16-17, Nov. 2025, doi: 10.1109/MMM.2025.3594272.

No abstract

"Recent reports of studies on the effects of microwave and RF exposure on molecular and cytogenetic materials have drawn considerable attention. They suggest that RF exposure could induce DNA damage at levels considered safe by promulgated guidelines and regulatory standards.

In particular, a new study described the observation of genetic alterations in rat cancers resulting from lifetime exposure to low-level RF radiation [1]...."

[1] A. M. Brooks et al., "Genetic profiling of rat gliomas and cardiac schwannomas from life-time radiofrequency radiation exposure study using a targeted next-generation sequencing gene panel," *PLoS One*, vol. 19, no. 1, 2024, Art. no. e0296699, doi: 10.1371/journal.pone.0296699.

Open access: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11195922

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**Experience of Polish Physicians on Electromagnetic Hypersensitivity**

Undas K, Kanclerz G, Popielak J, Tatoń G. Experience of Polish Physicians on Electromagnetic Hypersensitivity. *2025 Progress in Applied Electrical Engineering (PAEE)*, Koscielisko, Poland, 2025, pp. 1-4, doi: 10.1109/PAEE68231.2025.11155985.

Abstract

The aim of this project was to assess the knowledge of Polish physicians about the impact of electromagnetic fields (EMF) on human health, their knowledge of electromagnetic hypersensitivity (EHS), and their experiences with patients who consider themselves hypersensitive to EMF. A questionnaire survey was conducted among physicians in a traditional paper-based format, as well as using an online form. Responses were obtained from 355 doctors of various specialties and with different levels of experience, both clinical and scientific. A subjective and objective assessment of the respondents' knowledge about the impact of EMF on humans leads to the disturbing conclusion that their knowledge cannot be considered broad. For example, the subjective self-assessment of knowledge in 1/3 of the respondents is at a very low or low level. Physicians do not seem to be familiar with the WHO guidelines for dealing with people who perceive themselves as hypersensitive to EMF. Respondents are aware of the low level of their knowledge about EMF and most of them are ready to improve their qualifications in this field. They also see the need to spread reliable knowledge about the EMF and its impact on society. The low assessment of doctors' knowledge of EMF and EHS is even more concerning as EHS is a phenomenon many encounter in their daily professional practice. Almost 45% of physicians declared that they had to deal with patients who associated their symptoms with the impact of EMF, and some physicians claim that they deal with such patients even several times a month or more often. These findings may lead to significant for public health conclusions. EHS is not a marginal phenomenon, and physicians are striving to properly address this condition. At the same time, their knowledge about EHS and about EMF in general is limited. In such cases, they are unable to adequately help their patients and may become a source of unreliable or unverified information, which could lead to anxiety.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11155985&isnumber=11155907

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**Is Cellphone Carrying Below the Waist (Exposure to Non-Ionizing Radiation) Contributing to the Rapid Rise in Early-Onset Colorectal Cancer?**

Li DK, Ferber J, Hirst A, Odouli R, Quesenberry C, Levin T. Is Cellphone Carrying Below the Waist (Exposure to Non-Ionizing Radiation) Contributing to the Rapid Rise in Early-Onset Colorectal Cancer? ISEE 2024: 36th Annual Conference of the International Society of Environmental Epidemiology. Vol. 2024, Issue 1. doi: 10.1289/isee.2024.1903.

Abstract

BACKGROUND AND AIM: The incidence of early-onset (EO) (< 50 years of age) colorectal cancer (CRC) has been rising rapidly in recent decades, suggesting the presence of a new environmental risk factor. One emerging, yet under-investigated factor is increased exposure to radiofrequency (RF) non-ionizing radiation from widespread cellphone use. The young population has been documented to carry their cellphones in pants' pockets many hours a day, leading to extensive exposure to RF radiation in the colorectal region. Intestinal epithelial cells are among the tissue cells most sensitive to radiation

exposure. The study was designed to investigate whether cellphone carrying below the waist is associated with increased risk of EOCRC.

METHOD: We conducted a case-control study among 50 recently diagnosed EOCRC cases and 50 randomly selected age- and sex-matched controls. Information on carrying habits included specific locations below the waist before EOCRC diagnosis, the average amount of time carried per day and the ages at which they started and stopped carrying at a given location.[¤]RESULTS[|]After controlling for confounders, a longer duration (the highest tertile) in total hours of carrying a cellphone below the waist had more than 4-fold risk of EOCRC than shorter carrying duration (lower tertiles), adjusted odds ratio (aOR)=4.1, 95% confidence interval (CI):1.0-16.4. The association was stronger for rectal cancer (OR=6.4) vs. colon cancer (OR=1.9), given the closer proximity of pants' pockets to the rectum. Most strikingly, the association was much stronger for ipsilateral carrying (cellphone carrying on the same side of EOCRC tumor location) with a OR=12.1 (1.5-97) vs. contralateral carrying (cellphone carrying on the opposite side of tumor location) with OR=1.6.

CONCLUSIONS: A longer duration of cellphone carrying below the waist is associated with an increased risk of EOCRC. Though preliminary, the finding revealed an emerging environmental contributor to the rapid rise in EOCRC, whose reasons remain unknown.

https://ehp.niehs.nih.gov/doi/10.1289/isee.2024.1903

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**Causal relationship between the duration of mobile phone use and risk of stroke: A Mendelian randomization study**

Jin R, Jiang X, Lin Q, Huang X, Gao W, Wang B, Zheng F. Causal relationship between the duration of mobile phone use and risk of stroke: A Mendelian randomization study. Medicine (Baltimore). 2025 Sep 19;104(38):e44485. doi: 10.1097/MD.0000000000044485.

Abstract

This study investigates the causal relationship between the duration of mobile phone use (DMPU) and risk of stroke using Mendelian randomization (MR) analysis. Independent single nucleotide polymorphisms from genome-wide association study datasets were employed as instrumental variables to estimate the effects of DMPU on the risk of stroke, intracerebral hemorrhage, ischemic stroke, and its subtypes (cardioembolic infarction, small-vessel disease, large artery atherosclerosis [LAAS]). Inverse-variance weighting was utilized as the primary MR method and sensitivity analyses were performed. Ninety single nucleotide polymorphisms associated with stroke from genome-wide association study datasets were selected as instrumental variables. Inverse-variance weighted analysis showed a significant causality between DMPU and an increased risk of LAAS (odds ratio [OR] = 1.120; 95% confidence interval [CI] = 1.005–1.248; *P* = .040). No genetic association was found for stroke (OR = 1.000; 95% CI = 0.999–1.001, *P* = .677), intracerebral hemorrhage (OR = 1.020; 95% CI = 0.912–1.140, *P* = .734), ischemic stroke (OR = 1.020; 95% CI = 0.979–1.062, *P* = .344), cardioembolic infarction (OR = 1.066; 95% CI = 0.974–1.166, *P* = .166), and small-vessel disease (OR = 1.052; 95% CI = 0.944–1.173, *P* = .356). MR-Egger regression (intercept = $2.75 \times 10^{-3}$; *P* = .888) suggested multidimensionality was unlikely to bias the results; Cochran *Q* test and funnel plot showed no heterogeneity or asymmetry, indicating the robustness of present findings. The current investigation confirmed a causal relationship between

DMPU and an increased risk of LAAS, suggesting significant implications for public health initiatives and policy development.

Summary

This study used Mendelian randomization to explore if the duration of mobile phone use (DMPU) affects stroke risk. Researchers analyzed genetic data to see if DMPU is linked to different types of stroke. They found a significant link between DMPU and an increased risk of large artery atherosclerosis (LAAS), with an odds ratio of 1.120. However, no genetic association was found for other stroke types, including intracerebral hemorrhage and ischemic stroke. The study suggests that DMPU may specifically increase the risk of LAAS, highlighting potential public health concerns and the need for policy development.

Open access: https://journals.lww.com/md-journal/fulltext/2025/09190/mobile_phone_usage_duration_and_male_fertility__a.4.aspx

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**Mobile phone usage duration and male fertility: A two-sample Mendelian randomization analysis**

Xiang Y, Xu L, Sun Y, Hu C, Lv L. Mobile phone usage duration and male fertility: A two-sample Mendelian randomization analysis. Medicine (Baltimore). 2025 Sep 19;104(38):e44668. doi: 10.1097/MD.0000000000044668.

Abstract

Mobile phone use has become ubiquitous in modern life, raising public concern over its potential effects on male reproductive health. While several observational studies have reported associations between prolonged phone use and decreased sperm quality or testosterone levels, these findings remain inconclusive due to residual confounding, reverse causation, and inconsistent exposure measurement. We conducted a two-sample Mendelian randomization (MR) analysis using genetic variants associated with mobile phone usage duration to investigate its causal effects on male fertility. Inverse variance weighting (IVW) was employed as the primary analytical method. Genetic predisposition to longer mobile phone use was not associated with levels of sex hormone-binding globulin (SHBG), total testosterone, or the risk of abnormal sperm parameters, erectile dysfunction, or testicular dysfunction. These null findings were consistent across all MR methods and sensitivity analyses. Our findings suggest that mobile phone use is unlikely to have a direct causal impact on male reproductive hormones or sexual function. Future research incorporating precise exposure measurements and mechanistic evaluations is warranted.

Open access: https://journals.lww.com/md-journal/fulltext/2025/09190/mobile_phone_usage_duration_and_male_fertility__a.4.aspx

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**Differential metabolic responses of mouse Leydig and spermatogonia cells to radiofrequency electromagnetic field exposure**

Miao Xia , Lin Yanyun , Guo Juan , Lin Jiajin , Gao Peng , Zhang Wei , Zeng Lihua , Guo Guozhen , Li Jing. Differential metabolic responses of mouse Leydig and spermatogonia cells to radiofrequency

electromagnetic field exposure. Frontiers in Public Health. Volume 13 - 2025.
doi: 10.3389/fpubh.2025.1623701.

Abstract

Introduction: Although existing studies have shown that radiofrequency electromagnetic fields (RF-EMFs) have a variety of effects on living organisms, the specific impact of RF-EMFs on the metabolism of reproductive cells and their underlying mechanisms remain unclear.This study aims to explore the effects of RF-EMFs on the metabolism of mouse Leydig cells (TM3) and spermatogonia cells (GC-1) through metabolomics analysis, revealing the potential mechanisms by which RF-EMFs affect reproductive health.

Methods: We employed liquid chromatography-mass spectrometry (LC-MS) to analyze the metabolomic profiles of TM3 and GC-1 cells under two irradiation modalities: continuous and intermittent RF-EMF exposure. The data were further analyzed using KEGG pathway analysis to identify significantly enriched metabolic pathways. The ELISA (Enzyme-Linked Immunosorbent Assay) was used to detect glutathione levels.

Results: Our results showed that continuous irradiation had a more pronounced impact on the metabolism of TM3 cells, primarily affecting amino acid metabolism, the citric acid cycle, ABC transporters, bile secretion, and glutathione metabolism. In contrast, intermittent irradiation mainly altered the levels of fatty acyls and purine nucleosides, with significant enrichment in purine metabolism, biosynthesis of unsaturated fatty acids, and fatty acid metabolism. Compared to TM3 cells, GC-1 cells exhibited lower sensitivity to RF-EMF irradiation. Both irradiation modalities affected purine metabolism and lysine degradation pathways in TM3 cells, suggesting that changes in ADP levels may serve as a key metabolic signature in the cellular response to RF-EMF exposure.

Conclusion: Continuous irradiation significantly impacts TM3 cell metabolism, particularly amino acid and glutathione pathways, while intermittent irradiation mainly affects fatty acyls and purine metabolism. GC-1 cells show lower sensitivity to RF-EMF. ADP level changes may be a key metabolic signature of RF-EMF exposure.

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1623701/full

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**Radiofrequency regulates the BET-mediated pathways in radial glia differentiation in human cortical development**

Cakir B, Tanaka Y, Choe MS, Kiral FR, Kim J, Micali N, Kang YJ, Dharmadhikari B, Patterson B, Yang WS, Cho Y, Xiang Y, Zhong M, Lee SH, Patra P, Rakic P, Park IH. Radiofrequency regulates the BET-mediated pathways in radial glia differentiation in human cortical development. Cell Rep. 2025 Sep 24:116238. doi: 10.1016/j.celrep.2025.116238.

Abstract

The human brain represents one of the most complex organs in our body, with development regulated by an intricate genetic program. Recently, non-genetic factors, such as prenatal stress, infection, and

diet, have been shown to influence brain development. Radiofrequency radiation (RF; 800-2,400 MHz), emitted by natural and artificial sources such as microwaves and cell phones, represents a non-invasive environmental factor. Using human cortical organoids (hCOs) derived from human embryonic stem cells (hESCs), we investigate RF's effects on corticogenesis. We find that RF exposure regulates the differentiation of human and non-human primate radial glia progenitors, maintaining stem cell identity and delaying differentiation. Neurons differentiated under RF treatment show induction of expression of human endogenous retroviruses. Importantly, inhibitors for the BET (bromodomain and extraterminal) protein rescue RF-induced developmental defects in hCOs. Our findings reveal a mechanism by which RF modulates early brain development, offering a non-biological approach to regulate neural stem cell self-renewal.

Highlights

RF exposure alters radial glial differentiation in human cortical organoids

RF induces ASD-related gene and retroelement expression in cortical organoids

BET protein dysregulation mediates RF-induced neurodevelopmental defects

BET inhibitors rescue RF-induced developmental defects in cortical organoids

Open access: https://www.sciencedirect.com/science/article/pii/S2211124725010095

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**Investigation of fetal exposure to electromagnetic waves between 2.45 and 5 GHz during pregnancy**

İl N, Ateş K, Özen Ş. Investigation of fetal exposure to electromagnetic waves between 2.45 and 5 GHz during pregnancy. Radiat Prot Dosimetry. 2025 Sep 25:ncaf110. doi: 10.1093/rpd/ncaf110.

Abstract

In this paper, we have assessed the specific absorption rate (SAR) in fetal brain and lungs during the second trimester of pregnancy conditions of body exposure to radiofrequency electromagnetic field (RF-EMF). SAR calculations were performed for frontal and lateral incidences, with both vertical and horizontal polarization of the incident electromagnetic (EM) waves at frequencies ranging from 2.45 to 5 GHz. A realistic pregnant human model with a belly button piercing was implemented for numerical simulation for nonionizing dosimetry. The simulation results reveal that SAR tends to rise in the presence of belly-button piercing. The highest SAR10g recorded on the fetus's lungs was 16 mW/kg at a frequency of 2.45 GHz. Similarly, the maximum SAR10g value on the fetus's brain was measured 14 mW/kg, occurring at a frequency of 2.45 GHz. Results indicate that metal objects can lead to an increase in SAR values. However, obtained values remain below limits set by international organizations like the Institute of Electrical and Electronics Engineers and the International Commission on Non-Ionizing Radiation Protection.

https://pubmed.ncbi.nlm.nih.gov/40995977/

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**3.5GHz radiofrequency electromagnetic fields (RF-EMF) on metabolic disorders in Drosophila melanogaster**

Wang Y, Zhang Z, Zhang L, Liao Y, Cai P. 3.5GHz radiofrequency electromagnetic fields (RF-EMF) on metabolic disorders in Drosophila melanogaster. Ecotoxicol Environ Saf. 2025 Oct 6;304:119132. doi: 10.1016/j.ecoenv.2025.119132.

Abstract

The widespread implementation of fifth-generation (5 G) technology has raised concerns regarding its impact on biosafety. This study aims to uncover metabolic alterations in Drosophila melanogaster in response to electromagnetic radiation through metabolomics under 3.5 GHz radiofrequency electromagnetic fields (RF-EMF) conditions. Newborn male flies were continuously exposed to 3.5 GHz RF-EMF at intensities of 0.1 $W/m^2$, 1 $W/m^2$, and 10 $W/m^2$ throughout their entire life cycle under 24-hour constant darkness. Metabolomic analysis was performed on Drosophila samples after long-term exposure. The results indicate that long-term exposure to RF-EMF leads to disruptions in four metabolic pathways - alanine, aspartate and glutamate metabolism, tryptophan metabolism, ascorbate and aldehyde metabolism, and purine metabolism - as well as 34 differential metabolites across various power density in Drosophila melanogaster. Notably, the most significant metabolites (GABA, glucose-6-phosphate, AMP, N-formylglycinamide nucleotide, LPC, and MG) exhibited high sensitivity to RF-EMF showing significant decreases. The suggests that long-term exposure to electromagnetic wave treatment may reduce the overall metabolic levels in fruit fly. These findings provide valuable insights into the metabolic disturbance induced by RF-EMF and enhance our understanding of the potential health effects associated with 5 G radiation.

Highlights

Long-term 3.5 GHz RF-EMF exposure disrupts metabolism in Drosophila melanogaster.
Key pathways affected: energy, neurotransmitter, membrane lipid, purine metabolism.
34 altered metabolites did not exhibit a clear dose-dependent response to RF-EMF exposure.
Six sensitive biomarkers identified (e.g., GABA, glucose-6-phosphate), with significant decreases.
Results provide mechanistic insights into 5 G RF-EMF biosafety impacts.

Open access: https://www.sciencedirect.com/science/article/pii/S0147651325014770?via%3Dihub

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**Bacterial Adaptation to Radiofrequency Electromagnetic Fields Based on Experiences from Ionizing Radiation**

Said-Salman I, Mortazavi SMJ, Khatib SE, Mortazavi SA, Sihver L. (2025). Bacterial Adaptation to Radiofrequency Electromagnetic Fields Based on Experiences from Ionizing Radiation. *Journal of Biomedical Physics and Engineering*, (), -. doi: 10.31661/jbpe.v0i0.2405-1770.

Abstract

Bacteria, part of the three domains of life (Eukarya, Archaea, and Bacteria), are constantly exposed to man-made electromagnetic fields, which often exceed the intensity of natural electromagnetic sources. In response to this exposure, bacteria have developed various defensive and resistant traits. This article presents an overview of both historical and recent research on how bacteria adapt to common sources of Radiofrequency Electromagnetic Fields (RF-EMF. The widespread use of mobile phones and Wi-Fi,

both utilizing Radiofrequency (RF) radiation, raises potential public health concerns, which have been addressed by international organizations like the World Health Organization (WHO). Understanding how bacteria adapt to EMF is important for mitigating the risk of increased pathogenicity of radio-resistant bacteria in the human environment.

Conclusion

The exposure of bacteria to EMF can be appreciated when altering with bacterial survival mechanism and may compromise therapeutic success. However, continuous exposure of microorganisms to common sources of EMF such RF may emerge super-pathogens with high resistance to treatments.

Open access: https://jbpe.sums.ac.ir/article_51139_0eca0c408ce6ec99ffd5908dc60c3449.pdf

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**Associations between Individual and Geospatial Characteristics and Power of 4G Signals Received by Mobile Phones**

Laplanche A, Guida F, Moissonnier M, Launay L, Beranger R, Lagroye I, Orlacchio R, Fontaine M, Bories S, Mazloum T, Conil E, Huss A, Wiart J, Danjou A, Schüz J, Dejardin O, Deltour I. Associations between Individual and Geospatial Characteristics and Power of 4G Signals Received by Mobile Phones. Environ Res. 2025 Oct 6:123030. doi: 10.1016/j.envres.2025.123030.

Abstract

Background: The Received Signal Strength Indicator (RSSI) measures downlink signal intensity received by smartphones in 4th Generation LTE networks.

Objective: This study evaluated how individual, technical, and spatial factors influenced LTE-RSSI during daily activities.

Methods: Between November 2022 and October 2023, adults in France used the XMobiSensePlus Android smartphone application to record RSSI and GPS data. Distance to the operator's nearest antenna, obtained from Cartoradio, population and antenna density and urbanicity were analyzed using a geographic information system. Determinants of RSSI were assessed using an autoregressive mixed model incorporating restricted cubic splines for distance. Environmental exposures were estimated at 1800 MHz using conversion factors.

Results: From 1,969,913 records of 187 participants, with measurements taken every 30 seconds over 7.9 days, the average LTE-RSSI was -79.3 dBm. The estimated electric field strength was 0.12 V/m, albeit with large uncertainty. The median distance to the nearest antenna was 536 m. Proximity to antennas increased RSSI. Antenna density positively influenced RSSI (overall β = +0.37 dBm per additional antenna per km2). Lower RSSI was observed in the evening and night, particularly in urban areas. Smartphone's technical parameters (Android version and System-on-a-Chip) influenced RSSI, operators did not. Proximity to antennas had greater impact in rural areas.

Conclusion: Urbanicity, distance to the nearest 4G antenna, antenna density, time of day, and smartphone's technical parameters influenced RSSI levels in 4G networks in France, but not operator.

https://pubmed.ncbi.nlm.nih.gov/41061881/

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**Extremely Low-Frequency Magnetic Fields (ELF-MF) and Radiofrequency: Risk of Childhood CNS Tumors in a City with Elevated ELF-MF Exposure**

Correa-Correa V, Núñez-Enríquez JC, Mezei G, Rivera-Luna R, Peñaloza-González JG, Rivas-Carrillo SD, et al. Extremely Low-Frequency Magnetic Fields (ELF-MF) and Radiofrequency: Risk of Childhood CNS Tumors in a City with Elevated ELF-MF Exposure. Environmental Research, 2025, doi: 10.1016/j.envres.2025.122858.

Abstract

Background  Central nervous system tumors (CNSTs) are the second most common childhood cancer. While their etiology is unclear, exposure to extremely low-frequency magnetic fields (ELF-MF) and radiofrequency (RF) may be associated with increased risk. This study aims to examine the relationship between ELF-MF and RF exposure and CNST risk in Mexico City's pediatric population.

Methods  A case-control study was conducted in Mexico City (2017-2022), to assess ELF-MF and RF exposure in 200 CNST patients and 793 controls under 16 years old. Residential ELF-MF exposure was measured over 24 hours, and RF exposure was assessed through the total duration of cell phone calls and electronic device usage (with and without internet). ELF-MF exposure levels below 0.1 μT and the lowest RF exposure quartile (Q1) served as reference groups for adjusted odds ratio (aOR) analyses. Data analysis was performed using R and SPSS software.

Results  Of all participants, 5.1% had ELF-MF exposure ≥0.3 μT. Elevated ELF-MF exposure (≥0.4 μT) was significantly associated with an increased risk of CNST (aOR (95% confidence interval)=2.39 (1.15-5.00). While cell phone use showed no differences between cases and controls, prolonged tablet use (with and without internet) was significantly associated with increased CNST risk (aOR=2.53 (1.39-4.61), and 3.53 (1.45-8.59), respectively).

Conclusion  A high proportion of children in Mexico City are exposed to ELF-MF levels ≥0.3 μT, exceeding levels reported in other populations. Elevated residential ELF-MF exposure, as well as prolonged tablet use, both with and without internet connectivity, were significantly associated with an increased risk of developing CNST in childhood.

Highlights

- Many Mexico City children exposed to ELF-MF ≥0.3 μT, higher than global averages.
- Elevated ELF-MF exposure was associated with an increased risk of CNST.
- Prolonged tablet use increased CNST risk, especially in children aged 6-10.
- Cell phone use showed no association with CNST risk.

https://www.sciencedirect.com/science/article/pii/S0013935125021103

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**Dosimetric Electromagnetic Safety of People With Implants: A Neglected Population?**

Kranold L, Xi J, Goren T, Kuster N. Dosimetric Electromagnetic Safety of People With Implants: A Neglected Population? Bioelectromagnetics. 2025 Sep;46(6):e70023. doi: 10.1002/bem.70023. P

Abstract

Electromagnetic (EM) safety guidelines are designed to protect the general public and workers from the risks posed by exposure to EM sources of all types, with the exception of medical EM sources. However, it has never been systematically evaluated whether individuals with conductive implants are also protected by these guidelines or whether the local field enhancement due to presence of the implant may pose an unacceptable risk under certain realistic exposure conditions. To address this important knowledge and regulatory gap, we first evaluated the upper bound of the local enhancement of bare and insulated generic implants of 0.5 $\lambda$ (approximately equal to resonant) and 0.1 $\lambda$ lengths, but restricted the maximum length to 2 m, as a function of tissue properties and frequency (10 kHz to 1 GHz). Results for uniform electric field excitation showed local enhancement of $psSAR_{10mg}$ and of locally averaged E-field, respectively, compared to the background in the presence of a generic implant of 10 dB (1 GHz) to over 100 dB at frequencies under 100 MHz. In the next step, we tested the hypothesis that fields induced inside the human body by realistic near-field sources are not sufficiently uniform to generate results in enhancement that could pose unacceptable risk. Common implant trajectories were inserted into the Virtual Population human anatomical model Ella V3.0, and the model was exposed to the following conditions (i) a standard source representing a wireless power transfer source operating at 85 kHz and (ii) a dipole source that operates at 450 MHz within the current exposure limits. Results show that the safety limit is exceeded at the tip of the implant by a factor of > 10 ( > 20 dB) or > 115 V/m at 85 kHz, whereas the locally induced specific absorption rate averaged over 10 mg at 450 MHz was 7.9 W/kg, resulting in a temperature increase after 6 min of < 0.4 K. Hence, as the hypothesis was falsified at frequencies < 450 MHz, patients with implants are inadequately protected by current safety and product guidelines. In the discussions, proposals for how to close this regulatory gap are provided.

**Summary**

- In this study, we evaluated systematically whether people with conductive implants are protected by electromagnetic safety guidelines and standards or whether certain exposure conditions result in an unacceptable risk to the subpopulation.
- A systematic exposure study of generic insulated and non-insulated implants showed local enhancements of the $psSAR_{10mg}$ and locally averaged E-field in a frequency range of 10 kHz to 1 GHz of up to 100 dB.
- The human anatomical model ViP Ella v3 with common implant trajectories was exposed to a realistic 85 kHz wireless power transfer coil and a 450 MHz dipole source, resulting in a local field enhancement at the implant tip of over > 115 V/m and 7.9 W/kg, respectively, showing that people with implants are not adequately protected by current safety guidelines.

Open access: https://pmc.ncbi.nlm.nih.gov/articles/PMC12464515/

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**Numerical analysis of the thermal effects on adult with brain pacemaker implantation exposed to WIFI antennas**

Tian R, Zhao Y, Lu M, Deng J. Numerical analysis of the thermal effects on adult with brain pacemaker implantation exposed to WIFI antennas. Case Studies in Thermal Engineering, Volume 74, 2025, https://doi.org/10.1016/j.csite.2025.106941.

Abstract

In the regard of whether it's safe for the Parkinson's Disease (PD) patients with brain pacemaker (BP) implantation to use their cell phones, we investigated the electromagnetic (EM) radiation of cell phone to the patients. In this work, a three-dimensional model of the human brain including the real Basal Ganglia, two dual-frequency planar inverted-F antennas (PIFA) operating at WIFI/5G and two types of implanted BPs were modeled utilizing COMSOL finite element software. By varying the antennas operating frequency, the angles between the antennas and the human brain, the thermal conductivity of the Grey Matter (GM) and the electrode structure, we numerically analyzed the specific absorption rate (SAR), the temperature increase, the thermal strain and the displacement of the brain tissues. The results indicated that regardless of the frequencies and angles, the SAR value and temperature increase are below the limits of 2 W/kg and 2 °C specified by International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020, but they reached their maximum at the angle of 90°. The change in GM thermal conductivity and electrode geometry affected the trend of the temperature increase in the brain tissues. The thermal strain and displacement of brain tissues during their temperature increase were found to have a potential impact on the postoperative efficacy of PD patients. The displacement of brain tissues was the similar as the displacement that was observed in some medical literatures, and the two displacements approximately had the same order of magnitude. Therefore, we recommended that one should avoid using the cell phones in the gesture of θ= 90°. The PD patients should also maintain the distance as far as possible. Considering that the PD patients may use cell phones frequently, we also suggested that they might visit the hospital once in a while, in order to confirm that the pacemaker is working properly.

Open access: https://www.sciencedirect.com/science/article/pii/S2214157X25012018

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**Assessment of Electromagnetic Exposure Levels for Humans from Electric Vehicle DC Charging Stations**

Dong S, Lu M. Assessment of Electromagnetic Exposure Levels for Humans from Electric Vehicle DC Charging Stations. Sensors (Basel). 2025 Sep 14;25(18):5735. doi: 10.3390/s25185735.

Abstract

The potential health risks of DC charging piles to human health were investigated by quantifying the internal electromagnetic exposure level. In this study, the transformer in the DC/DC circuit of a DC charging pile was selected as the radiation source, and two realistic human models (adult and child) were used as exposure subjects. A simulation model, including the vehicle body, charging pile, and transformer, was established using COMSOL(COMSOL Multiphysics 6.2) Multiphysics software to calculate the magnetic induction intensity (**B**-field) and electric field intensity (**E**-field) in various organs at distances of 0.1 m, 0.3 m, and 0.6 m from the charging pile. The results show that at 0.1 m, the peak

**B**-field (1.91 μT) and **E**-field (447 mV/m) in the adult body were 1.91% and 2.07% of the ICNIRP occupational exposure limits, respectively, and 7.07% and 4.14% of the public exposure limits. For the child model, the peak electromagnetic exposure levels (2.31 μT and 259 mV/m) were only 8.56% and 2.40% of the public limits. Further evaluation of exposure levels for in-vehicle occupants during charging showed that the peak **B**-field and **E**-field for an adult driver and a child in the front passenger seat were $0.0225 \times 10^{-2}$ μT, $0.0237 \times 10^{-2}$ μT, 5.81 mV/m, and 5.82 mV/m, respectively, far below the ICNIRP public limits. Additionally, analyses at multiple frequency bands (85 kHz, 90 kHz, and 95 kHz) under a typical scenario (adult at 0.1 m from the charging pile) revealed that the **B**-field in the human body decreased with increasing frequency, while the **E**-field showed minimal variation due to shielding effects. All electromagnetic exposure levels were below both ICNIRP public and occupational limits, indicating the broad applicability of the results. Under normal operating conditions of DC charging piles, the electromagnetic exposure from the DC/DC transformer fully complies with safety standards and poses no threat to human health. This study provides a scientific basis for alleviating public concerns about the health risks of electromagnetic radiation from DC charging piles for electric vehicles.

## Conclusions

This study uses the transformer in the DC/DC circuit of a DC charging station module as the radiation source and employs realistic adult and child human models as exposure subjects. At an 80 kHz switching frequency, the electromagnetic field excited by the AC signal input to the primary winding was calculated, and electromagnetic exposure levels were assessed for individuals in proximity to the charging station and for an adult in the driver's seat and a child in the front passenger seat during EV charging. The main conclusions are as follows:

(1) For an adult standing 0.1 m from the charging pile, the peak **B**-field (1.91 μT) and the peak **E**-field (447 mV/m) in the body are 1.91% and 2.07% of the ICNIRP occupational exposure limits, respectively, and 7.07% and 4.14% of the public exposure limits. For the child, the electromagnetic exposure levels (2.31 μT and 259 mV/m) are 8.56% and 2.40% of the public exposure limits, respectively. These results indicate that electromagnetic exposure levels for occupational and private individuals near the DC charging pile are within safe limits.

(2) For an adult standing at distances of 0.1 m, 0.3 m, and 0.6 m from the DC charging pile, the peak **B**-field in the body corresponds to 7.07%, 3.02%, and 0.80% of the ICNIRP public exposure limits, respectively, while the peak **E**-field corresponds to 2.07%, 1.77%, and 0.44%. For a child at the same distances, the peak **B**-field is 8.56%, 3.45%, and 2.15% of the ICNIRP public exposure limits, and the peak **E**-field is 2.40%, 1.74%, and 1.43%. These findings demonstrate a significant negative correlation between the distance from the charging pile and the electromagnetic exposure level in the body.

(3) During electric vehicle charging, the peak **B**-fields in the body for an adult in the driver's seat and a child in the passenger's seat are $0.0225 \times 10^{-2}$ μT and $0.0237 \times 10^{-2}$ μT, respectively. The peak **E**-fields in the body and brain are 5.81 mV/m and 5.59 mV/m for the adult, and 5.82 mV/m and 5.67 mV/m for the child, all significantly below the ICNIRP public exposure limits.

(4) In the typical scenarios (adult at 0.1 m from the charging pile), analyses were conducted at multiple frequency bands, including 85 kHz, 90 kHz, and 95 kHz. The results show that as the frequency increases, the peak **B**-field in the human body gradually decreases, while the **E**-field in the body shows no

significant change, possibly influenced by the vehicle body. The electromagnetic exposure levels in all frequency bands are below the ICNIRP safety limits.

This study has certain limitations, and future research will focus on the following areas: (1) expanding the types of human models to include sensitive populations such as pregnant women and adolescent females; (2) evaluating electromagnetic exposure from multiple radiation sources (e.g., inverters and cables) acting concurrently; (3) conducting field measurements and validation of electromagnetic fields from DC charging stations.

This study addresses gaps in the safety assessment of electromagnetic environments associated with DC charging stations, providing a scientific basis for establishing electromagnetic environment standards and industry exposure limits for EV charging facilities, thereby contributing to public health protection.

Open access: https://www.mdpi.com/1424-8220/25/18/5735

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**Bioelectricity in Morphogenesis**

Nunes CO, Barriga EH. Bioelectricity in Morphogenesis. Annu Rev Cell Dev Biol. 2025 Oct;41(1):187-208. doi: 10.1146/annurev-cellbio-101323-032747. Epub 2025 Aug 19.

Abstract

Bioelectricity is likely as old as life itself. From the moment the first proto-cell was enclosed in a lipid bilayer, a membrane potential arose. Thus, one can expect that bioelectrical activities influence single-cell and collective cell behaviors in processes such as embryo development, tissue repair, and even disease. Despite the ubiquity of bioelectrical phenomena, most research has focused on bioelectrical control of neural tissues, and as a result, our knowledge of nonneural contexts remains comparatively less understood, scattered, and often misunderstood. Still, there are strong reasons for supporting the idea that bioelectricity contributes to diverse morphogenetic contexts. Thus, in this review we provide an overview of the current knowledge of how cells generate and perceive bioelectrical inputs, and discuss how cells translate these stimuli into responses that influence tissue morphogenesis in physiology and pathology.

Open access: https://www.annualreviews.org/docserver/fulltext/cellbio/41/1/annurev-cellbio-101323-032747.pdf?expires=1759524214&id=id&accname=guest&checksum=4B7FD77ABD1E5E6E4D9239BE689002C4

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**Evaluation of Exposure Assessment Methods and Procedures for Induction Hobs** (Stoves)

Xi J, Kühn S, Fortunato C, Ofli E, Kuster N. Evaluation of Exposure Assessment Methods and Procedures for Induction Hobs. Bioelectromagnetics. 2025 Oct;46(7):e70024. doi: 10.1002/bem.70024.

Abstract

Induction hobs generate strong alternating magnetic fields to heat pots by inducing eddy currents. These fields are the strongest close to the bottom of the cookware, but stray fields at large distances can still be substantial. In general, these are higher than the reference levels defined by international

electromagnetic exposure safety guidelines (ICNIRP 1998; ICNIRP 2010; IEEE 2019). That the reference levels are exceeded does not imply that the basic restrictions are also violated. In this study, we assess the exposures caused by the latest generation of induction hobs by applying the advanced instrumentation and different methods that include the procedures developed by the International Electrotechnical Commission (IEC) for household appliances (IEC 62233) (IEC International Electrotechnical Commission 2005), the 4-tier approach developed for inductive wireless power transfer systems (IEC 63184) (IEC International Electrotechnical Commission 2021), and their derivatives. First, methods for determining the maximum exposure configuration were assessed. Then, the 3D distribution of the incident magnetic field was sampled with a scanning system and analyzed, and the contact currents assessed. Lastly, numerical dosimetric evaluations were performed in anatomical models to determine the maximum fields induced by the measured incident fields directly or by a representative coil model converted from the measured fields. The study's findings reveal significant variations in exposure across different induction hobs, with differences of up to a factor of > 20 ( > 26 dB) as a function of power, coil size, and proximity to the coil. This suggests that low-exposure hobs can be designed without compromising cooking performance. Furthermore, the study strengthens the conclusions of previous studies that IEC 62233 (IEC International Electrotechnical Commission 2005) may underestimate the exposure for persons standing next to the hob by up to a factor of > 30-based on testing according to the exposure limits from (ICNIRP 1998; IEEE 2019)-and thus does not ensure safety. A dosimetric analysis, the most accurate method, would be relatively costly. Alternative approaches derived from (IEC International Electrotechnical Commission, 2021) that are affordable and not overly conservative are discussed.

Summary

- The low-exposure induction hobs can be achieved by employing small heating coils without compromising cooking performance.
- The product standards IEC 62233 (IEC International Electrotechnical Commission 2005) and EN 62233 (CENELEC, European Committee for Electrotechnical Standardization 2008) may significantly underestimate the exposure, and therefore require revision to ensure the safety of induction hobs.
- Conservative and affordable approaches from IEC 63184 (IEC International Electrotechnical Commission 2021) and IEC 60990 (IEC International Electrotechnical Commission 2016) are applied to demonstrate the compliance of induction hobs with the limits of incident/induced fields and contact current, respectively.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70024

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**Simultaneous 4G and 5G EMF Exposure and Field Uniformity in a Reverberation Chamber for Animal Studies**

Kwon D, Jeon S, Lee A-K, Choi H-D, Moon J-I. Simultaneous 4G and 5G EMF Exposure and Field Uniformity in a Reverberation Chamber for Animal Studies. *Applied Sciences*. 2025; 15(18):10286. https://doi.org/10.3390/app151810286.

Abstract

The design and validation of a reverberation chamber (RC) specifically constructed for conducting large-scale experimental animal carcinogenicity studies using RF electromagnetic fields (EMF) relevant to contemporary 4G and 5G mobile communication (900 MHz, 2.12 GHz, and 3.65 GHz) is proposed. The RC's electric field (E-field) uniformity is evaluated under four practical loading conditions: empty, apparatus only, and two apparatus variations with 80 experimental animals (Sprague–Dawley rats) with approximate weights 400 g and 520 g, respectively. Measurement results show E-field uniformity better than 1.36 dB under all test conditions, with frequency-dependent variation becoming negligible once the RC is loaded with cage racks and 80 rats. Additionally, a predictive method is introduced to estimate composite E-field intensities under simultaneous multi-frequency exposures, potentially reducing experimental measurements. These findings confirm that the designed RC is capable of accurately evaluating RF EMF exposure in biological studies.

Open access: https://www.mdpi.com/2076-3417/15/18/10286

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**Occupational exposure to extremely low-frequency magnetic fields (ELF-MF) and postmenopausal breast cancer risk**

Moayedi-Nia, S, Almadin C, Labrèche F, Goldberg MS, Richardson L, Cardis E, Ho V. Occupational exposure to extremely low-frequency magnetic fields (ELF-MF) and postmenopausal breast cancer risk. Journal of Occupational and Environmental Medicine ():10.1097/JOM.0000000000003564, October 1, 2025. | DOI: 10.1097/JOM.0000000000003564.

Abstract

Objective Estimate the association between occupational exposures to extremely low-frequency magnetic fields (ELF-MF) and postmenopausal breast cancer.

Methods Lifetime job histories from a population-based case-control study (2008-2011) of histologically-confirmed breast cancer in Montréal, Canada were linked to a job-exposure matrix to assign geometric mean ELF-MF exposure/workday. Logistic regression estimated odds ratios (OR) and 95% confidence intervals (CI) for cumulative, average, maximum, and duration of maximum exposure to ELF-MF (per interquartile range increase), adjusting for individual-level and ecological covariables.

Results Data from 663 cases and 592 controls revealed no association between occupational ELF-MF exposure and postmenopausal breast cancer, though restricting exposures to 0-10 years before interview and to those during breast development, some positive associations was observed, particularly for ER+/PR+ tumours.

Conclusions Our findings suggest no association between occupational ELF-MF exposure and postmenopausal breast cancer risk.

https://journals.lww.com/joem/abstract/9900/occupational_exposure_to_extremely_low_frequency.993.aspx

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**The effect of alpha-lipoic acid on liver damage induced by extremely low-frequency electromagnetic fields in a rat model**

Aydinbelge Dizdar N, Aylin Akbulut, Koca G, Demirel MK, Yumusak N, Umurhan G, Canseven Kursun AG, Korkmaz M. The effect of alpha-lipoic acid on liver damage induced by extremely low-frequency electromagnetic fields in a rat model. Toxicol Ind Health. 2025 Sep 29:7482337251383412. doi: 10.1177/07482337251383412.

Abstract

This study aimed to investigate the effect of alpha-lipoic acid (ALA) on liver damage caused by extremely low-frequency magnetic fields (ELF-MFs) in rats. Thirty-two male rats were arbitrarily assigned into four groups: Group 1 (control group), Group 2 (ELF-MF exposure group), Group 3 (ELF-MF exposure + ALA administration), and Group 4 (sham group). Groups 2 and 3 were exposed to ELF-MF at 2 mT intensity emitted by two Helmholtz coils for 4 hours/day throughout 30 days. Group 3 received ALA intraperitoneally (100 mg/kg/day) 1 hour prior to each exposure for 30 days. Group 4 was placed inside the coils, but the generator was turned off. Histopathological analysis of the liver revealed statistically significant increases in hyperemia, inflammation, fibrosis, vacuolization, multiple nuclei, and biliary proliferation in Group 2 compared to all other groups. Immunohistochemical evaluation showed that Group 2 had statistically significantly higher TUNEL and caspase-3 levels than all other groups. ELF-MF-induced alterations, including hyperemia, inflammation, vacuolization, and multiple nuclei, were significantly reduced in Group 3 compared with Group 2. However, no significant difference was observed between Group 2 and Group 3 regarding bile duct proliferation or fibrosis. No pathological changes were observed in Groups 1 and 4. ALA administration effectively reduced some histopathological changes caused by ELF-MF, particularly hyperemia, inflammation, vacuolization, and multiple nuclei, but did not improve fibrosis or biliary proliferation. Additionally, it reduced TUNEL and caspase-3 expression. Our findings suggest that ALA exhibits anti-apoptotic and anti-inflammatory effects against ELF-MF-induced liver damage.

https://pubmed.ncbi.nlm.nih.gov/41022467/

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**Female Crabs Are More Sensitive to Environmentally Relevant Electromagnetic Fields from Submarine Power Cables**

James E, Ghodsi M, Ford AT. Female Crabs Are More Sensitive to Environmentally Relevant Electromagnetic Fields from Submarine Power Cables. Environmental Science and Technology Letters. Sep 15, 2025. https://pubs.acs.org/doi/10.1021/acs.estlett.5c00862.

Abstract

The expansion of offshore wind and marine renewable energy devices (MREDs) is increasing anthropogenic electromagnetic fields (EMFs) from submarine power cables (SPCs). SPC-generated EMFs can exceed 2700 μT, well above the geomagnetic field, and may affect benthic animal behavior. In decapod crustaceans, sex-specific habitat uses and seasonal migrations are well-documented, yet their role in EMF sensitivity remains untested. We exposed juvenile shore crabs (Carcinus maenas) (n = 120;

1:1 sex ratio) to EMFs of 500, 1000, and 3200 µT using a Helmholtz coil system and tracked behavior over 10 min trials. Females exhibited strong attraction across EMF levels, spending up to 131% more time in the EMF-exposed zone and significantly less time in the low-field zone. They also drove differences in distance moved, whereas males showed no consistent spatial preference and indifferent activity at the highest field strength. These sex-specific responses suggest SPC EMFs could disrupt female-driven reproductive behaviors like seasonal migrations and larval release. Attraction may cause disorientation, aggregation, or delays in migration, potentially altering sex ratios and reducing larval export. This study provides the first evidence of sex-specific EMF responses in crustaceans and highlights the importance of incorporating sex as a key variable in ecological risk assessments of offshore infrastructure.

Open access: https://pubs.acs.org/doi/10.1021/acs.estlett.5c00862

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**A Systematic Review of the Impact of Electromagnetic Waves on Living Beings**

Danho S, Escobar Huertas J, Schoellhorn WI (August 17, 2025). A Systematic Review of the Impact of Electromagnetic Waves on Living Beings. Cureus 17(8): e90355. doi:10.7759/cureus.90355.

Abstract

The effects of electromagnetic fields (EMFs) have been extensively debated among researchers and the public, with their critical consequences often dismissed or deemed unscientific. In light of this, we conducted this systematic review that extensively focuses on the detrimental effects of EMFs on living organisms.

A comprehensive and systematic literature search was performed on various electronic databases, including PubMed, Scopus, and the Cochrane Library, using Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. This review concentrates on experimental studies published between 2017 and 2024 that investigated physiological or behavioral responses to EMF exposure, with particular attention given to those reporting harmful or concerning effects. Documented impacts include effects on humans, animals, and plants, targeting various cell types (e.g., blood, cancer, thyroid, cochlea), genotoxicity, cardiovascular parameters (e.g., heart rate, blood pressure), male fertility (e.g., testes, sperm), neuronal brain activity, and photosynthesis in plants. Methodological quality was assessed using established bias assessment tools, and certainty of evidence was evaluated according to the GRADE framework.

After screening, 24 studies were included in the present review; five studies were non-randomized and involved humans, seven studies were in vitro, and 12 studies were conducted on animals. The findings demonstrated that EMFs negatively affect a wide array of biological systems of living organisms, including mechanisms of oxidative stress, inflammatory responses, and disruptions in cellular, physiological, and ecological processes. Most of the included studies showed a moderate to high risk of bias, which contributed to a lower overall certainty of the evidence.

These findings underscore the significant health and environmental risks associated with rising exposure levels of EMF, highlighting the urgent need for strategies to mitigate the risks. Despite these valuable insights, significant research gaps persist because the long-term effects of EMF exposure, especially on

human populations, remain poorly understood and warrant further investigation and targeted mitigation strategies.

Conclusions

The rapid evolution of wireless communication technologies continues to introduce new applications and expand into higher frequency ranges. This review identifies many experimental studies reporting the biological effects of EMFs on humans, animals, and plants. These include changes in fertility parameters, cellular responses associated with oxidative stress, developmental outcomes, behavioral alterations, and cognitive effects. Our findings highlight why it is important to take a closer, structured look at how EMF exposure might affect both human health and the environment. This review focused on reported biological effects, without implying universality or disregarding studies that observed neutral or application-related outcomes. The diversity in reported results highlights the need for cautious interpretation and context-specific analysis.

Significant research gaps remain. Short-term effects have drawn much attention in past studies, but the more pressing question (what happens over time?) remains largely unanswered, especially concerning people and species highly sensitive to their environment. Additionally, a lack of standardized exposure protocols and inconsistent reporting of critical parameters such as field strength and frequency limit reproducibility and hampers the formulation of robust exposure guidelines. Addressing these challenges means committing to research that is not rushed, not vague, and not influenced by unclear funding. Long-term, transparent, and solid work is the only way forward. These should include clearly defined exposure parameters, attention to population-specific vulnerability factors (e.g., age, baseline health), and ecological relevance. As seen historically, public concern and scientific controversy can foster critical inquiry and the development of evidence-based safety standards. A coordinated effort is needed to enhance our understanding of EMF interactions with biological systems and to support informed decision-making in public health initiatives and policy.

Open access: https://www.cureus.com/articles/400923-a-systematic-review-of-the-impact-of-electromagnetic-waves-on-living-beings#!/

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**Effect of electromagnetic radiations from mobile towers on genetic damage and genetic polymorphism in humans: a review on India's perspective**

Priya, K., Singh, M., Haokip, L. *et al.* Effect of electromagnetic radiations from mobile towers on genetic damage and genetic polymorphism in humans: a review on India's perspective. *Toxicol. Environ. Health Sci.* (2025). doi: 10.1007/s13530-025-00273-9.

Abstract

There have been concerns about possible health implications of radiofrequency electromagnetic radiation owing to increased cell phone use and proliferation of cell phone towers. The amount of RF-EMR energy absorbed in the human tissues relies on both the exposure characteristics of frequency, intensity, and exposure duration. This effect could be due to the exposure of genetic material by RF, resulting in an increased risk of cancer development and death in cells. Genetic polymorphisms involve variation in the DNA sequence in and among people, populations, or groups. These polymorphisms

might contribute to susceptibility to RF effects. These genetic variations-which could be in the form of single nucleotide polymorphisms (SNPs) or copy number variations (CNVs-may occur either by a sheer chance process or by external factors such as viruses or radiation. Knowing the influence of genetic polymorphisms on RF exposure would help level off related health risks of cell phone use and cell towers. This scientific review examines related scientific research data about the effects that cell terminal EMR has on human genetic damage and polymorphism. We critically appraise literature and peer review journals relevant to data in assessing our current knowledge in this area. Our study reveals the fact that some studies indicate exposure to EMR does bear a relation with genetic damage, but such results should be further researched as to which health impacts they bring forward.

https://link.springer.com/article/10.1007/s13530-025-00273-9

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**Systematic reviews and meta-analyses for the WHO assessment of health effects of exposure to radiofrequency electromagnetic fields, an introduction**

Verbeek J, Zeeb H, van Deventer E, Ijaz S, Doré J-F, Driessen S, Roth N, Whaley P. Systematic reviews and meta-analyses for the WHO assessment of health effects of exposure to radiofrequency electromagnetic fields, an introduction. Environment International. 2025, doi: 10.1016/j.envint.2025.109751.

No abstract

Introduction

"We, the editors (SI, JFD, SD, NR, PW) and organizers (JV, EvD, HZ) of this special issue of Environment International on the World Health Organization's (WHO) assessment of the health effects of exposure to radiofrequency (RF) electromagnetic fields (EMF), are pleased to present this collection of systematic reviews of the effects of RF EMF. This issue represents the culmination of four years of meticulous, collaborative work by more than 80 scientific experts from around the world. We extend our sincere congratulations to the authors of the reviews and commend their dedication to producing reviews of such high scientific quality.

This Special Issue includes nine protocols and subsequent twelve systematic reviews, all designed to support the human health risk assessment of RF-EMF exposure. In this editorial, we summarize the processes used to commission and develop the systematic reviews, describe the methodological tools employed, and summarise the key findings. We also reflect on the successes and challenges encountered throughout this ambitious undertaking.

Collectively, these systematic reviews offer a robust model for global health risk assessments, contributing to the development of evidence-based norms, standards, and research priorities. This project stands as one of the most comprehensive evaluations of environmental health evidence to date – an effort from which we continue to learn how to best approach this task (Jarosińska et al., 2018, Pega et al., 2021, Pérez Velasco and Jarosińska, 2022)."

Excerpts

"Although no other mechanisms beyond nerve cell excitation and thermal effect are known to pose health risks (Sheppard et al. 2008), the possibility remains that other, as yet unknown, biophysical mechanisms could exist and potentially lead to health effects."

"The last EHC Monograph on RF fields was published in 1993 (World Health Organization 1993) and is currently being updated to reflect new scientific evidence."

"The approach to developing the overall scientific basis for the updated EHC Monograph on RF Field exposure had three sequential parts: a scoping review, a prioritisation of outcomes, and the set of systematic reviews presented in this special issue."

"For one of the review topics − heat-related effects − a systematic review was not completed. The protocol did not pass peer review process in time and proceeding with it would have significantly delayed the overall project. As a result, this systematic review was decommissioned."

"The systematic reviews report evidence for the effects of RF EMF on all important health outcomes but the number of studies finally included for each outcome varied significantly, ranging from five studies on cognitive function in human observational studies (Benke et al. 2024) to 215 studies on fertility in animal experimental studies (Cordelli et al., 2023, Cordelli et al., 2024).

The systematic reviews of human observational studies on cancer found moderate-certainty evidence of no or only a small effect for several important cancer types, such as glioma and lymphoma (Fig. 1), based on 74 studies/databases (Karipidis et al., 2024, Karipidis et al., 2025). Only for thyroid cancer and oral cavity/pharynx cancer the evidence was respectively low and very low. The review of cancer in experimental animals (Mevissen et al. 2025) identified 10 long-term bioassays and dozens of other studies. Based on only one or two of these studies, the authors concluded that there was high- to moderate-certainty evidence of an effect of RF EMF on five cancer types in animals."

"The review of fertility outcomes in experimental animals yielded the most varied results. It found high-certainty evidence of no or only a small effect on litter size, but also high-certainty evidence of a large adverse effect on male fertility (Cordelli et al., 2023, Cordelli et al., 2024).(Fig. 2) Unfortunately, there were only few human observational studies on fertility that produced only very low-certainty evidence (Johnson et al., 2024, Pw Kenny et al., 2024)."

"For cognition, human experimental studies provided consistent moderate- to high-certainty evidence of no or only a small effect across several domains of cognitive performance (Pophof et al. 2024). (Fig. 3) However, the corresponding human observational review (Benke et al. 2024) included only a few studies with results that were assessed as very low certainty."

"Regarding symptoms, human experimental studies (Bosch-Capblanch et al. 2022) showed moderate-certainty evidence of no or a small effect of RF EMF exposure. Yet again, the limited number of human observational studies resulted in very low certainty evidence (Roosli et al. 2024).(Fig. 4). "

"Finally, the review of effects of RF EMF on oxidative stress (Meyer et al. 2024) found highly variable results, ranging from large increases to large decreases in oxidative markers across all outcomes, even within one homogenous PECO. The certainty of evidence was rated very low largely due to a high risk of bias in the included studies. This was particularly evident in the exposure domain, where many

experimental studies still relied on mobile phones to generate exposure – a method prone to bias if not carefully controlled (Kuster and Schönborn 2000)."

"... separate reviews were conducted for human and animal evidence for fertility and for cancer. This led to clear conclusions of the individual reviews but, as is particularly clear in cases where the animal evidence appears to contradict the human evidence, will necessitate another step of integration of the conclusions of the reviews in an overall conclusion “what this evidence means for human health”. This is the next step still to be conducted by a dedicated WHO Task Group."

"One notable exception was the systematic review on the effects of RF EMF on cancer in experimental animals, which stood out due to its use of a different synthesis method. The authors concluded that there was an effect of RF EMF if two studies showed statistically significant results, disregarding null findings from other studies. This approach deviated from the protocol, which had indicated the use of relative risk as the primary synthesis method (Mevissen et al. 2025). Despite extensive discussions with editors and peer reviewers, the review ultimately concluded that there was high-certainty evidence of an effect on cancer. Whether this method proves valid – and whether alternative synthesis approaches would yield the same conclusion—remains to be seen."

"This complex project has led to high-quality summaries of the evidence of effects of RF EMF on the most important health outcomes reported in the WHO prioritization survey in a standardized and transparent way. The results and conclusions from the present set of systematic reviews provide the most solid achievable basis for further evaluation of the effects of EMF exposure on health by the WHO task group, and the upcoming EHC Monograph of RF fields."

"Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: 1. Jos Verbeek received financial support from WHO for preparing this introductory article based on financial support from the Australian Radiation Protection and Nuclear Safety Agency, the Public Health Agency of Canada, the Environmental Protection Agency of Ireland, the Swiss Federal Office of Public Health and the Bill and Melinda Gates Foundation. The funders had no role in the decision to publish or in the preparation of the manuscript. 2. Up until the end of 2022, PW’s contribution to the Special Issue was financially supported by the honorarium he received as an Associate Editor for Environment International. This contract ended in December 2022. From January 2023, PW’s contribution was pro bono as a Guest Editor at the journal. From April 2024 to May 2025, PW provided paid contractual services to WHO on a project to develop systematic review protocols and an evidence-mapping methodology for evaluating health effects of exposure to PFAS chemicals. 3. SI’s time is supported by the National Institute for Health and Care Research Applied Research Collaboration West (NIHR ARC West)."

Open access: https://www.sciencedirect.com/science/article/pii/S0160412025005021

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**Carcinogenicity of Radio-Frequency Radiation: Similarities and Differences Between Outcomes of Two Studies**

Peleg M, Berry EM, Deitch M, Nativ O, Richter E. Carcinogenicity of Radio-Frequency Radiation: Similarities and Differences Between Outcomes of Two Studies. Med Discoveries. 2025; 4(7): 1267

Abstract

We discuss the similarities and the differences between two papers published on the carcinogenicity of radio frequency radiation in the military setting with some overlap of the patients' groups. The first paper reported statistically significant increases of cancer cases while the second did not. We show that the two papers presented similar and non-conflicting characteristics of the reported cancers, mainly high hematolymphoid cancers percentage frequencies and earlier onset of cancers in the exposed group. We think that the conclusion of not identifying carcinogenicity, which is explained in the second paper by not reaching statistical significance, is due to much smaller size of the patients' group in that paper.

Open access: https://www.meddiscoveries.org/pdf/1267.pdf

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**Altered development in rodent brain cells after 900 MHz radiofrequency exposure**

Bodin R, Godin L, Mougin C, Lecomte A, Larrigaldie V, Feat-Vetel J, Méresse S, Montécot-Dubourg C, Marcelo P, Mortaud S, Villegier AS. Altered development in rodent brain cells after 900 MHz radiofrequency exposure. Neurotoxicology. 2025 Sep 2;111:103312. doi: 10.1016/j.neuro.2025.103312.

Abstract

Health risks related to 900 MHz 2 G frequency exposure remain inconclusive under current regulatory standards. Research into potential long-term effects is ongoing, particularly as the use of mobile networks and wireless devices increases. This study investigates the effects of non-thermal exposure levels of mobile phone 900 MHz radiofrequency electromagnetic field (RF-EMF) on rodent neurodevelopment. In vivo, the effects of pre- and post-natal 0.08 and 0.4 W/kg specific absorption rate (SAR) exposure were assessed for their impact on the proteomic profile at postnatal day 0 (PND 0). Brain-derived neurotrophic factor (BDNF), BrdU+ proliferative cells, synaptogenesis, and oxidative stress in the hippocampus and cortex of rat pups were studied at PND 8 and PND 17. Effects of the lowest SAR (0.08 W/kg) were assessed in vitro to afford mechanistic data regarding neural stem cells (NSCs) differentiation. In vivo results showed a decrease in BDNF level and BrdU+ proliferative cells with a decrease in synapse balance (excitatory synapses/inhibitory synapses). In vitro, at 0.08 W/kg there was an increase in Ki-67 + proliferative cells, apoptosis, and double-strand DNA breaks in NSCs. A lower ratio of B1 cells (primary progenitors of NSCs) among total cerebral cells and a higher ratio of oligodendrocyte progenitor cells and astrocytes were observed in the exposed NSCs. Our findings suggest that key cellular events for brain ontogenesis are likely to undergo changes with RF-EMF 900 MHz exposure during early development. These support the hypothesis that the developing central nervous system is vulnerable to RF-EMF exposures in rodents at regulatory thresholds.

Highlights

- In vivo exposure reduced cortex cell proliferation, BDNF and synapses balance.
- In vivo exposure reduced hippocampus synapses density and balance.

• Proteomic analysis showed dysregulation of proteins involved in synaptic signaling.
• In vitro exposure increased apoptosis, DNA damage and glial differentiation shift.
• 900 MHz exposure affect rodent neurodevelopmental at regulatory threshold levels.

Open access: https://www.sciencedirect.com/science/article/pii/S0161813X2500110X?via%3Dihub

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**Oxidative stress and testicular damage induced by chronic exposure to 35.5 GHz millimeter wave radiation in male Wistar rats**

Gautam R, Jha N, Tomar AK, Nirala JP, Arora T, Rajamani P. Oxidative stress and testicular damage induced by chronic exposure to 35.5 GHz millimeter wave radiation in male Wistar rats. Andrology. 2025 Aug 12. doi: 10.1111/andr.70107.

Abstract

Background: The widespread usage of millimeter waves (MMW) in different spheres of the public domain necessitates to have a better understanding of any possible health impacts caused by them. The latest example of this is the global implementation of 5G technology.

Objectives: The present investigation aimed to study the effects of 35.5 GHz frequency on reproductive parameters of male Wistar rats.

Methods: The study employed a randomized controlled design, with animals being assigned to control, sham-exposed, and exposed groups, with six animals in each group (n = 6). The experimental group was exposed to 35.5 GHz frequency for 2 h per day for 60 days. At the end of the exposure period, various sperm parameters such as sperm count, morphology, viability, and sperm mitochondrial activity were evaluated. The evaluation of oxidative stress was done by lipid peroxidation assay in testis homogenate. Superoxide dismutase, total sulfhydryl level, and total antioxidant capacity were assessed in testis homogenate. The DNA damage in the testis was assessed through the comet assay.

Results: The results showed a significant decrease in sperm viability and count, as well as morphometric changes in testis histopathology. Lipid peroxidation testis was significantly elevated in the exposed group, while superoxide dismutase (SOD), total sulfhydryl level, and total antioxidant capacity were significantly decreased in the exposed group. The comet assay revealed a significant increase in DNA damage in the exposed group, indicating genotoxic effects.

Discussion: The observed changes in sperm parameters, testicular morphology, and oxidative stress markers highlight the potential for testicular tissue damage via oxidative mechanisms. These results underscore the need for further research to elucidate the biological implications of chronic MMW exposure.

Conclusion: Chronic exposure to 35.5 GHz frequency may negatively impact male reproductive function and testicular tissue, primarily through mechanisms involving oxidative stress.

Open access: https://onlinelibrary.wiley.com/doi/abs/10.1111/andr.70107

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**Prospective long-term follow-up of patients with idiopathic environmental intolerance attributed to electromagnetic fields after a provocation trial**

Li KH, Guo HR. Prospective long-term follow-up of patients with idiopathic environmental intolerance attributed to electromagnetic fields after a provocation trial. Ecotoxicol Environ Saf. 2025 Sep 1;303:118944. doi: 10.1016/j.ecoenv.2025.118944.

Abstract

Previous short-term follow-ups of idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF) found no patients recovered after receiving provocation trials, and only a small portion were willing to consider something else caused their symptoms, although levels of their symptoms and concerns decreased. Few long-term follow-ups have been conducted, so we conducted a study to fill the data gap. We recruited participants of the initial provocation trial between 2010 and 2015 to assess changes in symptoms and concerns related to EMFs and the reversibility of IEI-EMF. The same questionnaire used in the trial was administered through telephone interviews. Of the 147 participants recruited, 70 completed the follow-up, including 35 IEI-EMF patients and 35 referents. Of the patients, 60 % were willing to consider something else caused their symptoms, and 62.9 % reported recovery from IEI-EMF after the trial in 1.80 years on average, among whom 86.4 % reported idiopathic recovery. Most of the proportions of symptoms and concerns related to EMFs among patients decreased after the trial although changes in concerns between the study groups did not reach significant differences. In conclusion, different from the previous short-term follow-ups, most patients recovered in our long-term follow-up. Most of recovered cases were idiopathic, indicating IEI-EMF is self-limited in most cases given sufficient time. Most of patients were willing to consider something else caused their symptoms, indicating most cases of IEI-EMF might be attributable to nocebo effects. Our findings suggest a possible therapeutic effect of provocation trials, which needs to be confirmed by further randomized controlled intervention studies.

Highlights

Previous studies found no IEI-EMF patients recovered after provocation trials.
We describe the first long-term follow-up of IEI-EMF after a provocation trial.
Most of the patients reported recovery, with 86.4 % being idiopathic recovery.
Most of the patients were willing to consider something else caused their symptoms.

Conclusions

Most participants with IEI-EMF had recovered in the current long-term follow-up study, while none of the participants with IEI-EMF in the two previous short-term follow-ups reported recovery, and most recovered cases in our study were idiopathic. This indicates that IEI-EMF is self-limited in most cases given sufficient time. In addition, provocation trials might accelerate the natural evolution course of IEI-EMF. A relatively large proportion, up to 60.0 %, of participants were willing to consider the possibility that their symptoms might have been caused by something other than EMFs, while the previous short-term studies observed much lower proportions. In addition, the proportion of feeling concerns that EMFs might be threatening their health and feeling worries about EMFs may affect every aspect of their

life decreased in the participants with IEI-EMF. However, these did not relieve them from the worries about visualizing large EMF devices in the environment. In conclusion, our findings supported that IEI-EMF may be related to the nocebo effect in most cases. Our study also suggested a possible therapeutic effect of provocation trials when the results are negative, which needs to be confirmed by further randomized controlled trials. These findings might be applied to other types of IEI and cast some light on its etiology.

https://pubmed.ncbi.nlm.nih.gov/40897052/

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**Looking for Biomarkers Which May Explain Idiopathic Environmental Intolerance Attributed to EMF (IEI-EMF): Does RF-EMF Exposure Influence Salivary Cortisol Response?**

My note: "... the current study tested predominantly young, healthy adults, the results cannot be generalized to other populations, including children, older adults, or those with poorer health." Since none of the participants were EHS, why do they consider this an IEI-EMF study?

Verrender A, Manley J, Wallace NK, Loughran SP, Croft RJ. Looking for Biomarkers Which May Explain Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields (IEI-EMF): Does RF-EMF Exposure Influence Salivary Cortisol Response? Bioelectromagnetics. 2025 Sep;46(6):e70021. doi: 10.1002/bem.70021.

Abstract

In order to understand Idiopathic Environmental Intolerance attributed to Electromagnetic Fields (IEI-EMF), it has been argued that it is crucial to test for effects of radiofrequency electromagnetic fields (RF-EMF) on biomarkers, given that they can be more objective than symptom reports. While no clear evidence links RF-EMF exposure to biomarker changes, research remains limited and largely speculative due to the lack of known bioeffect mechanisms. However, there is in vitro evidence that cortisol is affected by heating, which, as RF-EMF causes heating, raises the possibility that RF-EMF exposure may increase cortisol via thermally mediated processes. If cortisol is affected by RF-EMF exposure, it may form part of a broader aetiology of IEI-EMF, where RF-EMF-induced physiological (cortisol) inputs first generate somatic sensations, which are then fostered by expectancy or learning-based processes to generate symptoms. However, studies investigating whether RF-EMF exposure influences cortisol have reported inconsistent, but mostly null results, and many suffer from methodological issues. The current study was designed with several methodological improvements to determine whether RF-EMF affects cortisol. Seventy-two participants completed a randomized, double-blind, counterbalanced provocation study where they were exposed to both active (2 W/kg peak $SAR_{10g}$ in head) and sham RF-EMF (0 W/kg peak $SAR_{10g}$ in head). Despite implementing several methodological improvements, the current study failed to find an effect of RF-EMF exposure on salivary cortisol concentration. This study provides a valuable direction for future research and stresses the importance of establishing and testing theoretically plausible interactions between low-level RF-EMF exposure, the human body, and IEI-EMF symptoms.

Summary

- The current study incorporated several methodological improvements to test whether exposure to RF-EMF increases salivary cortisol concentration in humans.
- The current study failed to find an effect of RF-EMF exposure on salivary cortisol concentration, and there was no influence of participants' sex.
- Given the novelty of the methodological improvements implemented in this study, this lack of effect on salivary cortisol is very robust.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70021

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**Navigating Environmental Crossroads: Pesticides, Bee Pollinators, and the Wireless Revolution**

Davis D, Malkan S, Ogunseitan OA. (2025). Navigating Environmental Crossroads: Pesticides, Bee Pollinators, and the Wireless Revolution. *Environment: Science and Policy for Sustainable Development*, *67*(5), 3–4. https://doi.org/10.1080/00139157.2025.2518032.

The webinar series hosted by *Environment: Science and Policy for Sustainable Development* is open to the public and welcomes ongoing conversations about strategies for navigating environmental cross-roads. The webinar entitled “Navigating Environmental Crossroads: Pesticides, Bee Pollinators, and the Wireless Revolution” occurred on the Zoom platform on 26 March 2025 with 263 registrants and more than 80 attendees from a broad range of countries. The video recording of the webinar is embedded in the online version of this article, available here: https://doi.org/10.1080/00139157.2025.2518032

**Video 1. (1:04:02)**

As 2025 unfolds, we find ourselves at a critical environmental crossroads. In early January, wildfires driven by hurricane-force winds swept across Southern California, forcing hundreds of thousands to flee. Nearly 90 square miles burned where urban and wilderness areas meet—another stark signal of a changing climate.Footnote1

The fires were still smoldering on 20 January when the United States announced its withdrawal from the United Nations Paris Agreement.Footnote2 Weeks later, on 12 March, the U.S. Environmental Protection Agency launched what it called the “Biggest Deregulatory Action in U.S. History,” moving to roll back the mercury and air toxics standards, dismantle environmental justice programs, and restructure the agency’s Science Advisory Board.Footnote3

These events framed the launch of a new webinar series by Environment: Science and Policy for Sustainable Development, designed to engage a multidisciplinary audience in seeking solutions to complex challenges at the intersection of science, policy, and sustainability.

Scientific integrity is nonnegotiable. Yet translating research into regulatory policies involves negotiation among stakeholders with competing values. Our best tools for navigating environmental crossroads must maximize transparency and consider trade-offs across One HealthFootnote4—human, animal, plant, and ecosystems—as well as economics, equity, and resource conservation.Footnote5

The first webinar focused on two underrecognized global threats: the impact of neonicotinoid pesticides on bee pollinators and food security, and the growing risks of wireless radiation to all living systems. The

session underscored the urgency of turning robust scientific evidence into practical policy—limiting exposures, promoting safer alternatives, and closing critical research gaps.

Neonicotinoids (neonics), the most widely used insecticides in history, have come under intense scrutiny in recent years.Footnote[6] While they may protect some crops from pests, mounting evidence suggests they are also contributing to the alarming decline in bee populations worldwide—particularly honey bees, one of over 2,000 species vital to food production.Footnote[7] The long-term consequences for pollination and ecosystem stability are profound and deeply concerning.Footnote[8]

Research on neonics' broad-spectrum harms has provoked strong resistance from pesticide manufacturers, who often follow the tobacco-industry playbook:Footnote[9] casting doubt on science and attacking scientists. These industries fund research programs at universities and push back when government-sponsored studies, such as those from the National Toxicology Program, produce inconvenient results.Footnote[10]

Simultaneously, our world is increasingly bathed in electromagnetic radiation from mobile phones, Wi-Fi networks, and other wireless technologies. While these tools have reshaped communication and daily life, evidence continues to build around their potential health impacts, especially with long-term exposure.Footnote[11] Adverse effects have been observed not only in humans, but also in animals and bee populations.Footnote[12,]Footnote[13]

The electronics industry, now the most profitable in history, has shown little appetite for investigating or mitigating these harms. With the rise of generative artificial intelligence and global 5G expansion, exposure will only intensify. Yet industry investment in health risk research remains minimal.

A recent review for the World Health Organization examined 52 experimental studies and found high-certainty evidence linking radiofrequency radiation to tumors of the brain and heart nerves.Footnote[14] These findings, led by independent experts, add urgency to calls for applying the precautionary principle.Footnote[15]

We do not need perfect certainty to take protective action. In many cases, the science is already sufficient to justify precautionary policies. But we must also continue investing in independent research and accelerating the development of safer technologies.

For pesticides, nontoxic alternatives exist—but will not be widely adopted until manufacturers and users recognize the long-term benefits of sustainable practices. The same is true for wireless technology: We can innovate to reduce radiation exposure while maintaining connectivity. Doing so requires incentives, transparency, and public pressure.

When in doubt, we must err on the side of caution. This means restrictingFootnote[16] neonicotinoid use, especially in sensitive environments, and setting stricter guidelines for wireless radiation—particularly in schools and homes. It also means attentiveness to potential synergy between wireless radiation and chemical exposures leading to amplified adverse impacts on the productivity and stability of bee hives. These challenges cross borders, demanding international cooperation in science, regulation, and innovation.

Public education is essential. Informed citizens make better choices and demand better policies. The *Environment* webinar series aims to foster honest, inclusive dialogue about how we face today's environmental crossroads—and how we find a better path forward.

At stake is more than academic debate. The decisions we make now will shape the future of our health, our ecosystems, and our shared planet. We can find our way—but only if we insist on transparency, independent science, democratic participation, and precaution in the face of uncertainty. Without them, we risk losing the trail entirely—at a cost we cannot afford.

Disclosure Statement

Devra Davis is treasurer of the Board of Directors of Environmental Health Trust, a nonprofit organization that voluntarily discloses sources of funding more than $5,000: https://ehtrust.org/about/. Stacy Malkan is managing editor of U.S. Right to Know, a nonprofit newsroom and public health research group that also voluntarily discloses sources of funding more than $5,000 at https://usrtk.org/donors/. Oladele A. Ogunseitan is unpaid co-chair of Apple Inc.'s Green Chemistry Advisory Board.

https://www.tandfonline.com/doi/full/10.1080/00139157.2025.2518032

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**From particulates to pathways: environmental exposures and their impact on Alzheimer's disease**

Liu B, Ahmad MA, Abbas G, Ahmed U, Javed R, Ali I, Ao Q, Deng X. From particulates to pathways: environmental exposures and their impact on Alzheimer's disease. Brain Res. 2025 Aug 8:149880. doi: 10.1016/j.brainres.2025.149880.

Abstract

Alzheimer's disease (AD) is a leading cause of cognitive decline and mortality, with its neurobiological mechanisms and etiology still not fully understood. Emerging evidence highlights the significant role of environmental pollutants in AD onset and progression. This review examines the impact of environmental compartments-air, water, soil, and pollutants-on AD pathology. Prolonged exposure to particulate matter ($PM_{2.5}$), heavy metals (lead, cadmium, mercury, arsenic), and engineered nanomaterials (silver, iron oxide, silica) increases AD risk. Additional factors like obesity, smoking, infections, cardiovascular diseases, diabetes, and electromagnetic fields may exacerbate AD. These exposures potentially drive key pathological features such as amyloid-β plaque deposition and tau protein aggregation. By analyzing recent studies, this review highlights the intersection between environmental exposure and AD progression, emphasizing how such factors can accelerate the disease. It provides practical guidelines to mitigate these risks, aiming to reduce AD incidence while advancing understanding of its environmental contributions.

4.9. Electromagnetic fields

Electromagnetic fields (EMFs) are produced by various electronic devices, including those used in wireless communication, such as cell phones, Wi-Fi routers, and smart meters. EMFs are categorized into two main types: low-frequency (e.g., power lines) and high-frequency (e.g., radiofrequency radiation from wireless devices) (Meenu et al., 2024). The increasing prevalence of EMF exposure in

daily life has raised concerns regarding its potential impact on brain health, particularly its role in neurodegenerative diseases such as AD (Jiang et al., 2016).

One of the central hypotheses regarding EMF exposure and AD is based on the calcium hypothesis of neurodegeneration. High-intensity EMFs are thought to interact with voltage-gated calcium channels in brain cells, which are responsible for regulating the influx of calcium ions ($Ca^{2+}$) into neurons. Research suggests that the increased concentration of $Ca^{2+}$ ions resulting from EMF exposure may contribute to a cascade of pathological processes associated with neurodegeneration, including excessive calcium signaling, oxidative stress, and inflammation (Pall, 2022). The dysregulation of calcium homeostasis is a well-established mechanism in AD, where elevated intracellular calcium levels can lead to neuronal damage, synaptic dysfunction, and ultimately cell death.

Animal studies have provided compelling evidence supporting the role of EMFs exposure in the accumulation of amyloid-β, a hallmark protein involved in AD. For example, a study involving rats exposed to daily pulsed EMFs demonstrated elevated levels of amyloid-β plaques in the brain, suggesting that EMFs exposure could accelerate amyloid pathology and contribute to cognitive decline (Li et al., 2019). The deposition of amyloid-β plaques is a critical event in the pathogenesis of AD, as these plaques disrupt neuronal communication and promote inflammation, thereby exacerbating neurodegeneration. In addition to amyloid-β accumulation, neurodegeneration itself is another key consequence of EMF exposure. Human studies have shown that prolonged exposure to EMFs may lead to widespread loss of dendritic spines and synaptic connections in the brain (Pritchard et al., 2019). Dendritic spines are small protrusions on neurons that play a critical role in synaptic signaling and cognitive processes. Their loss is a key feature of neurodegenerative diseases, including AD (Wyszkowska et al., 2019). Increased calcium ion influx resulting from EMF exposure may disrupt the structural integrity of dendritic spines, leading to synaptic dysfunction and cognitive impairment (Glaser et al., 2019, Popugaeva et al., 2017, Tong et al., 2018).

In a study by Tong et al., (2018), exposure to EMFs was found to increase calcium ion levels in neuronal cells, which led to the activation of signaling pathways associated with neuroinflammation and oxidative stress. These pathways are implicated in the progressive damage to neurons seen in AD and other neurodegenerative disorders. Additionally, chronic EMFs exposure has been shown to induce neuroinflammatory responses, which play a central role in the pathophysiology of AD. Inflammation in the brain, often triggered by the activation of microglial cells, can lead to the release of cytokines and other inflammatory mediators that further exacerbate neuronal damage and amyloid plaque accumulation (Kim et al., 2021). Another key aspect of the EMF-AD connection is the role of oxidative stress. Exposure to EMFs has been shown to increase the production of reactive oxygen species (ROS) in neurons, which can lead to oxidative damage to cellular components, including lipids, proteins, and DNA. This oxidative damage is thought to be a major contributor to the pathogenesis of Alzheimer's Disease, as it impairs neuronal function and accelerates the formation of amyloid plaques and tau tangles, both of which are characteristic of AD pathology (Bektas and Dasdag, 2025). Some studies have even suggested that individuals living in close proximity to sources of high-intensity EMF radiation, such as cell towers or power lines, may have an increased risk of developing neurodegenerative diseases, including Alzheimer's (Huss et al., 2009).

4.10. Synergistic effects of combined environmental pollutants

While much of the research on environmental risk factors for AD focuses on individual pollutants, growing evidence suggests that the combined effects of multiple exposures may significantly increase the risk of developing the disease (Wang et al., 2025). The synergistic interactions between various pollutants, such as smoking and heavy metals, can lead to more severe neuroinflammation, oxidative stress, and neuronal damage than the effects of any single exposure (Krisanova et al., 2024). For example, smoking and heavy metal exposure are two well-established risk factors for AD. Smoking leads to the generation of ROS and inflammation, which can directly damage neurons and alter amyloid-β processing (Wallin et al., 2017). When combined with exposure to heavy metals like cadmium, lead, or arsenic, the effects of smoking are often amplified. Heavy metals, by disrupting cellular homeostasis and enhancing oxidative stress, can exacerbate the damage caused by smoking. Specifically, cadmium has been shown to increase the permeability of the blood–brain barrier (BBB), allowing for easier access of amyloid-beta peptides into the brain, and promoting tau hyperphosphorylation (Ramírez-Mendoza et al., 2024). The combination of these pollutants leads to a vicious cycle of neuroinflammation, neuronal death, and cognitive decline, significantly increasing the risk of AD development in individuals who are exposed to both factors (Fu et al., 2022). The synergistic effects of combined exposures to environmental pollutants underscore the complexity of AD risk factors and highlight the need for more comprehensive studies that examine multifactorial exposures (Ahmed et al., 2025). Current research often focuses on individual risk factors in isolation, but the combined impact of pollutants is likely to provide a more accurate representation of real-world exposures (Aderinto et al., 2025b).

7. Conclusions

This monograph has underscored the critical impact of environmental risk factors stemming from industrialization, modern agriculture, and other pollutants on mental health, particularly in the context of AD. As AD research reaches a pivotal moment, the multifaceted role of environmental influences in the onset and progression of this disorder is becoming increasingly clear. Despite significant advances in understanding the pathobiology of AD, many aspects remain unresolved, particularly regarding the early causative events triggered by environmental pollutants, which continue to be elusive.

Biochemical analyses and both *in vitro* and *in vivo* studies have confirmed the role of amyloid-beta (Aβ) aggregation in initiating AD, but therapeutic strategies targeting amyloid have thus far proven ineffective. This highlights the urgent need for a deeper exploration of the mechanisms that link environmental exposures to AD onset. Additionally, the rise of NMs as emerging contributors to AD progression further emphasizes the complexity of environmental impacts on neurological health.

By addressing the limitations of current research and pursuing the outlined future directions, we can gain valuable insights into how environmental factors contribute to AD and how these risks can be mitigated. This research holds the potential to enhance our understanding of AD and guide the development of public health policies and interventions aimed at reducing the burden of this devastating disease.

https://pubmed.ncbi.nlm.nih.gov/40784621/

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**Acoustic Pressures in the Head from Pulsed Microwaves: Can They Explain the Havana Syndrome?**

Foster KR, Diao Y, Chou C-K. Acoustic Pressures in the Head from Pulsed Microwaves: Can They Explain the Havana Syndrome?. *TechRxiv.* August 12, 2025. doi: 10.36227/techrxiv.175502739.93949559/v1

Abstract

The microwave auditory effect-referring to "clicks" or "buzzing" sensations that a person experiences when their head is exposed to pulsed microwave energy such as emitted by radar transmitters, has been known since the 1960s. Formerly a threshold hearing phenomenon, the effect has gained renewed interest due to the advent of high powered microwave sources in recent decades. Does it represent a potential danger to people exposed to high powered microwave pulses?

Open access: https://www.techrxiv.org/users/952786/articles/1322094-acoustic-pressures-in-the-head-from-pulsed-microwaves-can-they-explain-the-havana-syndrome

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***Panax ginseng* Ameliorates Pituitary-ovarian Dysfunction Induced by Radiofrequency Electromagnetic Radiation from Cell Phones via Upregulation of the CREM Signaling Pathway**

Oyewopo OA, Badejogbin OC, Ajadi IO, Enye LA, Ajadi MB, Ebuwa IV, Owolabi OV, Areloegbe SE, Olaniyi KS. *Panax ginseng* Ameliorates Pituitary-ovarian Dysfunction Induced by Radiofrequency Electromagnetic Radiation from Cell Phones via Upregulation of the CREM Signaling Pathway. Curr Drug Discov Technol. 2025;22(2):e300424229527. doi: 10.2174/0115701638279386240425050818.

Abstract

Background: Panax ginseng (PG) is a plant that contains ginsenosides, which are considered adaptogens that confer cellular protection. However, the impact of PG on pituitary-ovarian dysfunction and subsequent infertility is unknown. This study investigated the hypothesis that PG would attenuate pituitary-ovarian dysfunction associated with mobile phone's Radiofrequency Electromagnetic Radiation (RF-EMR) in experimental rat models and the possible involvement of a cAMP Response Element Modulator (CREM)-dependent pathway.

Methods: Twenty adult female Wistar rats were divided randomly into four groups, each consisting of five rats. The control group was administered a vehicle (distilled water) orally, while the P. ginseng group received 200 mg/kg of P. ginseng extract orally. The RF-EMR group was exposed to 900MHz radiation, and the RF-EMR + PG group was exposed to the same radiation while also being treated with 200 mg/kg of P. ginseng orally. These treatments were administered daily for a period of 56 days.

Results: The RF-EMR group exhibited significant reductions in serum levels of LH, FSH, estradiol, and progesterone compared to the control group. Moreover, levels of superoxide dismutase (SOD) and glutathione peroxidase (GPx) were significantly lower in the RF-EMR group compared to the control. Additionally, there was a notable decrease in the expression of the CREM gene, accompanied by disrupted pituitary/ovarian morphology in the RF-EMR group compared to the control. However, the administration of PG mitigated these changes.

Conclusion: The findings of this study indicate that P. ginseng extract shields against pituitary-ovarian impairment linked to RF-EMR exposure from cell phones by boosting antioxidant capacity and promoting the CREM-dependent pathway.

https://pubmed.ncbi.nlm.nih.gov/38693729/

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**Impact of in vitro exposure to 5G-modulated 3.5 GHz fields on oxidative stress and DNA repair in skin cells**

Haidar J, Nabos P, Orlacchio R*, et al.* Impact of in vitro exposure to 5G-modulated 3.5 GHz fields on oxidative stress and DNA repair in skin cells. *Sci Rep* **15**, 31214 (2025). https://doi.org/10.1038/s41598-025-15090-w.

Abstract

The rapid deployment of fifth-generation (5G) wireless networks has raised societal concerns regarding potential biological effects, particularly on human skin, due to the use of higher carrier frequencies that penetrate tissue less deeply. Consequently, whether 5G-modulated radiofrequency (RF) electromagnetic fields (EMFs) at 3.5 GHz affect oxidative stress and DNA repair in skin cells remains an open question. Using genetically encoded Bioluminescence Resonance Energy Transfer (BRET)-based biosensors targeted to the cytoplasm and mitochondria, we assessed whether exposure of human fibroblasts to 5G RF-EMF at specific absorption rates (SAR) of 0.08 and 4 W/kg for 24 h could alter basal reactive oxygen species (ROS) levels or potentiate the effects of known ROS inducers, including $H_2O_2$, Kp372-1, and Antimycin A. We also evaluated whether pre-exposure to 5G RF-EMF could induce an adaptive response (AR), by modulating ROS production following a subsequent challenge with arsenic trioxide ($As_2O_3$). Additionally, we investigated the impact of combined RF-EMF and ultraviolet-B (UV-B) exposure on the formation and repair of cyclobutane pyrimidine dimer (CPD) lesions in HaCaT keratinocytes. Our results showed no significant effect of 5G RF-EMF exposure, either alone or in combination with chemical ROS inducers, on oxidative stress markers in either compartment. Likewise, RF-EMF exposure did not induce an adaptive response to oxidative challenge, nor did it alter the kinetics or the efficiency of CPD repair by the nucleotide excision repair (NER) pathway. These findings support the conclusion that the exposure to 5G RF-EMF at 3.5 GHz up to 4 W/kg does not induce oxidative stress or impair DNA repair efficiency in human skin cells, within the experimental conditions tested.

Excerpt

In summary, our investigation—combining novel biosensing technology with robust experimental design—demonstrates that 5G-modulated 3.5 GHz RF-EMF does not affect oxidative stress levels, trigger adaptive response, or interfere with DNA repair processes in human skin cells at steady temperature. These results are consistent with current assessments by international experts and provide meaningful data for an evidence-based risk assessment of RF-EMF exposure in the context of 5G deployment. Nevertheless, it is important to note that our findings are based on acute in vitro exposure protocols lasting up to 24–48 h. While such durations are commonly used to assess direct cellular responses, they do not fully recapitulate the chronic or long-term exposures experienced in real-life settings. Therefore, future studies will be necessary to confirm these findings in more physiologically relevant models, including long-term or repeated exposures in 3D reconstructed skin or in vivo systems

Open access: https://www.nature.com/articles/s41598-025-15090-w

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**Dual Evaluation and Spatial Analysis of RF-EMF Exposure in 5G: Theoretical Extrapolations and Direct Measurements**

Najera A, Villaescusa-Tebar A, Gonzalez-Rubio J, Garcia-Pardo C. Najera A, Villaescusa-Tebar A, Gonzalez-Rubio J, Garcia-Pardo C. Dual Evaluation and Spatial Analysis of RF-EMF Exposure in 5G: Theoretical Extrapolations and Direct Measurements. Bioelectromagnetics. 2025 Sep;46(6):e70020. doi: 10.1002/bem.70020.

Abstract

This study evaluates radiofrequency electromagnetic field (RF-EMF) exposure in 5G networks using a dual approach that combines theoretical extrapolations and direct measurements in diverse semiurban and urban environments, specifically on the campus of the Polytechnic University of Valencia. Measurements were conducted using personal exposimeters under active traffic conditions on the 5G network, complemented by a code-selective measurement system based on an R&S TSME6 scanner. This approach enabled the calculation of maximum theoretical exposure by detailed analysis of 5G signals and the capture of key parameters such as cell ID and beam indices at 16 representative points across the campus. For precise spatial visualization, Kriging interpolation techniques in ArcGIS were employed to generate continuous exposure maps illustrating the spatial distribution of RF-EMF in the study area. The results indicate that both the extrapolated theoretical values and measured levels align with the limits recommended by the ICNIRP, even under high data demand scenarios, supporting current safety assessments of 5G infrastructure regarding electromagnetic exposure. The correlation between theoretical and instantaneous exposures validates the applied methodology and its effectiveness in assessing exposure in diverse environments. This study provides a robust framework for future research and highlights the importance of continuous monitoring to ensure public safety during the deployment of new telecommunications infrastructure in urban areas.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70020

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**Assessment of 5G RF-EMF Exposure during Large-Scale Public Events via Field Measurements**

Villaescusa-Tebar A, Garcia-Pardo C. Assessment of 5G RF-EMF Exposure during Large-Scale Public Events via Field Measurements. IEEE Access, 2025. doi: 10.1109/ACCESS.2025.3602263.

Abstract

The development of Fifth-Generation (5G) mobile networks has raised public concern regarding human exposure to radiofrequency electromagnetic fields (RF-EMF). Key 5G features such as higher operating frequencies, broader bandwidths, beamforming, and traffic-dependent signal variability significantly influence RF-EMF exposure dynamics. Although many studies have assessed EMF levels induced by specific base stations under controlled user traffic, little empirical data are available on population-wide 5G environmental exposure across diverse scenarios. This study addresses this gap through field measurements conducted during a large public festival in Valencia, Spain and a baseline day prior to the

event. Downlink signals from the 700 MHz and 3500 MHz 5G bands were measured across Spain's three main network operators. Five locations surrounding the event venue were selected to capture the influence of the measurement location, and two measurement durations (6 and 30 min) were compared to assess temporal dynamics. The results showed that during the event, the power density in the 3500 MHz band increased by up to a factor of eight compared to the baseline conditions. However, even the highest recorded exposure levels remained well below the international safety limits. Additionally, a 30-minute continuous measurement revealed an approximately 30% increase in average power density compared to a 6-minute snapshot. These findings confirm that 5G environmental RF-EMF exposure remains within safe limits, even under high-demand conditions, and underscore the relevance of considering measurement location and temporal variability in exposure assessments.

Open access:

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11135488&isnumber=6514899

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**5G RF EMF Spectral Exposure Assessment in Four European Countries**

Deprez K, Stroobandt B, Veludo AF, Vecsei Z, Necz PP, Politański P, Verloock L, Polanska K, Thuróczy G, Röösli M, Plets D, Joseph W. 5G RF EMF Spectral Exposure Assessment in Four European Countries. Bioelectromagnetics. 2025 Sep;46(6):e70019. doi: 10.1002/bem.70019.

Abstract

This study assesses the exposure to 5G radio frequency electromagnetic fields (RF EMF) across four European countries. Spot measurements were conducted indoor and outdoor in both public spaces and educational institutions, encompassing urban and rural environments. In total, 146 measurements were performed in 2023, divided over Belgium (47), Switzerland (38), Hungary (30) and Poland (31). At 34.9% of all measurement locations a 5G connection to 3.6 GHz was established. The average cumulative incident power density ($S_{avg}$) and maximum cumulative incident power density ($S_{max}$) were determined, for both "background" exposure (no 5G user equipment; No UE) and worst-case exposure (maximum downlink with 5G user equipment; Max DL). Furthermore, 3.6 GHz 5G-specific average $S_{avg,5G}$ and maximum $S_{max,5G}$ incident power density are considered as well. For the No UE scenario, the highest $S_{max}$ is 17.6 mW/m$^2$, while for the Max DL, the highest $S_{max}$ is 23.3 mW/m$^2$. Both values are well within the ICNIRP guidelines. The highest $S_{max,5G}$ measured over all countries and scenarios was 10.4 mW/m$^2$, which is 3.2% of the frequency-specific ICNIRP guidelines. Additionally, a comparison was made between big cities, secondary cities, and villages for all four countries. The ratio of power density measured in rural areas was significantly lower than in urban areas (−4.8 to −10.4 dB). Under LOS conditions, the average incident power density was 2.3 mW/m$^2$, whereas under NLOS conditions, the average incident power density decreases to 0.9 mW/m$^2$. Furthermore, the relative variation increases under NLOS scenarios. Lastly, an analysis was performed regarding the power density in educational institutions compared to all other measurement locations, both indoors and outdoors for the different city types. The measured incident power density is not extensively lower in or around schools compared to public places, neither in the big cities, secondary cities, or the villages.

Summary

- Radio frequency electromagnetic fields exposure assessment measurements across four European countries are conducted using a standardized measurement method.
- All measurements were well within the ICNIRP guidelines.
- The incident power density measured in rural areas was significantly lower than in urban areas.

Conclusion

The findings of this study provide a comparison of downlink RF EMF exposure from base stations for mobile telecommunications, presented in terms of spectral power density, across Belgium, Switzerland, Hungary, and Poland. First, a comparison was made of the RF EMF exposure regulations of all countries. While all countries follow similar RF EMF exposure regulations, Belgium and Switzerland have additional precautionary limits. In total, 146 measurement locations were assessed in 2023, divided over Belgium (47), Switzerland (38), Hungary (30) and Poland (31). 34.9% of all measurement locations had 5G coverage at 3.6 GHz, although there was a distinction between urban and rural areas in available 3.6 GHz 5G base stations. The study included both average and maximum cumulative incident power densities for two scenarios: "background" (No UE) and "worst-case" (Max DL) exposure. Furthermore, 3.6 GHz 5G-specific average and maximum incident power density ($S_{avg,5G}$ and $S_{max,5G}$) were included as well. The highest maximum cumulative power density for the No UE scenario was 17.6 mW/m$^2$. For the Max DL scenario, the highest maximum cumulative power density was 23.3 mW/m$^2$. These cumulative power densities, and by extension all measurements, remain well below 1, indicating compliance with ICNIRP guidelines. The highest 3.6 GHz 5G power density measured over all countries and scenarios was 10.4 mW/m$^2$, which is 0.1% of the frequency-specific ICNIRP guidelines. The ratio of power density measured in rural areas was significantly lower than in urban areas (−4.8 to −10.4 dB), for all countries over the two scenarios, as expected due to less nearby base stations and generally less users.

A comparison between LOS and NLOS measurement locations is made. Under LOS conditions, the average incident power density was 2.3 mW/m$^2$, whereas under NLOS conditions, the average incident power density decreases to 0.9 mW/m$^2$. Furthermore, the relative variation increases under NLOS scenarios. Lastly, an analysis was performed regarding the power density in educational institutions compared to all other measurement locations, both indoors and outdoors for the different city types. The measured incident power density is not extensively lower in or around schools compared to public places, in neither the big cities, secondary cities or the villages. The RF EMF exposure levels in all measured environments were well below the ICNIRP guidelines.

For future work, increasing the number of measurements and regularly reassessing exposure levels will be essential to monitor the continued rollout of 5G networks and related exposure trends. Therefore, these measurements will be repeated in 2025. Furthermore, the different measurement methods within GOLIAT will be combined to achieve an even better understanding regarding RF EMF exposure.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70019

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**Assessment of spatial-average absorbed power density and peak temperature rise in skin model under localized electromagnetic exposure**

Zheng J, Zhang Y, Diao Y, Shi D. Assessment of spatial-average absorbed power density and peak temperature rise in skin model under localized electromagnetic exposure. Radiat Prot Dosimetry. 2025 Aug 16:ncaf096. doi: 10.1093/rpd/ncaf096.

Abstract

Numerical dosimetry for assessments of the absorbed power density (APD) and temperature rise has been conducted using multi-layer skin models, incorporating skin, fat, muscle, and other components, providing a scientific foundation for setting exposure limits. However, the influence of the vasculature on dosimetry outcomes remains underexplored. In this study, we developed a synthetic blood vessel model and integrated it into multi-layer skin models. Electromagnetic computations were performed, followed by steady-state temperature rise evaluations using the Pennes bioheat transfer equation across a frequency range of 3 to 30 GHz. To quantify the effect of vascular modeling on dosimetry results, simulations incorporating vasculature with varying endpoint diameters were compared to those without vasculature. Results showed that the effect of vascular modeling on peak spatial-averaged APD was negligible, and its influence on peak temperature rise was ~8% at 3 GHz, decreasing to less than <3% above 6 GHz. And the effect of the endpoint diameter is marginal. These variations are smaller than those previously reported due to changes in tissue thickness and dielectric or thermal properties. While the effect on peak temperature rise is modest, including vasculature helps refine localized thermal distributions and may inform future improvements in anatomical modeling.

https://pubmed.ncbi.nlm.nih.gov/40817877/

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**Traceable Assessment of the Absorbed Power Density of Body Mounted Devices at Frequencies Above 10 GHz**

Chitnis N, Karimi F, Kühn S, Fallahi A, Christ A, Kuster N. Traceable Assessment of the Absorbed Power Density of Body Mounted Devices at Frequencies Above 10 GHz. Bioelectromagnetics. 2025 Sep;46(6):e70018. doi: 10.1002/bem.70018.

Abstract

In this study, a comprehensive approach for the experimental assessment of the absorbed power density (APD) is developed. The method includes several novel components: (i) a specialized probe, (ii) a composite phantom, (iii) a reconstruction technique, (iv) a calibration method, and (v) a validation process. The described solution has been developed for the frequency range from 24 to 30 GHz, but can be extended to all frequency bands between 10 and 45 GHz. A novel composite phantom emulates the reflection and transmission coefficients of human skin for propagating and evanescent modes, while its increased penetration depth, in comparison to dermis tissue, enables the measurement of the induced electromagnetic fields (EMFs) with a new miniaturized dosimetric broadband probe. The implementation has a wide dynamic range and sufficient spatial resolution to use it for type approval of mobile devices. Its probe is calibrated with low uncertainty in a novel, traceable setup. A set of reference antennas with known numerical target values for the APD has been compiled to validate the measurement system. The validation demonstrates that the deviation is within the expanded uncertainty of 1.6 dB for pAPD and 1.5 dB for psAPD.

Summary

- First traceable, broadband absorbed power density (APD) assessment method and procedures covering 10–45 GHz with a validated implementation for 24–30 GHz, having low uncertainty of < 1.6 dB for peak APD and < 1.5 dB for peak spatial-averaged APD (psAPD), enabling type approval of wireless devices.
- Composite phantom design that emulates reflection and APD of skin across propagating and evanescent modes.
- Reference-antenna-based validation that is instrumentation agnostic and covers realistic spatial gradients, spectral domain (*k*-space), and modulated signals in conformance with standard requirements for product test system qualification.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70018

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**Assessing exposure from different vehicular antennas in military applications: a computational study**

Micol C, Biscarini M, Ferrante D, Pellegrino G, De Meis M, Mei L, Cavagnaro M, Apollonio F, Liberti M. Assessing exposure from different vehicular antennas in military applications: a computational study. Frontiers in Public Health. Volume 13 - 2025. doi: 10.3389/fpubh.2025.1620240.

Abstract

Introduction  Military personnel frequently operate in close proximity to electromagnetic (EM) sources such as vehicular communication antennas. Despite this occurrence, detailed evaluations of exposure scenarios remain limited. This study bridges this gap by examining EM exposure from military vehicular antennas, covering a broad spectrum of frequencies (high frequency—HF, very high frequency—VHF, ultrahigh frequency—UHF), power levels, and positions.

Methods  The study used computational modeling to simulate realistic military scenarios, including personnel partially outside armored vehicles and equipped with personal protective equipment. Simulations accounted for a broad spectrum of frequencies (HF, VHF, and UHF) as well as different power levels, antenna types and locations.

Results  The analysis revealed substantial variability in EM exposure levels depending on the configuration and conditions. While all simulated scenarios complied with the ICNIRP Basic Restrictions (BR), certain cases exceeded the Reference Levels (RL), particularly under specific positioning and frequency combinations.

Conclusions  These findings, based on a detailed case-specific analysis, suggest that personnel safety in military contexts is generally maintained, even in the presence of variable exposure conditions and elevated levels of radiated E-field. Considering the basic structure of the radiating source (i.e., monopole) and the nature of near-field interactions, this paper suggests that safe exposure conditions could be expected to persist across a range of antenna-operator positioning configurations, and building on previous preliminary research on this topic, it provides relevant insights for operational instructions and improving safety regulations in the military field.

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1620240

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**In situ electric field dosimetry analysis for powerline frequency peripheral nerve magnetic stimulation**

Fresnel E, Bouisset N, Soyka F, *et al.* In situ electric field dosimetry analysis for powerline frequency peripheral nerve magnetic stimulation. *Sci Rep* **15**, 29887 (2025). https://doi.org/10.1038/s41598-025-12284-0.

Abstract

Humans are exposed to environmental 60 Hz magnetic fields (MFs), inducing in our body electric fields (EFs) and currents, potentially stimulating the peripheral nervous system (PNS). Uncertainties exist regarding the 60 Hz MF PNS stimulation threshold. The spatially extended nonlinear node model (SENN) is used to help define international MF exposure guidelines and standards protecting workers and the general public. However, other models exist, particularly the McIntyre–Richardson–Grill (MRG) model, the new gold standard for electrostimulation. This study aims (1) to model a new extremely low frequency MF exposure system for the human leg and (2) to investigate the in situ EFs generated by the system at 60 Hz at the skin level and in the nerves of the leg using a realistic human body model with both the SENN and the MRG models. A Helmholtz like-coil system was designed to generate in situ EFs sufficient for nerve stimulation, modeled using Biot–Savart and Faraday laws. Sim4Life simulations assessed the induced EFs at skin and nerve levels using a detailed human body model and two nerve excitation frameworks: the SENN and MRG models. High EF intensities were observed in four sensory and sensory-motor nerves, with MRG-derived thresholds lower than SENN-derived thresholds. Results also highlight the significance of nerve orientation in EF induction. This study emphasizes the critical role of comprehensive modeling for the design and validation of MF exposure systems and underscores the need for experimental data to refine models, standards, and guidelines.

Open access: https://www.nature.com/articles/s41598-025-12284-0

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**Instruments and Measurement Techniques to Assess Extremely Low-Frequency Electromagnetic Fields**

Rathebe PC, Kholopo M. Instruments and Measurement Techniques to Assess Extremely Low-Frequency Electromagnetic Fields. Sensors (Basel). 2025 Aug 7;25(15):4866. doi: 10.3390/s25154866.

Abstract

This study presents a comprehensive evaluation and selection framework for extremely low-frequency electromagnetic field (ELF-EMF) measurement instruments. Recognizing the diversity of application environments and technical constraints, the framework addresses the challenges of selecting appropriate tools for specific scenarios. It integrates a structured, quantitative approach through a weighted scoring matrix that evaluates instrumentation across six criteria: monitoring duration, sensitivity, environmental adaptability, biological/regulatory relevance, usability, and cost. Complementing this is a logic-based flowchart that visually guides decision-making based on user-defined operational needs. The framework is applied to a realistic occupational case study, demonstrating its effectiveness in producing evidence-based, scenario-sensitive instrument

recommendations. This method provides stakeholders with a transparent and adaptable tool for ELF-EMF device selection.

Open access: https://www.mdpi.com/1424-8220/25/15/4866

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**Weak anthropogenic electric fields affect honeybee foraging**

Mallinson VJ. Woodburn FA, O'Reilly KJ. Weak anthropogenic electric fields affect honeybee foraging. Cell Press. 2025. https://doi.org/10.1016/j.isci.2025.112550.

Highlights

• Weak anthropogenic-like electric fields reduce honeybee floral landing

• AC and positive DC fields deter honeybee landing, but negative DC does not

• Electric fields near power lines match experimental levels, spanning tens of meters

• These findings highlight electric pollution as a potential disruptor of pollination

Summary

Aerial electroreception, the detection of airborne electric fields (E-fields), is an emerging sensory system in arthropods, including bees, which can use floral E-fields as foraging cues. However, the influence of anthropogenic E-fields on these interactions remains underexplored. Through field experiments in urban meadows, we demonstrate that weak anthropogenic E-fields, including alternating current (AC) and direct current (DC) fields, significantly alter honeybee floral landing behaviors. AC and positive DC fields reduced landings by 71% and 53%, respectively, whereas negative DC fields had no statistically significant impact. Measurements of E-fields near high-voltage transmission lines revealed persistent field strengths comparable to those used experimentally, spanning tens of meters at heights relevant for bee foraging. These findings underscore the potential for anthropogenic E-fields to affect and potentially disrupt plant-pollinator interactions, threatening pollination efficiency, a cornerstone of agriculture and biodiversity. Our study highlights the need for advancing research on the ecological impacts of electric pollution.

Open access paper: https://www.cell.com/iscience/fulltext/S2589-0042(25)00811-9

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**Combined effects of constant temperature and radio frequency exposure on Aedes mosquito development**

Dom NC, Dapari R, Halim NMHNA, Rahman ATA. Combined effects of constant temperature and radio frequency exposure on Aedes mosquito development. Sci Rep. 2025 Aug 20;15(1):30571. doi: 10.1038/s41598-025-09383-3.

Abstract

Mosquito-borne diseases, such as dengue, Zika, and chikungunya, pose significant public health threats, particularly in tropical regions like Malaysia. Aedes aegypti and Aedes albopictus are primary vectors of these diseases, with their developmental stages being highly sensitive to environmental factors. While temperature is a well-known driver of mosquito biology, the potential influence of anthropogenic factors such as radio frequency (RF) exposure remains underexplored. This study investigates the combined effects of temperature and RF exposure on the developmental stages of these mosquito species to provide insights into their population dynamics and inform vector control strategies. A factorial experimental design was employed, incorporating four temperature conditions (20 °C, 25 °C, 30 °C, and 35 °C) and three RF exposure levels (900 MHz, 18 GHz, and a control group with no RF exposure). The developmental durations for hatching, larval, pupation, and adult emergence stages were monitored daily under controlled laboratory conditions. Data were analyzed using a quadratic response surface model to evaluate the main effects and interactions between temperature and RF exposure. Temperature emerged as the dominant factor influencing developmental durations, with optimal conditions observed at 30-32 °C. RF exposure, particularly at 18 GHz, acted as a secondary modulating factor, accelerating developmental stages under certain temperature conditions. Ae. aegypti exhibited greater sensitivity to temperature changes compared to Ae. albopictus, which displayed higher adaptability and resilience to environmental variations. Interaction effects were most evident at intermediate temperatures (25-30 °C), where RF exposure synergistically reduced developmental durations. However, extreme RF exposure levels and suboptimal temperatures prolonged developmental periods. This study highlights the critical role of temperature in mosquito development while identifying RF exposure as a potential modulator under specific conditions. The findings underscore the importance of considering both environmental and anthropogenic factors in vector management strategies. Future research should explore the molecular mechanisms underlying these interactions to refine predictive models and enhance vector control efforts in rapidly urbanizing regions.

Conclusion

In summary, temperature is the primary determinant of mosquito developmental durations, with RF exposure exerting secondary modulating effects under specific conditions. *Ae. aegypti* was more sensitive to environmental variations, while *Ae. albopictus* displayed greater resilience and adaptability. These findings provide a foundation for incorporating environmental variables, including anthropogenic factors such as RF exposure, into predictive models for mosquito population dynamics and vector management. Future research should explore the molecular mechanisms underlying these interactions and assess their implications for disease transmission and control in different ecological settings.

Open access: https://www.nature.com/articles/s41598-025-09383-3

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**Effect of Static Electromagnetic Field on Growth Parameters, Survival Rate, Sex Distribution, Ratio, and Liver and Gonadal Health of Zebrafish**

Çek Ş, Ünal E, Doğan EA, Yaraş KU, Dede K, Karaaslan M. Effect of Electromagnetic Field on Growth Parameters, Survival Rate, Sex Distribution, Ratio, and Liver and Gonadal Health of Zebrafish (Danio rerio). Bull Environ Contam Toxicol. 2025 Aug 25;115(3):33. doi: 10.1007/s00128-025-04103-z. PMID: 40855214.

Abstract

This study examines the impact of electromagnetic fields (EMF) on zebrafish (Danio rerio) sex ratio, survival, and organ health. Embryos were exposed to static EMFs for 63 days post-hatching across five aquariums, with varying intensities based on distance (30-99 cm). The control group remained EMF-free. The strongest exposure (30 cm) led to 100% feminization ($p < 0.001$), with all exposed groups showing significant deviations from the expected 1:1 sex ratio. Survival rates dropped below 35% in EMF-exposed groups, compared to 82.5% in controls. Histological analysis revealed gonadal abnormalities, necrosis, and liver degeneration in exposed fish. These findings provide the first documented evidence that EMF exposure disrupts sex ratios and health in fish, potentially affecting population stability in aquatic ecosystems. The predominance of females suggests long-term ecological consequences that could impact biodiversity in both aquatic and terrestrial environments.

https://pubmed.ncbi.nlm.nih.gov/40855214/

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**Exposure of human lymphocytes to sweeping-frequency extremely low frequency magnetic field**

Zastko L, Makinistian L, Petrovičová P, Tvarožná A, Belyaev I. Exposure of human lymphocytes to sweeping-frequency ELF MF. Int J Radiat Biol. 2025 Aug 7:1-10. doi: 10.1080/09553002.2025.2542322.

Abstract

Purpose  Whereas most of the research on possible bioeffects of extremely low frequency magnetic fields (ELF MF) on blood cells has been performed at 50/60 Hz regardless of background fields, here, we exposed human lymphocytes to sweeping-frequency ELF MF in a different range, defined by the DC background field of our incubator and the corresponding ion-cyclotron frequencies.

Materials and methods  Umbilical cord blood lymphocytes (UCBL) were isolated and exposed for 48 h to an ELF MF (sinusoidal, frequency sweeping 3–26 Hz) with 6 different amplitudes between 6 µT and 24 µT, utilizing an oblong coil. DNA double-strand breaks (DSB) were assessed by enumeration of γH2AX, 53BP1 and γH2AX/53BP1 co-localized DNA repair foci. Percentage of viable, early apoptotic (EA), and late apoptotic/necrotic (LAN) cells were determined.

Results  No statistically significant effects were seen for DNA repair foci or apoptosis induction after a 48-h exposure of UCBL with frequency-sweeping ELF MF. More than 2-fold decrease ($p = .064$) of γH2AX foci level was detected for 8 µT amplitude when compared to controls. For the same field intensity, a decrease in viable cells was suggested by the data.

Conclusions  Our findings suggest that at least part of the exposure could have had a preventive/blocking effect on DNA DSB formation suggesting the possibility of using sweeping-frequency ELF MF as a protective measure against genotoxic agents. It is desirable to continue testing variations of the exposure utilized in this work, in order to search for the most biologically effective frequencies/patterns of exposure.

https://pubmed.ncbi.nlm.nih.gov/40772784/

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**Magnetic effects in biology: Crucial role of quantum coherence in the radical pair mechanism**

Binhi V. Magnetic effects in biology: Crucial role of quantum coherence in the radical pair mechanism. Phys. Rev. E. **112**, 014409. 25 July 2025**.** doi: 1103/n3fs-fsnv.

Abstract

The spin-chemical radical pair mechanism (RPM) has emerged as a leading theory for explaining the biological effects of low-intensity magnetic fields. These intriguing effects occur when the quantum system of radicals is well isolated from the disturbing influence of the environment. In other words, these effects are closely related to the spin coherence relaxation time $\tau$, but an explicit relationship has not yet been established. In our study, we found an analytical solution to the Liouville-Neumann equation for an open system made up of two electrons and one nucleus, considering minimal interactions while concentrating on spin relaxation and chemical kinetics. This solution, supported by numerical integration, highlights the crucial role of quantum coherence. A straightforward expression is proposed that describes the RPM effect as a function of $\tau$, within the ranges of magnetic field strength $H$ and rate $\kappa$ of chemical kinetics relevant to magnetobiology. Our findings reveal that RPM effects become significant only when fundamental relation $\gamma H\tau>1+\kappa\tau$ holds: it controls the magnitude of the effects, and it is consistent with the principles of spin chemistry. Additionally, by comparing our results with existing experimental data, we estimate that the plausible spin decoherence times in magnetosensitive radical pairs within cryptochromelike proteins range from units to tens of nanoseconds. The effects of radio-frequency magnetic fields at the nT level were also examined, taking into account decoherence. These effects turned out to be negligible and incapable of disrupting the RPM patterns. The role of the quantum Zeno effect in magnetobiology is inspected from the perspective of the $\tau$ dependence of the RPM effect.

https://journals.aps.org/pre/abstract/10.1103/n3fs-fsnv

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**Radiofrequency Electromagnetic Field Emissions and Neurodevelopmental Outcomes in Infants: A Prospective Cohort Study**

Setia M S, Natesan R, Samant P, et al. (July 10, 2025) Radiofrequency Electromagnetic Field Emissions and Neurodevelopmental Outcomes in Infants: A Prospective Cohort Study. Cureus 17(7): e87671. doi:10.7759/cureus.87671.

Abstract

Purpose It has been argued that children are particularly at risk of developing health effects due to the emitted radiofrequency electromagnetic fields (RF-EMF). We designed this cohort to measure the association between exposure to RF-EMF radiation and neurodevelopmental changes in neonates and infants.

Methods We present an analysis of 261 observations from a cohort of 105 neonates. The cohort was formed of pregnant women, and the neonates born to these women were followed for a period of one

year. We assessed the level of radiation in the house using the Selective Radiation Meter 3006 (Narda Worldwide, Germany) and neurodevelopment using the Ages and Stages Questionnaire® (ASQ®)-3. We used random effects models for multiple observations in the same individual, and the main explanatory variable was household radiation levels (divided into tertiles as low/medium/high).

Results The median (interquartile range (IQR)) range of radiation in all the households was 8.66 (IQR: 1.58, 23.11) $mW/m^2$. It was 0.62 (IQR: 0.43, 1.58) $mW/m^2$ in the lowest tertile, 8.66 (IQR: 5.00, 10.78) $mW/m^2$ in the middle tertile, and 32.36 (IQR: 23.11, 45.60) $mW/m^2$ in the highest tertile (p=0.0001). The mean scores were significantly lower in the middle and higher tertiles of LOR for the gross motor, fine motor, and problem-solving domains. The odds of children classified as 'monitor/refer' was significantly higher in the 'high radiation group' compared with 'low radiation group' for the fine motor (adjusted odds ratio (aOR): 2.74, 95% CI: 1.10, 6.78; p=0.03) and problem-solving domains (aOR: 3.67, 95% CI: 1.41, 9.55; p=0.008). We also found that low birth weight babies were significantly more likely to be classified as 'monitor/refer' for fine motor (aOR: 4.19, 95% CI: 1.73, 10.14; p=0.001), and problem solving (aOR: 2.57, 95% CI: 1.08, 6.13; p=0.033) domains.

Conclusions Even after adjusting for low birth weight, we found that higher levels of radiation were associated with poorer outcomes for cognitive domains of development such as problem solving, and personal-social areas. Thus, there is a need to monitor the neuro-development of children in whom the RF-EMF radiations are expected to be higher (such as very close to cell phone towers, too many gadgets in the house).

Excerpts

"In this cohort study, we found that mean ASQ scores were, in general, lower in the highest radiation tertile for all five domains; and specifically, significantly lower for the gross motor, fine motor, and problem-solving domains. Poor development outcomes (such as monitor/refer) for the fine motor, problem-solving, and personal-social domains were associated with higher levels of radiation in the house. In addition, low birth weight was also significantly associated with poor development outcomes for fine motor and problem-solving. Finally, even though mean scores for the social-emotional domain were high in the higher radiation groups, the difference was not statistically significant."

"There are potential limitations in the present analysis. In this study, the focus was on the association between the levels of electromagnetic field radiation and neurodevelopmental outcomes in neonates and infants. Other studies have included prenatal cell phone use and exposure as the exposure variable; we did not include these in the present analysis. We also did not assess the parent-child interaction as another potential confounder. The EMF radiation in the house may not only be due to that from cell phone towers but also due to cordless phones, WiFi devices, and Bluetooth gadgets. Since we measured the radiation in the house, this would have included the EMF from all these. It is quite likely that a home far away from the tower may still have higher EMF radiation due to these gadgets. However, the measurement was only at baseline, and this may have led to some misclassification. As described earlier, some authors have not found an association between cell phone use, while others have found inconsistencies in the relationship. Most other authors have used other scales, such as the Bayley Scales of Infant Development or scales that were developed by the researcher. We have used the Ages and Stages Questionnaire, both for the developmental domain and the social-emotional domain. ASQ is useful for screening and not a diagnostic instrument. We also do not claim causality in these findings. These are interim results of the cohort, and we are still following the cohort. We intend to publish future

results on the neurodevelopmental outcomes. These outcomes will include the Bayley Scales of Infant Development and the Stanford-Binet test for intelligence. We did not use any imputation methods for missing observations and just used the random effects models with available observations. Though we had enough power to detect the difference in scores, some of the events were few (particularly social-emotional and communication domains). Thus, we may be underpowered at this point of analysis for these outcomes. Nonetheless, actual measurement of RF-EMF radiation in the house (which represents the actual exposure levels), a cohort design, and the use of random effects logistic regression models are the potential strengths of the study. These models are useful for longitudinal data, and one additional advantage of random effects models is their use in longitudinal data when observations are present at different time points [42,43].

Conclusions

These preliminary findings are an important contribution to the literature on the association between RF-EMF radiation and neurodevelopment in neonates and infants. The results have to be interpreted taking into account the limitations that have been mentioned. We used random effects models, which account for both within-subject and between-subject correlation, and are useful for time-varying variables. These models are useful for longitudinal data where the outcomes may vary with each observation. Even after adjusting for low birth weight, we found that higher levels of radiation were associated with poorer outcomes for cognitive domains of development such as the problem-solving and personal-social areas. Low birth weight was associated with poorer outcomes for the motor development domains (gross motor and fine motor). It is quite likely that obvious gross motor delays may be identified by parents and caregivers; however, cognitive development domains require specialist monitoring. Thus, there may be a need to consider monitoring of neurodevelopmental outcomes in children in whom RF-EMF radiations are expected to be higher (such as very close to cell phone towers and too many gadgets in the house)."

Open access: https://www.cureus.com/articles/381425-radiofrequency-electromagnetic-field-emissions-and-neurodevelopmental-outcomes-in-infants-a-prospective-cohort-study#!/

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**A scoping review and evidence map of radiofrequency field exposure and genotoxicity: assessing in vivo, in vitro, and epidemiological data**

Weller SG, McCredden JE, Leach V, Chu C, Lam AK-Y (2025) A scoping review and evidence map of radiofrequency field exposure and genotoxicity: assessing in vivo, in vitro, and epidemiological data. Front. Public Health 13:1613353. doi: 10.3389/fpubh.2025.1613353

Abstract

Background  Studies investigating genotoxic effects of radiofrequency electromagnetic field (RF-EMF) exposure (3 kHz−300 GHz) have used a wide variety of parameters, and results have been inconsistent. A systematic mapping of existing research is necessary to identify emerging patterns and to inform future research and policy.

Methods  Evidence mapping was conducted using guidance from the Preferred Reporting Items for Systematic reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR). A comprehensive search

strategy was applied across multiple research databases, using specific inclusion and exclusion criteria within each knowledge domain. Quantitative aggregation using tables, graphs and heat maps was used to synthesize data according to study type, organism type, exposure level and duration, biological markers (genotoxicity, cellular stress, apoptosis), RF-EMF signal characteristics, as well as funding source to further contextualize the evidence landscape. Quality criteria were applied as part of a focused analysis to explore potential biases and their effects on outcomes.

Results  Over 500 pertinent studies were identified, categorized as in vitro (53%), in vivo (37%), and epidemiological (10%), and grouped according to type of DNA damage, organism, intensity, duration, signal characteristics, biological markers and funding source. In vitro studies predominantly showed proportionally fewer significant effects, while in vivo and epidemiological studies showed more. DNA base damage studies showed the highest proportion of effects, as did studies using GSM talk-mode, pulsed signals and real-world devices. A complex relationship was identified between exposure intensity and duration, with duration emerging as a critical determinant of outcomes. A complex U-shaped dose-response relationship was evident, suggesting adaptive cellular responses, with increased free radical production as a plausible mechanism. Higher-quality studies showed fewer significant effects; however, the funding source had a stronger influence on outcomes than study quality. Over half (58%) of studies observing DNA damage used exposures below the International Commission of Non-Ionizing Radiation Protection (ICNIRP) limits.

Conclusion  The collective evidence reveals that RF-EMF exposures may be genotoxic and could pose a cancer risk. Exposure duration and real-world signals are the most important factors influencing genotoxicity, warranting further focused research. To address potential genotoxic risks, these findings support the adoption of precautionary measures alongside existing thermal-based exposure guidelines.

Implications for policy and practice

The evidence from the evidence map indicates that medium to long-term RF-EMF exposures, particularly at low intensities, can induce genetic damage through non-thermal mechanisms such as increased free radical production and oxidative stress. Genetic damage can have far-reaching, long-term, and potentially irreversible consequences for individual organisms and broader ecological and planetary health (112, 113).

Both In vivo and epidemiological RF-EMF studies provide credible evidence of genotoxicity, suggesting potential risks such as increased cancer susceptibility and reproductive harm. Studies on brain cells frequently reported positive findings for DNA damage, suggesting that brain cells may be particularly sensitive to RF-EMF, indicating a risk for neurological diseases and brain tumors, as observed in animal models (114–116).

Current RF-EMF exposure guidelines established by ICNIRP (15), prioritize the prevention of thermal effects by incorporating substantial safety margins (e.g., a 50-fold reduction from effect thresholds, setting a local SAR limit of 2 W/kg for the head and torso for the general public, averaged over 10 grams of tissue). However, the evidence mapping process found statistically significant DNA damage at extremely low intensities, with the lowest recorded effects occurring at a SAR of 0.000000319 W/kg in an epidemiological study (117) and at 0.000003 W/kg in several in vivo experiments (118, 119). These levels are substantially (>600,000 times) below the ICNIRP public exposure limits (15). This pattern

suggests non-thermal genotoxic effects, because temperature changes at these intensities would be negligible and not measurable.

ICNIRP (2020) guidelines (15) set RF-EMF exposure limits to protect against thermal effects from acute exposures, with averaging times of 6 min for local exposure (head and torso) and 30 min for whole-body exposure. However, the above analysis revealed that medium (1 day−3 months) and long-term RF-EMF exposures (>3 months or 1,000 h) were most strongly linked to genotoxic effects, even at very low exposure intensities. ICNIRP (2020) guidelines (15) do not set specific limits for chronic, low-level RF-EMF exposures, particularly for non-thermal effects like genotoxicity, citing “no substantiated evidence of health-relevant effects” [(15), p. 522].

The mapping process also revealed that RF exposures are associated with genetic damage in a wide range of organisms, with an observed sensitivity of non-mammalian organisms, such as plants, insects, and possibly amphibians. Current guidelines neglect potential effects on wildlife or ecosystems (78, 96). Notably, a recent WHO-commissioned systematic review of animal studies suggested carcinogenic effects from RF-EMF exposures (116). Other studies suggest biological effects on non-human species (120, 121). Together, these results suggest that the environmental implications of RF-EMF exposure merit greater scrutiny (122), even though the current evidence remains limited and debated (96).

While these findings do not yet establish causation or a clear No Observed Adverse Effect Level (NOAEL), they indicate risks that ICNIRP's current framework discounts by prioritizing only effects with confirmed harm [(15), p. 487]. ICNIRP's review process and position is best described as a hazard-based assessment focused only on confirmed effects. This approach is overly restrictive, as it delays updating guidelines until absolute certainty is achieved (123), which may not align with the precautionary needs of public health or environmental protection.

Currently, there is a widespread (6) and often non-consensual nature to RF-EMF exposure (92) from mobile phones, base stations, and other wireless technologies. While acknowledging the permanence of this technology in modern society, policy adjustments are required that prioritize health and environmental protection over economic interests. This can be achieved by adopting a precautionary approach to RF-EMF (123) and addressing potential risks from non-thermal RF-EMF effects, despite scientific uncertainty. Strategies such as justification (assessing net benefits of RF-EMF applications), optimization (balancing protection with societal needs), and As low as Reasonably Achievable or As Low as Technically Achievable - ALARA/ALATA (avoiding deterministic effects and minimizing stochastic effects) per International Commission on Radiological Protection (ICRP) recommendations - ICRP103 (124) could be considered. Further development and deployment of wireless technologies should incorporate improved safety measures in their design (125), such as creating devices that emit lower levels of RF-EMF or using materials and antenna designs to direct emissions away from the body.

Additionally, public information regarding potential health risks and personal protective measures could be disseminated through public health campaigns, making use of existing advice such as the EUROPAEM EMF Guideline 2016 (126); e.g. minimizing the use of wireless devices, prioritizing wired connections, maintaining distance between RF-EMF sources and the body, use of air-tube headsets or handsfree calls, turning off wireless when not in use, and mitigation of oxidative stress by incorporating antioxidants

into the diet.

While individual actions are valuable, they are not a substitute for robust regulatory standards and industry accountability. Ensuring the safety of wireless technologies requires a collective effort from manufacturers, policymakers, and consumers to develop comprehensive RF safety guidelines. Future regulatory guidelines could encompass workplace protection measures, including substitution, engineering, and administrative controls (127), integration of building biology standards (128), mandatory detailed product labeling to inform users of potential risks, and standardized safety hygiene practices.

Recommended actions

To address these concerns and bridge existing gaps, the following actions are recommended:

- Standardization of Research Protocols: Harmonizing methodologies across studies, particularly comet assay protocols, is critical for reducing heterogeneity and enabling robust meta-analyses.
- Focus on Long-Term and Low-Intensity Exposures: Future research should prioritize investigating the cumulative effects of prolonged and low-intensity RF-EMF exposures, which are most relevant to real-world scenarios and devices.
- Inclusion of Emerging Frequencies: Given the rapid deployment of 5G and other novel technologies, research focused on higher frequencies and new modulation schemes is urgently needed.
- Targeted Environmental and Health Studies: Targeted research in both human health and ecological systems needs to be conducted independently of vested interest influences, ensuring methodological rigor in each domain.
- Independent Funding and Research Oversight: To mitigate biases associated with industry funding, greater support for independent research is essential. Transparent disclosure of ALL funding sources and researcher affiliations should be mandatory.
- Re-evaluation of RF Standards: Regulatory bodies must update exposure guidelines to reflect non-thermal mechanisms and the potential health effects from long-term chronic exposure settings by incorporating findings from independent, high-quality studies.

Conclusions

The evidence map presented here reveals statistically significant DNA damage in humans and animals resulting from man-made RF-EMF exposures, particularly DNA base damage and DNA strand breaks. The evidence also suggests plausible mechanistic pathways for DNA damage, most notably through increased free radical production and oxidative stress. Sensitivity to damage varied by cell type, with reproductive cells (testicular, sperm and ovarian) along with brain cells appearing particularly vulnerable. A complex U-shaped dose-response relationship was observed for both exposure duration and intensity, with more DNA damage occurring in specific frequency and intensity combination windows. DNA damage was more likely to be found using *in vivo* studies, very weak or very strong signal intensities, very short or very long exposure durations, 900, 1,800 and 2,450 MHz frequencies, GSM-talk mode and pulsed modulations, particularly when using real-world devices. On the other hand, research

funded by vested interests has tended to use different experimental design parameters, with a high proportion of studies using *in vitro*, short-term exposures, medium-high intensity signals and using signal generators. Funding source is also a stronger determinant of experimental outcomes than study quality.

Overall, there is a strong evidence base showing DNA damage and potential biological mechanisms operating at intensity levels much lower than the ICNIRP recommended exposure limits. Public policy could benefit from the implementation of precautionary measures such as ALARA or ALATA, along with public information campaigns to better safeguard human and environmental health and wellbeing.

Open access: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1613353

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**Building the gulf of opinions on the health and biological effects of electromagnetic radiation**

Paul Héroux. Building the gulf of opinions on the health and biological effects of electromagnetic radiation. Front. Public Health, 22 July 2025. Volume 13 – 2025. xoi: 10.3389/fpubh.2025.1589021.

Using events that the author was personally involved with over many years, the article attempts to explain how different views solidified over time on the health effects of electromagnetic radiation, some believing they are negligible, while others believe they are substantial.

Introduction

The health impacts of Non-Thermal Electromagnetic Radiation, both in the ELF and RF domains, have been controversial since the early 1980s (1). The report of a link between childhood leukemia and ELF magnetic fields fueled discussion for more than a decade, ushering together two very different areas, electrical engineering and biology.

The arguments oppose the officers of industry and their followers to health environmentalists. Given that both should have access to the same scientific literature, the opposing positions rely on the selection of different experts, subsets of the literature, and on their interpretation.

This article attempts to explain how different views on the health effects of technological electromagnetic radiation solidified over time, some believing they are negligible, while others propose they are substantial.

We skirt around classically reported events such as the development of the ANSI (21), IEEE (22) and ICNIRP (23) recommendations as well as the Bioinitiative report (24), the ORSAA (25) database, Henry Lai's literature compilation (26), and the NTP (27) and Ramazzini (28) experiments to discuss other incidents that may seem minor but shed some light on the more human aspects of the formation of opinions about EMR health impacts.

To resolve the complex problem of EMR health impacts, several scientific meetings were held worldwide, seemingly to advance science and develop opinions.

We choose to report events where, over the years, the author was *physically* present; such direct experiences easily solidify into valuable memories. We think that assembling such recollections can be used to explain the development of diverging opinions on EMR health impacts.

Section headings

Adair, 1991

Armstrong, 1994

Lai, 1997

Phillips, 2009

Epilogue

The four examples above illustrate different aspects of the divergence of opinions. How are the basic terms of reference in the debate interpreted…are AC and DC fields in some ways equivalent (Adair)? Does the Specific Absorption Rate, a heat variable, provide more clarity than electric and magnetic fields? Should the engineering view of the problem smother its biological aspects? Can humans truly be simulated as a salt and sugar solution, as is done in SAR measurements? What of the issues of not pursuing challenging leads (Armstrong), pressuring the messengers of unwelcome observations (Lai) and undermining or underrating the techniques of biology (Phillips)?

In the recounts above, a leitmotiv is a divergent interpretation of the same facts according to personal education and employment. But control of the collective agenda in the public sphere is equally important, participation at scientific meetings by one group versus another can be strongly biased.

The issue of EMR health impacts was viewed as critical to industry interests at certain times, while for the bio-medical community it may have appeared less urgent.

So, was the industry justified in taking control of the debate and limiting it to heat, given that they had acute interests in the outcomes?

Was industry justified in publicizing its thermalist agenda through the IEEE with so many governments worldwide?

Was industry justified in controlling the evolution of EMR research, using its expertise in electromagnetism to dominate the area, while the most critical elements resided in biology and medicine?

The focus on ionization and thermal limits guaranteed peaceful outcomes for industry. The success of microwave ovens apparently crystallized a view of the human body as a dipole rather than a conductor, but this view may not be everlasting (20).

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1589021/full

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**Impact of Radiofrequency Electromagnetic Fields on Cardiac Activity at Rest: A Systematic Review of Healthy Human Studies**

Michelant L, Selmaoui B. Impact of Radiofrequency Electromagnetic Fields on Cardiac Activity at Rest: A Systematic Review of Healthy Human Studies. Bioelectromagnetics. 2025 Jul;46(5):e70014. doi: 10.1002/bem.70014.

Abstract

Radiofrequency electromagnetic fields (RF-EMF) exposure is increasingly prevalent, raising concerns about potential non-thermal health effects. This systematic review synthesizes current evidence regarding RF exposure effects on cardiac activity, focusing on heart rate (HR) and heart rate variability (HRV). Studies on healthy individuals were selected based on strict methodological criteria, including experimental design, control for confounding variables, and sufficient details on exposure parameters. Articles were included if they compared healthy subjects with and without exposure and provided cardiac measurements, specific absorption rate, or exposure measurement. A total of 28 articles were analyzed. This review included studies with RF exposure ranging from 100 to 110,000 MHz and exposure durations varying from short periods to 7 nights, with most studies lasting between 5 and 50 min. Most studies demonstrated no significant effects of RF exposure on HR, regardless of the exposure system, frequency, duration, age, sex, distance, or subject position. Findings for HRV were more nuanced, with most studies indicating no significant impact on key HRV parameters. However, some position-dependent variations emerged, particularly in antenna-based studies. Additionally, our analysis suggests that RF exposure may particularly interfere with cardiac regulatory mechanisms when the cardiovascular system is challenged and required to adapt, such as during postural changes or physiological maneuvers, although there are insufficient comparable studies to validate this hypothesis. Importantly, all included studies were conducted under resting or non-stressful conditions and involved only healthy participants. Therefore, our conclusions cannot be generalized to stressed states or clinical populations. Moreover, methodological harmonization is needed to improve comparability across future studies. The main limitation of the current evidence being the heterogeneity of experimental protocols, highlighting the need for methodological standardization in future studies. To address current heterogeneity, we propose specific methodological recommendations, including systematic blinding, accurate exposure measurement and detailed exposure, to improve comparability and reproducibility in future studies.

Summary

- Radiofrequency exposure under ICNIRP guidelines has no significant effect on heart rate across various exposure conditions at rest and for healthy subjects.
- Findings related to heart rate variability are more nuanced; while most studies show no significant impact in calm conditions and for healthy subjects, some position-dependent variations have been observed, particularly in antenna-based studies.
- RF exposure may modulate cardiac response during its physiological regulation, such as in the Valsalva maneuver or orthostatic test, and affect heart rate and variability in these cases, although limited studies prevent definitive conclusions.

- Methodological standardization is necessary for future research.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70014

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**Men with genetic predisposition face greater fertility challenges when exposed to electromagnetic radiation**

Pal S, Paladhi P, Dutta S, Ghosh P, Chattopadhyay R, Ghosh S. Men with genetic predisposition face greater fertility challenges when exposed to electromagnetic radiation. Mol Biol Rep. 2025 Jul 31;52(1):773. doi: 10.1007/s11033-025-10882-9.

Abstract

Purpose: This study investigates the synergistic effects of genetic variants in core meiotic regulator genes-SPO11, RNF212, and SYCP3-and co-occurring exposure to electronic radiation as risk factors for azoospermia among Bengali-speaking men from West Bengal, India.

Materials and methods: A total of 708 azoospermic individuals, who tested negative for Y chromosome microdeletions, and 640 healthy controls were genotyped using Sanger's dideoxy sequencing. Genetic variants identified included SPO11 rs3764674T > G, MN650122delA, MN708963insA, MN708964insA, MN720359T > A; RNF212 MN737491delA, rs4045481C > T; and SYCP3 rs10860779C > A, MN901901delA, and MN995822delA. Binary logistic regression was used to assess the interaction between genetic variants, electronic radiation exposure, and age, with fertility status as the outcome variable.

Results: The analysis revealed a significant association between genetic variations in meiotic regulators and increased risk of azoospermia, particularly among men aged 30 years or older who were exposed to electronic radiation. The findings suggest that effect of electronic radiation may exacerbate meiotic errors, impair germ cell development, and further reduce fertility in affected individuals.

Conclusions: Men carrying genetic variations in SPO11, RNF212, and SYCP3 and exposed to electronic radiation are at an elevated risk of azoospermia, particularly with advancing age. This information may be considered in routine screening of assisted reproductive technology (ART) practices, which will enable clinicians to tailor management strategies for male infertility.

https://pubmed.ncbi.nlm.nih.gov/40742570/

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**The modeling of the interaction of pulsed 5G/6G signals and the fine structure of human skin**

Betzalel N, Feldman Y, Ben Ishai P. The modeling of the interaction of pulsed 5G/6G signals and the fine structure of human skin. *Sci Rep* **15**, 28651 (2025). https://doi.org/10.1038/s41598-025-13777-8.

Abstract

Current regulations concerning the allowed levels of human exposure to electromagnetic radiation emanating from wireless technologies are governed by the Specific Absorption Rate standard (SAR). This

allows the absorption by tissue of up to 2 W/kg averaged for 6 minutes in a 10 g cube of homogenized tissue. Much criticized, the SAR standard relates only to thermal effects. However, with the advent of 5G and 6G technologies, exploiting frequencies above 4 GHz, the traditional methods of SAR measurement are proving to be inadequate. This is made more poignant as carrier wavelengths approach the dimensions of tissue structures. We present a detailed electromagnetic simulation of human skin that not only accounts for the multi-layered structure of skin, but also sweat ducts, capillaric and arterial blood vessels. The results show an inhomogeneous absorption pattern that reflects the vessels and sweat glands involved. As human skin hosts an array of sensing structures, from nociceptors to thermoreceptors, as well as millions of innervated sweat glands, we point out that the current methods for gauging the SAR rating of devices are wholly inadequate and may lead to a gross underestimation skin electromagnetic absorption, and that nerve excitation should be accounted for in risk assessment.

External electromagnetic source

To emulate realistic source signals as used in real wireless devices nowadays, we have created a sinusoidal signal with carrier frequency of each frequency of our interest (3.5 GHz, 27 GHz, 77 GHz and 300 GHz). We have multiplied the sinusoidal wave with *rect* function with 30% duty cycle, and created a periodical train pulsed signal as described in 6.

$$y(f,t) = sin(2\pi f_c t) rect(2\pi f_i t) \quad (6)$$

Where $f_c$ is the carrier frequency, $f_i$ is the information frequency and $t$ is the time vector.

Figure 12 shows the 77 GHz rectangular pulsed signal. The information frequency for that specific band in 1 GHz.

Conclusions

In this research we have demonstrated the EM vulnerability of skin components such as sweat ducts (its coiled section and sweat glands, in particular) and dermal blood vessels, which are ignored by standard regulation approval methods of wireless devices. We conclude that wireless and remote EM devices and applications, such as cellular phones, laptops, autonomous vehicles, smart cities etc. Working in the 5G bands and planned to be work in 6G bands, are not being treated correctly in terms of EM affects they might generate on humans. In our study, we see the vulnerability of the sweat gland and the coiled section of the gland, possessing almost an EM filter component, which filters in 5G and 6G frequencies (3.5, 27, 77 and 300 GHz) into the blood stream. Moreover, the peripheral area of the sweat gland also absorbs more electromagnetic energy (higher dosimetry) than its surrounding. 5G and 6G might pose unexpected risks to humans, due to the effect of energy dissipation to regulators, such as thermoreceptors or nociceptors, in the immediate vicinity of the sweat duct, with long- or short-term effects. We conclude that since human skin is a relatively complex organ, it cannot be treated as a homogeneous component when it interacts with millimeter waves and sub-THz frequencies.

Open access: https://www.nature.com/articles/s41598-025-13777-8

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**Exploring research trends in health effects of 5G antennas: a bibliometric analysis**

Turgut A, Korunur Engiz B. (2025). Exploring research trends in health effects of 5G antennas: a bibliometric analysis. *Electromagnetic Biology and Medicine*, 1–20. doi: 10.1080/15368378.2025.2539147.

Abstract

To better understand the developments and trends of studies on the health impacts of 5th Generation (5 G) antennas, a bibliometric analysis of the literature published in the Web of Science database from 2012 to 2025 was conducted. Before the analysis, the dosimetric quantities “specific absorption rate (SAR)” and “power density (Sab)” used in the examination of the health impacts of antennas were thoroughly defined, and their required limits were provided. Subsequently, information visualization technology was utilized to investigate the yearly distribution of literature, author contributions and collaboration, productive and influential institutions and countries/territories, co-citation analysis, and keyword co-occurrence. However, anticipated publication and citation numbers for the coming years (2025–2029) were predicted regarding the potential health impacts of 5 G antennas using artificial intelligence-assisted forecasting methods. There has been a considerable increase in studies related to health impacts measured by SAR and Sab dosimetric quantities over the last five years, in line with the number of articles published on 5 G antennas. Despite this, no bibliometric analysis has been done so far on the health impact of 5 G antennas below and above 6 GHz. The data presented in this bibliometric study to fill the gap on this subject will provide a better understanding of the health impacts and unique insights to offer good research guidance on 5 G antennas and their attributed adverse health impacts.

Plain Language Summary

This study explores research conducted on potential health effects related to 5G antennas. 5G is the latest wireless communication technology designed to increase internet speeds and connect more devices simultaneously. As 5G technology expands, antennas operating at different frequencies are being widely installed, raising public concerns about their safety and possible health impacts.

Our analysis covered studies from 2012 to 2025, examining how researchers measure human exposure to electromagnetic fields from these antennas, specifically focusing on two measures: Specific Absorption Rate (SAR) for lower frequency antennas and Power Density (Sab) for higher frequency antennas. SAR indicates the rate at which electromagnetic energy is absorbed by body tissues per unit mass, while Sab represents the absorbed power density at the body’s surface.

Using advanced methods, we analyzed the growing body of research, highlighting key trends and major contributors in the field. We found a rapid increase in studies, driven by growing public interest and technological advances. Most research currently emphasizes smartphone antennas, but interest in wearable devices and health-monitoring technologies is rising.

Our findings emphasize the need for ongoing research into 5G’s health implications, providing guidance for future studies. The study helps policymakers, researchers, and the public understand the safety considerations surrounding 5G technology and encourages continued attention to health-related issues as the use of 5G continues to grow.

Table 4. Top 7 institutions with the most publications on the health impacts of 5 g antennas.

| Rank | Institution | Country | TP | P | TLS | CPP | H |
|---|---|---|---|---|---|---|---|
| 1 | Ericsson | Sweden | 17 | 4.381% | 138 | 34.35 | 10 |
| 2 | Sony Corporation | Japan | 14 | 3.608% | 98 | 31.14 | 8 |
| 3 | University Teknikal Malaysia Melaka | Malaysia | 13 | 3.351% | 24 | 7.62 | 7 |
| 4 | National Institute Of Technology (NIT) System | India | 12 | 3.093% | 2 | 4.58 | 4 |
| 5 | Polytechnic University Of Milan | Italy | 12 | 3.093% | 28 | 7.08 | 6 |
| 6 | Zhejiang University | China | 12 | 3.093% | 99 | 18.17 | 6 |
| 7 | Consiglio Nazionale Delle Ricerche (CNR) | Italy | 11 | 2.835% | 13 | 7.18 | 5 |

TP: Total Publications; P: Percentage (%); TLS: Total Link Strength; CPP: Citations Per Paper; H: h-index.

## Conclusion

This study presents a comprehensive bibliometric analysis of research on 5 G antennas and their health impacts, mapping knowledge domains through visualization techniques. The findings indicate that as the deployment of 5 G networks expands, research on SAR (Specific Absorption Rate) and Power Density (Sab) will continue to grow, particularly with the increasing demand for human exposure assessments and safety regulations.

The AI-assisted prediction models applied in this study project a steady increase in research output and citations over the next three years, highlighting the importance of bioelectromagnetic safety and multidisciplinary collaborations in fields such as medicine, chemistry, and physics. This trend suggests a growing scientific and regulatory focus on the potential biological effects of 5 G radiation.

While bibliometric approaches provide valuable insights, they also present certain limitations. The accuracy and completeness of the dataset depend on database indexing and data retrieval methods. Additionally, preprocessing techniques for author and institutional name variations require further refinement to minimize errors. The study also highlights challenges in data visualization, particularly in overlapping clusters and network mapping, which may require advanced machine learning techniques for optimization.

Despite these limitations, the study offers a solid foundation for understanding the evolution of 5 G antenna research, particularly in the context of health risk assessments and SAR compliance studies. The findings emphasize the need for continued interdisciplinary collaboration to ensure that future wireless communication technologies are both efficient and safe for public health.

These findings are further supported by AI-assisted forecasting, which projects stable research output through 2029, driven by ongoing interest in SAR and Sab-based exposure analysis. Current developments – such as increased focus on wearable antennas, improved EMF simulation methods, and regulatory initiatives – are expected to shape future research directions. The results also highlight the

need for continued interdisciplinary collaboration and refinement of data analysis techniques to better assess potential health effects of 5 G technologies.

https://www.tandfonline.com/doi/full/10.1080/15368378.2025.2539147

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**Comparative Analysis of Beamforming Techniques and Beam Management in 5G Communication Systems**

Andras CM, Barb G, Otesteanu M. Comparative Analysis of Beamforming Techniques and Beam Management in 5G Communication Systems. *Sensors*. 2025; 25(15):4619. doi: 10.3390/s25154619.

Abstract

The advance of 5G technology marks a significant evolution in wireless communications, characterized by ultra-high data rates, low latency, and massive connectivity across varied areas. A fundamental enabler of these capabilities is represented by beamforming, an advanced signal processing technique that focuses radio energy to a specific user equipment (UE), thereby enhancing signal quality—crucial for maximizing spectral efficiency. The work presents a classification of beamforming techniques, categorized according to the implementation within 5G New Radio (NR) architectures. Furthermore, the paper investigates beam management (BM) procedures, which are essential Layer 1 and Layer 2 mechanisms responsible for the dynamic configuration, monitoring, and maintenance of optimal beam pair links between gNodeBs and UEs. The article emphasizes the spectral spectrogram of Synchronization Signal Blocks (SSBs) generated under various deployment scenarios, illustrating how parameters such as subcarrier spacing (SCS), frequency band, and the number of SSBs influence the spectral occupancy and synchronization performance. These insights provide a technical foundation for optimizing initial access and beam tracking in high-frequency 5G deployments, particularly within Frequency Range (FR2). Additionally, the versatility of 5G's time-frequency structure is demonstrated by the spectrogram analysis of SSBs in a variety of deployment scenarios. These results provide insight into how different configurations affect the synchronization signals' temporal and spectral occupancy, which directly affects initial access, cell identification, and energy efficiency.

Open access: https://www.mdpi.com/1424-8220/25/15/4619

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**Numerical Analysis of Human Head Exposure to Electromagnetic Radiation Due to 5G Mobile Phones**

Chietera FP, Usmani WU, Caggiano D, Lamacchia C, Chimenti G, Mescia L. Numerical Analysis of Human Head Exposure to Electromagnetic Radiation Due to 5G Mobile Phones. 2025 10th International Conference on Smart and Sustainable Technologies (SpliTech), Bol and Split, Croatia, 2025, pp. 1-5, doi: 10.23919/SpliTech65624.2025.11091791.

Abstract

This paper investigates human exposure to electromagnetic fields from 5G mobile phones operating in the 26 GHz frequency band, recently designated for 5G mm-wave communications. Numerical simulations assess near-field exposure generated by a realistic mobile phone model and the thermal

effects on a detailed head model, providing valuable insights into the potential impact of this emerging technology on human health.

Conclusion

A preliminary analysis conducted using a realistic head model with medium-resolution voxels suggests that 5G mm-wave communication in the 26 GHz band results in only moderate, localized thermal increases in superficial tissues. However, further investigations are necessary to better characterize the impact of prolonged exposure and higher spatial detail. Future simulations should consider higher-resolution voxel models, more refined tissue segmentation, and extended exposure durations. In addition, variable phone placements should be explored, as they can lead to higher incidence angles and higher peak irradiation levels in biological tissues.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11091791&isnumber=11091382

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**Pilot questionnaire survey shows the lack of diagnostic criteria for electromagnetic hypersensitivity: a viewpoint**

Leszczynski D.  Pilot questionnaire survey shows the lack of diagnostic criteria for electromagnetic hypersensitivity: a viewpoint. MHealth. vol 11. Jul 14, 2025. doi: 10.21037/mhealth-25-4.

Abstract

Wireless communication devices and networks are currently prevalent in human environment. Some persons claim to be sensitive to emitted by them microwave radiation. Commonly, this sensitivity is called electromagnetic hypersensitivity (EHS) or microwave disease. However, because of the yet scientifically unproven link between radiation exposures and EHS symptoms, this sensitivity is also called idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF). The sensitivity is not recognized by the World Health Organization as a disease or as being caused by exposures to wireless radiation. There are no medical tests for detecting sensitivity to wireless radiation. Physicians are not being educated to deal with persons who claim to be sensitive to wireless radiation. However, some persons who consider themselves to be sensitive to wireless radiation exposures claim to have medical diagnoses made by physicians or other health professionals. This project looked at the contradiction of the lack of diagnostic criteria for sensitivity to wireless radiation with the medical diagnoses claimed by some of the self-declared sensitive persons. Analysis of questionnaire responses of 142 self-declared sensitive persons suggests that, currently, it is not possible to diagnose sensitivity to wireless radiation exposures. The claimed medical diagnoses appear to be based on the anecdotal evidence presented by the self-declared sensitive persons. In some cases, medical tests were used but these tests lacked scientific proof of their ability to detect the sensitivity of a person to wireless radiation exposure. The proof of the existence of sensitivity to wireless radiation remains inadequate. However, logically and by analogy to other environmental stressors, it is likely that individual sensitivity to wireless radiation exists. Because provocation studies in wireless radiation-exposed volunteers alone seem unable to provide definite answers, further research using both, provocation and biochemical methods with controlled wireless radiation exposures in volunteers is necessary to discover diagnostic biomarkers of EHS.

Table 1: Symptoms claimed to be caused by exposures to wireless radiation

• Skin problems: itching; eczema; getting acne; bad skin rash on the face; face gets hot; burning feeling on neck and thyroid area; creeping skin, like something is walking on it; feeling a tinkling on the forehead; red stripes on the skin of hands; skin of hands becoming very dry, splits and bleeds
• Nervousness feelings: exhaustion and fatigue; insomnia; feeling agitated; cardiac arrhythmia; pulsations in chest and heart; anxiousness; over activity; overstimulation; shaking or trembling; panic attacks; fear feeling; psychosis; suicidal thoughts; vertigo—the sensation that the environment around is moving or spinning; buzzing from the bottom of the feet; nervous tension throughout the body; pulsations in arms; restlessness; restless leg syndrome; tingling in fingers and toes; vibration feeling in the head, body, and pelvic area
• Digestive tract problems: belching; diarrhea; digestion problems; increased food sensitivities painful constipation; food intolerance to e.g., cow's milk, eggs yeast, wheat, or gluten
• Brain functioning problems: brain fog; memory problems; problems with concentration; difficulty speaking/stuttering; disorientation; distorted sense of time and space; dizziness; drowsiness; nausea
• Effects on moving, seeing, hearing, breathing: difficulty walking; fuzzy vision; blurred vision; shimmering visual effects; easily lost balance; uncoordinated movements; tinnitus; hearing loss; hearing persistent hum; respiratory depression; shortness of breath; coughOpen access: https://mhealth.amegroups.org/article/view/140469/html

Table 3: Some values of the blood tests of the self-declared EHS persons were elevated and some lower than the average levels

• Elevated: Cu, glucose, IgE, histamine, orotic acid, 3-methyl-glutaric, bacterial metabolites, fungal metabolites, glutaric acid, hippuric acid, oxalic acid, succinic acid, citric acid, homovanillic acid indicating elevated dopamine, methylmalonic acid (vitamin B12 deficiency), quinolinic acid, erythrocyte glutathione-S-transferase, serum glutathione-S-transferase, and blood sedimentation rate, high lactic acid, chronic acidosis
• Low: malic acid, 2-oxoglutaric acid, aconitic acid, serotonin, ratio of adrenalin/noradrenalin, blood sugar

EHS, electromagnetic hypersensitivity; IgE, immunoglobulin E.

Conclusions

Individual sensitivity of people to all kinds of environmental factors, natural and man-made, is common and, therefore, it is logical to consider that also individual sensitivity to man-made EMF exists, even if we still rely on anecdotal evidence from self-declared EHS persons and do not have sufficiently robust scientific proof of it.

Trust in each other is of paramount importance in such a type of survey study. Volunteers need to trust that the information they provide will be kept private and analyzed without bias. Scientists need to trust that volunteers provide honest and not exaggerated responses to all of the questions. Without such trust execution and analysis of such survey studies is very difficult.

The observations collected in this pilot questionnaire survey study show that currently, it is not possible to medically diagnose EHS as being a result of low-level wireless radiation exposures. It is possible that

further development of the questionnaire might increase the likelihood of correct identification of EHS persons but, for the final confirmation of the EHS status, some physiological tests might be necessary. Currently, the medical diagnoses of EHS, claimed by some of the EHS persons, are based solely on the anecdotal evidence presented by the EHS person and, in rare cases, on tests that lack scientific proof of their validity as EHS diagnostic tools.

Further research on the causes of EHS and on the development of methods to diagnose it is necessary. However, it is necessary to keep in mind that the biomarkers of EHS might, or will likely, overlap with markers for other IEI-sensitivities or allergies. Future research studies should concomitantly examine both, physiological (12) and cognitive (30,31) responses of the human body to exposures to electromagnetic fields.

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**Smartphone Usage Patterns and Sleep Behavior in Demographic Groups: Retrospective Observational Study**

Wang T, Seiger A, Markowetz A, Andone I, Błaszkiewicz K, Penzel T. Smartphone Usage Patterns and Sleep Behavior in Demographic Groups: Retrospective Observational Study. J Med Internet Res 2025;27:e60423. doi: 10.2196/60423.

Abstract

Background: Although previous studies have examined the relationship between smartphone usage and sleep disorders, research on demographic differences in smartphone usage and nocturnal smartphone inactivity patterns remains limited. This study introduces “nocturnal smartphone inactivity duration” as a proxy indicator to address the limitation of lacking direct sleep data and to further investigate the association between smartphone usage patterns and sleep characteristics.

Objective: This study aimed to investigate demographic differences and relationships between daily smartphone usage and nocturnal smartphone inactivity patterns.

Methods: We conducted a retrospective analysis of data collected from the Murmuras app from January 1, 2022, to December 31, 2022. A total of 1074 participants were included, categorized by gender, age, highest degree, employment status, and smartphone usage purpose. All participants consented to participate in the study through the app. To explore the relationship between smartphone usage and nocturnal smartphone inactivity, we first calculated each participant’s daily smartphone usage duration (including app usage) and duration of nocturnal smartphone inactivity; then, we assessed the normality and homogeneity of variance tests within each demographic category. Based on the results, the Kruskal-Wallis tests were applied to potentially identify differences between groups. Finally, correlation and regression analyses were conducted to explore associations between smartphone usage and nocturnal smartphone inactivity.

Results: The findings revealed distinct patterns of smartphone use across demographics. Participants predominantly used smartphones for social contact (average daily usage duration=1.52 h) and recreational activities (average daily usage duration=1.08 h) through apps like Facebook and YouTube. Frequent users, especially of social media and entertainment, often increased their phone usage at

night. Female participants used their phones more frequently, mainly for digital shopping and social interactions, whereas male participants used phones more at nighttime ($P$<.001). Both younger users and non–full-time employees engaged more in activities such as gaming and chatting ($P$<.01 for those comparisons). Higher education was correlated with lower use ($P$<.001). Those using smartphones for work-related purposes generally decreased their phone usage after work ($P$<.05 for those comparisons). Correlation and regression analyses of smartphone usage duration and nighttime inactivity across groups indicated that only a small subset of groups exhibited significant positive correlations, a moderate number displayed significant negative correlations, and the majority showed no significant correlation.

Conclusions: This study underscores the significant association between demographic factors and smartphone usage patterns, including nocturnal inactivity patterns. Female individuals, young people, individuals with lower educational qualifications, and those who were unemployed demonstrated higher smartphone usage. Frequent engagement with social media and leisure apps was particularly pronounced during nighttime hours, a behavior that may contribute to disruptions in sleep patterns. These findings underscore the need for targeted interventions addressing excessive smartphone use, particularly at night, to mitigate its potential adverse effects on sleep.

Open access: https://www.jmir.org/2025/1/e60423

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**Temporal change of outdoor RF-EMF levels in four European countries: a microenvironmental measurement study**

Beláčková L, Veludo AF, Aminzadeh R, Van Bladel H, Griffon V, Cardis E, Dongus S, Eeftens M, Guxens M, Joseph W, de Llobet P, Mazet P, Van Torre P, Thielens A, Vermeulen R, Wiart J, Röösli M, Huss A. Temporal change of outdoor RF-EMF levels in four European countries: a microenvironmental measurement study. Environ Res. 2025 Jul 11;285(Pt 1):122315. doi: 10.1016/j.envres.2025.122315.

Abstract

Introduction: Over the past two decades, the amount of transmitted mobile data has increased rapidly. It is unknown whether the implementation of the new technologies enabling this has resulted in changes of outdoor radio-frequency electromagnetic fields (RF-EMF) exposure. Therefore, microenvironmental measurements were used to investigate temporal trends in RF-EMF exposure between 2016 and 2023, in the Netherlands, Switzerland, Belgium and Spain, following a similar protocol across campaigns. Microenvironmental measurements refer to exposure measurements performed at predefined small areas that have been differentiated with a specific function in that particular area. This allowed us to compare exposure trends between countries and years.

Methods: The data was collected as part of the ACCEDERA (2016-2018), ETAIN (2023), and GOLIAT (2023) projects, walking repeatedly the same routes with RF-EMF exposimeters. Identical microenvironments were identified in each country and measurements of the exposure from mobile base stations, mobile phones and the total exposure were compared across years.

Results: Comparing measurements between 6 and 14 unique microenvironments in each country, our

data did not suggest significant changes in the exposure from the mobile base station origin (total downlink exposure) between baseline measurements in 2016 to follow up and 2023 for the four countries. Across all countries and years the median values of the mobile base station exposure ranged from 0.11 mW/m2 (Switzerland, 2023) to 0.62 mW/m2 (Netherlands, 2018). There was no consistent trend in the individual microenvironments across the countries.

Conclusions: Our measurements of RF-EMF outdoor exposure levels across included microenvironment groups do not indicate change in exposure levels between 2016 and 2023 despite an increase in mobile data traffic by a factor of 8 in Western Europe[1].

Open access: https://www.sciencedirect.com/science/article/pii/S001393512501566X?via%3Dihub

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**Assessment of Electromagnetic Exposure to a Child and a Pregnant Woman Inside an Elevator in Mobile Frequencies**

Karatsi I, Bakogianni S, Koulouridis S. Assessment of Electromagnetic Exposure to a Child and a Pregnant Woman Inside an Elevator in Mobile Frequencies. *Telecom*. 2025; 6(3):52. https://doi.org/10.3390/telecom6030052.

Abstract

This study presents an in-depth dosimetry analysis of energy assimilation from EM waves and increase in the temperature during mobile phone usage within an elevator cabin. The cellphone operates at two different frequencies (1000 MHz and 1800 MHz) and is simulated at three different talk positions vertical, tilt, and cheek. Realistic numerical models of a woman in the third trimester of pregnancy and a girl at the age of 5 years are employed. The analysis highlights the necessity of a comprehensive approach to fully grasp the complexities of EM exposure.

Conclusions

A comprehensive investigation into electromagnetic (EM) exposure and thermal safety has been conducted, focusing on three distinct subjects: a girl of five years named Roberta, a gestating female at seven months gestation known as Pregnant II, and her fetus. This study employed anatomically precise computational virtual humans along with a cellular device functioning at two different frequency bands, 1000 MHz and 1800 MHz. A total of 48 separate arrangements involving these numerical phantoms in various configurations and with different phone orientations were meticulously analyzed. The study presented detailed results of SAR10g, SAR-wb, and Tmax for every anatomical virtual human, including the fetus within the confines of an elevator cabin. The results here add to the findings in our prior work [55]. Here, contrary to [55], we examined how exactly, and in which scale, the positioning of the humans affects the quantities measured for all the utilized models, including the seven-month fetus.

Notably, it becomes evident that an integrated approach is essential to fully understand the complexities of EM exposure. Each configuration offers unique insights into how specific absorption rate values and temperature rises differ across subjects and settings. The variations observed underscore the necessity of examining every possible configuration to draw comprehensive conclusions about EM safety.

Moreover, the investigation highlights the importance of further exploring the effects of EM exposure in elevator cabins under various occupancy conditions and at different portable device frequencies. Such studies are crucial for developing targeted safety guidelines and protective measures, particularly in environments where RF exposure is compounded by enclosed spaces like elevators. This research not only enhances our understanding of EM field interactions with human tissues but also aids in the formulation of better health and safety standards for vulnerable populations such as children and pregnant women.

Open access: https://www.mdpi.com/2673-4001/6/3/52

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**Comparison Between Broadband and Personal Exposimeter Measurements for EMF Exposure Map Development Using Evolutionary Programming**

Nájera A, Sánchez-Montero R, González-Rubio J, Guillén-Pina J, Chocano-del-Cerro R, López-Espí P-L. Comparison Between Broadband and Personal Exposimeter Measurements for EMF Exposure Map Development Using Evolutionary Programming. *Applied Sciences*. 2025; 15(13):7471. https://doi.org/10.3390/app15137471

Abstract

In this study, we provide a comparison of radiofrequency electromagnetic field exposure level maps as determined using two approaches: a broadband meter (NARDA EMR-300) equipped with an isotropic probe in the range of 100 kHz to 3 GHz, and a Personal Exposimeter (Satimo EME Spy 140) in the range of 88 MHz to 5.8 GHz. The aim of this research was to determine the necessary adjustments to the measurements made with personal exposimeters to obtain RF-EMF exposure maps equivalent to those made with broadband meters. We evaluated different possibilities to obtain the best equivalence of measurements between both devices. For this purpose, the datasets obtained in both cases were analyzed, as well as the possible correction factors. First, the possibility of establishing a single or double correction factor depending on the existence (or lack thereof) of a line of sight with respect to the base stations was analyzed by minimizing the average value of the error between the values of the broadband meter and the corrected values of the personal exposure meter. Due to the differences observed in the exposure maps, a second procedure was carried out, in which a genetic algorithm was used to determine the ratio between the measurements from both methods (the broadband meter and personal exposure meter), depending on the existence (or lack thereof) of a line of sight, and we compared the exposure maps generated using kriging interpolation.

Conclusions

We conclude that exposure assessments based on spot measurements can serve as a practical proxy to evaluate personal RF-EMF exposure, whether using a static probe or a portable PEM. The developed methodology offers a reliable and efficient approach to characterizing personal exposure levels, enabling continuous monitoring and the detection of potential changes over time. The result of the different proportionality factors obtained is shown in Table 4.

The application of correction factors, particularly the differentiation between LOS and NLOS conditions, significantly improves the accuracy of PEM measurements, bringing them closer to those obtained with

BBMs. This highlights the importance of accounting for the line of sight to antennas when estimating exposure levels, as direct exposure to base stations considerably affects measurement accuracy due to body shielding effects. By applying appropriate correction factors, the inherent limitations of PEMs, such as underestimating exposure levels in LOS conditions, can be mitigated.

Moreover, using genetic algorithms to optimize these corrections further enhances the precision of the exposure maps, demonstrating that this method can be a valuable tool in urban RF-EMF monitoring. The ability to generate accurate spatial exposure distributions through PEMs makes this methodology more accessible and cost effective, especially in large-scale studies where deploying multiple BBMs might not be feasible.

Nevertheless, further validation is needed in various environments to refine the correction models and ensure broader applicability. Future studies should focus on refining these algorithms and exploring other factors that could influence exposure, such as linearity, urban infrastructure, and signal interference. Despite these challenges, the methodology developed in this study represents a significant advancement in RF-EMF exposure assessment, offering a flexible and scalable approach to creating consistent EMF exposure maps using PEMs.

Open access: https://www.mdpi.com/2076-3417/15/13/7471

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**Machine Learning Approach for Ground-Level Estimation of Electromagnetic Radiation in the Near Field of 5G Base Stations**

Famoriji OJ, Shongwe T. Machine Learning Approach for Ground-Level Estimation of Electromagnetic Radiation in the Near Field of 5G Base Stations. *Applied Sciences*. 2025; 15(13):7302. https://doi.org/10.3390/app15137302

Abstract

Electromagnetic radiation measurement and management emerge as crucial factors in the economical deployment of fifth-generation (5G) infrastructure, as the new 5G network emerges as a network of services. By installing many base stations in strategic locations that operate in the millimeter-wave range, 5G services are able to meet serious demands for bandwidth. To evaluate the ground-plane radiation level of electromagnetics close to 5G base stations, we propose a unique machine-learning-based approach. Because a machine learning algorithm is trained by utilizing data obtained from numerous 5G base stations, it exhibits the capability to estimate the strength of the electric field effectively at every point of arbitrary radiation, while the base station generates a network and serves various numbers of 5G terminals running in different modes of service. The model requires different numbers of inputs, including the antenna's transmit power, antenna gain, terminal service modes, number of 5G terminals, distance between the 5G terminals and 5G base station, and environmental complexity. Based on experimental data, the estimation method is both feasible and effective; the machine learning model's mean absolute percentage error is about 5.89%. The degree of correctness shows how dependable the developed technique is. In addition, the developed approach is less expensive when compared to measurements taken on-site. The results of the estimates can be used to save test costs and offer useful guidelines for choosing the best location, which will make 5G base station electromagnetic radiation management or radio wave coverage optimization easier.

Open access: https://www.mdpi.com/2076-3417/15/13/7302

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**Cluster Analysis of RF-EMF Exposure to Detect Time Patterns in Urban Environment: A Model-Based Approach**

Pasquino N, Solmonte N, Djuric N, Kljajic D, Djuric S. Cluster Analysis of RF-EMF Exposure to Detect Time Patterns in Urban Environment: A Model-Based Approach. IEEE Access, vol. 13, pp. 118724-118732, 2025, doi: 10.1109/ACCESS.2025.3586905.

Abstract

The increase in human exposure to electromagnetic fields (EMFs), driven by advancements in telecommunication systems like the 5G mobile system, highlights the need for continuous EMF monitoring. Advanced techniques for data analysis, based on machine learning like clustering, can decompose daily variations in EMF exposure into distinct patterns, providing a clearer understanding of how exposure fluctuates over time. Although several exposure monitoring systems exist in Europe, only a few studies have thoroughly examined the time variability. This study addresses the gap by applying model-based clustering techniques to analyze the temporal patterns. Specifically, the study focuses on characterizing fluctuations in field strength during workdays and holidays, thereby contributing to a deeper understanding of time-distributed exposure. Continuous monitoring data, collected through the Serbian EMF RATEL network's sensors installed in Novi Sad, were processed and analyzed using the Log-Normal Mixture Model (LNMM), a model-based clustering algorithm resorting to mixture distributions. The analyses reveal that the LNMM can separate night and day exposure values and identify periods when values persist longer over the day. This suggests that model-based clustering can be useful for understanding the temporal patterns of local EMF exposure.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11072665&isnumber=10820123

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**Impact of Anthropomorphic Shape and Skin Stratification on Absorbed Power Density in mmWaves Exposure Scenarios**

Gallucci S, Benini M, Bonato M, Galletta V, Chiaramello E, Fiocchi S, Tognola G, Parazzini M. Impact of Anthropomorphic Shape and Skin Stratification on Absorbed Power Density in mmWaves Exposure Scenarios. Sensors (Basel). 2025 Jul 17;25(14):4461. doi: 10.3390/s25144461.

Abstract

As data exchange demands increase also in widespread wearable technologies, transitioning to higher bandwidths and mmWave frequencies (30-300 GHz) is essential. This shift raises concerns about RF exposure. At such high frequencies, the most crucial human tissue for RF power absorption is the skin, since EMF penetration is superficial. It becomes thus very important to assess how the model used to represent the skin in numerical dosimetry studies affects the estimated level of absorbed power. The present study, for the first time, assesses the absorbed power density (APD) using FDTD simulations on two realistic human models in which: (i) the skin has a two-layer structure made of the stratum corneum and the viable epidermis and dermis layers, and (ii) the skin is modelled as a homogeneous dermis

stratum. These results were compared with ones using flat phantom models, with and without the stratified skin. The exposure assessment study was performed with two sources (a wearable patch antenna and a plane wave) tuned to 28 GHz. For the wearable antenna, the results evidence that the exposure levels obtained when using the homogeneous version of the models are always lower than the levels in the stratified skin version with percentage differences from 16% to 30%. This trend is more noticeable with the female model. In the case of plane wave exposure, these differences were less pronounced and lower than 11%.

Open access: https://www.mdpi.com/1424-8220/25/14/4461

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**Weak Radiofrequency Field Effects on Biological Systems Mediated through the Radical Pair Mechanism**

Gerhards L, Deser A, Kattnig DR, Jörg Matysik J, Solov'yov IA. Weak Radiofrequency Field Effects on Biological Systems Mediated through the Radical Pair Mechanism. Chemical Reviews. July 14, 2025. doi: 10.1021/acs.chemrev.5c00178.

Abstract

The widespread use of radiofrequency (RF) communication has increased the exposure of organisms to electromagnetic fields, sparking a debate over the potential health effects of weak RF electromagnetic fields. While some experimental studies suggest that low-amplitude RF radiation may influence cellular metabolism or sleep patterns or even promote cancer, these claims remain controversial due to limited theoretical plausibility. Central to this debate is the radical pair mechanism (RPM), a quantum-mechanical framework proposed to mediate RF effects. Despite its role in magnetoreception and various magnetic field effects on chemical reactions, the RPM often fails to align with observations at low, nonthermal RF field strengths. This review examines these contrasting perspectives by discussing experimental findings and theoretical models that aim to explain putative biological effects of RF magnetic fields. Emphasis is placed on the challenges of reconciling theoretical predictions with empirical data, particularly in the context of weak RF exposure. Additionally, an overview of the theoretical framework used in current modeling efforts highlights the complexity of applying the RPM to biological systems and underscores the importance of critical interpretation. The goal is to clarify the state of understanding and inform future research on RPM-mediated biological effects under weak RF exposure.

Concluding Remarks

This review provides a detailed overview of the current state of research on weak RF-MF-induced biological effects in the context of the RPM. While several experimental studies suggest observable effects, their reproducibility and dosimetry remain significantly challenging. The RPM is frequently proposed as a mechanistic explanation, yet current theoretical models based on spin dynamics often struggle to fully account for experimental findings.

As demonstrated, accurately modeling the RPM is nontrivial, requiring consideration of multiple interactions and features. Essential interactions, such as spin–orbit coupling or dipolar coupling, are

often overlooked in studies of potential MFEs. Additionally, decoherence due to spin relaxation and the short lifetimes of SCRPs impose further limitations on the detectability of weak RF-MF effects.

Despite these challenges, this review highlights a clear need for more systematic and interdisciplinary investigations. Experimental studies require robust statistical designs, standardized

methodologies, and improved dosimetry to enhance reproducibility. Meanwhile, theoretical approaches must incorporate the full complexity of spin dynamics beyond simplified models.

Advances such as the SSE method offer promising directions to overcome current limitations.

Ultimately, bridging the gap between experiment and theory will be key to unraveling the role of the RPM in weak RF-MF effects. Future research integrating rigorous theoretical frameworks with high-quality experimental data will be essential to clarify whether and how weak RF fields influence biological systems.

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**Magnetic Field Measurement of Various Types of Vehicles, Including Electric Vehicles**

Fukui H, Minami N, Tanezaki M, Muroya S, Ohkubo C. Magnetic Field Measurement of Various Types of Vehicles, Including Electric Vehicles. *Electronics*. 2025; 14(15):2936. doi: 10.3390/electronics14152936

Abstract

Since around the year 2000, following the introduction of electric vehicles (EVs) to the market, some people have expressed concerns about the level of magnetic flux density (MFD) inside vehicles. In 2013, we reported the results of MFD measurements for electric vehicles (EVs), hybrid electric vehicles (HEVs), and internal combustion engine vehicles (ICEVs). However, those 2013 measurements were conducted using a chassis dynamometer, and no measurements were taken during actual driving. In recent years, with the rapid global spread of EVs and plug-in hybrid electric vehicles (PHEVs), the international standard IEC 62764-1:2022, which defines methods for measuring magnetic fields (MF) in vehicles, has been issued. In response, and for the first time, we conducted new MF measurements on current Japanese vehicle models in accordance with the international standard IEC 62764-1:2022, identifying the MFD levels and their sources at various positions within EVs, PHEVs, and ICEVs. The measured MFD values in all vehicle types were below the reference levels recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for public exposure. Furthermore, we performed comparative measurements with the MF data obtained in 2013 and confirmed that the MF levels remained similar. These findings are expected to provide valuable insights for risk communication with the public regarding electromagnetic fields, particularly for those concerned about MF exposure inside electrified vehicles.

Conclusions

As the adoption of EVs and PHEVs increases, public concern about MFs from these vehicles has also grown. Narrowing the perception gap between scientific risk assessments and public anxiety is essential for effective risk communication. In this study, we conducted measurements of MFs emitted by

domestic vehicles in Japan using IEC 62764-1:2022 methods and were able to provide reliable and easily accessible data to the public as a basis for risk communication.

The results confirmed that the measured MFs comply with ICNIRP guidelines and remain at levels that do not cause known acute adverse effects, such as nerve stimulation. The locations and characteristics of the maximum MF strengths for EVs, PHEVs, and ICEVs were identified.

For EVs and PHEVs, the highest MF values were observed on the rear seat at a 6.5 cm measurement distance, while for ICEVs, the maximum was recorded at the driver's side dashboard at 20 cm. Among the vehicle types, PHEVs showed the highest MF levels, followed by ICEVs, which had higher values than EVs.

As a result of the frequency analysis, both speed-dependent and speed-independent MF components were detected across all vehicle types. Speed-dependent peaks included 6–29 Hz frequency components near the front seats, attributed to magnetized tires. Fixed-frequency peaks included a 294 Hz component observed during air conditioner operation. Low-frequency peaks around 1 Hz were observed near wiring routes around the rear seat area and were attributed to current flow during vehicle operation, with notably higher values in the PHEV during deceleration. In ICE vehicles, low-frequency components in the 1–5 Hz range were associated with wiper motor operation, while higher-frequency peaks at 847 Hz and 1268 Hz were detected but could not be clearly linked to specific sources.

A comparison with a previous study conducted in 2013 revealed that the MF levels are comparable to those of current vehicles as of 2025.

A comparison with the MF measurement results from Seibersdorf Laboratory in Austria revealed that their reported values were significantly higher. This difference is attributed to their capturing of rapid increases in MFD due to transient phenomena occurring on timescales below 200 ms, which were not considered in this study, and reflects differences in measurement conditions.

These findings are expected to provide valuable insights for risk communication with the general public regarding EMFs, particularly for those concerned about MF exposure inside electrified vehicles.

As a future perspective, as the performance of EVs continues to improve each year, with increases in motor output and battery capacity, exposure to MFs is expected to rise. Therefore, it is important to continue publishing measurement results regularly in the future.

This study focused on the vehicle itself and did not include measurements of the charging equipment. Wireless charging systems are being developed as an emerging technology [27,28,29,30,31], and demonstration experiments are currently underway in Japan. As their adoption is expected to increase in the future, opportunities for risk communication with the general public are likely to grow. It is therefore important to conduct MF exposure measurements in line with public road deployment and to advance risk communication accordingly.

In addition to passenger cars, the electrification of other vehicles such as buses is advancing, and the introduction of new mobility technologies, including the construction of linear motor cars, is expected to progress in the future. As such technologies are introduced, public concern about EMF exposure is likely to increase. Therefore, it is important to consider conducting measurements in line with the pace of their deployment.

Open access: https://www.mdpi.com/2079-9292/14/15/2936

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**Analysis of Human Exposure to Electric and Magnetic Fields While Charging and Driving an Electric Vehicle**

Gliga, M. *et al.* (2025). Analysis of Human Exposure to Electric and Magnetic Fields While Charging and Driving an Electric Vehicle. In: Vlad, S., Roman, N.M. (eds) 9th International Conference on Advancements of Medicine and Health Care Through Technology. MEDITECH 2024. IFMBE Proceedings, vol 130. Springer, Cham. https://doi.org/10.1007/978-3-031-95671-3_25

Abstract

The transition to electric vehicles is a promising strategy to reduce or eliminate harmful emissions, including carbon dioxide, nitrogen oxides, and particulate matter, from internal combustion vehicles. While electric vehicles offer environmental benefits, their operation involves the generation of electromagnetic fields (EMFs) in their immediate vicinity. Although the biological effects of EMFs have been extensively studied, the specific health risks to humans remain uncertain.

In electric vehicles, occupants are exposed to artificial EMFs due to their close proximity to high-capacity electrical systems operating for extended periods. Recognizing these potential concerns, electric vehicle manufacturers have incorporated various technological solutions during the design and manufacturing processes to mitigate EMF exposure. This study will conduct experimental measurements of the electromagnetic field generated by an electric vehicle under a range of operational conditions.

https://link.springer.com/chapter/10.1007/978-3-031-95671-3_25

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**Standards: Exposure Limits for Brief High Intensity Pulses of Radiofrequency Energy Between 6 and 300 GHz**

K. R. Foster, I. Laakso and Q. Balzano, "Standards: Exposure Limits for Brief High Intensity Pulses of Radiofrequency Energy Between 6 and 300 GHz," in *IEEE Access*, vol. 13, pp. 134648-134654, 2025, doi: 10.1109/ACCESS.2025.3592532.

Abstract

This Standards paper considers limits of the International Commission on Nonionizing Radiation (ICNIRP) and Institute of Electrical and Electronics Engineers (IEEE C95.1-2019) on “brief exposures” to radiofrequency energy (RF-EMF), that vary significantly within the 6 minute averaging time specified in the limits. This situation arises in two important contexts: exposures from cellular base stations employing Multiple Input Multiple Output (MIMO) antennas with beamforming that sweep beams around the service area, and exposure to pulsed RF-EMF with high peak power but low duty cycle. The ICNIRP and IEEE limits on brief exposures between 6 and 300 GHz are assessed using numerical and analytical solutions to a one-dimensional thermal model of tissue. Analysis is done both for rectangular pulses of RF-EMF (i.e., the step response to a suddenly imposed RF-EMF field), and to impulses of RF-EMF energy. The analysis shows that both sets of guidelines are uneven in the level of protection they offer against excessive transient heating of skin, with the IEEE limits being far more conservative than

the ICNIRP limits. The thermal model suggests a simple modification to the pulse fluence limits that provides a more consistent level of protection against excessive temperature increases for pulses of varying duration and frequency. **The Standards Paper does not consider possible nonthermal hazards or possible thermoacoustic effects produced by brief but very high amplitude RF-EMF pulses that produce high rates of change of tissue temperature but small temperature increases**. The conclusion points to the need for further research and development to establish and refine exposure limits for pulsed RF-EMF.

Open access: https://ieeexplore.ieee.org/document/11095721

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**Weak Radiofrequency Field Effects on Biological Systems Mediated through the Radical Pair Mechanism**

Luca Gerhards, Andreas Deser, Daniel R. Kattnig, Jörg Matysik, and Ilia A. Solov'yov. Weak Radiofrequency Field Effects on Biological Systems Mediated through the Radical Pair Mechanism. *Chemical Reviews.* doi: 10.1021/acs.chemrev.5c00178

Abstract

The widespread use of radiofrequency (RF) communication has increased the exposure of organisms to electromagnetic fields, sparking a debate over the potential health effects of weak RF electromagnetic fields. While some experimental studies suggest that low-amplitude RF radiation may influence cellular metabolism or sleep patterns or even promote cancer, these claims remain controversial due to limited theoretical plausibility. Central to this debate is the radical pair mechanism (RPM), a quantum-mechanical framework proposed to mediate RF effects. Despite its role in magnetoreception and various magnetic field effects on chemical reactions, the RPM often fails to align with observations at low, nonthermal RF field strengths. This review examines these contrasting perspectives by discussing experimental findings and theoretical models that aim to explain putative biological effects of RF magnetic fields. Emphasis is placed on the challenges of reconciling theoretical predictions with empirical data, particularly in the context of weak RF exposure. Additionally, an overview of the theoretical framework used in current modeling efforts highlights the complexity of applying the RPM to biological systems and underscores the importance of critical interpretation. The goal is to clarify the state of understanding and inform future research on RPM-mediated biological effects under weak RF exposure.

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**Effect of the radiation emitted from a cell phone on T lymphocytes in mice**

Pei, Y., Gao, H., Li, J., Li, J., Hou, Z., & Han, X. (2025). Effect of the radiation emitted from a cell phone on T lymphocytes in mice. *Radiation Effects and Defects in Solids*, 1–13. https://doi.org/10.1080/10420150.2025.2526402

Abstract

This present study aims to explore the potential impact of cell phone radiation on T lymphocytes in mice. One hundred twenty-eight healthy male BALB/C mice (2–3 weeks old) were randomly distributed into four groups: blank control, control, TD-SCDMA and LTE-Advanced groups, respectively, with 32 mice in each group. Mice were exposed to phone radiation for 2–8 weeks. 8 mice in each group were taken out for measurement, and given exposure periods were 2, 4, 6 and 8 weeks, respectively. Flow cytometry was performed for the examination of T lymphocyte subsets, molecular and cell biological techniques were carried out to detect the apoptosis and transformation of T lymphocytes, respectively, while the enzyme-labelled immune technique was conducted to measure the cytokines secreted by T lymphocytes. The results showed that the percentage of CD4 T lymphocyte subsets was similar among the 4 groups during the entire exposure period, and so were the CD8 T lymphocyte subsets. Compared to the 2 sham groups, the apoptosis ratios of T lymphocytes in the TD-SCDMA and LTE-Advanced groups increased significantly after more than six weeks of exposure, while the transformation rates decreased significantly. The impacts of radiation on apoptosis and transformation are time-dependent. The concentrations of IL-10 and IL-12 remained unchanged in the 2 control groups during the entire experimental period. Compared to the 2 control groups, the concentrations of IL-10 in the 2 exposure groups decreased significantly, while the concentrations of IL-12 increased statistically. Furthermore, the decrease in IL-10 lagged behind the increase in IL-12. Therefore, it could be deduced that radiation from mobile phones resulted in T lymphocyte injury, and this adverse effect was seemingly more severe as the radiation exposure continued. Additionally, cell phone radiation was seen to suppress the secretion of IL-10 while enhancing the production of IL-12.

https://www.tandfonline.com/doi/full/10.1080/10420150.2025.2526402

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**Genotoxic and histopathological effects of 6 GHz radiofrequency electromagnetic radiation on rat liver tissue**

Ilgaz NS, Karamazı Y, Emre M, Toyran T, Karaoğlan Ö, Emre T, Dönmez Kutlu M, Öksüz Üçkayabaşı H, Aydın Ç, Yılmaz MB. Genotoxic and histopathological effects of 6 GHz radiofrequency electromagnetic radiation on rat liver tissue. Electromagn Biol Med. 2025 Jul 22:1-12. doi: 10.1080/15368378.2025.2534381.

Abstract

In this study, the genotoxic and histopathological effects of 6 GHz (0.065 W/kg) Radiofrequency-Electromagnetic Radiation (RF-EMR) on rat liver tissue were investigated. Sham (control) and Radiofrequency Radiation (RFR) groups were formed with 10 adult male rats in each group. Rats in the sham group received no treatment. Rats in the RFR group were exposed to 6 GHz RF-EMR for 4 h/day for 42 days. Immediately after the completion of the exposure, the rats in both groups were sacrificed and liver tissues were removed. Comet Test was performed to determine the genotoxic effect in the samples. Masson Trichrome and Hematoxylin Eosin staining methods were applied histopathologically. According to the Comet Analysis results, the genetic damage index (GDI) and damaged cell percentage (DCP) of the RFR group were higher than the sham group, but this difference was not statistically significant ($p > 0.05$). In histopathologic examinations, portal inflammation, single cell necrosis, vascularity and congestion were more prominent in the RFR group compared to the sham group. In our study, it was shown that 6 GHz RF-EMR can cause histopathologic and DNA level changes in rat liver

tissue. As a result of the literature review, no prior studies have specifically examined the genotoxic and histopathological effects of 6 GHz RF-EMR. This makes our study important as it addresses the biological impacts of the 6 GHz frequency band.

https://www.tandfonline.com/doi/full/10.1080/15368378.2025.2534381

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**Single-cell analysis reveals the spatiotemporal effects of long-term electromagnetic field exposure on the liver**

Zhang M, Lv Z, Zhao L, Zeng Q, Wu Y, Zhou J, Xi J, Pei X, Wang H, Li C, Yue W. Single-cell analysis reveals the spatiotemporal effects of long-term electromagnetic field exposure on the liver. Front Cell Dev Biol. 2025 Jun 27;13:1579121. doi: 10.3389/fcell.2025.1579121.

Abstract

Introduction: Artificial electromagnetic fields (EMFs) can impair the functions of several organs. The impact of long-term artificial EMF on the liver, the synthetic and metabolic center of the body, has become concerning. The aim of this study was to systematically evaluate the effect of long-term EMF exposure on the liver.

Methods: Mice were exposed to 2.45 GHz EMF daily for up to 5 months, and serum liver function test, lipidomic analysis, and histological analysis were performed to detect the general impact of EMF on the liver. Furthermore, EMF-induced liver transcriptome variations were investigated using single-cell RNA sequencing and a spatiotemporally resolved analysis.

Results: Different hepatic cells exhibited diverse sensitivities and response patterns. Notably, hepatocytes, endothelial cells, and monocytes showed higher sensitivity to electromagnetic radiation, with their lipid metabolic functions, immune regulation functions, and intrinsic functions disturbed, respectively. Moreover, transcriptomic alterations were predominantly observed in the hepatocytes and endothelial cells in peri-portal regions, suggesting a zonation-related sensitivity to EMF within the liver.

Conclusion: Our study provided a spatiotemporal visualization of EMF-induced alterations in hepatic cells, which ultimately elucidated the biological effects of EMF exposure.

Open access: https://www.frontiersin.org/journals/cell-and-developmental-biology/articles/10.3389/fcell.2025.1579121/full

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**Effects of coenzyme Q10 on sperm parameters and pathological changes induced by Wi-Fi waves in the testicular tissue of rats**

Safaeinezhad, Ali et al. Effects of coenzyme Q10 on sperm parameters and pathological changes induced by Wi-Fi waves in the testicular tissue of rats. Annals of Medicine & Surgery 87(7):p 4073-4079, July 2025. | doi: 10.1097/MS9.0000000000003340

Abstract

Background: Despite safety boundaries set by authorities, there is public concern about the health effects of wireless communication tools using radiofrequency. The World Health Organization has advised further research in this area.

Objective: The aim of this study was to investigate the effect of coenzyme Q10 (CoQ10) on sperm parameters and pathological changes in the testicular tissue in rats.

Methods: Twenty healthy rats were divided into four groups (n = 5). The first group was kept in a Wi-Fi-free environment for 2 months. The second group was exposed to Wi-Fi waves for 7 h a day for 2 months. The third group was exposed to Wi-Fi waves for 7 h a day for 2 months and received 150 mg/kg of CoQ10 daily. The fourth group was not exposed to Wi-Fi waves but received 150 mg/kg of CoQ10 daily. Serum testosterone levels, sperm parameters, and pathological findings of testis and epididymis were investigated.

Results: Treatment with CoQ10 (150 mg/day) resulted in a significant increase in sperm concentration from baseline, viability, and motility compared with the Wi-Fi group. CoQ10 therapy also increased testosterone levels compared with the Wi-Fi group. The pathology findings showed that in the treatment with CoQ10, fewer tubes had stopped the process of spermatogenesis due to Wi-Fi.

Conclusion: The study results indicated that the intake of CoQ10 can reduce the complications caused by Wi-Fi on sperm parameters, testosterone levels, and pathological findings.

Open access: https://journals.lww.com/annals-of-medicine-and-surgery/fulltext/2025/07000/effects_of_coenzyme_q10_on_sperm_parameters_and.16.aspx

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**A Prolonged exposure to Wi-Fi Radiation Induces Neurobehavioral Changes and Oxidative Stress in Adult Zebrafish**

Swati Fumakiya, Jahnavi Mehta, Aditi Punekar, Payal Sharma, Gowri Kumari Uggini. A Prolonged exposure to Wi-Fi Radiation Induces Neurobehavioral Changes and Oxidative Stress in Adult Zebrafish. International Journal For Multidisciplinary Research. 7(4): July-August 2025. doi: 10.36948/ijfmr.2025.v07i04.52286.

Abstract

The rapid development and use of wireless technologies have raised concerns about the possible harmful effects of long-term exposure to non-ionizing electromagnetic radiation (EMR). Wi-Fi routers are the most commonly used devices at households, offices, hotels, hospitals, airports, train stations etc., to provide wireless internet access to multiple devices. Therefore, prolonged exposure to EMR warrants thorough scientific investigation and risk assessment. Herein, we evaluated the impact of 2.45GHz Wi-Fi radiation exposure for 4 hours daily over a consecutive 30-day period on neurobehavioral and brain oxidative stress parameters in adult zebrafish. Post-exposure assessments revealed significant neurobehavioral impairments, altered locomotion, decreased neurotransmitter levels (AChE), and

increased oxidative stress. Further studies are needed to better understand the molecular mechanisms involved and to assess the broader implications for vertebrate neurobiology and public health.

Open access: https://www.ijfmr.com/research-paper.php?id=52286

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**Investigation of the Effects of 2.45 GHz Near-Field EMF on Yeast**

Angelova B, Paunov M, Kitanova M, Atanasova G, Atanasov N. Investigation of the Effects of 2.45 GHz Near-Field EMF on Yeast. Antioxidants (Basel). 2025 Jul 3;14(7):820. doi: 10.3390/antiox14070820.

Abstract

The study of the effects of 2.45 GHz electromagnetic fields on the health and safety of people and organisms as a whole is essential due to their widespread use in everyday life. It is known that they can cause thermal and non-thermal effects-at the molecular, cellular and organismal level. Yeast suspensions were treated with 2.45 GHz microwave radiation in the near-field of antenna at two distances (2 and 4 cm) and two time periods (20 and 60 min)-setups resembling the use of mobile devices. The release of UV-absorbing substances from the cells was studied as an indicator of membrane permeabilization, total intracellular antioxidant activity and reduced glutathione were determined, and a comet assay for damage to the DNA was performed. A correlation between reduced antioxidants and increased membrane permeability during EMF treatment was observed at a distance of 2 cm for 20 min, suggesting the presence of oxidative stress, while a similar effect was not observed with conventional heating. Slightly increased membrane permeability was observed after irradiation for 60 min at a distance of 4 cm, but this was not related to the antioxidant status of the cells. A trend towards increased DNA damage was observed under both conditions.

Open access: https://www.mdpi.com/2076-3921/14/7/820

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**Low frequency magnetic field exposure and neurodegenerative disease: systematic review of animal studies**

Stam R. Low frequency magnetic field exposure and neurodegenerative disease: systematic review of animal studies. Electromagn Biol Med. 2025 Aug 3:1-15. doi: 10.1080/15368378.2025.2540435.

Abstract

Epidemiological studies have found an association between occupational exposure to low frequency magnetic fields and the occurrence of motor neuron disease and Alzheimer's disease. No association has been found for Parkinson's disease and the evidence for multiple sclerosis is insufficient. Animal models studying the effects of low frequency magnetic fields on neurodegenerative disease induction or progression could provide more evidence on causation and the underlying mechanisms. A systematic search and review was conducted of peer-reviewed research articles involving animal experiments on the effects of low frequency magnetic field exposure on behavioural and neuroanatomical outcomes relevant for neurodegenerative diseases in humans. Firstly, experimental studies in *naive animals* do not support a causal relationship between exposure to low frequency magnetic fields and the induction of neuropathology relevant for Alzheimer's disease, but the number of studies relevant for motor neuron

disease, multiple sclerosis and Parkinson's disease is too limited to draw conclusions. Secondly, experimental studies in *existing animal models for neurodegenerative disease* support a therapeutic (beneficial) effect of low frequency magnetic field treatment on behavioural and neuroanatomical abnormalities relevant for dementia (including Alzheimer's disease), multiple sclerosis and Parkinson's disease and no effect on disease progression in models relevant for motor neuron disease.

https://pubmed.ncbi.nlm.nih.gov/40754996/

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**Proteomic Characterization of Human Peripheral Blood Mononuclear Cells Exposed to a 50 Hz Magnetic Field**

Bracci M, Lazzarini R, Piva F, Giulietti M, Marinelli Busilacchi E, Rossi E, Di Criscio F, Santarelli L, Poloni A. Proteomic Characterization of Human Peripheral Blood Mononuclear Cells Exposed to a 50 Hz Magnetic Field. Int J Mol Sci. 2025 Jun 24;26(13):6035. doi: 10.3390/ijms26136035.

Abstract

Exposure to extremely low-frequency magnetic fields (ELF-MF) can induce biological alterations in human cells, including peripheral blood mononuclear cells (PBMCs). However, the molecular mechanisms and key regulatory factors underlying this cellular response remain largely unknown. In this study, we analyzed the proteomic profiles of PBMCs isolated from three human subjects. PBMCs were exposed to 50 Hz, 1 mT of ELF-MF for 24 h and compared to unexposed PBMCs from the same individuals. ELF-MF exposure altered the expression levels of several PBMC proteins without affecting cell proliferation, cell viability, or cell cycle progression. A total of 51 proteins were upregulated, 36 of which were intercorrelated and associated with the *Cellular Metabolic Process* (GO:0044237) and *Metabolic Process* (GO:0008152). Among them, solute carrier family 25 member 4 (SLC25A4), which catalyzes the exchange of cytoplasmic ADP for mitochondrial ATP across the inner mitochondrial membrane, was consistently upregulated in all ELF-MF-exposed samples. Additionally, 67 proteins were downregulated, many of which are linked to *T cell costimulation* (GO:0031295), *Cell activation* (GO:0001775), and *Immune system processes* (GO:0002376) included ASPSCR1, PCYT1A, PCYT2, QRAS, and REPS1. In conclusion, ELF-MF exposure induces metabolic reprogramming in human PBMCs, characterized by the upregulation of mitochondrial proteins and downregulation of immune-activation-related proteins, without compromising cell viability or proliferation.

Open access: https://www.mdpi.com/1422-0067/26/13/6035

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**Microleakage of Amalgam Restorations after Exposure to Electromagnetic Fields of a Commercial Hair Dryer: An Ex-Vivo Study**

Paknahad M, Dehghani A, Khaleghi I, Eghildespour M, Mortazavi G, Mortazavi SMJ. Microleakage of Amalgam Restorations after Exposure to Electromagnetic Fields of a Commercial Hair Dryer: An *Ex-Vivo* Study. J Biomed Phys Eng. 2025 Jun 1;15(3):263-270. doi: 10.31661/jbpe.v0i0.2210-1551.

Abstract

Background: Dental amalgam is a popular restorative material used in posterior teeth. Hair dryers can emit electromagnetic fields (EMFs) that may affect the microleakage of the amalgam-tooth interface.

Objective: The aim of this experimental study was to investigate whether the EMFs produced by commercial hair dryers could cause microleakage in amalgam restorations.

Material and methods: In this experimental study, a total of 100 human extracted teeth without cavities were selected and prepared for class V preparations on their buccal aspects. The teeth were divided into five groups (G1-G5), each containing 20 teeth. Group 1 served as the control group and was not subjected to any treatment. Groups 2 to 5 were exposed to EMFs of a hair dryer (2000 W, 220 V, and 50 Hz). Groups 2 and 3 were exposed to "EMFs +Hot Air" for 20 min at 10 cm and 30 min at 5 cm, respectively. Groups 4 and 5 were exposed to "EMFs +Cool Air" for 20 min at 10 cm and 30 min at 5cm, respectively. After preparation, the sectioned teeth were evaluated for microleakage using dye penetration measurement.

Results: The microleakage scores showed a significant difference among the three exposure groups (G2, G3, and G5) and the control group (P=0.001, 0.002, and 0.01, respectively). However, there was no significant difference between G4 and G1. The microleakage score in G2 was higher than that in G4.

Conclusion: This study suggests that the common use of hair dryers can lead to damage in amalgam restorations.

Open access: https://jbpe.sums.ac.ir/article_49466.html

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**Radiofrequency electromagnetic fields reduce bumble bee visitation to flowers**

Treder M, Glück M, England SJ, Traynor KS. Radiofrequency electromagnetic fields reduce bumble bee visitation to flowers. Environ Pollut. 2025 Jul 14:126836. doi: 10.1016/j.envpol.2025.126836.

Abstract

Radiofrequency electromagnetic fields (RF-EMF) are an integral part of our daily lives and we may struggle to imagine life without them, using them to transmit and stream data for television, the internet, or cell phones. Debates circulate on whether this anthropogenic radiation may be an additional stress factor for pollinators, potentially disrupting important habitats and refugia, especially in highly developed areas. Could these anthropogenic fields interfere with foraging pollinators, influence their foraging behavior or reduce the attractiveness of entire habitats? Current data on sublethal impacts is sparse. We tested the effects of realistic 2.4 and 5.8 GHz radiation on flower visitation rates of different pollinators over two years in a blinded study using a standardized radiation source and a novel study design. Documenting 2,876 pollinators, we found no effect of this radiation on honey bee visitation rates on Salvia and Lavandula plants. However, we found a significant reduction in the number of bumble bee visits per observation when the plants were subjected to RF-EMF exposure, highlighting the need for in-depth and long-term studies to elucidate the underlying mechanisms of this effect.

https://www.sciencedirect.com/science/article/abs/pii/S0269749125012096?via%3Dihub

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**Perspectives on terahertz honeybee sensing**

Prokscha A, Sheikh F, Jalali M, De Boose P, De Borre E, Jeladze V, Ribas FO, Carvajal DT, Svejda JT, Kubiczek T, Aqlan B, Alibeigloo P, Mutlu E, Watermann J, Abts J, Kress R, Preuss C, Clochiatti S, Wiedau L, Weimann NG, Balzer JC, Thielens A, Kaiser T, Erni D. Perspectives on terahertz honey bee sensing. Sci Rep. 2025 Mar 27;15(1):10638. doi: 10.1038/s41598-025-91630-8.

Abstract

Terahertz (THz) technology provides precise monitoring capabilities in dynamic environments, offering unique insights into insect habitats. Our study focuses on environmental monitoring of European honey bees (Apis mellifera) through a combination of measurements and simulations. Initially, the dielectric material properties of honey bee body parts are characterized across the spectral range of 1-500 GHz to collect heterogeneous empirical data. To extend the study, honey bee mockups made from polyamide 12 (PA12) and epoxy resin are employed and validated as effective substitutes for real bees through comparative scattering analyses. The research further explores radar cross-section (RCS), imaging, and spectral properties using advanced THz technologies, including resonant tunneling diodes (RTDs) operating at 250 GHz and THz time-domain spectroscopy (THz-TDS) for frequencies exceeding 250 GHz. High-resolution imaging, utilizing a 450 GHz bandwidth, captures intricate anatomical features of both real and 3D-printed bees, showcasing the potential of THz technology for detailed environmental monitoring. Finally, simulations at 300 GHz assess the dosimetry and feasibility of non-invasive, continuous monitoring approaches based on the heterogeneous honey bee model.

Open access: https://www.nature.com/articles/s41598-025-91630-8

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**13.56 MHz RFID Module – From Application to Process Modelling and Effects on Human Health**

Constantinescu, C. *et al.* (2025). 13.56 MHz RFID Module – From Application to Process Modelling and Effects on Human Health. In: Vlad, S., Roman, N.M. (eds) 9th International Conference on Advancements of Medicine and Health Care Through Technology. MEDITECH 2024. IFMBE Proceedings, vol 130. Springer, Cham. doi: 10.1007/978-3-031-95671-3_22

Abstract

RFID (Radio Frequency Identification) is a technology very used in the last few years due to its reliability and ease of use. The applications are present in a large range of frequencies, but this paper is focused on a13.56 MHz module which is usually combined with an Arduino board. First, a simple application for student monitoring capable of storing information about each student and the time he/she checked in and out of class is presented. The advantages of such a system are highlighted and the components used to construct this system are described. The next step of this paper is to determine how the RFID module functions by numerically modelling it with and without the tags and cards near it, attempting also to show how the positioning of the tags influences the characteristics of the active tag's antenna. The last step of the study is centered on determining the influence of such a tag near human tissues and concludes by determining if it is safe or not to use an RFID for long periods of time.

https://link.springer.com/chapter/10.1007/978-3-031-95671-3_22

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**Greater prevalence of symptoms associated with higher exposures to mobile phone base stations in a hilly, densely populated city in Mizoram, India**

Sailo L, Laldinpuii, Zosangzuali M, Weller S, Varte CL, Tochhawng L, McCredden JE, Zothansiama. Greater prevalence of symptoms associated with higher exposures to mobile phone base stations in a hilly, densely populated city in Mizoram, India. Electromagn Biol Med. 2025 Jun 8:1-20. doi: 10.1080/15368378.2025.2513900.

Abstract

Members of the scientific community and the general public are raising concerns about the potential health and environmental effects of radio-frequency electromagnetic fields (RF-EMF) for those living nearby mobile phone base stations (MPBS). This study examined the impact of RF-EMF (900-1900 MHz) on symptoms spanning four health categories: mood-energy, cognitive-sensory, inflammatory, and anatomical issues. A questionnaire identifying health symptoms within these categories, was given to 183 highly exposed and 126 reference residents, matched on demographics. While years of residing near the MPBS influenced the prevalence of some symptoms, proximity to the base station and higher levels of exposure (measured using power density) influenced the prevalence of many of the symptoms. A higher proportion of symptoms was found in residents who were either living within 50 meters of a MPBS or who were exposed to power densities of 5-8 $mW/m^2$, for all four health categories. This relationship between exposure level and symptom prevalence was further influenced by age, daily mobile phone use (over 5 h per day), and lifestyle factors, for certain symptoms. Hierarchical regression analysis revealed that level of exposure (power density) was the only factor contributing to the number of symptoms experienced by residents, for all four health categories. An unexpected finding was that among the more highly exposed residents, the younger individuals (under 40 years) reported more inflammation related issues than older individuals. These results underscore the need to inform policymakers regarding the benefits of adopting a precautionary approach to potential risks associated with RF-EMF exposures from MPBS.

Plain language summary

Investigating the health effects of man-made electromagnetic fields (RF-EMF) created by telecommunications signals from mobile phone base stations is relevant to people living in cities across the world today. The study was conducted in a hilly, highly populated city in Mizoram, India, where many people live close to and in line of sight of the masts on telecommunications towers. A survey was given to residents in their homes, asking about what health symptoms they were experiencing across a range of health categories (mood-energy, cognitive-sensory, inflammatory, and anatomical). At the same time, the level of RF-EMF in their lounge room was measured. The symptoms reported by people living closer to mobile phone base stations (less than 300 m) were compared with those from people living further away (more than 400 m). More people who lived closer to base stations reported health symptoms in all of the health categories investigated. Relatively fewer people who lived further away reported symptoms. Other factors such as age, high mobile phone use (more than 5 h/day) and smoking and drinking also influenced this outcome, for some of the symptoms. The most significant contributor

to the number of symptoms reported by residents was the strength of RF-EMF to which they were exposed in their home. A surprising result was that younger people up to 40 years old showed more inflammatory conditions that were related to higher exposures than older people (such as headache, allergy and chest pain). These health effects of RF-EMF should be heeded by those responsible for the installation of mobile phone base stations in cities.

Study implications

"The maximum recorded power density measured at any dwelling was 7.2 $mW/m^2$. Most of the measurements taken in dwellings close to the base stations () exceeded the safety limits suggested by the Bioinitiative Report 2012. However, all measured values were significantly lower than both the current ICNIRP whole body exposure public limits of 4500 $mW/m^2$ (900 MHz) to 10,000 $mW/m^2$ (2000 MHz and higher frequencies) as well as the present Indian Standard of 450 $mW/m^2$ (Saravanamuttu et al. 2015). These standards for public RF-EMF exposures are predominantly focused on the mitigation of “known” harmful thermal effects, but do not comprehensively cover a range of biological consequences that are intrinsically linked to non-thermal biological responses and health, especially for those who are continuously being exposed to this man-made radiation without choice or informed consent. In this context, the ALARA principle (As Low As Reasonably Achievable), which has widely been used with ionising radiation, has been recommended (Leach and Bromwich 2018).

Table 3 reveals that symptom prevalence was associated with duration of exposure. In toxicology research, the dose of a toxicant is understood to incorporate both intensity and duration of exposure (Tsatsakis et al. 2018).

The ICNIRP guidelines set safety limits based on exposure intensity, averaged over 6 or 30 minutes. Therefore, they do not factor in cumulative doses occurring over time in the real world. Laboratory studies are mostly restricted to timescales of minutes to weeks. Within studies using the longer of these timescales, biphasic effects have been observed (where effects are positive in the short term but then return to baseline as exposure duration increases and become negative with even longer exposure times) suggesting very short -term protective effects such as immune system priming, but detrimental effects after longer exposures (e.g., Fesenko et al. 1999). While adaptive responses have been suggested for long term exposures (Vijayalaxmi et al. 2014), the longer timescales of laboratory experiments show more negative effects. However, there are very few long-term laboratory studies.

Epidemiological data, such as that presented in this study, measures exposures over years and thus has been more able to reveal detrimental, cumulative effects that occur over time. Epidemiological research and intensity x time calculations need to be factored in when setting safety limits for populations who are continuously exposed over a lifetime.

While this study sampled only a moderate sized population from the city of Aizawl, the results can be used to inform public policy on this matter. Our results add to the understanding of health effects related to chronic exposure to RF-Fields emitted from MPBS. Risk management does not require definitive conclusions. Early warnings such as the results of this study provide adequate evidence for policy makers to act, including requiring industry to seek solutions (Gee 2009; Leach et al. 2024). The study results indicate that exposure to RF-EMF at levels lower than the Government recommended general public “safety” threshold can still lead to significant health challenges. The study revealed that the level of MPBS RF-EMF exposure was a primary contributor to the elevated prevalence of a range of

health symptoms observed among residents in close proximity to MPBS. Concerning results that have revealed more inflammatory symptoms in resident younger than 40 years living close to MPBS require follow up.

Following these important findings, it is crucial to critically reassess current public RF exposure safety limits in order to include the growing evidence of non-thermal biological impacts of RF-EMF emitted by MPBS over years. The study results emphasize the importance of establishing exposure limits that are based on biological factors, other than heating, to minimize exposure and address the long-term potential for serious health consequences; i.e., “An independent re-evaluation of RFR exposure limits based on the scientific knowledge gained over the past 25 years is needed and is long overdue” (Belyaev et al. 2022)."

https://www.tandfonline.com/doi/10.1080/15368378.2025.2513900

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**Trends in Malignant and Benign Brain Tumor Incidence and Mobile Phone Use in the U.S. (2000–2021): A SEER-Based Study**

My note: The age-standardized incidence rate for benign (i.e., non-malignant) brain and other nervous system tumors was 9.56 per 100,000 in 2004 and 18.48 in 2021, a 93% increase. Yet the authors of this paper misleadingly claimed contrary to their own result (APC = 1.9, p = .00003): "The incidence rates for benign tumors (primarily meningiomas) were also stable, but did increase slightly over this period [44]. This is unlikely to be due to mobile phone use."  The authors' assumption that this substantial increase in non-malignant brain tumors was caused simply by changes in screening practices and tumor classification criteria should be challenged.

Analysis of the SEER data also indicates that the trend for glioblastoma (GBM) varied by age group. Although it was quite stable for younger age groups, the GBM age-standardized incidence rate for seniors 65 years of age and older was 11.97 per 100,000 in 2001 and 13.66 in 2021, a 14% increase. Since 1,000 hours of mobile phone use may be necessary to initiate a brain tumor and 20-30 years for a tumor to be diagnosed, continued surveillance is essential.

For more information see Brain Tumor Rates Are Rising in the US: The Role of Cellphone & Cordless Phone Use.

Zhang L, Muscat JE. Trends in Malignant and Benign Brain Tumor Incidence and Mobile Phone Use in the U.S. (2000–2021): A SEER-Based Study. *International Journal of Environmental Research and Public Health*. 2025; 22(6):933. doi: 10.3390/ijerph22060933.

Abstract

(1) Background: There has been an ongoing concern for several decades that radiofrequencies emitted from mobile phones are related to brain cancer risk. We calculated temporal trends in brain cancer incidence rates in adults and children and compared them to mobile phone subscription data over the same time period.

(2) Methods: We analyzed the Surveillance, Epidemiology and End Results (SEER 22) cancer database between 2000 and 2021. Age-standardized incidence rates (ASR) per 100,000 people were calculated

and the annual percentage change (APC) for malignant and benign brain cancer and vestibular schwannomas (acoustic neuromas of the 8th cranial nerve) was established. The total number of mobile phone subscriptions in the United States was plotted for the period 1985–2024.

(3) Results: The APC for adolescents and adults was −0.6 (p = 0.0004) for malignant tumors, −0.06 (p = 0.551) for temporal lobe tumors, and **1.9 (p = 0.00003) for benign tumors**. The APC for benign acoustic neuroma was 0.09 (p = 0.8237), suggesting that mobile phone use is unlikely to be associated with this tumor type. There was a 1200-fold increase in the number of cell phone subscriptions during this period.

(4) Conclusions: These findings suggest that mobile phone use does not appear to be associated with an increased risk of brain cancer, either malignant or benign.

Open access paper: https://www.mdpi.com/1660-4601/22/6/933

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**5G Radio-Frequency-Electromagnetic-Field Effects on the Human Sleep Electroencephalogram: A Randomized Controlled Study in CACNA1C Genotyped Volunteers**

Sousouri G, Eicher C, D' MariaAngelo R, Billecocq M, Fussinger T, Studler M, Capstick M, Kuster N, Achermann P, Huber R, Landolt H-P. 5G Radio-Frequency-Electromagnetic-Field Effects on the Human Sleep Electroencephalogram: A Randomized Controlled Study in CACNA1C Genotyped Volunteers. NeuroImage, 2025. doi: 10.1016/j.neuroimage.2025.121340.

Abstract

Background  The introduction of 5G technology as the latest standard in mobile telecommunications has raised concerns about its potential health effects. Prior studies of earlier generations of radiofrequency electromagnetic fields (RF-EMF) demonstrated narrowband spectral increases in the electroencephalographic (EEG) spindle frequency range (11-16 Hz) in non-rapid-eye-movement (NREM) sleep. However, the impact of 5G RF-EMF on sleep remains unexplored. Additionally, RF-EMF can activate L-type voltage-gated calcium channels (LTCC), which have been linked to sleep quality and EEG oscillatory activity.

Objective  This study investigates whether the allelic variant rs7304986 in the CACNA1C gene, encoding the α1C subunit of LTCC, modulates 5G RF-EMF effects on EEG spindle activity during NREM sleep.

Methods  Thirty-four participants, genotyped for rs7304986 (15 T/C and 19 matched T/T carriers), underwent a double-blind, sham-controlled study with standardized left-hemisphere exposure to two 5G RF-EMF signals (3.6 GHz and 700 MHz) for 30 min before sleep. Sleep spindle activity was analyzed using high-density EEG and the Fitting Oscillations & One Over f (FOOOF) algorithm.

Results  T/C carriers reported longer sleep latency compared to T/T carriers. A significant interaction between RF-EMF exposure and rs7304986 genotype was observed, with 3.6 GHz exposure in T/C carriers inducing a faster spindle center frequency in the central, parietal, and occipital cortex compared to sham.

Conclusion  These findings suggest 3.6 GHz 5G RF-EMF modulates spindle center frequency during NREM sleep in a CACNA1C genotype-dependent manner, implicating LTCC in the physiological response to RF-EMF and underscoring the need for further research into 5G effects on brain health.

Open access paper: https://www.sciencedirect.com/science/article/pii/S105381192500343X

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**Exposure to radiofrequency electromagnetic fields and IARC carcinogen assessment: Risk of Bias preliminary literature assessment for 10 key characteristics of human carcinogens**

Simkó M, Repacholi MH, Foster KR, Mattsson MO, Croft RJ, Scarfi MR, Vijayalaxmi. Exposure to radiofrequency electromagnetic fields and IARC carcinogen assessment: Risk of Bias preliminary literature assessment for 10 key characteristics of human carcinogens. Mutat Res Rev Mutat Res. 2025 May 27;796:108545. doi: 10.1016/j.mrrev.2025.108545

Highlights

• We analyzed if the ten key characteristics (KCs) of human carcinogens according to IARC are influenced by RF-EMF exposure.
• We reviewed 159 articles by extracting relevant exposure and experimental data.
• A risk of bias (RoB) analysis was conducted using 6 criteria.
•There is a strong negative association between study quality and the likelihood of reporting effects of RF-EMF exposures.
• The heterogeneity and overall poor study quality suggest the need for high-quality studies.

Abstract

This is the first assessment of evidence needed to determine whether exposure to radiofrequency electromagnetic fields (RF-EMF) exposures, below the levels recommended in the ICNIRP (2020) guidelines, can influence any of the ten key characteristics (KCs) of human carcinogens developed by the International Agency for Research on Cancer (IARC). We define the 10 KCs and their relevance to carcinogenesis; review in vivo and in vitro studies relevant to the KCs; and conduct a risk of bias (RoB) analysis using 6 criteria. We did not include KC studies on genotoxicity or oxidative stress since Romeo et al. (2024) and Meyer et al. (2024) recently published relevant systematic reviews, but note their respective conclusions. From the other 8 KCs we identified 119 in vitro and 40 in vitro measurements of in vivo studies through 30 June 2023, with 38 % reporting statistically significant effects of exposure. We identified a strong association between the quality of study and outcome, with those meeting more RoB criteria less likely to report statistically significant effects. Effects were reported over the entire frequency range, exposure levels, and biological endpoints with no apparent pattern of exposure parameters resulting in effects. Only KC10 (alters cell proliferation, cell death or nutrient supply) has sufficient studies to analyse, but the other KCs had few studies and diverse endpoints. A few relatively high-quality positive studies require follow-up through additional targeted studies. The heterogeneity and overall poor study quality suggest the need for high-quality studies on these endpoints, preferably adhering to standards such as the Organization for Economic Co-operation and Development [28].

Limitation of the review

A significant limitation of the present review is that it was not a PRISMA-compliant systematic review or scoping review. However, the present review did not fully adhere to the standard guidelines for a scoping review, although our approach bore some similarities to the approach adopted in Peters et al. [31]. It is not feasible to adjust the present review (eight reviews in total) to conform to such guidelines. This limitation is acknowledged, and the necessity for comprehensive scoping reviews and, where applicable, SRs, is emphasized.

Conclusions

This review aimed to assess the extent and adequacy of experimental data bearing on whether exposure to RF-EMF could influence any of the 10 IARC key characteristics of human carcinogenesis. Since two PRISMA-compliant SRs on the KCs genotoxicity and oxidative stress were recently published [35], [23], this present review was limited to the 8 remaining KCs for which no systematic reviews have been conducted so far. It became apparent that the present database of in vitro and in vivo studies was so diverse and scattered in their quality that helpful outcomes of SRs on most of the KCs would be unfeasible, and any conclusions from such reviews would have a very low confidence. The two PRISMA-compliant SRs as well as previous comprehensive reviews on in vitro and in vivo genotoxicity studies (e.g. [46], and our review of studies on the 8 KCs, have all reached the same conclusion: there is clearly a need for much higher quality RF-EMF bioeffects studies on these KCs.

There are, however, a few statistically significant results in the highest quality studies (Tier 1 studies in Romeo et al. [35] and studies meeting 5 or 6 RoB criteria (present study). These deserve close examination, and replication if warranted by stronger studies, preferably done under GLP [28], or are otherwise compliant with OHAT recommendations.

As a final comment, it is not useful for systematic reviews to examine hundreds of papers on a given topic, only to find that the overall quality of the large majority of the studies is too low to permit conclusions with a high level of confidence.

Open access paper: https://www.sciencedirect.com/science/article/pii/S138357422500016X

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**Does Electromagnetic Pollution in the ART Laboratory Affect Sperm Quality? A Cross-Sectional Observational Study**.

Baldini GM, Lot D, Ferri D, Montano L, Tartagni MV, Malvasi A, Laganà AS, Palumbo M, Baldini D, Trojano G. Does Electromagnetic Pollution in the ART Laboratory Affect Sperm Quality? A Cross-Sectional Observational Study. Toxics. 2025 Jun 18;13(6):510. doi: 10.3390/toxics13060510.

Abstract

In recent decades, exposure to electromagnetic fields (EMFs) generated by standard devices has raised concerns about possible effects on reproductive health. This cross-sectional observational study examined the impact of EMFs on sperm motility in a sample of 102 healthy males aged 20-35 years in the IVF laboratory. Semen samples were exposed to different sources of EMF for one hour, and motility was assessed immediately thereafter. The results showed a significant reduction in progressive sperm motility after exposure to EMFs generated by mobile phones and Wi-Fi repeaters in the laboratory. In contrast, other equipment showed no significant effects. The study demonstrated a statistically

significant reduction in progressive sperm motility following in vitro exposure to electromagnetic fields (EMFs) emitted by mobile communication devices and wireless local area network access points. Conversely, other electromagnetic emitting devices evaluated did not elicit significant alterations in this parameter. These findings suggest a potential negative impact of specific EMF sources on semen quality, underscoring the necessity for further comprehensive research to elucidate the clinical implications and to develop potential mitigation strategies aimed at reducing risks to male reproductive health. This study discourages the introduction of mobile phones in IVF laboratories and recommends positioning Wi-Fi repeaters on the ceiling.

Excerpt

- Group 3—iPhone Cell Phone. The samples were exposed to radiation emitted by an Apple iPhone 12 mobile phone (output power: 0.1 W) (Apple Computer, Cupertino, CA, USA). The device was kept at a distance of 10 cm from the semen sample for 1 h.
- Group 4—Ubiquiti Wi-Fi Repeater. The samples were exposed to EMFs emitted by a Ubiquiti UniFi 6 long-range Wi-Fi repeater (Ubiquiti, 685 Third Avenue, New York, NY, USA), utilising 2.4 GHz and 5 GHz Wi-Fi technology with an emission power of approximately 20 dBm (decibel milliwatts), which corresponds to approximately 100 mW (milliwatts). As in all other cases, the sample was placed at a distance of 10 cm for 1 h.

Open access paper: https://www.mdpi.com/2305-6304/13/6/510

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**A novel approach for assessments of radiofrequency electromagnetic fields exposure in buildings near telecommunication infrastructure**

de F H Silva RQ, Rodrigues MEC, Pinheiro FSR, da Silva GS, da C Muniz M, Pinto LS, Mendonça HB, de Sousa VA Jr. A novel approach for assessments of radiofrequency electromagnetic fields exposure in buildings near telecommunication infrastructure. Sci Total Environ. 2025 Jun 25;992:179853. doi: 10.1016/j.scitotenv.2025.179853. Epub ahead of print. PMID: 40570395.

Highlights

• Determines the worst-case exposure in buildings directly exposed to RF-EMF.
• Enables large-scale assessments by limiting specific measurement locations.
• Evaluates all buildings in a city using the proposed approach.
• Novel RF-EMF exposure results in vertical dwellings.
• Unprecedented discussions on recommendations for exposure to RF-EMF in buildings.

Abstract

This paper proposes to complement the current regulatory agencies' methodology for evaluating exposure to Radiofrequency Electromagnetic Fields (RF-EMF) in buildings under the direct incidence of emissions from Base Station (BS) antennas. The key contribution is the refinement of measurement point selection within buildings, ensuring that assessments more accurately capture exposure levels. The approach employs technical criteria for selecting target buildings, considering the location of the BSs and the configuration of the surrounding antenna structures. The proposed approach was applied to

measurements in four buildings in the city of Natal, the capital of Rio Grande do Norte, located in the Northeast region of Brazil. The results show electric field intensity peaks up to 17.40 times higher and averages up to 14.13 times higher than values obtained from measurements conducted at ground level, such as those carried out by the National Telecommunications Agency (ANATEL). The highest exposure rates reached 82.27% and 59.43% of the limits established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for the frequency bands of FM radio and mobile telephony, respectively. Our proposal can improve and complement the normative guidelines for RF-EMF exposure assessment, providing more representative evaluations of exposure in indoor building environments near modern telecommunication infrastructure.

This paper proposes to complement the current regulatory agencies' methodology for evaluating exposure to Radiofrequency Electromagnetic Fields (RF-EMF) in buildings under the direct incidence of emissions from Base Station (BS) antennas. The key contribution is the refinement of measurement point selection within buildings, ensuring that assessments more accurately capture exposure levels. The approach employs technical criteria for selecting target buildings, considering the location of the BSs and the configuration of the surrounding antenna structures. The proposed approach was applied to measurements in four buildings in the city of Natal, the capital of Rio Grande do Norte, located in the Northeast region of Brazil. The results show electric field intensity peaks up to 17.40 times higher and averages up to 14.13 times higher than values obtained from measurements conducted at ground level, such as those carried out by the National Telecommunications Agency (ANATEL). The highest exposure rates reached 82.27% and 59.43% of the limits established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for the frequency bands of FM radio and mobile telephony, respectively. Our proposal can improve and complement the normative guidelines for RF-EMF exposure assessment, providing more representative evaluations of exposure in indoor building environments near modern telecommunication infrastructure.

## 8. Conclusions

This study presented a novel approach for assessing RF-EMF exposure in buildings directly exposed to emissions from BS antennas, in addition to criteria for selecting target buildings and determining the precise location of the potential worst-case exposure scenario within these structures. The measurement methodology conformed to internationally recognized standards (ICNIRP, 2020) and Brazilian guidelines for evaluating exposure to electromagnetic fields from radiofrequency services (ANATEL, 2023).

Applying the proposed approach for selecting target buildings resulted in obtaining an electrical field intensity peak value higher than those of studies found in the literature that carried out indoor measurements, in addition to presenting values close to those recorded by works that carried out outdoor measurements. These data were acquired from measures over 30 min, as recommended by ICNIRP (2020). This provides a time optimization in exposure assessment compared to approaches that select measurement locations randomly and/or perform measurements over 24 h. Furthermore, this approach provides a more accurate evaluation than methods that use measurements with 6 min or less.

The measurements conducted at the target floor yield average and peak electric field intensity values lower than ICNIRP (2020) exposure limits but up to 17.40 times higher than those obtained at the ground level. These findings indicate the necessity for specific investigations for the discussed exposure

scenario and the importance of improving regulatory agencies' methods to consider the complexities and particularities of modern RF-EMF exposure contexts.

In addition, the proposed approach can be improved using geographic and structural datasets on buildings of the analyzed region, enabling the automation of the selection process of BSs and target buildings, as described in Sections 4.1 Target BSs selection, 4.2 Target buildings selection, respectively. Using methods for measuring in the external part of the façade of target buildings, such as drones, can reduce the number of authorizations required to carry out measurements, making more measurements feasible.

Finally, future work aims to conduct measurements in all 22 buildings in Natal and establish partnerships with other institutions to apply the methodology in different cities and countries, promoting a more comprehensive analysis of the exposure scenario in apartments and analyzing reproducibility.

https://pubmed.ncbi.nlm.nih.gov/40570395/

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**Effect of elevation on cumulative radiofrequency exposure from multiple communication towers**

Osei S, Quarshie E, Azah CK, Fuseini A-R, Dogbey R, Deatanyah P, Hagan GB, Hodasi JAM, Sam F, Amoako JK. Effect of elevation on cumulative radiofrequency exposure from multiple communication towers, *Radiation Protection Dosimetry*, 2025. doi: 10.1093/rpd/ncaf068.

Abstract

A densely populated place like a public university needs good internet and communication connectivity for effective academic work. As such, University campuses in Ghana are inundated with communication antennas. This study investigated how radiofrequency (RF) power density levels are affected by the elevations of different floors of high-rise buildings of a public university. A spectrum analyser coupled to a log-periodic antenna was used. The RF power density decreased from the ground floor to the third floor and only increased to maximum levels on the fourth floor. The variation across different floors indicates the influence of elevation on the measured EMF levels. The 900 MHz band produced the highest power density of 1.16E-03 $W/m^2$ on the last (fourth) floor, suggesting that communication applications in the 900 MHz band are the most used by the university community.

https://academic.oup.com/rpd/advance-article/doi/10.1093/rpd/ncaf068/8177309

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**Evaluation of Personal Radiation Exposure from Wireless Signals in Indoor and Outdoor Environments**

Ruijie P, Sali A, Li L, Mohyedin MZ. Qahtan S. Evaluation of Personal Radiation Exposure from Wireless Signals in Indoor and Outdoor Environments. IEEE Access, doi: 10.1109/ACCESS.2025.3579085.

Abstract

With the development of wireless technology, the public is exposed to electromagnetic fields (EMF), which has led to concerns about the potential health effects of EMF exposures. This paper aims to evaluate personal EMF exposures from wireless signals in indoor and outdoor micro-environments in Malaysia. According to the influencing factors, four different types of micro-environments are selected.

A radiation exposure meter called ExpoM-RF 4 is used to measure the electric field strength across these micro-environments. From the measurement campaigns, three machine learning (ML) techniques are simulated to model the Electric Field Strength in each micro-environment. The ML techniques are Fully connected neural network (FCNN), eXtreme Gradient Boosting (XG Boost), and Linear Regression (LR) to predict the RMS and Maximum radiation exposure. From the ML models, Total Emission Ratio (TER), Root Mean Square Error (RMSE) and Coefficient of Determination (R2) are evaluated to measure the performance of ML. By comparison, it is found that LR performs well with single and simple data set, while XG Boost and FCNN demonstrate superior capabilities in handling multiple types of data sets. The FCNN model provides the most accurate predictions, particularly in urban and suburban areas where extreme values are observed. Finally, the measured data and the predicted radiation exposure levels are compared against public exposure limit by International Commission on Non-Ionizing Radiation Protection (ICNIRP), Malaysian Communications and Multimedia Commission (MCMC) and Federal Communications Commission (FCC). The results demonstrate that typically personal radiation exposure is lower than the exposure limit (61.4 V/m), which is similar to the most research results. However, in areas with dense population and numerous base stations, the maximum exposure can approach 56.7365 V/m (measured data), which is close to the exposure limit.

CONCLUSION

LR has better prediction results under single and simple data sets, while XG Boost and FCNN have stronger analysis capabilities for multiple types of data sets. In addition, FCNN predicts best in the presence of extreme values and analyzing large and complex data.

By comparing and analyzing the measured data and predicted values across different micro-environments, it is observed that the highest levels of personal radiation exposure typically occur in outdoor urban areas, which is characterized by high population density, high concentration of base stations, and close proximity to these stations. In contrast, park areas with dense vegetation exhibit significantly lower personal radiation exposure. The dense trees act as natural attenuators, absorbing and scattering the electromagnetic waves, which reduces their intensity. Indoor environments generally exhibit lower electromagnetic field strengths compared to outdoor environments. This can be attributed to structural shielding provided by building materials and fewer high-power sources.

Typically, Electric Field Strength is much lower than the international exposure limits, which is similar to the most research results [2, 6, 13, 14, 16]. However, in areas with dense population and base stations, the maximum value of Electric Field Strength would increase at some point, even close to the exposure limit.

Open access paper:
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11031433&isnumber=6514899

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**The use of different exposure metrics in the research about the health impacts of electromagnetic fields**

European Research Cluster on EMF and Health (CLUE-H). The use of different exposure metrics in the research about the health impacts of electromagnetic fields. 2024, Policy brief, 1: 1-8.

No abstract.

Excerpts

Figure 5. Near-field sources contribute most to the RF-EMF energy absorbed by the human body. However, the contribution of individual near-field sources depends on their positioning with respect to the investigated organ or part of the body. The mean overall cumulative dose for whole-body was calculated at 0.29 J/kg/day and for brain it was 0.81 J/kg/day [1].

For RF-EMF, well-established effects include tissue heating, microwave hearing for highly pulsed radiation (e.g., from a radar), and tissue stimulation (e.g., from contact currents). Accordingly, different metrics are specified in the regulations to prevent these effects from happening. For instance, thermal effects are only a problem for health if a certain threshold is exceeded. Below this threshold, temperature rise is not expected to cause health effects.

In RF-EMF research, thermal effects are of limited interest because they are well understood. However, research has provided indications for biological effects below the thermal threshold such as effects on brain physiology or oxidative balance. Such biological effects, which per se are not health effects, could be the consequences of unknown biological mechanisms or could occur due to subtle warming of the tissue below the thermal damage threshold. Historically, epidemiology has been investigating health effects without prior knowledge of the underlying disease mechanism by comparing people who are exposed to a variable extent to the agent of interest. In this case a common approach for complex exposure situations is the time weighted average (TWA), i.e., exposure levels in different situations (e.g., at home, at work, during commuting) are averaged taking into account the time spent in these situations. This approach has also been applied in RF-EMF research dealing with far field exposures. However, it is not suitable for combining near and far field exposures since different metrics are used for these two types of exposure. Thus, a cumulative dose metric was introduced in RF-EMF research a few years ago. In an approach to the TWA concept, SAR for various exposure situations (e.g., mobile phone call, WiFi access point exposure, etc.) is multiplied with the corresponding exposure duration to obtain a cumulative RF-EMF dose, often expressed per day (J/kg/day).

Calculation of cumulative dose in RF-EMF epidemiology allows combining different exposure situations into one metric. It considers magnitude and duration of each exposure situation and is based on the same philosophy as a time weighted average. In principle, cumulative dose refers to a linear-no-threshold model but is actually correlated to most other plausible effect models such as time spent above a certain threshold. It is a conservative approach, since it considers the possibility that long-term exposure to low levels might affect health, which is a common concern of parts of the population in relation to environmental RF-EMF exposure. It may also be helpful for risk communication as it enables to compare the contribution of various RF-EMF exposure situations to a combined metric of the absorbed RF-EMF.

The use of a cumulative dose metric in research should not be mistaken as an indication or proof that

cumulative exposure to very low levels can be harmful to health. It just serves as the currently best metric to analyse if there could be effects on health, outside of a known biological mechanism.

In conclusion, the existence of various exposure measures in the field of RF-EMF research on health reflects the involvement of different biophysical concepts and exposure situations. Further, different metrics are used for different purpose:

• For biological research, physical quantities that best represent an underlying biophysical mechanism are usually the preference (e.g., SAR value, internal electrical field).
• For observational research aiming to explore a yet unknown effect on health, preference may be given to metrics that combine similar sources (e.g., time-weighted average, cumulatively absorbed dose) and are seen as superior in capturing exposures experienced over a long time period.).
• For regulation purposes, the suitable metric depends on the exposure situation (e.g., external electric field strength or power density for far field sources or spatially averaged SAR for localized near field exposures).
• For risk communication with the public, metrics which are intuitively understood, are considered most useful (e.g., fraction of regulatory limit).

There is a Council Recommendation [2] that is currently being amended due to the fact that new measurement methods have emerged. The work of CLUE-H contributes to improving our knowledge base on measurement methods and limit values, which will be useful for future updates of the Recommendation.

Open access: https://www.emf-health-cluster.eu/wp-content/uploads/2024/06/CLUE-H_First_Policy_Brief_DEF_approved.pdf

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**Auto-Induced Downlink Radiofrequency Electromagnetic Field Exposure at 3.5 GHz With Focusing Near the Head**

Herssens H, Thielens A. Auto-Induced Downlink Radiofrequency Electromagnetic Field Exposure at 3.5 GHz With Focusing Near the Head. *IEEE Access*, vol. 13, pp. 56659-56670, 2025, doi: 10.1109/ACCESS.2025.3555388.

Abstract

The auto-induced downlink exposure at 3.5 GHz is evaluated in networks where the power density is focused at the user equipment (UE), leading to a highly localized exposure. To achieve this focusing, various precoding techniques can be applied. Two of these are compared using Finite-Difference Time-Domain simulations. For each technique, three different exposure scenarios are considered: UE located next to the ear (phone call), UE located in front of the eyes, and the nose (video call). The exposure is evaluated in terms of the localized specific absorption rate using a female and a male phantom. We find that the exposure highly depends on the location of the UE and precoding technique. According to the International Commission on Non-Ionizing Radiation protection (ICNIRP)'s guidelines, this exposure should be normalized to the maximum incident power density. In this work, we suggest normalization strategies of this highly focused exposure and compare these. We show that the choice of normalization can create a situation where the ICNIRP basic restrictions can be exceeded while complying with the

reference levels. This is important because compliance with the reference levels should ideally ensure compliance with the basic restrictions.

Open access paper:

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10943211&isnumber=10820123

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**In-Situ Measurements of Radiofrequency Electromagnetic Fields Measurements Around 5G Macro Base Stations in the UK**

Calderon C, Addison D, Peyman A. In-Situ Measurements of Radiofrequency Electromagnetic Fields Measurements Around 5G Macro Base Stations in the UK. Bioelectromagnetics. 2025 Jul;46(5):e70012. doi: 10.1002/bem.70012.

Abstract

Radiofrequency (RF) electromagnetic field spot measurements were performed in line-of-sight to 56 active 5G macro base stations across 30 publicly accessible locations in the United Kingdom (UK). Four different exposure scenarios were assessed: background (no traffic instigation), streaming videos, downlink speed test, and extrapolation of SS-RSRP decoder measurements. Power density measurements across the 420 MHz-6 GHz frequency range were also performed at each site to assess the total exposure from various RF sources in the environment. Both total RF and 5G specific power density levels were found to be well within the 1998 ICNIRP public reference levels, even when extrapolating to worst-case scenario (≤ 5%). 4G downlink was the dominant contributor to total RF exposure, with 5G contributing on average less than 10%. No statistically significant difference was observed between beamforming and non-beamforming sites. Streaming did not seem to contribute materially to exposure levels, suggesting that background measurements are a good representation of typical downlink exposure at current urban and suburban 5G sites.

Open access: https://onlinelibrary.wiley.com/doi/10.1002/bem.70012

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**Exposure to 26.5 GHz, 5G modulated and unmodulated signal, does not affect key cellular endpoints of human neuroblastoma cells**

Sannino A, Allocca M, Scarfì MR, Romeo S, Peluso V, Panariello G, Schettino F, Chirico G, Zeni O. Exposure to 26.5 GHz, 5G modulated and unmodulated signal, does not affect key cellular endpoints of human neuroblastoma cells. Sci Rep. 2025 Jul 1;15(1):20614. doi: 10.1038/s41598-025-04834-3.

Abstract

The fifth generation (5G) network is currently being worldwide spread out, raising questions about its potential health impact. The current study aimed to investigate the effects of a 26.5 GHz 5G electromagnetic field on key cellular endpoints of human neuroblastoma cells. A reverberation chamber-based exposure system was designed and realized which allowed the exposure/sham exposure of cell cultures under highly controlled exposure conditions of both electromagnetic and biological parameters. The suitability of the reverberation chambers to host cell cultures was verified by

evaluating cell proliferation and cell cycle progression. The effect of 3 h exposure at specific absorption rate of 1.25 W/kg under both continuous wave and 5G modulated signal was evaluated in terms of cell cycle and DNA damage. In the latter case, the exposure was also given in combination with menadione to account for possible cooperative effects. Results showed absence of effects of exposure given alone and in combination with menadione, when both continuous wave and modulated signals were applied at the mentioned exposure level. Further investigations are needed by varying the exposure and biological parameters to strengthen the absence of effects due to 5G signals in the range of millimeter waves.

Open access: https://www.nature.com/articles/s41598-025-04834-3

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**Histomorphometric study of thyroid tissue in juvenile rats exposed to 5G electromagnetic fields**

Ramelet M, Ronger L, Al-Salameh A, Pelletier A, Desailloud R, Seewooruttun C. Histomorphometric study of thyroid tissue in juvenile rats exposed to 5G electromagnetic fields. Annales d'Endocrinologie.86(3), 2025. doi: 10.1016/j.ando.2025.101755.

Abstract

Introduction  5G network deployment raises the issue of the health impact of these electromagnetic fields. Their effect on thermal regulation is of a “cold reesponse” type. In rats exposed to 900MHz, vasoconstriction was induced in the tail, with behavioral preference for warmer compartments. The hypothalamo-pituitary-thyroid axis is involved in thermogenesis: in response to cold, thyroid activity increases, stimulating heat production.

Objective  To assess thyroid activity after 5G exposure.

Method  Ten 3-week-old male Wistar rats were randomized between 2 weeks’ 5G exposure at 3.5GHz and 1.5V/m (5G group; n=5) and no exposure (controls; n=5). After sacrifice, the thyroid gland was harvested for histomorphometry. Thyroid follicle and colloid areas were measured and the thyroid activation index (TAI: ratio of follicle to colloid area) was assessed.

Results  Follicle and colloid areas were significantly greater in 5G (2729µm2 vs 2444µm2, P=0.0063; and 1317µm2 vs 1015µm2, P=0.0027 respectively) and TAI was significantly lower (5.62 vs 7.07, P <0.001). These results indicate thyroid hypoactivity.

Discussion  There was a 5G effect, with histomorphometry demonstrating thyroid hypoactivity, suggesting mechanisms different from those underlying cold response. Impact of electromagnetic fields on thyroid function was previously reported, but results were heterogeneous and discordant depending on the type of exposure.

Conclusion  TSH and thyroid hormone assays are underway to reinforce assessment of thyroid function. Further studies are needed to explore the underlying mechanism.

https://www.sciencedirect.com/science/article/pii/S0003426625000745

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**Protective effects of quercetin against 3.5 GHz RF radiation-induced thyroid dysfunction and oxidative stress in rats**

Bektas H, Bese Akgun BB, Cakir S, Dogu S, Ahnas B. Protective effects of quercetin against 3.5 GHz RF radiation-induced thyroid dysfunction and oxidative stress in rats. Electromagn Biol Med. 2025 Jul 8:1-12. doi: 10.1080/15368378.2025.2528732.

Abstract

The global expansion of 5 G communication networks has heightened concerns about the biological effects of high-frequency radiofrequency (RF) radiation, particularly on endocrine organs such as the thyroid gland. This study investigated the effects of 3.5 GHz RF radiation on thyroid hormone levels and oxidative stress markers in male Wistar rats and assessed the potential protective role of quercetin, a natural antioxidant. Twenty-eight rats were randomly assigned to four groups: Sham, RF, Quercetin, and RF + Quercetin. RF exposure was administered at 3.5 GHz (2 W) for 2 hours/day, 5 days/week, for 30 days. Quercetin (20 mg/kg) was administered intraperitoneally. Serum levels of T3, T4, and TSH, as well as thyroid tissue levels of TAS, TOS, GSH, and MDA, were analyzed using ELISA. RF exposure significantly decreased T3 and T4, increased TSH, elevated MDA and TOS, and reduced TAS and GSH levels. Quercetin treatment showed trends toward reversing some of these effects, although not all changes reached statistical significance. SAR simulations confirmed higher energy absorption in the thyroid region (average SAR: 1.128 W/kg). These findings suggest that 3.5 GHz RF radiation may impair thyroid function and redox homeostasis, and that quercetin may exert limited biochemical protection, though further studies are needed to confirm its efficacy. Further long-term molecular studies are warranted to elucidate the mechanisms involved.

Plain Language Summary

With the increasing rollout of 5 G networks, concerns have emerged regarding the potential health impacts of high-frequency radio signals, especially on sensitive organs like the thyroid gland. In this study, researchers explored how repeated exposure to 3.5 GHz RF radiation affects thyroid health in rats, and whether quercetin – a plant-based antioxidant – can offer protection. Rats were exposed to RF radiation for one month, and key hormone and oxidative stress indicators were measured. The results showed that RF exposure disrupted thyroid hormone levels and increased cellular stress. Quercetin treatment showed some potential in alleviating certain changes, though its effects were not consistent across all measured parameters. Simulations also showed high absorption of RF energy in the thyroid area. These findings raise awareness about the possible biological effects of long-term 5 G exposure and suggest that natural antioxidants like quercetin may offer partial protection. Further research is needed to understand how these findings may apply to human health.

https://pubmed.ncbi.nlm.nih.gov/40625224/

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**The effects of short-term and long-term 2100 MHz radiofrequency radiation on adult rat auditory brainstem response**

Er H, Basaranlar G., Derin N., Kantar D, Ozen S. (2025). The effects of short-term and long-term 2100 MHz radiofrequency radiation on adult rat auditory brainstem response. *Open Chemistry*, *23*(1), 20250173. doi: 10.1515/chem-2025-0173.

Abstract

Although mobile phones that work with RFR provide very important benefits for our lives, they may have negative effects. Namely, side effects, such as headaches, sleep disorders, dizziness, lower sperm quality, changes in brain potentials, an increase in oxidative stress levels, and a decrease in antioxidant parameters, have been reported due to mobile phone use. Accordingly, the aim of this research is to investigate the effects of acute and chronic 2100 MHz radiofrequency radiation (RFR) exposure on the auditory brainstem response (ABR) in adult rats. Study groups (*n* = 10 rats): Sh-1: sham for 1 week; Sh-10: sham for 10 weeks; 2100-1: 2100 MHz for 1 week; and 2100-10: 2100 MHz for 10 weeks. RFR groups were applied for 2 h/day (5 day/week) 2100 MHz RFR, whereas sham groups were kept under identical circumstances without RFR. ABR were recorded, and biochemical and ultrastructural examinations in the rat brain were carried out. In the acute RFR group, the latencies of all ABR waves were prolonged compared to the sham group. In the acute RFR group, brain 4-hydroxynonenal, thiobarbituric acid reactive substances, and protein carbonyl content levels increased and catalase and superoxide dismutase activities decreased compared to the acute sham group. Edema in acute RFR group neurons, astrocytes, astrocytic end-feet, and mitochondrial damage in astrocytes were observed. Our data imply that acute exposure to 2100 MHz RFR may have adverse impacts on the auditory system, while chronic exposure with certain rest days has no harmful effects.

Excerpt

In this study, the experimental apparatus and RFR application were identical to those previously reported [5]. However, the RFR frequency, the distance of the rats from the antenna, and therefore, the specific absorption rate (SAR) values were different. In this system, a 2100 MHz radiofrequency generator (Universal Mobile Telecommunication System [UMTS] Simulator 2100 MHz; Everest Company, Adapazari, Turkiye) was used to simulate exposure to UMTS radiation. The electric-field strength measured above the rat's head in the "signal-on" condition was found to be 35.2 V/m. The average SARs for the whole body and brain were 128 mW/kg and 0.27 W/kg, respectively. The computational analysis was conducted utilizing the finite difference time domain method [12]. Published sources were utilized to obtain data on electrical properties, dielectric constant, and conductivity [13,14].

Open access paper: https://www.degruyterbrill.com/document/doi/10.1515/chem-2025-0173/

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**Electromagnetic fields from mobile phones: A risk for maintaining energy homeostasis?**

Seewooruttun C, Mai TC, Corona A, Delanaud S, de Seze R, Bach V, Desailloud R, Pelletier A. Electromagnetic fields from mobile phones: A risk for maintaining energy homeostasis? Annales d'Endocrinologie. 86(3). 2025. doi: 10.1016/j.ando.2025.101782.

Abstract

In the world, there is a near ubiquitous presence of a low-intensity radiofrequency electromagnetic field (RF-EMF) radiation, due to telecommunications as mobile phones. However, their rapid expansion raises concerns about possible interaction with biological mechanisms. The RF-EMF safety guidelines recommended limits to protect against the thermal heating, the most recognized effect at high intensity levels with a known biophysical mechanism. Among all the effects studied, the impact of RF-EMF exposure on thermoregulation is one of the most important aspects of this research. This review aims to present the complex relationship between RF-EMF exposure and thermoregulation, at intensity levels below the threshold to produce thermal effects. In fact, most studies showed that RF-EMF exposure at 900MHz seems to elicit physiological and biological effects similar to responses inducing by cold environment in two different rodent models. In this brief review, we will describe the effects and underlying mechanisms induced by RF-EMF exposure at low levels and discuss the potential implications for environmental health and safety.

Conclusion

In modern society, exposure to RF-EMF is very common and nearly impossible to avoid. Despite its major impact in driving technological advancements, it is important to address the growing public concern in regards to RF-EMF exposure. The thermal effects of high-intensity RF-EMF exposure (SAR > 4 W/kg) are well documented in the literature. However, there is now emerging evidence that low-intensity RF-EMF exposure (SAR < 4 W/kg) can also elicit thermoregulatory responses associated with a cold sensation. The present review highlights the behavioural thermoregulation associated with a cold sensation in rodents exposed to 900 MHz. We also provide molecular insights on RF exposure effects on different thermogenic mechanisms. The first results suggest that RF exposure primarily influences WAT browning rather than BAT thermogenesis, as reported by the up-regulation of UCP1 staining and reduced adipocyte size in WAT depots. In contrast, the cold-induced transcriptional changes on BAT thermogenesis were not observed after exposure to RF, although we detected increased plasma levels of noradrenaline, fatty acids in exposed rats. At short term, these adaptive responses do not seem to compromise homeostasis and therefore the health of organisms, but what about the long-term consequences?

With the introduction of 3.5 GHz for 5G and early use of wireless technology by infants, further research is needed to determine these thermoregulatory effects. Investigating the peripheral tail temperature and thermal preference of 5G-exposed rats at different ages could provide valuable insights into their thermoregulatory responses. Additionally, the implication of the thyroid on these responses need to be more investigated. In fact, the hormones secreted by the thyroid regulate the basic metabolism and the processes implicated in lipolysis in adipose tissues to increase the production of energy in cells and heat by the thermogenesis.

https://www.sciencedirect.com/science/article/pii/S0003426625001015

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**Characterization of the Core Temperature Response of Free-Moving Rats to 1.95 GHz Electromagnetic Fields**

Bala N, Croft RJ, McIntosh RL, Iskra S, Frankland JV, McKenzie RJ, Deng C. Characterization of the Core Temperature Response of Free-Moving Rats to 1.95 GHz Electromagnetic Fields. Bioelectromagnetics. 2025 Jul;46(5):e70013. doi: 10.1002/bem.70013.

Abstract

The present study investigated the core body temperature (CBT) response of free-moving adult male and female Sprague Dawley rats, during and following a 3-h exposure to 1.95 GHz radiofrequency electromagnetic fields (RF-EMFs) within custom-built reverberation chambers, using temperature capsules implanted within the intraperitoneal cavity and data transmitted via radiotelemetry. Comparing RF-EMF exposures (at Whole-Body Average-Specific Absorption Rate [WBA-SAR] levels of 0.1, 0.4, and 4 W/kg) to the sham exposed condition, we identified a statistically significant peak increase in CBT after 26 min of RF-EMF exposure at 4 W/kg (+0.49°C), but not in the 0.1 or 0.4 W/kg conditions at the same timepoint. In the last 30 min of the RF-EMF exposure, temperature was significantly increased in both the 4 W/kg (0.62°C) and 0.4 W/kg (0.14°C) conditions, but not 0.1 W/kg, when compared to sham. After 20 min following cessation of exposure, post temperature was still significantly higher in the 4 W/kg condition when compared to the sham (0.37°C), but not in either 0.1 or 0.4 W/kg. Based on our findings, it is apparent that rats can effectively compensate for increased thermal loads of up to 4 W/kg as the maximum temperature rise was substantially lower than 1°C. In addition, the elevated CBT during exposure in the 4 W/kg condition was significantly reduced immediately after exposure cessation, indicating that measures of CBT following RF-EMF exposure cessation may not reflect maximum RF-EMF-mediated changes in the CBT of rats.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.70013

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**The Influence of an Electromagnetic Field at a Radiofrequency of 900 MHz on the Behavior of a Honey Bee**

Migdał P, Plotnik M, Bieńkowski P, Berbeć E, Latarowski K, Białecka N, Murawska A. The Influence of an Electromagnetic Field at a Radiofrequency of 900 MHz on the Behavior of a Honey Bee. *Agriculture*. 2025; 15(12):1266. doi: 10.3390/agriculture15121266.

Abstract

The development of wireless technology and the desire to improve communication electromagnetic fields (EMFs) of various frequencies have become common across the honey bee's foraging landscape. There has been discussion for many years about the possible impact of electromagnetic fields on living organisms. Artificial radio fields emit frequencies ranging from 100 kHz to 300 GHz. The presented research aimed to demonstrate the influence of the radiofrequency electromagnetic field (RF-EMF) with a frequency of 900 MHz on the behavior of honey bees in laboratory conditions. For this experiment, we used wooden cages to house honey bee workers immediately after they emerged. Bee workers were divided into control and experimental groups. Bees in the control group were not exposed to RF fields, while the experimental groups were exposed to 900 MHz electromagnetic fields of different intensities and durations of exposure. Bees' behavior was analyzed with an appropriate computer program. Behavioral analysis of bees was performed immediately after exposure and seven days after exposure. Our research has shown that the radio field (900 MHz) affects the behavior of bees compared to the

control group, although not all results are statistically significant. Significant effects were observed seven days after exposure in walking, flight, and individual contact. However, it is worth extending the study to include the impact of an RF-EMF on the expression of genes responsible for bee behavior.

Open access paper: https://www.mdpi.com/2077-0472/15/12/1266

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**Mitigation of 3.5 GHz Electromagnetic Field-Induced BV2 Microglial Cytotoxicity by Polydeoxyribonucleotide**

Pachhapure S, Mufida A, Wei Q, Choi J-S, Jang B-C. Mitigation of 3.5 GHz Electromagnetic Field-Induced BV2 Microglial Cytotoxicity by Polydeoxyribonucleotide. *Current Issues in Molecular Biology*. 2025; 47(6):386. doi: 10.3390/cimb47060386

Abstract

Emerging evidence highlights the biological risks associated with electromagnetic fields (EMFs) generated by electronic devices. The toxic effects and mechanisms induced by exposure to EMFs on microglial cells and natural substances that inhibit them are limited to date. Here, we investigated whether exposure to 3.5 GHz EMF radiation, potentially generated by smartphones working in 5G communication or cooking using microwave ovens, affects the growth of BV2 mouse microglial cells and polydeoxyribonucleotide (PDRN), a DNA preparation derived from salmon sperm, inhibits it. Of note, exposure to 3.5 GHz EMF radiation for 2 h markedly inhibited the growth and triggered apoptosis in BV2 cells, characterized by the reduced number of surviving cells, increased genomic DNA fragmentation, increased reactive oxygen species (ROS) levels, and altered phosphorylation and expression levels of JNK-1/2, p38 MAPK, ERK-1/2, eIF-2α, and procaspase-9. Pharmacological inhibition studies revealed that JNK-1/2 and p38 MAPK activation and ROS generation were crucial for 3.5 GHz EMF-induced BV2 cytotoxicity. Of interest, PDRN effectively countered these effects by inhibiting the activation of JNK-1/2, p38 MAPK, and caspase-9, and the production of ROS, although it did not affect eIF-2 phosphorylation. In conclusion, this study is the first to report that PDRN protects against 3.5 GHz EMF-induced toxicities in BV2 microglial cells, and PDRN's protective effects on 3.5 GHz EMF-induced BV2 cytotoxicity are mediated primarily by modulating ROS, JNK-1/2, p38 MAPK, and caspase-9.

Open access paper: https://www.mdpi.com/1467-3045/47/6/386

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**The influence of Wi-Fi on the mesonephros in the 9-day-old chicken embryo**

Almášiová V, Andrašková S, Karaffová V, Hudáková P, Molnár J, Tóth Š, Holovská K. The influence of Wi-Fi on the mesonephros in the 9-day-old chicken embryo. Vet Res Commun. 2025 Jun 10;49(4):216. doi: 10.1007/s11259-025-10777-x.

Abstract

The use of wireless devices has increased rapidly in recent times, especially in developed countries. As a result, all living systems are to some extent permanently exposed to this artificial electromagnetic non-ionizing radiation (NIR). These modern devices provide countless benefits to the users, but the disadvantage of their excessive use is the production of electrosmog. This physical pollutant of the

environment can be particularly dangerous especially during the developmental period of the individual. The aim of the current study was to elucidate the effect of Wi-Fi radiation on the mesonephros development in the chicken embryo on day 9 of incubation. Continual 9-day application of radiation with a frequency of 2.4 GHz and a power density of 200-500 $\mu W/m^2$ had no adverse effect on the general development of the mesonephros, however moderate diffuse degenerative changes were found in the developing mesonephric corpuscles and tubules. Also congested blood vessels were present in the surrounding interstitium, but no signs of inflammatory infiltrate were detected. In the Wi-Fi group, we also noted a significantly increased number of apoptotic and proliferating cells as well as a significant up-regulation of caspase-1 gene expression. The results indicated that non-ionizing radiation at the frequency and power density used in the study can interfere with the key regulatory mechanisms involved in the normal development of tissues and organs.

https://link.springer.com/article/10.1007/s11259-025-10777-x

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**The proliferation rates of HT-1080 human fibrosarcoma cells can be accelerated or inhibited by weak static and extremely low frequency magnetic fields**

Marek B, Nhat D, de Mingo Isabel L, Jason K, Hakki G, Ladislav J, Barnes F. The proliferation rates of HT-1080 human fibrosarcoma cells can be accelerated or inhibited by weak static and extremely low frequency magnetic fields. Frontiers in Public Health. Volume 13 - 2025. doi: 10.3389/fpubh.2025.1535155.

Abstract

Introduction Weak static and low-frequency magnetic fields (MFs) have been hypothesized to influence biological systems through mechanisms involving nuclear spin coupling. This study investigates how such fields modulate the proliferation of HT-1080 fibrosarcoma cells.

Methods HT-1080 cells were exposed in vitro for 4 days to weak MFs with a 10 µT amplitude and frequencies between 12 Hz and 33 Hz, superimposed on a 45 µT static background field. Changes in cell growth, mitochondrial superoxide (O2−), calcium ion (Ca2+) concentrations, and membrane potential were measured.

Results Results revealed that MFs could either increase or decrease fibrosarcoma cell growth in a frequency- and amplitude-dependent manner. Inversions in growth rates were observed near 16.5 Hz, where a 0.5 Hz shift or amplitude changes as small as 250 nT reversed effects relative to controls. Reversing the static field direction also inverted growth outcomes. Changes in membrane potential, Ca2+, and mitochondrial superoxide levels supported a role for bioenergetic modulation.

Discussion These findings suggest that weak MFs affect cell proliferation through spin-dependent chemical reaction rate changes. The pronounced sensitivity of fibrosarcoma cells compared to normal fibroblasts points to potential therapeutic applications via selective MF-based modulation.

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1535155

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**Impact of magnetic fields from tablets, laptops, smartphones, and household/leisure magnets on cardiac implantable electronic devices**

Kamitani N, Miyazaki A, Tomida S, Shimizu K, Ohira N, Kondo K, Miura H, Koyama D, Tominaga S, Henmi R, Sugiura R, Masui H. Impact of magnetic fields from tablets, laptops, smartphones, and household/leisure magnets on cardiac implantable electronic devices. J Arrhythm. 2025 Jun 30;41(4):e70106. doi: 10.1002/joa3.70106.

Abstract

Background Cardiac implantable electronic devices (CIEDs) activate the magnet response at a magnetic flux density of ≥10 gauss (G), which may cause unintended pacing, leading to discomfort or even severe arrhythmias. Information processing devices have recently incorporated magnets, which may activate the magnet mode in patients with abdominally implanted devices, subcutaneous implantable cardioverter-defibrillators (ICDs), or extravascular ICDs.

Methods We investigated the effects of the magnetic fields generated by information processing devices (tablets, laptops, and smartphones) and household/leisure magnets on 13 models of CIEDs, analyzing their association with magnet mode activation in different manufacturers' CIEDs.

Results The tested magnet materials exhibited a maximum magnetic flux density of 290–1360 G. The magnetic flux density distribution in the information processing devices was as follows: accessory connectors, speakers, cameras, and microphones ($p = 0.0001$). The median activation distances for the magnet mode were 6.5 (range, 4–15), 5 (4–11.3), and 0.01 (activated only when attached; 0–7) mm for tablets and laptops, smartphones, and household/leisure magnets, respectively ($p < 0.0001$). The maximum distance at which the magnetic flux density decreased below 10 G was the longest for tablets and laptop computers at 18 mm.

Conclusion Information processing devices and household/leisure magnets can affect CIEDs when placed in close proximity. Among the devices tested, magnet mode activation did not occur at distances of ≥20 mm. Considering the increasing prevalence of information processing devices and the growing adoption of nonthoracic CIED placements, raising awareness among patients about potential interactions is crucial.

Open access: https://pmc.ncbi.nlm.nih.gov/articles/PMC12209319/

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**SAR Estimations in a Classroom with Wireless Computers**

Soares NE, Bulla G, Fernández-Rodríguez CE, de Salles AAA. SAR Estimations in a Classroom with Wireless Computers. J. Microw. Optoelectron. Electromagn. Appl. 24 (02) • 202. https://doi.org/10.1590/2179-10742025v24i3288526

Abstract

This research provides detailed examination of the peak spatial Specific Absorption Rate (psSAR) in different age students in a classroom with wireless computers. This is motivated by the escalating inclusion of electronic devices in educational settings and the necessity to estimate the implications of this on the overall radio-frequency exposure. Two classrooms with posable realistic human models are

simulated. One filled with several 7 years old children and another with several 43 years old adult, each using a laptop. The 1 g and 10 g psSAR are calculated for the head, back and hands. The distances between students are varied and the results compared to one student alone. A small free distance between rows (10 cm) produces significant reduction in psSAR (around 13 dB). Results are less sensitives to changes in lateral distance. While the maximum simulated psSAR values are below the recommended limits, it is observed that, in some classroom arrangements, the psSAR can be substantially increased (e.g., up to 26 dB in the back) comparing to just one student with his laptop. One objective of this study is to provide guidelines for the design of safer classrooms in the context of widespread laptop usage.

Excerpts

"The psSAR simulation in a classroom should consider the interaction between multiple EMF sources and the matter in the environment. While other sources such as smartphones and routers can be present, for simplicity, only the laptop of each student connected in a Wi-Fi network is considered.

The 2.45 GHz band was chosen for computational reasons. Using the 5 GHz band would have increased the mesh by 10-fold.

According to the IEEE 802.11-2020 Standard, the maximum delivered power is 100 mW. This value is used in the simulations. The simulated signals are continuous waves (CW) at the center of the band or CW modulated by a gaussian pulse to cover the whole band."

"The psSAR values obtained in this study, even for the worst case, are below the safety limits recommended by the ICNIRP [2] and IEEE [14]. However, since children can stay in the classrooms for a long time, it is important to observe that long-term exposure to low levels of electromagnetic radiation should also be considered, since they can produce health effects too [1]. Among others, long time exposure can be of serious concern, due to possible biochemical effects not considered in the simulations. Further to that, other EMF sources, such as smartphones, can be used simultaneously in the classrooms and therefore should also be considered in the simulations."

"CONCLUSIONS

The results show that, generally the psSAR decreases as the distance between students' desks increases, as expected. Increased EMF exposure in the classroom were observed when comparing with one student alone, such as up to 4-fold in the hands, 45-fold in the head and 40-fold in the back/dorsal.

Fluctuations in the psSAR plots can be due to the EMF multipath random combinations in amplitude and phase. Also, it is observed that as the distance is increased, the positions of the psSAR are displaced along the body. For instance, in the head, the psSAR is displaced from one ear to the nose and to the other ear. Simulations show that hot spots position varies, since EMF may be increased or diminished when distance is varied, depending on the EMF phase.

Overall, simulations show that if the distance between the chair and the back desk is increased, then the EMF exposure is reduced. E.g., for 5 cm distance increase, the EMF exposure in the back can be reduced around 63 percent and for 50 cm distance increase, the EMF exposure can be reduced around 90 percent.

In order to reduce the EMF health risks, the authors suggest that wireless communications should be avoided in places where people could stay for long time, such as in the classrooms, libraries, offices,

homes, etc., and the devices should then be connected using cables (e. g., ethernet or fiber optic), increasing therefore the bandwidth and reducing energy consumption."

Open access paper: https://www.scielo.br/j/jmoea/a/hS9VJvKddrTsTtyqLrVdNZx/?lang=en#

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**Bus-exposure matrix, a tool to assess bus drivers' exposure to physicochemical hazards**

Remy VFM, Innocent G, Vernez D, Guseva Canu I. Bus-exposure matrix, a tool to assess bus drivers' exposure to physicochemical hazards. Ann Work Expo Health. 2025 Jun 20:wxaf036. doi: 10.1093/annweh/wxaf036.

Abstract

Swiss bus drivers suffer from musculoskeletal disorders, fatigue, and stress and have an excessive mortality from lung cancer and suicide compared to other workers. However, their occupational exposure is poorly documented. We created a bus-exposure matrix (BEM) to determine occupational exposures to 10 types of physical-chemical hazards for 705 bus models used in Switzerland since 1980. For this, we made a comprehensive bus inventory and review of 50 technical characteristics of each bus model, identified 10 bus models representative of the Swiss bus fleet evolution, and conducted static and dynamic exposure measurement campaigns in the representative buses. The measured values were then extended to the entire fleet using Integrated Nested Laplace Approximation (INLA) models. The choice of predictors and technical bus characteristics included in the models were based on directed acyclic graphs. To demonstrate the usefulness of the BEM as an exposure assessment tool, we used data from the 2022 survey of Swiss bus drivers who listed the bus models they had driven during their careers. The BEM linkage with these bus drivers' histories enabled us to estimate annual exposure to PM10 ratio (-), ultrafine particle ratio (-), whole-body vibration (m/s2), floor vibration (m/s2), equivalent noise (dB(A)), peak noise (dB(C)), high-frequencies electric fields (V/m), low-frequencies magnetic field (μT), low-frequencies electric fields (V/m), and air exchange rate (1/h) of 809 Swiss bus drivers. Historical data assessment from 1985 through 2022 showed that peak noise, high- and low-frequencies electric field levels have increased, while PM10 ratio, ultrafine particle ratio, equivalent noise, whole-body vibration levels, and air exchange rate have decreased. This, first in the world, BEM is an original tool for retrospective exposure assessment that will enable further research in the occupational health of bus drivers.

https://pubmed.ncbi.nlm.nih.gov/40578599/

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**Human achromatic flickers and phosphenes thresholds under extremely low frequency electric stimulations**

Bouisset N, Carvallo A, Laporte M, Legros A. Human achromatic flickers and phosphenes thresholds under extremely low frequency electric stimulations. Sci Rep. 2025 Jul 3;15(1):23779. doi: 10.1038/s41598-025-06271-8.

Abstract

Human exposure to extremely low-frequency (< 300 Hz) electric/magnetic fields elicits a stroboscopic visual perception called electro/magneto phosphenes. The induction of phosphenes is the most exhaustively documented effect of in-situ electric fields. Thus, they are used by international guidelines as the basis for limiting human exposure to extremely low-frequency electric and magnetic fields. This study aimed to estimate the phosphene perception locus and threshold during an electric current stimulation for four different frequencies (20, 50, 60, and 100 Hz) and to estimate the associated in-situ electric field. Phosphene perception probabilities were calculated in 20 volunteers using binary logistic regressions applied to perceptual responses resulting from non-invasive transcranial alternating current stimulation between 0 and 2 mA delivered at 20, 50, 60, and 100 Hz. A dosimetry analysis was done to study the in-situ electric field induced in the retina during the electric stimulation. The data indicate that the stimulation current plays a significant role in the model's predictions across all frequencies. Phosphene perception thresholds were lowest at 20 Hz, while no perceptible phosphene were observed at 100 Hz. The findings of this study are crucial for understanding the mechanisms of phosphene induction and further support the retinal origin of phosphenes. The observed thresholds and trends will inform updates to international guidelines and standards.

Open access: https://www.nature.com/articles/s41598-025-06271-8

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**Influence of geomagnetic disturbances on myocardial infarctions in women and men from Brazil**

Rezende LFC, De Paula ER, Muella MTAH, Dutra SLG, Rosa RR, Saldiva PHN, Ometto JPHB. Influence of geomagnetic disturbances on myocardial infarctions in women and men from Brazil. Commun Med (Lond). 2025 Jul 1;5(1):247. doi: 10.1038/s43856-025-00887-7.

Abstract

Background  Understanding the role of space weather, specifically Geomagnetic Disturbances (GMDs) caused by solar activity, on health outcomes is unclear. One emerging link includes the impact of space weather on myocardial infarctions (MI). In this study we examined the correlation between MI and GMDs in Brazil.

Methods  We used a database from the public health in Brazil, focusing on the city of São José dos Campos (23° 10′ 44″ S, 45° 53′ 13″ W), located in the state of São Paulo, during the period of 1998–2005. We focused on admissions for MIs, which included a total of 871 men and 469 women. We categorized the MI data into three age groups: age 30 and younger, age 31–60, and age over 60. Additionally, we incorporated Planetary Index (Kp) data as an indicator of variations in the Earth's geomagnetic field resulting from solar disturbances, categorized as quiet, moderate, or disturbed days. In our analysis, we employed two methods: statistical counting and the unsupervised clustering known as K-Means, considering the attributes of age, sex, and geomagnetic condition.

Results  Here we show that geomagnetic conditions have an impact on MI cases, particularly for women. The rate of relative frequency of MI cases during disturbed geomagnetic conditions is almost three times greater compared to quiet geomagnetic conditions. Using the unsupervised K-Means algorithm, the results indicate that the group associated with disturbed geomagnetic conditions has a higher incidence of MIs in women.

Conclusions  Overall, our results provide evidence that women may exhibit a higher susceptibility to the effects of geomagnetic disturbances caused by solar activity on MI.

Open access: https://pmc.ncbi.nlm.nih.gov/articles/PMC12216950/

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**A comprehensive mechanism of biological and health effects of anthropogenic extremely low frequency and wireless communication electromagnetic fields**

My note: This well-referenced literature review (373 refs.) explains how electromagnetic fields (EMF) produced in wireless communications--which are polarized, coherent microwaves with highly variable intensity and modulated and pulsed at extremely low frequencies--cause "cancer, infertility, electro-hypersensitivity, and various other pathologies."

Panagopoulos DJ, Yakymenko I, De Iuliis GN, Chrousos GP. A comprehensive mechanism of biological and health effects of anthropogenic extremely low frequency and wireless communication electromagnetic fields. Front. Public Health, Volume 13 – 2025. https://doi.org/10.3389/fpubh.2025.1585441.

Abstract

Exposure to anthropogenic electromagnetic fields (EMFs), especially those of wireless communications (WC) has increased tremendously. This is an unprecedented phenomenon throughout biological evolution because, all anthropogenic EMFs, being fully polarized, coherent, and, especially WC EMFs, highly variable, differ substantially from the natural EMFs. WC EMFs consist of Microwave (MW) carrier waves, modulated, by Extremely Low Frequency (ELF) signals, and included in on/off pulses repeated at various ELF rates. Moreover, they exhibit intense random variability, mainly in the Ultra Low Frequency (ULF) band. Thus, WC EMFs are a combination of MW and ELF/ULF EMFs. The combination of polarization/coherence and intense low-frequency (ELF/ULF) variability seems to be the key to EMF-bioactivity. Epidemiological and laboratory studies highlight a connection between ELF or WC EMF exposure and cancer, infertility, electro-hypersensitivity, and various other pathologies. Studies also find DNA damage and Oxidative Stress (OS) which explain these pathologies. While man-made EMFs cannot directly ionize molecules, they are capable of doing this indirectly in biological tissue, by triggering the biosynthesis of Reactive Oxygen Species (ROS) which can damage biomolecules, including DNA. The (over)production of ROS and the consequent OS are triggered by irregular gating of Voltage-Gated Ion Channels (VGICs) in the cell membranes as described by the Ion Forced Oscillation (IFO)-VGIC mechanism: Mobile ions within VGICs forced to oscillate by the applied ELF/ULF EMFs exert forces on the voltage sensors of the VGICs, similar to or greater than the forces that physiologically gate those channels, resulting in their irregular gating (dysfunction). Dysfunction of ion channels disrupts intracellular ionic concentrations. This triggers ROS overproduction and OS by the ROS-generating systems/enzymes in the cells, such as the electron transport chain (ETC) in the mitochondria, or the NADPH/NADH oxidases (NOXs), the Nitric Oxide synthases (NOS), etc. The IFO-VGIC mechanism and the consequent OS constitute a comprehensive mechanism that explains all known adverse biological and health effects reported to be induced by anthropogenic EMFs.

Excerpts

"The recorded human and animal carcinogenicity, the DNA/genetic damage, the OS findings, and the reproductive declines due to DNA damage in ovarian or sperm cells or embryonic death, all point toward the same direction: Man-made EMFs induce OS and DNA damage, infertility, cancer, and other related pathologies. The reason why the same effects are observed in a wide variety of animals such as mammals, birds, insects, etc., and humans, is that all biological and health effects initiate in cells and all cells are essentially identical in all animals, humans, and even plants. They have identical membranes, ions, ion channels and pumps, biomolecules such as DNA, RNA, proteins, etc., water, ROS, identical cellular organelles such as nuclei, mitochondria, ribosomes, endoplasmic reticulum, etc., and very similar metabolic processes and regulatory mechanisms. These similarities at the cellular level between all animals and humans are much more fundamental than differences in volume, mass, shape, macroscopic functions, intelligence, etc. As a result, any effect induced by EMFs in animal cells such as OS, DNA damage, etc., is expected to be induced also in the human cells, and vice-versa (7, 66).

The exposure levels in the vast majority of all the aforementioned studies were significantly below the officially accepted exposure limits for ELF and RF EMFs, which are recommended by a private organization called the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to prevent discharges on humans in the case of ELF and acute heating of living tissues in the case of RF/WC EMFs. It is remarkable that this organization arbitrarily ignores the overwhelming evidence of non-thermal effects which constitute the vast majority of effects of anthropogenic EMFs, and yet, governments adopt its recommendations instead of following the Precautionary Principle which dictates the obvious, that no new technology should be applied unless those who promote it have proven its safety beyond any doubt (50, 217–226).

The International Agency for Research on Cancer (IARC) branch of the World Health Organization (WHO), has, since long time, classified both ELF and “RF” (in fact WC) EMFs as possibly carcinogenic to humans (Group 2B) (204, 205, 227). Based on additional scientific evidence after the 2011 IARC classification for “RF” EMFs, several studies have argued that “RF”/WC EMFs should be re-evaluated and classified as probably carcinogenic (Group 2A) or carcinogenic (Group 1) to humans (50, 63, 64, 66, 118–120, 171, 179, 182, 183, 218, 219). Moreover, studies have asked for the urgent application of the Precautionary Principle, stricter exposure limits, especially for WC EMFs, and a moratorium on 5G rollout (50, 215, 217, 218, 225, 228)."

"In conclusion, the IFO-VGIC mechanism that explains VGIC dysfunction, and the subsequent OS, provide a comprehensive biophysical/biochemical mechanism explaining the plethora of experimental and epidemiological findings connecting anthropogenic EMF exposures with OS, DNA/cellular damage and related pathologies such as poor health, EHS, infertility, organic/neurodegenerative diseases, cancer, etc. Even though the mechanistic details of how exactly the ionic perturbations stimulate ROS production by their sources need to be further explored, the basic scheme of the complete EMF-bioeffects mechanism is revealed already. The long existing experimental and epidemiological findings connecting exposure to man-made EMFs and DNA damage, infertility, and cancer, are now explained by the presented comprehensive mechanism. We hope this provides a better understanding of the involved science, a basis for future research, and the establishment of biologically relevant EMF exposure guidelines for effective protection of public health and the environment."

Open access paper:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1585441/full

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**Rapid Deployment of 5G Wireless Communication and Risk Assessment on Human Health: Quid Novi?**

Selmaoui B, Jamal L, Michelant L. Rapid Deployment of 5G Wireless Communication and Risk Assessment on Human Health: Quid Novi? Bioelectromagnetics. 2025 May;46(4):e70005. doi: 10.1002/bem.70005. PMID: 40276940.

No abstract.

Excerpt

"... the swift and widespread rollout of 5G has not been without controversy. Alongside the excitement over its potential, significant concerns have emerged regarding its potential impact on human health. These concerns stem from the increased exposure to electromagnetic fields (EMFs) associated with 5G technology, particularly as it operates on higher frequency bands, including millimeter waves. Consequently, given the lack of publications concerning the effects of frequencies implemented for 5G (3.5–26 GHz) for the general public, more in-depth studies need to be established due to the increased debates and inconclusive reports about the subject.

Given that 5G is a relatively new technology, short- and long-term studies are still in progress to assess its health implications comprehensively. For this purpose, the European Union Commission via their institutions has launched a call for proposals in the environmental health topic (HORIZON-HL-TH-2021-ENVHLTH-02). This program was implemented to answer to the public concern about the health effect of 5G exposure. The total amount of funding was 30 million euros from Horizon Europe 2021–2027. The results should fill the current knowledge gaps on the effects of wireless technologies on health and the environment. Four projects funded by Horizon Europe have been brought together under the CLUE-H network, involving more than 60 European research organizations across four research consortia: ETAIN, GOLIAT, NextGEM, and SEAWave. Additionally, scientists from outside Europe, including the USA, Korea, and Japan, are also collaborating on these projects...."

Conclusion

"The rapid deployment of 5G brings unprecedented opportunities for technological innovation but also necessitates thorough and ongoing risk assessment regarding its potential health impacts. While current scientific consensus generally supports the safety of 5G under existing guidelines, the evolving nature of the technology, coupled with the long-term uncertainty, underscores the importance of continued research, transparent communication, and adaptive regulatory frameworks. As 5G becomes more ubiquitous, balancing its benefits with precautionary health measures will be crucial to ensuring public trust and safety."

Open access paper: https://onlinelibrary.wiley.com/doi/full/10.1002/bem.70005

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**5G-exposed human skin cells do not respond with altered gene expression and methylation profiles**

(My note: Contrary to the title of this paper and media reports, this was not a 5G study because it tested continuous waves in the millimeter band.)

Jyoti J, Gronau I, Cakir E, Hütt M-T, Lerchl A, Meyer V. 5G-exposed human skin cells do not respond with altered gene expression and methylation profiles, *PNAS Nexus*, 4(5), May 2025, doi: 10.1093/pnasnexus/pgaf127.

Abstract

Due to the ever-increasing wirelessly transmitted data, the development of new transmission standards and higher frequencies in the 5G band is required. Despite basic biophysical considerations that argue against health effects, there is public concern about this technology. Because the skin penetration depth at these frequencies is only 1 mm or less, we exposed fibroblasts and keratinocytes to electromagnetic fields up to ten times the permissible limits, for 2 and 48 h in a fully blinded experimental design. Sham-exposed cells served as negative, and UV-exposed cells as positive controls. Differences in gene expression and methylation due to exposure were small and not higher than expected by chance. These data strongly support the assessment that there is no evidence for exposure-induced damage to human skin cells.

This study was funded by the Bundesamt für Strahlenschutz (FKZ 3619S82470).

Open access paper: https://academic.oup.com/pnasnexus/article/4/5/pgaf127/8124427

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**Impact of mobile phone-emitted non-ionizing electromagnetic radiation on parotid gland function: A comprehensive study**

Jacob RA, Jose M, Pai VR, Kalal BS. Impact of mobile phone-emitted non-ionizing electromagnetic radiation on parotid gland function: A comprehensive study. *International Journal of Risk & Safety in Medicine*. 2025;0(0). doi:10.1177/09246479251342488.

Abstract

Background and Objective  The rapid proliferation of mobile technology has intensified debates on the potential adverse effects of non-ionizing electromagnetic radiation (NIER) from mobile phones on various human organs and cells. This study aimed to evaluate the impact of mobile phone-emitted NIER on parotid gland function.

Methodology  This cross-sectional study included 104 student volunteers from the University campus, categorized based on their mobile phone usage and exposure duration. Saliva samples were collected from the dominant (test) and non-dominant (control) sides. Key metrics measured were salivary flow rate, pH, albumin, Ischemia-Modified Albumin (IMA), and the IMA/albumin ratio (IMAR). Data analysis was performed using one-way ANOVA and Fisher's LSD multiple comparisons, with $p \leq 0.05$ considered

statistically significant.

Results  The salivary flow rate and pH were higher on both sides in all groups, correlating with increased mobile phone usage duration. Although albumin levels were lower on the dominant side, they increased with longer mobile phone use. Salivary IMA and IMAR were higher on the dominant side in subjects using mobile phones for ≤3 years compared to those using them for >3 years.

Interpretation and Conclusion  Consistent exposure to NIER and the heat generated by mobile phones adversely affects parotid gland function, as indicated by increased salivary flow rate, pH, and altered levels of albumin, IMA, and IMAR. Public health recommendations should encourage reducing long-duration conversations and using earphones to minimize NIER exposure. Further studies are needed to evaluate the long-term effects of NIER on parotid gland function.

https://journals.sagepub.com/doi/10.1177/09246479251342488

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**Epidemiological criteria for causation applied to human health harms from RF-EMF exposure: Bradford Hill revisited**

Frank JW. Epidemiological criteria for causation applied to human health harms from RF-EMF exposure: Bradford Hill revisited. Front. Public Health, 26 May 2025. Volume 13. doi: 10.3389/fpubh.2025.1559868.

Abstract

Purpose: This paper reviews the applicability of standard epidemiological criteria for causation, to the multidisciplinary studies of RF-EMF exposure and various adverse biological and health effects, with the aim of demonstrating that these criteria, although 60 years old, are still helpful in this context—albeit in some cases not entirely straightforward to apply.

Methods: This is a commentary, based on Bradford Hill's criteria for assessing evidence of causation, applied to recent primary studies and systematic reviews of the RF-EMF/health-effects literature. Every effort has been made to use non-epidemiological language to reach a wide readership of biologists, physicists, and engineers now active in this field.

Results: A rapidly growing number of human observational epidemiological studies have assessed the association of diverse adverse health effects with RF-EMF exposures. However, existing systematic reviews and meta-analyses of these primary studies have substantially diverged in their conclusions. The application of Bradford Hill's epidemiological criteria for assessing evidence of causation, originally designed for use in occupational and environmental health, casts light on some of reasons for this divergence, mostly reflecting the key weaknesses in the primary literature, which are discussed in detail. As a result of these threats to their validity—particularly the facts that (1) exposure measurement is typically subject to substantial error, and (2) insufficient time has elapsed, since modern cell phone use began in earnest, to allow tumors of longer latency to develop—most primary studies to date, and therefore many published systematic reviews of them, probably underestimate the true potential for

causation, if in fact this association is causal.

Conclusion and recommendations: In view of these findings, international experts representing professional and scientific organizations in this field should convene an independent Guidelines development process to inform future epidemiological studies of associations between RF-EMF exposures and human health outcomes. Wide dissemination of such Guidelines could help researchers, journals and their reviewers in this field to execute, review and publish higher-quality studies to better inform evidence-based policy.

Open access paper:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1559868

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**Skin Fibroblasts from Individuals Self-Diagnosed as Electrosensitive Reveal Two Distinct Subsets with Delayed Nucleoshuttling of the ATM Protein in Common**

Sonzogni L, Al-Choboq J, Combemale P, Massardier-Pilonchéry A, Bouchet A, May P, Doré J-F, Debouzy J-C, Bourguignon M, Dréan YL, et al. Skin Fibroblasts from Individuals Self-Diagnosed as Electrosensitive Reveal Two Distinct Subsets with Delayed Nucleoshuttling of the ATM Protein in Common. *International Journal of Molecular Sciences*. 2025; 26(10):4792. doi: 10.3390/ijms26104792.

Abstract

Electromagnetic hyper-sensitivity (EHS) and its causal link with radio-frequencies raise a major question of public health. In the frame of the clinical study DEMETER, 26 adult volunteers self-diagnosed as EHS-positive agreed to reply to a self-assessment questionnaire and to provide a skin biopsy sampling to establish a primary fibroblast cell line. The questionnaire and the biological data revealed, independently, 2 subsets of donors associated each with a low background, highly responsive (LBHR) and a high background, lowly responsive (HBLR) phenotype. A couple of subsets based on questionnaire data and based on the yield of spontaneous DNA double-strand breaks were found to be composed of the same donors at 64% identity. After exposure to X-rays, and application of anti-γH2AX, pATM, and MRE11 immunofluorescence, all the DEMETER fibroblasts (26/26) elicited a delayed radiation-induced ATM nucleoshuttling (RIANS). The use of RIANS biomarkers showed that the 2 phenotypes described above corresponded to DEMETER donors with a high risk of cancer (LBHR) or high risk of accelerated aging (HBLR). By exposing DEMETER cells to $H_2O_2$ followed by an antioxidative agent, we confirmed that EHS may be related to the management of DNA strand breaks. A preliminary molecular model of EHS inspired by the RIANS model was proposed.

Open access paper: https://www.mdpi.com/1422-0067/26/10/4792

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**Exposure Perception and Symptom Reporting in Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields Using a Co-Designed Provocation Test**

Ledent M, Bordarie J, Vatovez B, Dieudonné M, Prignot N, Vanderstraeten J, Bouland C, De Clercq EM. Exposure Perception and Symptom Reporting in Idiopathic Environmental Intolerance Attributed to

Electromagnetic Fields Using a Co-Designed Provocation Test. Bioelectromagnetics. 2025 Apr;46(3):e70006. doi: 10.1002/bem.70006.

Abstract

Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields (IEI-EMF) is a syndrome that defines people who report symptoms that they attribute to their exposure to EMF sources, without any identified underlying medical condition to explain these symptoms. To date, provocation protocols have failed to demonstrate a consistent relationship between EMF exposure and reported symptoms, raising questions among some researchers and individuals with IEI-EMF about the relevance of these protocols for studying the syndrome. To address these criticisms, a provocation protocol was co-designed in collaboration with individuals with IEI-EMF. This study presents the results of the tests, with a focus on exposure perception and symptom reporting among IEI-EMF volunteers. A total of 47 IEI-EMF volunteers were enrolled and participated in an open-field habituation session. Of these, 27 completed the first double-blind controlled exposure session, while 26 and 16 volunteers, respectively, participated in three sessions for collective analyses and 12 sessions for individual-level analyses. At the individual level, no consistent association was found between exposure perception certainty level and exposure status, except for one volunteer whose perception was mostly consistent with exposure status. Similarly, symptom reporting did not align with exposure status, except for the same volunteer, whose symptom reporting showed a borderline significant result with exposure status. However, for half of the volunteers, symptom reporting was significantly correlated with exposure perception certainty level, supporting a nocebo hypothesis. At the collective level, no consistency was observed between exposure perception certainty level, symptom reporting, and exposure status. This study discusses the conditions necessary for future provocation protocols to enhance their relevance, acceptability, and potential utility in a possible care-oriented approach. It also considers criticisms of using exposure perception and symptom reporting as outcomes in provocation protocols, despite their central role in how individuals identify themselves as individuals with IEI-EMF.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.70006

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**Electrohypersensitivity: what is belief and what is known?**

de Vocht F, Martin Röösli M. Electrohypersensitivity: what is belief and what is known? Frontiers in Public Health. Vol. 13. 2025. doi:10.3389/fpubh.2025.1603692.

No abstract

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1603692/full

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**What is the effect of alarmist media and radiofrequency electromagnetic field (RF-EMF) exposure on salivary cortisol and non-specific symptoms?**

Verrender A, Wallace NK, Loughran SP, Wallace C, Beange J, Croft RJ (2025). What is the effect of alarmist media and radiofrequency electromagnetic field (RF-EMF) exposure on salivary cortisol and non-specific symptoms? *Applied Psychology: Health and Well-Being*, 17(3), e70044. https://doi.org/10.1111/aphw.70044.

Abstract

While there is consistent evidence that the symptoms reported by people who experience Idiopathic Environmental Intolerance attributed to Electromagnetic Fields (IEI-EMF) are closely associated with a nocebo effect, and that alarmist media reports may contribute to this nocebo effect, some methodological criticisms remain to be resolved. This study aimed to replicate previous findings and determine whether viewing an alarmist media report and being openly exposed to radiofrequency electromagnetic fields (RF-EMF) could induce a salivary cortisol response. A total of 144 participants were randomly assigned to watch either an alarmist or control video before completing an open-label provocation trial where they were either exposed or not exposed to RF-EMF. Personality factors, RF-EMF risk perception (pre- and post-video), symptoms and salivary cortisol were assessed. Consistent with previous studies, participants who were aware that they were being exposed had increased symptoms compared to participants who were aware they were not being exposed. However, the current study failed to replicate an effect of viewing an alarmist media report and being openly exposed to RF-EMF on symptoms and failed to identify an effect on salivary cortisol. This suggests that awareness and belief of exposure play a more important role in symptom perception than underlying physiological processes.

CONFLICT OF INTEREST STATEMENT

Sarah P. Loughran receives funding from the National Health and Medical Research Council of Australia (NHMRC). She is the Director of Radiation Research and Advice at the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), a member of the Scientific Expert Group at the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and a member of the World Health Organisation Task Group on Radiofrequency Fields and Health Risks. Rodney J. Croft receives funding from the National Health and Medical Research Council of Australia (NHMRC) and is a member of the Scientific Expert Group at the International Commission on Non-Ionizing Radiation Protection (ICNIRP). No potential competing interests were reported by the remaining authors.

Open access paper: https://iaap-journals.onlinelibrary.wiley.com/doi/full/10.1111/aphw.70044

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**Exploring the impact of environmental factors on male reproductive health through epigenetics**

Zhang Y, Song JY, Sun ZG. Exploring the impact of environmental factors on male reproductive health through epigenetics. Reprod Toxicol. 2025 Mar;132:108832. doi: 10.1016/j.reprotox.2025.108832. Epub 2025 Jan 6. PMID: 39778664.

Abstract

Male infertility has become an increasingly severe global health issue, with its incidence significantly rising over the past few decades. This paper delves into the crucial role of epigenetics in male reproductive health, focusing particularly on the effects of DNA methylation, histone modifications,

chromatin remodeling and non-coding RNAs regulation on spermatogenesis. Exposure to various environmental factors can cause sperm DNA damage, leading to epigenetic abnormalities. Among these factors, we have discussed heavy metals (including Zinc, Cadmium, Arsenic, Copper), phthalates, electromagnetic radiation, and temperature in detail. Notably, aberrations in DNA methylation are closely associated with various symptoms of male infertility, and histone modifications and chromatin remodeling are essential for sperm maturation and function. By synthesizing existing literature and experimental data, this narrative review investigates how environmental factors influence male reproductive health through epigenetic mechanisms, thus providing new theoretical foundations and practical guidelines for the early diagnosis and treatment of male infertility.

Excerpt

3.3 Electromagnetic radiation and sperm epigenetics

The operating frequencies for analog mobile phones are 450–900 MHz, digital phones (Global System for Mobile Communications) range from 850 to 1900 MHz, and third-generation phones operate around 2000 MHz[144]. Electromagnetic waves (EMW) can affect sperm epigenetics through two mechanisms: 1. EMW-specific effects 2. Thermal molecular effects [145].

Experiments have found that when male rats were exposed to Wi-Fi from laptops for seven hours daily, there was a reduction in sperm count and motility within a week [146,147]. Additionally, the thermal effects of electromagnetic radiation increase free radicals around the testes, which oxidize the phospholipids in the sperm outer membrane, thus reducing membrane fluidity and impairing motility [148].

Furthermore, oxidative stress mediated by electromagnetic radiation leads to the phosphorylation of heat shock proteins, causing chromatin damage [148], thereby altering sperm epigenetics. Mice lacking Hsp90 or with highly phosphorylated Hsp proteins show cessation of spermatogonia during meiosis, leading to loss of germ cells and reduced testicular size [149]. Research indicates that Hsp90 possesses ATPase activity, stimulated by nuclear autoantigenic sperm protein (NASP) in mouse sperm nuclei [150]. A deficiency in Hsp90 or high phosphorylation of Hsp proteins can halt spermatogonia during meiosis, leading to germ cell loss and reduced testicular size [149].

In vitro animal studies by Liu et al. [151] concluded that radiofrequency radiation could have detrimental effects on human semen quality. Research has found that carrying a mobile phone or Bluetooth headset in a trouser pocket or on the waist can decrease the proportion of sperm with rapid progressive motility and increase the rate of abnormal sperm morphology [152]. Therefore, men should avoid placing mobile phones near the trousers pocket or close to the testicles to prevent potential harmful effects of radiofrequency radiation on the male reproductive system [153].

https://pubmed.ncbi.nlm.nih.gov/39778664/

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**Laptop and tablet use and their influence on total motile sperm count parameters: are laptops linked to infertility in Jamaican men?**

Sterling L, Carroll K, Harris LR. Laptop and tablet use and their influence on total motile sperm count parameters: are laptops linked to infertility in Jamaican men? Rev Int Androl. 2024 Dec;22(4):25-32. doi: 10.22514/j.androl.2024.027.

Abstract

Background: This study aims to determine the impact of laptop and tablet use on total motile sperm count (TMSC) in men being investigated for assisted reproduction.

Methods: A cross-sectional study was conducted on 156 men attending a fertility clinic in Jamaica. Routine semen analyses were performed and parameters specific to TMSC assessed. All data analyses were performed using SPSS Version 26. Logistic regression analyses were performed to independently predict the impact of quantifiable measures of laptop and tablet use. The main outcome measures were the parameters associated with TMSC.

Results: Overall, 64% of the participants reported using laptops and 36% reported using tablets. There was a significant relationship seen with time spent on laptops and time trying to conceive ($p = 0.015$). Regression analyses showed that persons who used their laptops for 2 to 5 h daily were approximately 16 times (adjusted Odds Ratio (aOR) = 15.9; 95% Confidence Interval (CI), 2.5-103.3, $p = 0.004$) more likely to be diagnosed with low semen volume (hypospermia). Although no significant association was found between total motile sperm count (TMSC) and laptop use, a trend towards significance was observed with high laptop use ($p = 0.052$), suggesting potential implications for TMSC as a predictor of pregnancy outcomes.

Conclusions: Our findings highlight the need for clinicians to take into consideration wireless device usage in men undergoing fertility investigations.

Open access paper: https://files.intandro.com/files/article/20241230-28/pdf/RIA20240615001.pdf

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**Electromagnetic fields from mobile phones: a risk for maintaining energy homeostasis?**

Seewooruttun C, Mai TC, Corona A, Delanaud S, Seze R, Bach V, Desailloud R, Pelletier A. Electromagnetic fields from mobile phones: a risk for maintaining energy homeostasis? Ann Endocrinol (Paris). 2025 May 6:101782. doi: 10.1016/j.ando.2025.101782.

Abstract

In the world, there is a near ubiquitous presence of a low-intensity radiofrequency electromagnetic field (RF-EMF) radiation, due to telecommunications as mobile phones. However, their rapid expansion raises concerns about possible interaction with biological mechanisms. The RF-EMF safety guidelines recommended limits to protect against the thermal heating, the most recognized effect at high intensity levels with a known biophysical mechanism. Among all the effects studied, the impact of RF-EMF exposure on thermoregulation is one of the most important aspects of this research. This review aims to present the complex relationship between RF-EMF exposure and thermoregulation, at intensity levels

below the threshold to produce thermal effects. In fact, most studies showed that RF-EMF exposure at 900 MHz seems to be elicited physiological and biological effects similar to responses inducing by cold environment in two different rodent models. In this brief review, we will describe these responses observed during or after RF-EMF exposure to give physiological and molecular mechanisms of the interaction between the organism and RF-EMF exposure at low levels and the potential implications for environmental health and safety.

Conclusion

In modern society, exposure to RF-EMF is very common and nearly impossible to avoid. Despite its major impact in driving technological advancements, it is important to address the growing public concern in regards to RF-EMF exposure. The thermal effects of high-intensity RF-EMF exposure (SAR>4 W/kg) are well documented in the literature. However, there is now emerging evidence that low-intensity RF-EMF exposure (SAR<4 W/kg) can also elicit thermoregulatory responses associated with a cold sensation. The present review highlights the behavioural thermoregulation associated with a cold sensation in rodents exposed to 900 MHz. We also provide molecular insights on RF exposure effects on different thermogenic mechanisms. The first results suggest that RF exposure primarily influences WAT browning rather than BAT thermogenesis, as reported by the increased UCP1 staining and reduced adipocyte size in WAT depots. In contrast, the cold-induced transcriptional changes on BAT thermogenesis were not observed after exposure to RF, although we detected an increased plasma levels of noradrenaline, NEFA in exposed rats. In the short term, these adaptive responses do not seem to compromise homeostasis and therefore the health of organisms, but what about the long-term consequences?

With the introduction of 3.5 GHz for 5G and early use of wireless technology by infants, further research is needed to determine these thermoregulatory effects. Investigating the peripheral tail temperature and thermal preference of 5G-exposed rats at different age could provide valuable insights into their thermoregulatory responses. Additionally, the implication of the thyroid on these responses need to be more investigate since this organ could allow a long-term adaptative response.

https://pubmed.ncbi.nlm.nih.gov/40339686/

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**Potential Impacts of Radiofrequency Electromagnetic Fields on the Central Nervous System, Brain Neurotransmitter Dynamics and Reproductive System**

Eskandarpour M, Nooramin A. Potential Impacts of Radiofrequency Electromagnetic Fields on the Central Nervous System, Brain Neurotransmitter Dynamics and Reproductive System. *AUT Journal of Electrical Engineering*, 2025. doi: 10.22060/eej.2025.23753.5631.

Abstract

Human life has been increasingly affected by the rapid advancement of electronic technology and the widespread use of devices emitting electromagnetic radiation (EMR), such as Wi-Fi and mobile phones. While much remains unclear, studies suggest that electromagnetic fields (EMFs) can influence human health, particularly reproduction and the nervous system. EMF exposure, including from non-ionizing radiation produced by Wi-Fi and mobile phones, has been linked to potential effects on the male and

female reproductive systems, embryonic development, and neuronal health. Key mechanisms include oxidative stress, thermal effects, changes in neurotransmitter metabolism, receptor function, nerve cell apoptosis, and ion channel dynamics. However, the long-term health risks, especially in children and adolescents due to prolonged exposure, remain a topic of debate. Despite current studies not confirming that RF-EMW from Wi-Fi exceeds safety guidelines, further research is essential to fully understand the implications of RF-EMW exposure on human health, particularly regarding reproduction and neurological effects. This review highlights the need for updated safety standards, more refined regulatory frameworks, and long-term investigations to clarify the potential biological and neurobiological consequences of EMF exposure.

Conclusion

RF-EMR is a form of nonionizing radiation that does not have the energy to destroy biological structures directly. However, it impressively and importantly acts on the human nervous system. Although RF-EMR itself does not act by ionizing molecules, the exposure to it can further bring about thermal effects at higher frequencies whereby raised temperature of the tissue may have an impact on cellular processes. Other than thermal effects, RF-EMR exposure can cause non-thermal biological responses through mechanisms such as oxidative stress, altered neurotransmitter activity, and changes in the flux of calcium ions within neurons. These cellular disruptions can lead to neuronal apoptosis, which hampers appropriate brain function and can potentially affect cognition and behavior. While the effects on human health are still debated, it is evident that the nervous system, given its sensitivity to electromagnetic disturbances, may be vulnerable to prolonged exposure. While radiofrequency electromagnetic radiation from Wi-Fi, for example, does involve much smaller power compared with mobile phones, and exposure is much farther from the body, there remains considerable ignorance regarding its long-term outcomes, particularly to sensitive populations of children and teenagers.

While various studies have tended to address a number of questions about RF-EMR risk, especially for brain function and reproductive health, current evidence remains conflicting and thus has necessitated further detailed investigation. It is not possible to decide on a definite conclusion because of the complexity of the biological systems implicated and the difficulty in extrapolating from animal models to human health. However, while neutral or even positive effects can be envisaged at specific levels of RF-EMR exposure, particularly in medical uses, there is still concern about possible risks that may occur above threshold values, particularly in the nervous and reproductive systems. These are potentially very disruptive to neurotransmitter functions, neuronal health, and even sperm and egg cell integrity. Larger, more comprehensive, long-term studies are urgently needed to ascertain the level of exposure that is not harmful and for a full understanding of all biological effects. In summary, exposure to RF-EMR continues to increase with each new generation of technology, including 5G. It is, therefore, of crucial importance that accurate safety guidelines and regulatory frameworks are updated. Continued research into the possible health risks, in particular the cumulative effects of long-term exposure, is essential to safeguarding public health, especially for the younger generation who are exposed more frequently and for longer periods.

Open access paper: https://eej.aut.ac.ir/article_5734.html

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**Assessing RF EMF exposure in multiple microenvironments across ten European countries with a focus on 5G**

Veludo AF, Stroobandt B, Van Bladel H, Sandoval-Diez N, Deprez K, Aerts S, ..., de Vocht F, Joseph W, Röösli M. Assessing radiofrequency electromagnetic field exposure in multiple microenvironments across ten European countries with a focus on 5G. Environment International, 2025. https://doi.org/10.1016/j.envint.2025.109540.

Abstract

To evaluate the implementation of 5G in Europe, we have systematically measured environmental, auto-induced downlink (DL) and uplink (UL) radiofrequency electromagnetic field (RF-EMF) exposure in more than 800 microenvironments in ten European countries. Outdoor, indoor, and public transport microenvironments were measured in two cities and three villages in each country. Exposure was measured during three mobile-phone user scenarios: flight mode (non-user), inducing maximum DL traffic (max DL) or maximum UL traffic (max UL). The mobile phone was carried in a backpack, placed 30 cm from an ExpoM-RF 4 that continuously measured 35 frequency bands (87.5 MHz–6 GHz). For each user scenario, mean exposure levels were calculated. In the non-user scenario, mean exposure levels ranged from 0.33 to 1.72 mW/m2 per country and were lower in Switzerland, Belgium and Italy. RF-EMF levels were, on average, 80 % lower in villages compared to cities, with DL bands contributing the most in this scenario. During max DL, exposure increased mainly due to the 5G band at 3.5 GHz (mean exposure per country 2.61–11.12 mW/m2). However, the time-division nature of this band prevents distinguishing between DL and UL signals with the ExpoM-RF4. Exposure levels were the highest during max UL, particularly in the Netherlands, Italy and Belgium, with 50 % of the mean levels per country above 16 mW/m2. Exposure was, on average, 35 % higher in villages compared to cities. Environmental exposure levels were below international guideline values. Countries with precautionary limits had lower environmental exposure levels but higher auto-induced uplink exposure during data upload.

Conclusions

In this comprehensive European RF-EMF measurement study, environmental exposure levels during a non-user scenario are in line with previous research in Europe and well below international guidelines, suggesting that environmental exposure has not substantially changed since the introduction of 5G. Moreover, we could demonstrate that environmental RF-EMF exposure is mainly attributed to the Mobile DL frequency bands emitted from base stations and increases with increased urbanisation, a result of the dense network in urban settings. Additionally, we observed that environmental exposure levels are generally lower in countries with precautionary limits, namely Switzerland, Italy, and Belgium. Inducing DL traffic resulted in higher personal exposure levels, attributed to the Mobile TDD 3.5 GHz in countries where 5G is widely available. However, more studies are needed to understand the real contribution of beamforming when inducing traffic. RF-EMF exposure from an own phone during data upload was attributed mainly to 4G Mobile UL bands, and to a lower extent to the 5G band at 3.5 GHz. Additionally, in this scenario exposure levels decreased with increasing urbanisation.

Future research should monitor the evolution of environmental and auto-induced RF-EMF exposure in the different countries alongside the ongoing deployment of 5G networks in Europe.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412025002910

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**5G EMF Exposure at 3.6 GHz in Greece Using Data From Frequency-Selective Monitoring Sensors**

Iakovidis S, Manassas A, Apostolidis C, Samaras T. 5G EMF Exposure at 3.6 GHz in Greece Using Data From Frequency-Selective Monitoring Sensors. Bioelectromagnetics. 2025 May;46(4):e70008. doi: 10.1002/bem.70008.

Abstract

The introduction of 5G networks has raised public concerns about potential changes in environmental electromagnetic field (EMF) exposure. This study analyzes continuous monitoring data collected over 2 years (August 2022-October 2024) from 13 frequency-selective monitoring sensors located in Greece's five largest cities. Focusing on the 3.6 GHz band, we evaluated trends and weekly variations in EMF levels. Results indicated a gradual increase in EMF exposure at 3.6 GHz, driven by the growing penetration of 5G infrastructure and devices. Notably, this band exhibited higher maximum-to-median power density ratios compared to other frequency bands, attributable to active antenna systems' characteristics and traffic variations. Applying the ICNIRP 2020 guidelines, we found that 30-min averaged values significantly reduced these variations. All measured EMF levels, including maximum values, remained well below Greek and international safety limits. These findings, especially the increasing trend identified for the EMF levels, underscore the importance of continuous monitoring networks for assessing EMF exposure to existing and emerging telecommunications networks and ensuring compliance with safety standards.

Summary

- Over the last 2 years, 5G EMF levels at the 3.6 GHz frequency band increased due to network expansion but stayed well below ICNIRP and Greek reference levels.
- The 3.6 GHz band showed much higher maximum-to-median E-field variability than other frequency bands, driven by active antenna systems and traffic variations.
- Using 30-min averaging, as recommended by ICNIRP (2020), significantly reduced exposure variability at 3.6 GHz, aligning it with the one observed in frequency bands used by cellular networks of previous generations.

Excerpts

"A more representative view of all 13 monitoring sensors used in this study is provided in Figure 4. The figure shows clearly that in the 3.6 GHz frequency band the ratio of the maximum 6-min-averaged power density in a week can become 12 times higher than the median 6-min-averaged power density of that week."

"The maximum-to-median ratio for the 30-min averaged values at the 3.6 GHz frequency band, became of the same order of magnitude (≈3) as those at frequency bands of older generation cellular networks (≈2)."

"The highest 6-min-averaged power density registered over 2 years was 0.053 W/m$^2$, which is much lower than both the ICNIRP and the Greek reference levels for general public exposure, that is, 10 and 6 W/m$^2$, respectively. It's worth mentioning that any E-field value used in this study corresponds to the 6-min RMS, that is, it is immediately comparable to established safety limits in Greece. However, the significantly higher E-field variability at the 3.6 GHz frequency band, compared to other cellular network bands, highlights the need for application of “extrapolation to the maximum” techniques when 6-min spot (in situ) measurements are performed for compliance assessment. This point should also be considered when exposure assessment studies are performed."

"Conclusions

In this study, continuous measurements of E-field from 13 monitoring sensors located in the five largest Greek cities and collected over the last 2 years were analyzed with a focus on the 3.6 GHz frequency band, where 5G networks operate. An increasing trend in environmental EMF levels at this band over these years was identified but the maximum registered incident power density remained well below the reference levels of ICNIRP and the Greek legislation. A considerably higher variation of exposure levels within a week at the 3.6 GHz band compared to other frequency bands was observed in terms of weekly maximum-to-median incident power ratio. This result highlights the necessity of extrapolation to the actual maximum when short-time measurements (e.g., of 6 min) are used as a proxy for compliance assessment. However, this high maximum-to-median ratio considerably decreases by considering 30-min averaging of the measurements, as suggested by the 2020 ICNIRP guidelines. Notably, the median E-field values at the 3.6 GHz band are lower than those of legacy networks.

No significant trends at older frequency bands were identified possibly due to limited spatial sampling, with only 13 measurement locations. Therefore, further research with broader geographical coverage and additional monitoring sensors would be valuable to evaluate these trends of exposure in the context of 5G rollout."

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.70008

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**Deduction of Extrapolation Factors in Realistic Scenarios for In-Situ Assessment of 5G Base Stations**

Villaescusa-Tebar A, Peris JR, Garcia-Pardo C. Deduction of Extrapolation Factors in Realistic Scenarios for In-Situ Assessment of 5G Base Stations. 2025 19th European Conference on Antennas and Propagation (EuCAP), Stockholm, Sweden, 2025, pp. 1-5, doi: 10.23919/EuCAP63536.2025.10999421.

Abstract

Accurate assessment of electromagnetic field (EMF) exposure in 5G networks presents challenges due to beamforming and advanced technologies. Traditional frequency-selective methods provide actual exposure values but cannot distinguish beams or cells. Code-selective techniques differentiate cells and beams, but require complex extrapolation processes based on unavailable network parameters like beamforming patterns. This study investigates extrapolation factors like Fextbeam in realistic indoor and outdoor 5G environments, using frequency-selective and code-selective measurements. Measurements under different traffic conditions evaluated the effect of beam patterns and power. Results showed higher variability in extrapolated values due to differences in antenna radiation patterns. Outdoor

environments exhibited more stable values, indicating the critical role of antenna patterns, especially indoors.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10999421&isnumber=10999162

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**An approach for annual analysis of EMF exposure in highly sensitive areas of kindergartens and schools**

Kljajic D, Djuric N, Pasquino N, Solmonte N, Djuric S. An approach for annual analysis of EMF exposure in highly sensitive areas of kindergartens and schools. Radiat Prot Dosimetry. 2025 May 19:ncaf047. doi: 10.1093/rpd/ncaf047.

Abstract

Continuous increase of electromagnetic field (EMF) emission in the environment causes worldwide research on various short- and long-term EMF measurements and exposure assessments. Measurements are usually performed in sensitive areas, with conventional measuring approaches and worst-case exposure assessments, which are unable to provide any deeper EMF behavior analyses. Therefore, this paper brings an innovative EMF exposure analysis approach, based on time-averaging of time series data, disclosing some concealed information on long-term exposure. The averaging was done on the set of EMF time series acquired by three sensors in the EMF Regulatory Agency for Electronic Communications and Postal Services (RATEL) monitoring network. Sensors are installed at extremely sensitive locations-on buildings of two kindergartens and an elementary school. Analyses revealed patterns of daily/weekly exposure changes and their differences between working days and weekends, as well as annual decrease/increase, at each location. Comparative analysis among locations showed differences in exposure behavior regarding its peaks, slopes of the decrease/increase, and time intervals of the day with higher exposure.

https://pubmed.ncbi.nlm.nih.gov/40384509/

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**Assessment of RF EMF Exposure to Car Driver from Monopole Array Antennas in V2V Communications Considering Thermal Characteristics**

My note: This paper only addresses estimated RF-EMF exposure relative to inadequate ICNIRP guidelines which only protect against heating risk.

Wang S, Lu M. Assessment of RF Electromagnetic Exposure to Car Driver from Monopole Array Antennas in V2V Communications Considering Thermal Characteristics. *Sensors*. 2025; 25(10):3247. https://doi.org/10.3390/s25103247.

Abstract

Vehicles are rapidly evolving into objects of intelligent interconnection. Vehicle-to-Vehicle (V2V) communications enable the interconnection between vehicles, while also leading to new electromagnetic exposure scenarios. This paper integrates a monopole array antenna into a shark-fin

antenna on the car roof for V2V communications and evaluates the specific absorption rate (SAR) and temperature rise of a human body in a smart mobility communication scenario operating at 5.9 GHz. The V2V antenna is modeled and placed on a 3D vehicle model using COMSOL Multiphysics (v.6.2) to numerically estimate the SAR in the head and body regions of the human body model (adult male) inside the vehicle. Both the localized and whole-body 30 min average SAR are lower than the International Commission on Non-Ionizing Radiation Protection (ICNIRP) occupational restrictions for electromagnetic field exposure from 100 kHz to 6 GHz, being equal in the worst-case scenario to 0.981 W/kg (for the head), which is 9.81% of the ICNIRP limit (10 W/kg), and 0.008728 W/kg (for the whole-body average), which is 2.18% of the ICNIRP limit (0.4 W/kg). The 30 min average human core temperature rise is 0.055 °C, which is 5.5% of the ICNIRP limit. This indicates that, in typical automotive scenarios, the electromagnetic exposure from a monopole array antenna for V2V communications does not pose threat to the human body. This study provides knowledge related to emerging exposure scenarios in intelligent mobility communication, which is beneficial for evaluating possible health impacts and designing public health management policies.

Open access paper: https://www.mdpi.com/1424-8220/25/10/3247

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**Exposure to radiofrequency electromagnetic fields and IARC carcinogen assessment: Risk of Bias preliminary literature assessment for 10 key characteristics of human carcinogens**

**My note**: Apparently, ICNIRP supporters plan to dismiss the IARC Group 2B classification of RF-EMF carcinogenicity and the recent WHO systematic review on animal laboratory carcinogenicity studies (Mevissen et al., 2025) by claiming that all of the *in vitro* and *in vivo* studies that found evidence for carcinogenicity are poor quality.

Simkó M, Repacholi MH, Foster KR, Mattsson M-O, Croft RJ, Scarfi MR, Vijayalaxmi. Exposure to radiofrequency electromagnetic fields and IARC carcinogen assessment: Risk of Bias preliminary literature assessment for 10 key characteristics of human carcinogens. Mutation Research - Reviews in Mutation Research, Volume 796, 2025, https://doi.org/10.1016/j.mrrev.2025.108545

**Highlights**

We analyzed if the ten key characteristics (KCs) of human carcinogens according to IARC are influenced by RF-EMF exposure.

We reviewed 159 articles by extracting relevant exposure and experimental data.

A risk of bias (RoB) analysis was conducted using 6 criteria.

There is a strong negative association between study quality and the likelihood of reporting effects of RF-EMF exposures.

The heterogeneity and overall poor study quality suggest the need for high-quality studies.

**Abstract**

This is the first assessment of evidence needed to determine whether exposure to radiofrequency electromagnetic fields (RF-EMF) exposures, below the levels recommended in the ICNIRP (2020) guidelines, can influence any of the ten key characteristics (KCs) of human carcinogens developed by the International Agency for Research on Cancer (IARC). We define the 10 KCs and their relevance to carcinogenesis; review in vivo and in vitro studies relevant to the KCs; and conduct a risk of bias (RoB) analysis using 6 criteria. We did not include KC studies on genotoxicity or oxidative stress since Romeo et al. (2024) and Meyer et al. (2024) recently published relevant systematic reviews, but note their respective conclusions. From the other 8 KCs we identified 119 in vitro and 40 in vitro measurements of in vivo studies through 30 June 2023, with 38 % reporting statistically significant effects of exposure. We identified a strong association between the quality of study and outcome, with those meeting more RoB criteria less likely to report statistically significant effects. Effects were reported over the entire frequency range, exposure levels, and biological endpoints with no apparent pattern of exposure parameters resulting in effects. Only KC10 (alters cell proliferation, cell death or nutrient supply) has sufficient studies to analyse, but the other KCs had few studies and diverse endpoints. A few relatively high-quality positive studies require follow-up through additional targeted studies. The heterogeneity and overall poor study quality suggest the need for high-quality studies on these endpoints, preferably adhering to standards such as the Organization for Economic Co-operation and Development [28].

## 6. Conclusions

This review aimed to assess the extent and adequacy of experimental data bearing on whether exposure to RF-EMF could influence any of the 10 IARC key characteristics of human carcinogenesis. Since two PRISMA-compliant SRs on the KCs genotoxicity and oxidative stress were recently published [35], [23], this present review was limited to the 8 remaining KCs for which no systematic reviews have been conducted so far. It became apparent that the present database of in vitro and in vivo studies was so diverse and scattered in their quality that helpful outcomes of SRs on most of the KCs would be unfeasible, and any conclusions from such reviews would have a very low confidence. The two PRISMA-compliant SRs as well as previous comprehensive reviews on in vitro and in vivo genotoxicity studies (e.g. [46], and our review of studies on the 8 KCs, have all reached the same conclusion: there is clearly a need for much higher quality RF-EMF bioeffects studies on these KCs.

There are, however, a few statistically significant results in the highest quality studies (Tier 1 studies in Romeo et al. [35] and studies meeting 5 or 6 RoB criteria (present study). These deserve close examination, and replication if warranted by stronger studies, preferably done under GLP [28], or are otherwise compliant with OHAT recommendations.

As a final comment, it is not useful for systematic reviews to examine hundreds of papers on a given topic, only to find that the overall quality of the large majority of the studies is too low to permit conclusions with a high level of confidence.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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Open access paper: https://www.sciencedirect.com/science/article/pii/S138357422500016X

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**Electromagnetic fields regulate iron metabolism: From mechanisms to applications**

Wang S, Yang J, Zhen C, Wang H, Shang P. Electromagnetic fields regulate iron metabolism: From mechanisms to applications. Journal of Advanced Research. 2025, https://doi.org/10.1016/j.jare.2025.04.044.

Highlights

• Electromagnetic fields (EMFs) can influence the progression of various diseases by regulating iron metabolism.

• The regulation of iron metabolism by EMFs is highly parameter-specific and varies across different tissues and cells.
• The electromagnetic properties of iron-containing molecules/proteins and iron-rich tissues influence iron metabolism modulation by EMFs.
• EMFs can modulate iron metabolism through their effects on membrane structure and ion channels.
• EMFs can modulate iron metabolism by regulating the generation and activity of Reactive Oxygen Species (ROS).

Abstract

Background  Electromagnetic fields (EMFs), as a form of physical therapy, have been widely applied in biomedicine. Iron, the most abundant trace metal in living organisms, plays a critical role in various physiological processes, and imbalances in its metabolism are closely associated with the development and progression of numerous diseases. Numerous studies have demonstrated that EMF exposure induces significant changes in both systemic and cellular iron metabolism.

Aim of Review  This review aims to summarize the evidence and potential biophysical mechanisms underlying the role of EMFs in regulating iron metabolism, thereby enhancing the understanding of their biological mechanisms and expanding their potential applications in biomedical fields.

Key Scientific Concepts of Review  In this review, we have synthesized research findings and proposed the hypothesis that the biophysical mechanisms of EMFs regulate iron metabolism involve the special electromagnetic properties of iron-containing proteins and iron-enriched tissues, as well as the modulation of membrane structure and function, ion channels, and the generation and activity of Reactive Oxygen Species (ROS). Then, the review summarizes the latest advances in the effects of EMFs

on iron metabolism and their safety, as well as their impact on immunoregulation, cardiovascular diseases, neurological diseases, orthopedic diseases, diabetes, liver injury, and cancer.

Conclusion and perspective

EMFs have been widely applied as a non-invasive physical alternative or adjunctive therapy in translational medicine. The regulation of iron metabolism by EMFs is a crucial mechanism underlying their biological effects and plays a significant role in their translational applications. On one hand, iron metabolism-related indicators can be used to evaluate the biological safety of EMFs. On the other hand, the effects of EMFs on iron metabolism have potential applications in the research and treatment of various diseases, including immunoregulation, cardiovascular diseases, neurological diseases, orthopedic diseases, diabetes, liver injury, and cancer. Moreover, the synergistic regulation of iron metabolism through the combination of EMFs with drugs—particularly iron-based NPs—has notably enhanced the potential of EMFs in the biomedical field. However, conflicting results in many studies regarding the effects of EMFs on iron metabolism make it challenging to systematically summarize the regulatory patterns of EMFs on iron metabolism. Despite these inconsistencies, several general characteristics of EMF-mediated regulation of iron metabolism can still be summarized. First, the effects of EMFs on iron metabolism vary depending on the properties of the EMFs (such as intensity, gradient, frequency, etc.) and exposure time [17]. Additionally, the effects of EMFs on iron metabolism appear to exhibit a biological “window”. It has been reported that the biological effects induced by EMFs of specific intensities, frequencies, and exposure durations within this “window” may differ significantly from those outside it [123]. Furthermore, the regulation of iron metabolism by EMFs also shows significant tissue- and cell-type specificity. Compared to changes in biochemical indicators, biophysical mechanisms are typically used to provide a deeper explanation of the biological effects and patterns of EMFs. In this review, we have summarized several potential biophysical mechanisms through which EMFs regulate iron metabolism, aiming to better understand the underlying reasons for the complex regulatory characteristics of EMFs on iron metabolism, and to provide research insights for utilizing EMFs in the modulation of iron metabolism in the future. Furthermore, the descriptions of EMFs parameters and exposure forms in many studies are often vague, which limits the comparability of results across different studies. Therefore, more precise descriptions of EMF parameters and exposure methods are needed in future research on the effects of EMFs on iron metabolism and related diseases. We expect that with extensive and in-depth studies on the effects and mechanisms of EMFs in iron metabolism, the scope of EMF applications in disease prevention and treatment is likely to expand.

Open access paper: https://www.sciencedirect.com/science/article/pii/S2090123225002887

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**Active matter as the underpinning agency for extraordinary sensitivity of biological membranes to electric fields**

Mathew A, Kulkarni Y. Active matter as the underpinning agency for extraordinary sensitivity of biological membranes to electric fields. Proc Natl Acad Sci U S A. 2025 Mar 25;122(12):e2427255122. doi: 10.1073/pnas.2427255122.

Abstract

Interaction of electric fields with biological cells is indispensable for many physiological processes. Thermal electrical noise in the cellular environment has long been considered as the minimum threshold for detection of electrical signals by cells. However, there is compelling experimental evidence that the minimum electric field sensed by certain cells and organisms is many orders of magnitude weaker than the thermal electrical noise limit estimated purely under equilibrium considerations. We resolve this discrepancy by proposing a nonequilibrium statistical mechanics model for active electromechanical membranes and hypothesize the role of activity in modulating the minimum electrical field that can be detected by a biological membrane. Active membranes contain proteins that use external energy sources to carry out specific functions and drive the membrane away from equilibrium. The central idea behind our model is that active mechanisms, attributed to different sources, endow the membrane with the ability to sense and respond to electric fields that are deemed undetectable based on equilibrium statistical mechanics. Our model for active membranes is capable of reproducing different experimental data available in the literature by varying the activity. Elucidating how active matter can modulate the sensitivity of cells to electric signals can open avenues for a deeper understanding of physiological and pathological processes.

Significance

What is the minimum electric field that biological cells can detect? This question has inspired significant research as certain cells and organisms are known to possess extraordinary sensitivity to weak electrical signals. However, existing models that consider this threshold to be the electrical noise arising from equilibrium thermal fluctuations yield puzzling results that are many orders of magnitude larger than experimental measurements. We resolve this paradox by proposing a nonequilibrium statistical mechanics model in which cell membranes can exploit energy-driven active mechanisms to modulate their electrical sensitivity to sense electric fields that are far weaker than the thermal electrical noise. Our study could open avenues for harnessing the sensitivity of biological cells to electric fields for diagnostics and therapeutics.

Conclusion

In summary, we investigated the role of activity in the sensitivity of biological membranes (and cells) to electric fields by way of a nonequilibrium statistical mechanics–based model. Our study reveals that activity, attributed to different sources, can endow the membranes with the ability to sense and respond to electric fields that are far weaker than the thermal noise limit estimated from purely equilibrium statistical mechanics. Our model for active membranes is capable of reproducing different experimental data available in the literature by varying the activity and thus provides a possible resolution for a long-standing discrepancy between theoretical studies and experimental measurements for the minimum electric field that can be detected by cells. As part of future study, we intend to enrich the model to incorporate electromechanical coupling through flexoelectricity and investigate its role in the interaction of active membranes with electric fields. Understanding electromechanical biological phenomena that may be impacted by increased fluctuations due to active noise in polarization is another interesting direction of study. Elucidating how cells can modulate their interaction with electric signals through activity can proffer deeper insights into physiological processes and open avenues for applications in biotechnology and medicine.

https://pubmed.ncbi.nlm.nih.gov/40117314/

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**Single exposure to near-threshold 5G millimeter wave modifies restraint stress responses in rats**

Matsumoto A, Endo I, Ijima E, Hirata A, Kodera S, Ichiba M, Tokiya M, Hikage T, Masuda H. Single exposure to near-threshold 5G millimeter wave modifies restraint stress responses in rats. Environ Health Prev Med. 2025;30:33. doi: 10.1265/ehpm.24-00321.

Abstract

Background: In response to growing concerns about the health effects of quasi-millimeter waves (qMMW) used in 5th-generation wireless systems, conservative whole-body exposure thresholds based on indirect evidence have been proposed. The guidelines define a whole-body average specific absorption rate (WBA-SAR) of 4 W/kg which causes a 1 °C increase in core temperature, as the operational threshold for adverse health effects. To address the lack of direct evidence, we recently reported that a 30-minute exposure to qMMW at 4.6 W/kg resulted in a 1 °C increase in rat core temperature. Here, we further analyzed the near-threshold stress response for the first time, using biological samples from the aforementioned and additional experiments.

Methods: A total of 59 young Sprague-Dawley rats (240-322 g) were exposed to 28 GHz for 40 minutes at WBA-SARs of 0, 3.7, and 7.2 W/kg, under normal (22.5 °C, 45-55% humidity), and heat (32 °C, 70% humidity) conditions. Rats were restrained in acrylic holders for dose control. We repeatedly measured serum and urinary biomarkers of stress response, aggregated the data, and analyzed them using a single statistical mixed model to subtract the effects of sham exposure and between-subject variation.

Results: Sham exposure induced stress responses, suggesting an effect of restraint. After the subtraction of the sham exposure effect, 28 GHz appeared to induce stress responses as evidenced by elevated serum-free corticosterone 1 or 3 days after the exposure, which was more evident in animals with a change in rectal temperature exceeding 1 °C. Urinary-free catecholamines demonstrated an inhibitory property of 28 GHz frequency exposure on the stress response as evidenced by noradrenaline on the day of exposure. Heat exposure enhanced this effect, suggesting a possible role of noradrenaline in heat dissipation by promoting cutaneous blood flow, a notion supported by the correlation between noradrenaline levels and tail surface temperature, a critical organ for heat dissipation.

Conclusions: This study is the first to demonstrate that qMMW whole-body exposure can alter the stress response as indicated by corticosterone and noradrenaline at near-threshold levels. Our findings may provide insight into the biological basis of the whole-body exposure thresholds in the international guidelines.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC12062831/

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**Effects of non-ionizing radiation on the thyroid gland in rats**

Sarhad ZS, Ebrahimbabaei A, Tavassoli A, Shojaeifard M. Effects of non-ionizing radiation on the thyroid gland in rats. BMC Res Notes. 2025 May 24;18(1):231. doi: 10.1186/s13104-025-07297-x.

Abstract

Objectives: This study evaluated the effects of non-ionizing electromagnetic radiation on rat thyroid function and histopathology. Forty female and thirty male Sprague-Dawley rats (200-220 g, 2 months old) were exposed to 2.45 GHz Wi-Fi, mobile jammer radiation, or a sham condition. In Group A, male rats were exposed to Wi-Fi or mobile jammers for 2 h daily for two weeks. The devices were located within a one-meter radius of the animal cage, either on or off. In the Sham group, the experimental setup was like the other groups, but the irradiating devices were turned off. Group B included non-pregnant females, pregnant (exposed and control subgroups), and their offspring. Thyroid hormones in the serum were measured, and the histology was microscopically analyzed, focusing on areas of colloid and epithelium in the thyroid follicles.

Results: Compared to the control group, T4 hormone levels were significantly different in male rats exposed to mobile jammer radiation (p-value = 0.037). In group B, significant differences were found solely in the male offspring regarding T3 levels due to jammer exposure (average = 109.00 for male offspring in the experiment vs. average = 65.50 for those in the control, p-value < 0.001). Additionally, histopathological findings indicated significant differences as well. These results highlight a potential link between exposure to electromagnetic radiation and changes in thyroid endocrine and histological parameters. Our findings suggest that ongoing assessment of existing safety guidelines on non-ionizing radiation exposure is necessary, especially concerning its effects on thyroid hormone levels and follicular histology.

Open access paper: https://bmcresnotes.biomedcentral.com/articles/10.1186/s13104-025-07297-x

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**An 1800 MHz Electromagnetic Field Affects Hormone Levels, Sperm Quality, and Behavior in Laboratory Rats**

Pawlak K, Bojarski B, Jagusiak W, Wojnar T, Nieckarz Z, Arent Z, Ludwiczak M, Lasko M. An 1800 MHz Electromagnetic Field Affects Hormone Levels, Sperm Quality, and Behavior in Laboratory Rats (*Rattus norvegicus*). *Applied Sciences*. 2025; 15(9):5160. https://doi.org/10.3390/app15095160.

Abstract

In addition to natural electromagnetic fields (EMFs), so-called artificial electromagnetic fields exist in the biosphere, with mobile communications being one of their main sources. This study aimed to determine the impact of EMF at a frequency of 1800 MHz on the concentrations of selected hormones, sperm motility, viability, morphology and behaviors in laboratory rats. We used 28 rats divided into two equinumerous groups: control (n = 14) and experimental (n = 14). The rats in the experimental group were exposed to EMF for 12 weeks (for 10 min, four times daily); at the same time, the control specimens were kept in standard conditions. After 12 weeks, half of each group was killed, while the other half was maintained for another 4 weeks with no EMF emission. Elevated corticosterone levels and decreased thyroid-stimulating hormone levels were observed in the experimental specimens, which persisted for 2 weeks after the cessation of EMF emission. Exposure to EMF also resulted in decreased sperm motility and viability, as well as increased rat anxiety. This study shows that exposure to EMF

(1800 MHz) may affect the endocrine status of the body and the behavior and reproductive functions of animals. However, hormonal disorders appear to be reversible.

Excerpts

"The experimental group was exposed to electromagnetic waves for 10 min, four times daily: 8:00–8:10, 14:00–14:10, 18:00–18:10, and 22:00–22:10. The source of electromagnetic radiation was a generator emitting electromagnetic waves in the frequency range of the GSM cellular network (1100–2100 MHz). The average output power of the generator was 330 mW, with an instantaneous maximum power of 2 W. The load for the power stage was a Yagi GSM antenna with omnidirectional characteristics. The distance between the field generator antenna and the animals (depending on their position in the cage) was 30–40 cm."

"The electromagnetic field emitted by the generator within the rat cages was characterized by the following parameters: the average electric field intensity ranged from 2.8 to 5.7 V/m (0.1 V/m), the average magnetic field intensity ranged from 7.2 to 14.0 mA/m (±0.2 mA/m), and the average power density ranged from 17.7 to 63.6 mW/$m^2$ (±0.5 mW/$m^2$) at a frequency of 1800 MHz. Throughout the experiment, the EMF background was monitored, with an average value of 0.22 ± 0.07 V/m."

Open access paper: https://www.mdpi.com/2076-3417/15/9/5160

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**Impairment of Oogenesis and Folliculogenesis in Neonatal Rats after Maternal Exposure to Mobile Phones**

Yousefi B, Jadidi M, Nabizadeh Z, Amjad MHT, Ardekanian M. Impairment of Oogenesis and Folliculogenesis in Neonatal Rats after Maternal Exposure to Mobile Phones. Reprod Sci. 2025 May 19. doi: 10.1007/s43032-025-01880-0.

Abstract

Today's lifestyle has led to an increase in infertility. The study investigated the effects of cell phone radiation on oogenesis, folliculogenesis, and gestation stage. Also, its impact on neonates' ovarian hormones and their ovarian development during gestation was investigated. Fifty-four virgin female Wistar rats were randomly divided into three groups: the study group (conversation and stand-by mode, n = 24), the control group (stand-by mode, n = 24), and the sham (turn off, n = 6). The study and control groups were separated into 4 subgroups, including early stage (1st week), mid-stage (2nd week), late stage (3rd week), and all stages (3 weeks). The results showed that the concentration of plasma estrogen and progesterone, ovarian primordial follicle/primary oocyte, the number of primordial follicles, and nuclei diameters in the study and control subgroups decreased significantly in comparison with the sham group. The most significant reduction was observed in subgroups in which mothers were exposed to radiation for a long period during their pregnancy. Compared to the control and sham groups, the number of primordial follicle apoptosis markedly increased in the study subgroups. The pregnant rats showed significant effects in the entire stages of pregnancy, especially during the first stage (the first week) of development, which has not been reported previously. Exposure to cell phones during the different gestation stages probably decreases ovarian hormone secretion and may harm

oogenesis. It also inversely increases the apoptosis of primordial follicles. Therefore, the gestational stages and duration of exposure to cell phone radiation affect the risk of ovarian harm.

Conclusion

This study examined the effects of cell phone exposure on estrogen, progesterone, and ovarian follicles in neonatal rats immediately after birth (natal day). Compared to the sham group, the results showed that cell phone radiation in both the study and control groups caused a decrease in the number and diameter of the primordial follicle, primary oocyte, its nucleus, and the amount of estrogen and progesterone hormones in neonatal rats during different and entire weeks of gestation. Also, these radiations cause an increase in apoptosis (atretic) of primordial follicles and a reduction in the diameter of the neonates' ovaries, which depends on the duration of radiation. Meanwhile, for the first time, the impact of mobile phones during different weeks of pregnancy was examined in this study. In sum, the most effects were observed in the third week of pregnancy. The results showed that the first week of pregnancy was also affected by cell phone effects. Although this study has investigated the effects of EMF on infertility in an animal model (rat), these findings can highlight the potential risks of exposure to mobile phone radiation during pregnancy on the future fertility of the fetus in the womb. However, further research is needed to establish a direct link between EMR exposure and infertility. Non-human primate models (monkeys) are recommended to achieve more reliable results.

Open access paper: https://link.springer.com/article/10.1007/s43032-025-01880-0

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**Analyzing the Impact of Occupational Exposures on Male Fertility Indicators: A Machine Learning Approach**

Mohammadi H, Khoddam S, Golbabaei F, Dehghan SF. Analyzing the Impact of Occupational Exposures on Male Fertility Indicators: A Machine Learning Approach. Reprod Toxicol. 2025 May 29:108959. doi: 10.1016/j.reprotox.2025.108959.

Highlights

• Combines occupational epidemiology with cutting-edge machine learning for risk stratification
• Provides actionable thresholds for workplace exposure limits (e.g., WBGT ≥ 28°C linked to decreased testosterone levels)
• Bridges methodological gaps in reproductive health research through model interpretability (SHAP, feature importance analysis)

Abstract

Occupational exposures are critical factors affecting workers' reproductive health. This study investigates the impact of magnetic fields, electric fields, whole-body vibration, noise levels, and heat stress on male reproductive indicators using advanced machine learning models. The aim is to identify key risk factors and provide predictive insights into workers' reproductive health over the next decade. Data were collected from 80 male workers in an automobile part manufacturing plant, capturing demographic characteristics, occupational exposures, biochemical markers, hormone levels, and sperm parameters. Five machine learning models logistic regression, bagging classifier, extreme gradient

boosting, random forest, and support vector machine were trained and evaluated using 5-fold cross-validation to determine effective predictors of reproductive health outcomes. Exposure to whole-body vibration, magnetic fields, electric fields, and heat stress closely affected free testosterone levels, with SHAP importance indicating: Magnetic Field Exposure (0.339) and Wet Bulb Globe Temperature (0.138). Worker Age (0.244) was the most influential demographic factor negatively impacting Free Testosterone. The XGBoost and random forest achieved the highest AUC (0.99), outperforming other models in predictive accuracy. The Random Forest model Importance (% Increase in MSE) predicted that Electric Field Exposure (5%) and Magnetic Field Exposure (4.7%) would have the most substantial negative impact on Free Testosterone, followed by Worker Age (4.1%). This study underscores the need for targeted interventions, such as improved workplace safety protocols and regular health monitoring, to protect workers' reproductive health.

Conclusion

This study concludes that machine learning, particularly tree-based models like Random Forest and XGBoost, can effectively identify key occupational and demographic factors influencing male reproductive health. Electric and magnetic field exposures, age, work experience, and oxidative stress biomarkers emerged as the most critical predictors. Explainable AI methods revealed complex interactions among these factors. The 10-year forecast highlighted electric field exposure as the most significant long-term risk. These findings emphasize the need for targeted interventions to reduce electromagnetic and vibration exposures and to protect aging workers.

https://pubmed.ncbi.nlm.nih.gov/40449633/

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**A Mini-Review of the Potential Health Impacts of Indoor Radiation Exposure in Companion Animals**

Maipas S, Vardiambasis IO, Nikolopoulos CD, Kavantzas N. A Mini-Review of the Potential Health Impacts of Indoor Radiation Exposure in Companion Animals. Environ Health Insights. 2025 May 28;19:11786302251342972. doi: 10.1177/11786302251342972.

Abstract

Poor indoor environmental quality is a major concern for both humans and companion animals-yet its impact on the latter is often overlooked. This mini review sheds light on indoor radiation sources that may affect the health of companion animals. Radon, primarily from the ground and possibly also from cat litter, naturally occurring radionuclides in feed, radiofrequency radiation from mobile and cordless phones, Wi-Fi networks, pet tracking devices, solar radiation, and various sources of extremely low frequency radiation are all common examples. Indoor radiation, an odorless and tasteless pollutant, may have the potential to negatively impact the health and well-being of companion animals, which are involuntarily exposed to this environmental health risk factor. Therefore, preventive and precautionary measures are necessary.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC12120279/

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**Melatonin ameliorates RF-EMR-induced reproductive damage by inhibiting ferroptosis through Nrf2 pathway activation**

Wang J, Dong J, Xu Q, Yan S, Wang H, Lei H, Ma X, Yang T, Wang K, Li Z, Wang X. Melatonin ameliorates RF-EMR-induced reproductive damage by inhibiting ferroptosis through Nrf2 pathway activation. Pathol Res Pract. 2025 May 7;270:156003. doi: 10.1016/j.prp.2025.156003.

Abstract

In recent years, there has been increased attention to the deleterious impacts of radiofrequency electromagnetic radiation (RF-EMR) on male reproductive ability, necessitating the exploration of effective protective measures. Melatonin has antioxidant and anti-apoptotic effects, and there is growing evidence of its benefit to the reproductive process. However, the biochemical mechanisms by which melatonin protects against reproductive damage from RF-EMR exposure are unknown. Here, we found that prolonged (8 weeks) exposure to RF-EMR [2.45 GHz; power density, 2.5 $W/m^2$; whole-body specific absorption rate (SAR), 0.125-0.5 W/kg] induced ferroptosis and oxidative stress in testicular tissue, leading to a decrease of sperm quality in male mice. Notably, the administration of melatonin mitigated the oxidative harm to the testicles and ferroptosis caused by RF-EMR in mice. Mechanistically, melatonin could inhibit ROS production and ferroptosis by stimulating the nuclear factor-erythroid 2-related factor 2 (Nrf2) signaling pathway through its receptors (MT1/MT2). Taken together, these results indicate that melatonin could potentially improve RF-EMR-induced reproductive damage in male mice by blocking ferroptosis through activation of the Nrf2 pathway.

Conclusions

In conclusion, this study demonstrated that RF-EMR harms male reproduction by triggering ferroptosis, a cell death process, in mouse testes. Melatonin, by activating the Nrf2 pathway via MT1/MT2 receptors, suppresses ferroptosis and protects against RF-EMR damage (Fig. 6). These findings suggest melatonin's potential clinical value. Future controlled trials will explore its efficacy in treating male infertility caused by RF-EMR exposure, making melatonin a promising candidate therapy. ...

https://pubmed.ncbi.nlm.nih.gov/40344840/

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**Exposure at 3.6 GHz in Greece Using Data From Frequency-Selective Monitoring Sensors**

Iakovidis S, Manassas A, Apostolidis C, Samaras T. 5G EMF Exposure at 3.6 GHz in Greece Using Data From Frequency-Selective Monitoring Sensors. Bioelectromagnetics. 2025 May;46(4):e70008. doi: 10.1002/bem.70008.

Abstract

The introduction of 5G networks has raised public concerns about potential changes in environmental electromagnetic field (EMF) exposure. This study analyzes continuous monitoring data collected over 2 years (August 2022-October 2024) from 13 frequency-selective monitoring sensors located in Greece's five largest cities. Focusing on the 3.6 GHz band, we evaluated trends and weekly variations in EMF levels. Results indicated a gradual increase in EMF exposure at 3.6 GHz, driven by the growing penetration of 5G infrastructure and devices. Notably, this band exhibited higher maximum-to-median

power density ratios compared to other frequency bands, attributable to active antenna systems' characteristics and traffic variations. Applying the ICNIRP 2020 guidelines, we found that 30-min averaged values significantly reduced these variations. All measured EMF levels, including maximum values, remained well below Greek and international safety limits. These findings, especially the increasing trend identified for the EMF levels, underscore the importance of continuous monitoring networks for assessing EMF exposure to existing and emerging telecommunications networks and ensuring compliance with safety standards.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.70008

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**Terahertz Radiation Affects the Dynamics of Neurons by Decreasing Membrane Area Ratio**

Ma S, Li S, Wang H, Li Y, Lu C, Li X. Terahertz Radiation Affects the Dynamics of Neurons by Decreasing Membrane Area Ratio. Brain Res Bull. 2025 May 6:111373. doi: 10.1016/j.brainresbull.2025.111373.

Abstract

Terahertz radiation at specific frequencies and energies can mediate cellular morphology or function changes by exciting nonlinear resonance effects in proteins or DNA. However, the effects of terahertz radiation on neuronal morphology and function are currently unknown, and the correlation between neuronal morphology and kinetic properties after terahertz radiation remains to be elucidated. In this paper, we first characterized the changes in neuronal morphology by the relative ratio of neuronal cytosol to protruding membrane area. Analyzed the pattern of the influence of terahertz radiation on neuronal morphology and the cumulative effect. On this basis, this paper constructs a kinetic model of neurons regulated by terahertz radiation, investigates the influence law of terahertz radiation on the kinetic properties of neurons, and analyzes the correlation between neuronal morphology and kinetic properties. The results showed that terahertz radiation caused a decrease in the membrane area ratio of neuronal cytosol to protrusion, and this effect started on the first day of terahertz radiation and lasted until the end of terahertz radiation; terahertz radiation changed the neuronal discharge pattern by decreasing the membrane area ratio of neuronal cytosol to protrusion and lowered the frequency of neuronal inter-cluster discharges and amplitude of action potentials, and increased the neuronal intra-cluster discharge. In addition, terahertz radiation can increase the peak value of neuronal postsynaptic currents by decreasing the membrane area ratio. In summary, terahertz radiation can modulate neurons' morphology and change their firing patterns and kinetic properties by affecting their morphology. These predict that terahertz radiation at specific frequencies and energies can be developed as a novel, molecular-level neuromodulation technique for intervening or treating neuronal degenerative diseases.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0361923025001856?via%3Dihub

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**Exploring the influence of Schumann resonance and electromagnetic fields on bioelectricity and human health**

Nelson I. Exploring the influence of Schumann resonance and electromagnetic fields on bioelectricity and human health. Electromagn Biol Med. 2025 May 20:1-11. doi: 10.1080/15368378.2025.2508466.

Abstract

This article explores the relationship between electromagnetic fields (EMF) and biological systems, focusing on the influence of extremely low-frequency electromagnetic frequencies (ELF), particularly Schumann's resonance (SR) at 7.83 hz. Cells and proteins may have evolved to take advantage of frequencies naturally present in the Earth's EMF, potentially enhancing cellular energy levels and affecting resting membrane potential (RMP). Thus, changes in or absence of SR may have adverse effects on the functioning of the whole organism. Bioelectricity, independent of genes, has been shown to modulate health, suggesting the potential for using controlled application of EMF frequencies in treating certain types of cancer or conditions affecting the RMP. Research indicates that human brainwave activity is highly dependent on the SR, implying a correlation between atmospheric electromagnetic frequencies and brain activity. ELF, including SR, appears to modulate cellular calcium influx/efflux, likely via indirect mechanisms involving field-sensitive molecules or radical pairs that affect ion channel behavior which plays a critical role in cell signaling and regulation of various processes. It can also trigger a cascade of molecular events that ultimately lead to the generation of action potentials, affecting consciousness and behavior. The influence of atmospheric electromagnetic frequencies on human brainwave activity, modulation of cellular calcium influx/efflux, and potential effects on cellular energy levels and RMP highlight the significance of ELF in biological systems. However, further research is required to fully understand these mechanisms and their implications for human health and well-being.

Plain Language Summary

This study looks at how very low-frequency electromagnetic fields – especially the Schumann Resonance at 7.83 hz – may affect our health. These natural frequencies come from the Earth’s atmosphere and may play an important role in how our bodies and cells work. The research explores how these signals could influence the electrical activity inside our cells, including how ions like calcium move in and out. This process is essential for brain function, heart rhythm, sleep patterns, and overall health. The study suggests that human cells may have evolved to respond to these natural frequencies. Changes in, or the absence of, these signals – such as when we’re exposed to artificial electromagnetic fields from modern technology – might disrupt important processes in the body. For example, the paper highlights evidence that some low-frequency signals may help stop cancer cells from growing or improve healing, while unnatural frequencies might do harm. A key point is that our brain activity seems to align with Earth’s natural electromagnetic rhythms. This could explain why changes in these fields can affect our mood, sleep, or concentration. The study also points out that future space missions should consider simulating these natural frequencies to help astronauts stay healthy outside Earth’s environment. In short, this research helps us understand how our bodies interact with the invisible electromagnetic environment around us – and how both natural and man-made signals could influence our health in powerful ways.

Conclusions

Solar and geomagnetic activities appear to affect biological organisms in diverse ways. SR appears to be a biophysical mechanism that coordinates such a relationship.

Human EEG is highly dependent on SR, which suggests that the natural electromagnetic frequencies in the Earth's atmosphere, known as SR, influence human brainwave activity. This suggests a correlation between atmospheric electromagnetic frequencies and brain activity.

While earlier models focused on calcium influx as the primary target of ELF fields, more recent findings indicate that weak magnetic fields likely act first on radical pairs within mitochondria. This radical pair mechanism (RPM) may influence reactive oxygen species (ROS) dynamics, which are tightly linked to intracellular calcium signaling via mitochondria-associated membranes (MAMs). These pathways can alter membrane potential, gene expression, and cellular communication.

Given this context, VGCC activation and calcium fluxes may be secondary consequences of mitochondrial redox modulation. Since calcium ions are involved in nearly all critical cellular processes – from apoptosis to signal transduction – these downstream effects can profoundly influence bioelectric regulation and health outcomes.Biological systems may have evolved to be influenced by electromagnetic frequencies in the ELF range that are naturally present in the environment. These frequencies, particularly the SR at 7.83 hz, could potentially enhance cellular energy levels and affect the RMP. Healthy cells typically have a higher RMP than those with dysfunction or disease.

During the silent phase, thalamocortical neurons might be entrained with SR, which suggests that during this phase, the electromagnetic frequencies of SR could potentially synchronize or entrain the activity of thalamocortical neurons, thereby justifying the coordination between SR and EEG.

There are ongoing studies on the potential health effects of exposure to electromagnetic fields. With the information collected from these studies, it seems plausible that unnatural EMF might affect organisms and cells in multiple ways, such as abnormal ion channels that function to coordinate the whole organism, and improper circadian rhythms.

https://www.tandfonline.com/doi/10.1080/15368378.2025.2508466

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**Effect of Occupational Exposure to Low-frequency Electromagnetic Fields on Cataract Development**

Validad MH, Mahjoob M, Pishjo M, Diani M, Rakhshandadi T. Effect of Occupational Exposure to Low-frequency Electromagnetic Fields on Cataract Development. J Ophthalmic Vis Res. 2025 Apr 25;20:1-6. doi: 10.18502/jovr.v20.12281.

Abstract

Purpose: Cataracts are the second leading cause of visual impairment worldwide. This study aimed to examine the impact of occupational exposure to low-frequency electromagnetic fields on cataract development.

Methods: One hundred employees of Zahedan Electricity Company participated in this study. They were assigned to four groups based on their level of exposure: regular, operational, operator personnel, and non-exposure. Based on LOCS III grading, the risk of developing different types of cataracts (i.e., nuclear, posterior subcapsular, and cortical) was evaluated for all participants.

Results: The frequency of cataracts was 62.2% in the exposure group (which includes three subgroups:

the regular, operational, and operator personnel) and 53.8% in the non-exposure group. There was a significant difference between the study groups in terms of nuclear opacity grading (P = 0.003). The correlation between nuclear and posterior subcapsular cataract grading and work experience duration in the exposure group was statistically significant (P < 0.018).

Conclusion: This study's findings indicate that exposure to low-frequency electromagnetic fields such as power lines, power plants, and power distribution posts may be a risk factor for cataract development, particularly nuclear cataracts.

https://pubmed.ncbi.nlm.nih.gov/40400659/

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**Carcinogenicity of extremely low-frequency magnetic fields: A systematic review of animal studies**

Luukkonen J, Roivainen P, Nieminen V, Naarala J, Mustafa E, Juutilainen J. Carcinogenicity of extremely low-frequency magnetic fields: A systematic review of animal studies. Environ Res. 2025 May 13:121819. doi: 10.1016/j.envres.2025.121819.

Abstract

Possible carcinogenicity of extremely low frequency (ELF) magnetic fields (MFs), associated with the use and transmission of electricity, has been under scientific and public debate for decades. This review aims to provide an update on studies testing carcinogenicity of ELF MFs in experimental animals. Emphasis was placed on identifying possible connections between study characteristics and the results obtained. This review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement, and the methodological quality of the studies was evaluated using the Risk of Bias Rating Tool for Human and Animal Studies developed by the National Toxicology Program's Office of Health Assessment and Translation (OHAT). Publication bias was assessed using the caliper test. Fifty-four eligible studies were identified. Despite poor ratings in certain aspects of the risk of bias evaluation, the quality of the studies was generally relatively good, with only four studies receiving the weakest rating. Overall, there was very little evidence that ELF MFs alone are carcinogenic. Evidence of co-carcinogenicity, from studies that have used ELF MFs in combination with other agents, remains inconclusive. A clear indication of publication bias was observed, though it is unlikely that this bias alone explains all reported MF-modified effects. Based on the current literature, future studies on co-carcinogenicity of ELF MFs should employ approaches other than classical initiation-promotion models. Additionally, well-designed studies to better understand the reported effects of ELF MFs and the underlying mechanisms are warmly welcomed.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0013935125010709

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**Weak anthropogenic electric fields affect honeybee foraging**

Mallinson VJ. Woodburn FA, O'Reilly KJ. Weak anthropogenic electric fields affect honeybee foraging. Cell Press. 2025. https://doi.org/10.1016/j.isci.2025.112550.

Highlights

• Weak anthropogenic-like electric fields reduce honeybee floral landing

• AC and positive DC fields deter honeybee landing, but negative DC does not

• Electric fields near power lines match experimental levels, spanning tens of meters

• These findings highlight electric pollution as a potential disruptor of pollination

Summary

Aerial electroreception, the detection of airborne electric fields (E-fields), is an emerging sensory system in arthropods, including bees, which can use floral E-fields as foraging cues. However, the influence of anthropogenic E-fields on these interactions remains underexplored. Through field experiments in urban meadows, we demonstrate that weak anthropogenic E-fields, including alternating current (AC) and direct current (DC) fields, significantly alter honeybee floral landing behaviors. AC and positive DC fields reduced landings by 71% and 53%, respectively, whereas negative DC fields had no statistically significant impact. Measurements of E-fields near high-voltage transmission lines revealed persistent field strengths comparable to those used experimentally, spanning tens of meters at heights relevant for bee foraging. These findings underscore the potential for anthropogenic E-fields to affect and potentially disrupt plant-pollinator interactions, threatening pollination efficiency, a cornerstone of agriculture and biodiversity. Our study highlights the need for advancing research on the ecological impacts of electric pollution.

Open access paper: https://www.cell.com/iscience/fulltext/S2589-0042(25)00811-9

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**Effect of short-term extremely low-frequency electromagnetic field on respiratory functions**

Sirinyildiz F, Cesur G, Elmas O, Elmas S, Comlekci S, Yazıcı O, Keskin A, Keskin HE. Effect of short-term extremely low-frequency electromagnetic field on respiratory functions. Rev Assoc Med Bras (1992). 2025 Jun 2;71(4):e20241812. doi: 10.1590/1806-9282.20241812. PMID: 40465999.

Abstract

Objective: Exposure to extremely low-frequency electromagnetic fields can cause harmful or beneficial effects on living organisms. The aim of this study was to examine the potential effects of extremely low-frequency electromagnetic fields on respiratory physiology by investigating possible changes in respiratory function parameters during and after short-term extremely low-frequency electromagnetic field exposure.

Methods: Twenty Wistar albino rats were included in the study, and these rats were randomly divided into two groups: control and electromagnetic field. A noninvasive head-out plethysmography technique was used to accurately assess lung function in rats. Rats in the electromagnetic field group were exposed to electromagnetic field at a frequency of 50 Hz and a magnetic flux density of 0.3 mT for 2 min. Respiratory function parameters of both groups were recorded in three separate periods before, during

and after electromagnetic field exposure. Respiratory rate, respiratory cycle duration, inspiration time, expiration time, tidal volume, minute volume, peak inspiratory flow, and peak expiratory flow were measured in these periods.

Results: There was no significant difference in the parameters measured before electromagnetic field exposure between the groups. During the electromagnetic field exposure period, the mean respiratory rate measured in the electromagnetic field group was lower compared to the control group data, while the mean respiratory cycle duration, inspiration time, and tidal volume measured in the electromagnetic field group were higher compared to the control group data. There was no significant difference in the parameters measured after electromagnetic field exposure between the groups.

Conclusion: Short-term extremely low-frequency electromagnetic field exposure decreases respiratory rate and increases respiratory cycle duration, inspiration time, and tidal volume.

Open access paper: https://www.scielo.br/j/ramb/a/9mQPKdGLX8DJ3mPwSqygwTG/?lang=en

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**Electromagnetic wireless remote control of mammalian transgene expression**

Lin Z, Guha Ray P, Huang J. *et al.* Electromagnetic wireless remote control of mammalian transgene expression. *Nat. Nanotechnol.* (2025). https://doi.org/10.1038/s41565-025-01929-w.

Abstract

Communication between wireless field receivers and biological sensors remains a key constraint in the development of wireless electronic devices for minimally invasive medical monitoring and biomedical applications involving gene and cell therapies. Here we describe a nanoparticle–cell interface that enables electromagnetic programming of wireless expression regulation (EMPOWER) of transgenes via the generation of cellular reactive oxygen species (ROS) at a biosafe level. Multiferroic nanoparticles coated with chitosan to improve biocompatibility generate ROS in the cytoplasm of cells in response to a low-frequency (1-kHz) magnetic field. Overexpressed ROS-responsive KEAP1/NRF2 biosensors detect the generated ROS which is rewired to synthetic ROS-responsive promoters to drive transgene expression. In a proof-of-concept study, subcutaneously implanted alginate-microencapsulated cells stably expressing an EMPOWER-controlled insulin expression system normalized blood-glucose levels in a mouse model of type 1 diabetes in response to a weak magnetic field.

Open access paper: https://www.nature.com/articles/s41565-025-01929-w

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**Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies, a systematic review**

Mevissen M, Ducray A, Ward JM, Kopp-Schneider A, McNamee JP, Wood AW, Rivero TM, Straif K. Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies, a systematic review. Environment International. 2025, doi: 10.1016/j.envint.2025.109482.

Abstract

Background  More than ten years ago, the World Health Organization's (WHO) International Agency for Research on Cancer (IARC) published a monograph concluding there was limited evidence in experimental animals for carcinogenicity of Radio Frequency Electromagnetic Field (RF EMF).

Objective  The objective of this review was to systematically evaluate the effects of RF EMF exposure on cancer in experimental animals.

Methods

Eligibility criteria: Based on pre-established Populations, Exposures, Comparators, Outcomes, and Study Type (PECOS) criteria, studies in experimental animals of the following study types were included: chronic cancer bioassays, initiation-(co–)promotion studies, and studies with tumor-prone animals.

Information sources: MEDLINE (PubMed), Science Citation Index Expanded and Emerging Sources Citation Index (Web of Science), and the EMF Portal.

Data abstraction and synthesis: Data are publicly available online as interactive visuals with downloadable metadata. We adapted the risk-of-bias (RoB) tool developed by Office of Health Assessment and Translation (OHAT) to include considerations pertinent to the evaluation of RF EMF exposure and cancer bioassays. Study sensitivity was assessed with a tool adopted from the Report on Carcinogens (RoC). We synthesized studies using a narrative approach. Effect size was calculated as the 1% Bayesian Average benchmark dose (BMD) of a respective study when dose–response or a trend was identified (see BMDAnalysisSupplementaryMaterial) (Supplement 1).

Evidence Assessment: Certainty of the evidence (CoE) was assessed using the Grading of Recommendations, Assessment, Developing and Evaluations (GRADE) approach, as refined by OHAT. Evidence from chronic cancer bioassays was considered the most directly applicable to evaluation of carcinogenicity.

Results  We included 52 studies with 20 chronic bioassays. No studies were excluded based on risk of bias concerns. Studies were not considered suitable for meta-analysis due to heterogeneity in study design, species, strain, sex, exposure characteristics, and cancer outcome. No or minimal evidence of RF EMF exposure-related cancer outcomes was found in most systems or organs in any study (these included gastrointestinal/digestive, kidney, mammary gland, urinary, endocrine, musculoskeletal, reproductive, and auditory). For lymphoma (18 studies), with 6 chronic bioassays (1,120 mice, 1,780 rats) inconsistency between two chronic bioassays was not plausibly explainable, and the CoE for lymphoma was rated 'moderate'. For brain tumors (20 studies), including 5 chronic bioassays (1,902 mice, 6,011 rats), an increase in glial cell-derived neoplasms was reported in two chronic bioassays in male rats. The CoE for an increased risk in glioma was judged as high. The BMD analysis was statistically significant for only one study and the BMD was 4.25 (95% CI 2.70, 10.24). For neoplasms of the heart (4 chronic bioassays with 6 experiments), 3 studies were performed in rats (∼2,165 animals), and 1 in mice (∼720 animals). Based on 2 bioassays, statistically significant increases in malignant schwannomas was judged as high CoE for an increase in heart schwannomas in male rats. The BMDs from the two positive studies were 1.92 (95 %CI 0.71, 4.15) and 0.177 (95 %CI 0.125, 0.241), respectively. Twelve studies reported neoplasms in the adrenal gland (5 chronic bioassays). The CoE for an increased risk in pheochromocytoma was judged as moderate. None of these findings were dose-dependent when compared to the sham controls. Sixteen studies investigated tumors of the liver with 5 of these being

chronic bioassays. The CoE was evaluated as moderate for hepatoblastomas. For neoplasms of the lung (3 chronic bioassays), 8 studies were conducted in rats (~1,296 animals) and 23 studies in mice (~2,800 animals). In one chronic bioassay, a statistically significant positive trend was reported for bronchoalveolar adenoma or carcinoma (combined), which was rated as moderate CoE for an increase in lung neoplasms with some evidence from 2 initiation-(co–)promotion studies.

Discussion  Meta-analysis was considered inappropriate due to the heterogeneity in study methods. The GRADE/OHAT CoE framework has not been frequently applied to animal studies and experience to date suggests refinements are needed. We deferred to standard methods in environmental health where CoE is framed in the context of strength of the evidence providing positive support for carcinogenicity. High CoE can be interpreted as the true effect is highly likely to be reflected in the apparent relationship. Moderate CoE indicates the true effect may be reflected in the apparent relationship. Cancer bioassays conducted in experimental animals are commonly used to identify potential human carcinogens. We note that the two tumor types with high CoE in animals in this systematic review are the same as those identified with limited evidence in humans by the IARC Working Group. However, even in cases where the animal evidence demonstrates high CoE, the extrapolation of risk from cancer bioassays to humans is particularly complex for RF EMF. Without a better understanding of the mechanism of the carcinogenicity of RF-EMF, the choice of exposure metric for risk extrapolation (whole body versus localized), intensity or cumulative exposure, whether or not a monotonic dose–response holds for carcinogenic effects, and whether SAR is the appropriate dose metric for adverse effects induced by RF-EMF may be critical.

Other  This review was partially funded by the WHO radioprotection programme. The protocol for this review was registered in Prospero reg. no. CRD42021265563 and published in Environment International 2022 (Mevissen et al. 2022).

Final conclusions

The findings of this systematic review indicate that there is evidence that RF EMF exposure increases the incidence of cancer in experimental animals with the CoE being strongest for malignant heart schwannomas and gliomas.

Despite the high level of certainty that evidence of carcinogenicity in experimental animals may predict a carcinogenic hazard to humans, extrapolation of risk from cancer bioassays to humans is particularly complex for RF EMF. Without an understanding of the mechanism of the carcinogenicity of RF-EMF the choice of exposure metric for risk extrapolation (whole body versus localized), intensity or cumulative exposure whether or not a monotonic dose–response holds for carcinogenic effects, and whether SAR is the appropriate dose metric for adverse effects induced by RF-EMF may be critical.

Besides the integration of the sensitivity domain adopted from the RoC, more work is needed to tailor the GRADE approach to assessing the CoE from animal cancer bioassays designed to identifying risks of environmental agents.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412025002338

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**The association of widely used electromagnetic waves exposure and pregnancy and birth outcomes in Yazd women: a cohort study**

Razavimoghadam M, Sefidkar R, Ehrampoush MH, Teimouri F, Hassanabadi MHZ, Nokhostin F. The association of widely used electromagnetic waves exposure and pregnancy and birth outcomes in Yazd women: a cohort study. BMC Pregnancy Childbirth. 2025 Apr 11;25(1):427. doi: 10.1186/s12884-025-07512-4.

Abstract

Background: The present study investigated the association between exposure to electromagnetic waves from widely used devices and pregnancy and birth outcomes among women in Yazd City.

Methods: This study was conducted on a total of 1,666 participants enrolled in the Yazd Mother and Child Cohort Center between 2015 and 2019. Cell phones, cordless phones, and Wi-Fi instruments were considered electromagnetic wave sources. Pregnancy and birth outcomes examined in this study include miscarriage, preterm labor, abnormal birth weight, and deviations in newborn height and head circumference. SPSS version 24 and R-studio version 4.3.1 software were used for statistical analysis.

Results: The current study revealed that 41 (2.5%) mothers had miscarriage and 174 (10.4%) mothers experienced preterm labor. Furthermore, 181 (10.9%) infants with abnormal birth weights, 117 (7%) infants with abnormal height, and 124 (7.4%) infants with abnormal head circumference were observed in this study. Individuals with longer cell phones call duration during pregnancy had higher risk of miscarriage ($p < 0.001$, RR (95% CI), 1.0061(1.003-1.0093)), abnormal birth weight ($p = 0.002$, RR (95% CI), 1.0012 (1.0004-1.002)) and height ($p = 0.003$, RR (95% CI), 1.0014 (1.0004-1.0023)) in comparison with those with lower cell phone call duration in this period.

Conclusion: The findings of the study revealed that an increase in exposure to cell phones during pregnancy can increase the risk of pregnancy and birth outcomes, namely miscarriage, abnormal weight and height of the infant. Furthermore, cordless phone conversations could increase the risk of abnormal weight in newborns.

Open access paper: https://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/s12884-025-07512-4

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**Effects of Mobile Electromagnetic Exposure on Brain Oscillations and Cortical Excitability: Scoping Review**

Torkan A, Zoghi M, Foroughimehr N, Yavari A, Jaberzadeh S. Effects of Mobile Electromagnetic Exposure on Brain Oscillations and Cortical Excitability: Scoping Review. *Sensors*. 2025; 25(9):2749. doi: 10.3390/s25092749.

Abstract

With the widespread adoption of smartphones, concerns about increased exposure to non-ionizing radiofrequency have emerged. This scoping review examines the effects of mobile phone exposure on

neural oscillations and cortical excitability, focusing on both motor and non-motor regions of the cerebral cortex. A scoping review identified seventy-eight studies that involved healthy individuals and employed electroencephalography and only two studies that investigated transcranial magnetic stimulation as primary technical tools. The findings suggest that mobile phone exposure may affect brain oscillations and cortical excitability. However, inconsistencies in experimental methods across studies make it difficult to draw definitive conclusions. Additionally, research on fifth-generation technology, particularly mmWave exposure from next-generation mobile networks, remains limited and needs further exploration. These gaps highlight the need for more in-depth studies on how mobile phone exposure impacts brain function.

Conclusions and Future Work

Our literature review indicates that mobile EM exposure can induce changes in brain oscillations, primarily increasing the amplitude of alpha, beta, theta, and delta bands, particularly in the eyes closed condition. This review suggests that mobile EM exposure may enhance CSE due to strengthened facilitator mechanisms and weakened inhibitory mechanisms. Despite extensive research over the years, several gaps remain in the literature, which require further investigation, particularly regarding the effects of 5G as an emerging technology. This is linked to the non-thermal effect even at exposure levels below current thermal thresholds. These findings underscore the need to revise SAR limits and to incorporate neurophysiological EEG and TMS metrics as non-invasive measures. Furthermore, the advent of 5G technology, with its use of higher frequency mmWave bands (>24 GHz), demands urgent investigation into potential unique tissue interactions and indirect neural impacts, which warrants precautionary measures until robust safety data are available. The conclusions of this review may be judged as consistent with the evidence. However, they should be treated with caution due to key limitations, such as limited TMS studies (only two), which resulted in a lack of data and some methodological and technical problems in EEG studies, as mentioned in the discussion and limitations section. Additionally, the lack of research verifying 5G frequencies above 6 GHz prevents definitive claims.

The following recommendations are suggested for future research in this field: (1) Conduct more comprehensive examinations of the effects of 5G mobile EM exposure on brain oscillations and brain excitability. This requires additional experimental research, including exposure systems operating at 5G frequencies and post-exposure assessments. (2) Study the impact of age factors on brain structure and physiology by assessing mobile EM exposure effects on both young and older adults to better understand age-related differences. (3) Investigate potential gender effects of mobile EM exposure on brain structure and function. (4) Enhance the precision of future research by refining methodological aspects, from data acquisition to result analysis, in EEG and TMS studies. This includes careful attention to study design, optimal sample size determination, and comprehensive study setup, all contributing to improved accuracy in future investigations. (5) Standardize exposure parameters (frequency, SAR, distance from the head), sham/control conditions (double-blind protocols), and reporting EEG/TMS technical details (electrode placement, filtering) in EEG and TMS protocols, which are critical updates to international EM exposure guidelines.

Open access paper: https://www.mdpi.com/1424-8220/25/9/2749

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**Sleep and Arousal Hubs and Ferromagnetic Ultrafine Particulate Matter and Nanoparticle Motion Under Electromagnetic Fields: Neurodegeneration, Sleep Disorders, Orexinergic Neurons, and Air Pollution in Young Urbanites**

Calderón-Garcidueñas L, Cejudo-Ruiz FR, Stommel EW, González-Maciel A, Reynoso-Robles R, Silva-Pereyra HG, Pérez-Guille BE, Soriano-Rosales RE, Torres-Jardón R. Sleep and Arousal Hubs and Ferromagnetic Ultrafine Particulate Matter and Nanoparticle Motion Under Electromagnetic Fields: Neurodegeneration, Sleep Disorders, Orexinergic Neurons, and Air Pollution in Young Urbanites. Toxics. 2025 Apr 8;13(4):284. doi: 10.3390/toxics13040284.

Abstract

Air pollution plays a key role in sleep disorders and neurodegeneration. Alzheimer's disease (AD), Parkinson's disease (PD), and/or transactive response DNA-binding protein TDP-43 neuropathology have been documented in children and young adult forensic autopsies in the metropolitan area of Mexico City (MMC), along with sleep disorders, cognitive deficits, and MRI brain atrophy in seemingly healthy young populations. Ultrafine particulate matter (UFPM) and industrial nanoparticles (NPs) reach urbanites' brains through nasal/olfactory, lung, gastrointestinal tract, and placental barriers. We documented Fe UFPM/NPs in neurovascular units, as well as lateral hypothalamic nucleus orexinergic neurons, thalamus, medullary, pontine, and mesencephalic reticular formation, and in pinealocytes. We quantified ferromagnetic materials in sleep and arousal brain hubs and examined their motion behavior to low magnetic fields in MMC brain autopsy samples from nine children and 25 adults with AD, PD, and TDP-43 neuropathology. Saturated isothermal remanent magnetization curves at 50-300 mT were associated with UFPM/NP accumulation in sleep/awake hubs and their motion associated with 30-50 μT (DC magnetic fields) exposure. Brain samples exposed to anthropogenic PM pollution were found to be sensitive to low magnetic fields, with motion behaviors that were potentially linked to the early development and progression of fatal neurodegenerative diseases and sleep disorders. Single-domain magnetic UFPM/NPs in the orexin system, as well as arousal, sleep, and autonomic regions, are key to neurodegeneration, behavioral and cognitive impairment, and sleep disorders. We need to identify children at higher risk and monitor environmental UFPM and NP emissions and exposures to magnetic fields. Ubiquitous ferrimagnetic particles and low magnetic field exposures are a threat to global brain health.

Open access paper: https://www.mdpi.com/2305-6304/13/4/284

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**Understanding Electromagnetic Hypersensitivity (EHS) From Mobile Phone Radiofrequency Radiation (RFR) Exposure: A Mixed-Method Study Protocol**

Razak NSZM, Rahman AA, Minhat HS, Fauzi FA. Understanding Electromagnetic Hypersensitivity (EHS) From Mobile Phone Radiofrequency Radiation (RFR) Exposure: A Mixed-Method Study Protocol. Bioelectromagnetics. 2025 May;46(4):e70007. doi: 10.1002/bem.70007.

Abstract

More than 7 billion mobile phone users were recorded worldwide in 2022. Radiofrequency radiation (RFR) from mobile phones can produce radiobiological effects, which may lead to electromagnetic

hypersensitivity (EHS) in humans. This study employs a mixed-method approach: the quantitative component identifies predictors of EHS from mobile phone RFR using the biopsychosocial model, whereas the qualitative component explores individual experiences that contribute to EHS. Quantitative analysis is conducted using the Statistical Package for the Social Sciences (SPSS) version 25.0 for descriptive and analytical statistics, whereas qualitative analysis is carried out with NVivo version 14 for thematic analysis. Findings from both analyses are compared and discussed to highlight similarities and differences, providing a richer, in-depth understanding of EHS resulting from mobile phone RFR exposure among undergraduate students. The study sample consists of 351 undergraduate students aged 18-25 from Universiti Putra Malaysia (UPM), conducted between April 2023 and December 2023. Approval was obtained from the Ethics Committee for Research Involving Human Subjects at UPM before the study. The quantitative component uses a proportionate simple random sampling method with a validated questionnaire, whereas the qualitative component utilizes purposive sampling through in-depth interviews. Enhancing understanding of EHS may contribute to new knowledge and raise awareness of its potential effects on the population.

https://pubmed.ncbi.nlm.nih.gov/40293416/

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**Temporal Change of Outdoor Rf-Emf Levels Four in European Countries: A Microenvironmental Measurement Study**

Belackova L, Veludo AF. Aminzadeh R, Van Bladel H, Griffon V, Cardis E. et al. Temporal Change of Outdoor Rf-Emf Levels Four in European Countries: A Microenvironmental Measurement Study. Available at SSRN: https://ssrn.com/abstract=5146655 or http://dx.doi.org/10.2139/ssrn.5146655.

Abstract

Introduction  Over the past two decades, the amount of transmitted mobile data have increased rapidly. It is unknown whether the implementation of the new technologies enabling this has resulted in changes of outdoor radio-frequency electromagnetic fields (RF-EMF) exposure. Therefore, microenvironmental measurements were used to investigate temporal trends in RF-EMF exposure between 2016 and 2023, in the Netherlands, Switzerland, Belgium and Spain, following a similar protocol across campaigns. This allowed us to compare exposure trends between countries and years.

Methods  The data was collected as part of the ACCEDERA (2016-2018), ETAIN (2023), and GOLIAT (2023) projects, walking repeatedly the same routes with RF-EMF exposimeters. Identical microenvironments were identified in each country and measurements of the exposure of mobile base station, contribution of mobile phones and the total levels were compared across years.

Results  Comparing measurements between 6 to 14 unique microenvironments in each country, our data did not suggest significant changes in the exposure from the mobile base station origin (total downlink exposure) between 2016 and 2023 for the four countries. Across all countries the median values of the mobile base station exposure ranged from 0.12 mW/m2 in Switzerland and 0.24 mW/m2 in Belgium in 2016 to 0.28 mW/m2 in the Netherlands in 2023, 0.20 mW/m2 in Belgium, 0.11 mW/m2 in Switzerland and 0.19 mW/m2 in Spain in 2023. There was no consistent trend in the individual microenvironments across the countries.

Conclusions  Our measurements of across included environment groups RF-EMF outdoor exposure levels do not indicate change in exposure levels between 2016 and 2023 despite an increase in mobile data traffic by a factor of 8 in Western Europe.

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5146655

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**Assessing EMF Exposure in Greek Urban and Suburban Areas During 5G Deployment: A Focus on 5G EMF Levels and Distance Correlation**

Manassas A, Christopoulou M, Papanikolaou N, Delidimitriou S, Karabetsos E, Samaras T. Assessing EMF Exposure in Greek Urban and Suburban Areas During 5G Deployment: A Focus on 5G EMF Levels and Distance Correlation. *Electronics*. 2025; 14(8):1554. doi: 10.3390/electronics14081554

Abstract

This study presents an extensive analysis of electromagnetic field (EMF) exposure in Greek urban and suburban areas during the ongoing deployment of the 5G technology. A total of 400 in situ measurements of electric field strength were conducted at ground level across four distinct regions. The first part of the study provides a statistical analysis of the overall EMF exposure, highlighting the contributions of different cellular generations (2G–5G) to the total field. The results show that 4G networks are the dominant contributors, while the impact of 5G remains limited. The second part investigates the correlation between electric field levels in the 3.5 GHz band and the distance from 5G base stations (BS). Using geospatial analysis, we computed distances to the nearest BS and examined their relationship with measured EMF levels. The findings indicate a general inverse correlation between EMF levels and BS distance, although variations occur due to factors such as line-of-sight conditions and urban built environment characteristics. These results confirm that distance remains a key predictive feature for AI-based EMF exposure models, even in the case of 5G networks.

Conclusions

This study presents a descriptive statistical analysis of electric field measurements in four different regions in Greece, focusing on both the existing cellular networks and the emerging 5G technology. The findings reveal that electric field levels vary considerably across different environments, with urban areas exhibiting higher values due to greater population density and a higher concentration of BS. Cellular networks, especially 4G, contribute significantly to the overall electric field levels, whereas the 5G network shows only a minor contribution. Recording the electric field at the 3.5 GHz band without generating data traffic and examining its correlation with distance from BS, we observed that, in general, as distance increased, the recorded electric field decreased. Our results confirm that distance from BS antennas should be included as a predictive feature in AI models for EMF levels, not only for 2G, 3G, and 4G networks, but also for 5G. This finding highlights the enduring significance of distance as a key factor for accurately predicting EMF levels in the 5G band, where its influence on field strength is clearly observed.

Open access paper: https://www.mdpi.com/2079-9292/14/8/1554

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**Impact of expectancy on fatigue by exposure to the fifth generation of mobile communication signals**

Yang L, Ding X, Zhang S, Wu T. Impact of expectancy on fatigue by exposure to the fifth generation of mobile communication signals. Electromagn Biol Med. 2025 Apr 23:1-12. doi: 10.1080/15368378.2025.2496151.

Abstract

There is a long-standing debate about the relationship between Radio Frequency Electromagnetic Field (RF-EMF) exposure and fatigue. Past studies primarily rely on self-report scales to assess fatigue, but these methods are often susceptible to personal biases. Notably, the role of psychological factors in the fatigue response induce by RF-EMF exposure remains unclear. Therefore, our study focuses on exploring the impact of 5G signal exposure on human fatigue, particularly considering the influence of expectancy induced by psychological priming on the outcomes. In this study, we recruited 21 healthy subjects who were tested in three sessions. Each session included two 30-min exposures to either real or sham 5 G signals, with the order randomized. The experiment was conducted under varying informational conditions: subjects were provided with correct, false, or no information about the order of exposure. Additionally, subjects completed a fatigue scoring questionnaire and underwent Electroencephalogram (EEG) measurements during the experiment. The statistical comparison indicates that 5 G RF-EMF exposure at routine levels does not lead to changes in EEG power. The finding reveals that the report of fatigue can be altered by the conveyed information of being exposed by 5 G signals although there is no real exposure and no detectable electrophysiological indicator. Our findings suggest that it is necessary to prevent psychological priming in any kind or to take its possible consequence into consideration, to reveal this effect of RF-EMF exposure.

https://pubmed.ncbi.nlm.nih.gov/40269539/

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**Determining the relationship between mobile phone network signal strength and RF-EMF exposure: protocol and pilot study to derive conversion functions**

Sandoval-Diez N, Belácková L, Fernandes Veludo A, Jalilian H, Guida F, Deltour I, Thielens A, Zahner M, Fröhlich J, Huss A, Röösli M. Determining the relationship between mobile phone network signal strength and radiofrequency electromagnetic field exposure: protocol and pilot study to derive conversion functions. Open Res Eur. 2025 Mar 31;4:206. doi: 10.12688/openreseurope.18285.2.

Abstract

Mobile phones continuously monitor and evaluate indicators of the received signal strengths from surrounding base stations to optimise wireless services. These signal strength indicators (SSIs) offer the potential for assessing radiofrequency electromagnetic field (RF-EMF) exposure on a population scale, as they can be related to exposure from both base stations and handset devices. Within the ETAIN (Exposure To electromAgnetic fields and plaNetary health) project, an open-access RF-EMF exposure app for smartphones, named "ETAIN 5G-Scientist", has been developed using citizen science. This paper delineates a measurement protocol for deriving formulas to convert the app SSIs into electric field values to estimate RF-EMF exposure. It presents pilot study results from measurements taken at four locations in France (FR), and 14 locations in the Netherlands (NL), using three different phone models

and the most common network providers in each country. The measurements were conducted while executing different usage scenarios, such as calls or data transmission. The exposimeter ExpoM-RF4 and on-body electric field probes were used to measure exposure from far-field sources and the handset, respectively. Two-minute aggregates were considered the sample unit for analyses (n=891 in NL, n=395 in FR). Regression analyses showed a positive log-linear relationship between Long Term Evolution (LTE) Received Signal Strength Indicator (RSSI) and far-field RF-EMF exposure when aggregating data by location (coefficients for normalised RSSI: 0.91 [95% CI: 0.55 - 1.28] in FR, 1.09 [95% CI: 0.96 - 1.22] in NL). Negative log-linear trends were observed for handset-related RF-EMF exposure at the ear (-0.31 [95% CI: -0.46 - -0.16]) and chest (-0.20 [95% CI: -0.37 - -0.03]) during data transmission scenarios. These results demonstrate that the ETAIN 5G-Scientist app can be implemented for smartphone-based RF-EMF estimation. However, uncertainties in individual measurement points highlight the need for further data collection and analysis to improve the accuracy of exposure estimates.

Plain language summary

In this study, we looked at how mobile phones can help us measure exposure to radiofrequency electromagnetic fields (RF-EMF) from mobile wireless communication. As part of the ETAIN project (Exposure To electromAgnetic fields and plaNetary health), we developed an app called "5G Scientist" to keep track of the signal strength indicators (SSIs) that smartphones continuously use to establish and improve wireless connections. Our goal is to study how these indicators are related to RF-EMF exposure and to develop formulas for converting them into exposure values. To achieve this, we developed a measurement protocol and tested it in a pilot study. In this pilot study, we took spot measurements in France and the Netherlands using various phone models and network providers, while applying different usages of the phone, e.g. voice or video calls and data transmission. We used a personal exposimeter to measure exposure from far-field sources (such as base stations) and on-body electric field probes to measure exposure from near-field sources (such as own phone use). Our measurements indicate that as signal quality improves, exposure from mobile phone base stations increases, whereas exposure from one's own device decreases in both strength and duration. These results suggest that smartphone apps could serve as valuable tools for large-scale exposure assessment, as they show the potential to capture ambient exposure as well as exposure coming from the own mobile phone. However, more extensive measurement campaigns are needed to make this method more accurate.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC12032521/

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**Chicken or egg? Attribution hypothesis and nocebo hypothesis to explain somatization associated to perceived RF-EMF exposure**

Ariccio S, Traini E, Portengen L, Martens A, Slottje P, Vermeulen R, Huss A. Chicken or egg? Attribution hypothesis and nocebo hypothesis to explain somatization associated to perceived RF-EMF exposure. Front Public Health. 2025 Apr 9;13:1561373. doi: 10.3389/fpubh.2025.1561373.

Introduction: The aim of this study is to understand the temporal relationship between the somatization usually attributed to RF-EMFs, and to evaluate the attribution hypothesis and the nocebo hypothesis in this context.

Method: In this longitudinal study, data from the Dutch Occupational and Environmental Health Cohort Study (AMIGO) was analyzed, consisting of a baseline questionnaire collected in 2011 (14,829 participants) and a follow-up questionnaire collected in 2015 (7,904 participants). Participants completed a questionnaire providing information on their health status, perceived environmental exposures, and demographics. Two sets of multiple regressions were conducted to evaluate the two hypotheses.

Results: Results show that the attribution hypothesis overall explained symptom reporting in association to perceived RF-EMF base station exposure and perceived electricity exposure more frequently than the nocebo hypothesis.

Discussion: This finding stands out from most of the existing literature, which primarily points to the nocebo effect as the main explanation for somatization in response to RF-EMF exposure. While this does not exclude, in absolute terms, the existence of a nocebo effect, potentially at other time scales, this finding has relevant consequences at the policy making level. The emerging relevance of the attribution hypothesis moves the focus on the discomfort of people with unexplained symptoms and their need to find a plausible explanation for their discomfort.

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1561373/full

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**Electromagnetic fields regulate iron metabolism: From mechanisms to applications (Review)**

Wang S, Yang J, Zhen C, Wang H, Shang P. Electromagnetic fields regulate iron metabolism: From mechanisms to applications. J Adv Res. 2025 Apr 29:S2090-1232(25)00288-7. doi: 10.1016/j.jare.2025.04.044.

Abstract

Background: Electromagnetic fields (EMFs), as a form of physical therapy, have been widely applied in biomedicine. Iron, the most abundant trace metal in living organisms, plays a critical role in various physiological processes, and imbalances in its metabolism are closely associated with the development and progression of numerous diseases. Numerous studies have demonstrated that EMF exposure induces significant changes in both systemic and cellular iron metabolism.

Aim of review: This review aims to summarize the evidence and potential biophysical mechanisms underlying the role of EMFs in regulating iron metabolism, thereby enhancing the understanding of their biological mechanisms and expanding their potential applications in biomedical fields.

Key scientific concepts of review: In this review, we have synthesized research findings and proposed the hypothesis that the biophysical mechanisms of EMFs regulate iron metabolism involve the special electromagnetic properties of iron-containing proteins and iron-enriched tissues, as well as the modulation of membrane structure and function, ion channels, and the generation and activity of Reactive Oxygen Species (ROS). Then, the review summarizes the latest advances in the effects of EMFs

on iron metabolism and their safety, as well as their impact on immunoregulation, cardiovascular diseases, neurological diseases, orthopedic diseases, diabetes, liver injury, and cancer.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S2090123225002887?via%3Dihub

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**Efficient design of electromagnetic field exposure maps with multi-method evolutionary ensembles**

Guillén-Pina J, Pérez-Aracil J, Chocano-del-Cerro R, Sánchez-Montero R, López-Espí P-L, Salcedo-Sanz S. Efficient design of electromagnetic field exposure maps with multi-method evolutionary ensembles. Environmental Research, 2025, doi: 10.1016/j.envres.2025.121636.

Abstract

Radio-frequency electromagnetic field (EMF) exposure is a growing concern among the population. This concern has led to a need for practical tools to contribute to an adequate risk perception. Representing spatial variations after measurements from fixed sites and interpolating using different techniques is the most suitable method for obtaining EMF high-quality exposure maps. This paper uses evolutionary computation to obtain the optimal set of points to construct high-quality electromagnetic field exposure maps (minimizing an error measure with respect to a reference exposure map). A multi-method ensemble evolutionary approach, able to combine different search operators in a single population (PCRO-SL), is introduced for this particular problem, and it has been tested over actual measurements at Meco town, Madrid, Spain, obtaining good quality electromagnetic field exposure map reconstructions in terms of the differences with a reference EMF exposure map. The results obtained show that reducing the number of measurement points necessary to obtain significant exposure maps, while maintaining their representativeness, is possible.

Conclusions

In this work, an evolutionary multi-method ensemble algorithm for optimization (PCRO-SL) has been used to determine the best points that allow a true representation of the EMF exposure values to be obtained in an ur- ban area. This choice makes it possible to optimize the effort involved in producing these type of maps, for which measurements are taken from fixed locations. The density of points required has been reduced from the initial 8-10 points/km$^2$ to just over 5 points/km$^2$.

The division of the territory to be sampled into 250-meter squares can be useful to establish a first analysis of the area, but it is necessary to determine those points of largest interest in order to optimize the sampling effort. The analysis of the results obtained with the proposed multi-method ensemble for optimization, has made possible to establish the following criteria for the preparation of future exposure maps:

- At least one point in direct line-of-sight (LOS) conditions shall be cho- sen within a first radius of 250 meters.
- Within a second radius of 500 meters, sampling points should be chosen in different radial directions, regardless of their LOS/NLOS status, to determine the rate of variation in the different directions.

- If they are not included in the above criteria, points should be chosen on the perimeter of the surface to be analyzed to avoid artifacts due to interpolation at the extremes of the exposure map.

The above criteria allow obtaining a spatial representation of EMF expo- sure while also maintaining the basic statistical properties of the chosen set of points: mean, variance and approximation to the lognormal distribution.

The effort required to produce these type of maps has been reduced using an evolutionary-type algorithm. This has make possible to obtain exposure maps leading to an adequate perception of the risk of exposure by the general public. For future work, the specific analysis depending on the type of mobile technology or radio service, and the comparison of the results obtained when the measurements are taken by means of exposure meters or other meters are still pending.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0013935125008874

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**High Radiofrequency Radiation in the Surroundings of 10 Schools in Örebro, Sweden**

Hardell L, Nilsson M. High Radiofrequency Radiation in the Surroundings of 10 Schools in Örebro, Sweden. Fortune Journal of Health Sciences. 8 (2025): 306-310.

Abstract

In Sweden as well as in many other countries the fifth generation, 5G, for wireless communication is rolled-out since 2019/2020. This has caused increasing environmental exposure to radiofrequency (RF) radiation. Children and adolescents are especially vulnerable to RF radiation. Exposure sources in schools such as Wi-Fi routers, wireless connected mobile phones, and computers may cause high RF-exposure inside the schools but also outside sources, such as mobile phone base stations, may contribute significantly. In this study outside environmental exposure to RF radiation from 4G and 5G base stations was measured in October 2024 in close proximity to 10 schools in Sweden. The maximum levels ranged from 10,716 to 68,452 μ/m$^2$. These levels far exceed the EUROPAEM EMF guidelines for daytime RF radiation exposure 10-1,000 μW/m$^2$, nighttime 1-100 μW/m2, and for sensitive persons 0.1-10 μW/m$^2$.

Excerpts

The measurements were made with the Narda broadband field meter NBM-550, with the probe EF-1891, measuring frequencies between 3 MHz-18 GHz and measurement range 0.6 V/m (955 μW/m2) to 65 V/m (11,206,897 μW/m2). This meter shows results in root mean square (RMS) for both minimum, maximum and average RF radiation level. The frequencies used for 5G in city environments in Sweden are in general around 3.5 GHz while frequencies used for 4G are primarily around 2.6 GHz (https://www.induo.com/b/lte-band-mobilt-bredband/)...

The Narda meter RMS results were considerably lower than Safe and Sound maximum peak exposure values. As one example, at two different spots, the Safe and Sound meter showed max peak levels of 749,000 μW/m 2 (sleeping room, desk, daughter) and 504,000 μW/m2 (sleeping room, pillow,

daughter). The Narda RMS maximum levels at the same spots were 137,889 µW/m2 and 88,616 µW/m2, respectively (22). Both measurements were made at the same time.

Open access paper: https://cdn.fortunejournals.com/articles/high-radiofrequency-radiation-in-the-surroundings-of-10-schools-in-oumlrebro-sweden.pdf

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**The effect on rat peripheral nerve morphology and function of a 900-MHz electromagnetic field applied in the prenatal period**

Hancı H, Yenilmez E, Demir S, Yıldırım M, Gedikli Ö, Kaya H. (2025). The effect on rat peripheral nerve morphology and function of a 900-MHz electromagnetic field applied in the prenatal period. *Electromagnetic Biology and Medicine*, 1–16. doi: 10.1080/15368378.2025.2479517

Abstract

The purpose of this study was to investigate the effects of a 900 megahertz (MHz) electromagnetic field (EMF) applied in the prenatal period on rat peripheral nerve morphology, nerve conduction velocity, and locomotor activity. Nine pregnant Sprague Dawley rats were assigned into three groups. No procedure was applied to the first group (control). The second (sham) group was placed inside an EMF cage for 1 h a day throughout the experiment (days 1–21 of pregnancy), but was not exposed to EMF. The third group (EMF) was placed inside the EMF cage for 1 h a day throughout the experiment (days 1–21 of pregnancy) and exposed to a 900 MHz EMF. No procedure was applied to the newborn pups until postnatal (PN) day 21, and new groups were constituted from among these. All the newly established groups were subjected to the open field and rotarod tests on PN days 21 and 60, after which electrophysiological measurements were performed on the groups in line with the study protocol. Sciatic nerves obtained from the animals sacrificed on PN day 60 were subjected to histopathological, histomorphometric, immunohistochemical, and biochemical analyses. In light of the study results, we concluded that prenatal application of a 900 MHz EMF adversely affects rat peripheral nerve development, and that these effects persist up to adulthood such as to be detectable in the sciatic nerve morphology, but that these morphological changes are not sufficiently severe to affect functional associated with the sciatic nerve.

Plain Language Summary

This study explores the impact of a 900 MHz electromagnetic field (EMF) applied during the prenatal period on the peripheral nerve morphology, nerve conduction velocity, and locomotor activity of rats. Nine pregnant Sprague Dawley rats were divided into three groups: control, sham, and EMF. The control group received no treatment, the sham group was placed in an EMF cage without exposure, and the EMF group was exposed to the 900 MHz EMF for 1 hour daily throughout pregnancy. The offspring were tested on postnatal days 21 and 60 using open field and rotarod tests, followed by electrophysiological assessments. Sciatic nerves from the sacrificed animals on postnatal day 60 underwent histopathological, histomorphometric, immunohistochemical, and biochemical analyses. The results indicated that prenatal EMF exposure negatively affects peripheral nerve development in rats, with these effects persisting into adulthood, though not severe enough to impair functional outcomes associated with the sciatic nerve. Additionally, the study provides context on the evolution of communication technologies, emphasizing the increasing use of EMF-emitting devices like cell phones.

Given that these devices emit EMF even in standby mode, understanding their potential effects on peripheral nerve integrity is crucial, especially considering the vital role of Schwann cells in nerve development and function. The findings underscore the need for further investigation into the long-term impacts of EMF exposure on peripheral nerve health, particularly during critical developmental periods.

https://doi.org/10.1080/15368378.2025.2479517

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**Experimental Study of Animal Behavior under the Influence of the Electromagnetic Field of the 5G Mobile Communication Standard**

Nikitina VN, Kalinina NI, Dubrovskaya EN *et al.* Experimental Study of Animal Behavior under the Influence of the Electromagnetic Field of the 5G Mobile Communication Standard. *Biol Bull Russ Acad Sci* **51**, 3473–3480 (2024). doi: 10.1134/S1062359024701875.

Abstract

A pilot experimental study was carried out to assess the effect of unmodulated and modulated electromagnetic fields of the 5G mobile communication standard on the central nervous system of animals. Mature male Wistar rats were exposed to electromagnetic fields with a frequency of 4.9 GHz and an intensity of 250 μW/cm$^2$ for 15 days for two hours a day. The animals of the two irradiated groups and the control group were in identical conditions in a semi-anechoic shielded chamber. The effect of the electromagnetic field on the functional state of the central nervous system was assessed by a comprehensive analysis of behavior patterns in the “open field” test before and after irradiation. The study did not reveal clear differences in animal behavior when exposed to unmodulated and modulated 5G electromagnetic fields. Statistically significant changes in animal behavior were recorded in the dynamics of the experiment in two irradiated and control groups, which may be due to a change in the natural electromagnetic background in a semi-anechoic shielded chamber.

https://link.springer.com/article/10.1134/S1062359024701875

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**Effect of Repeated Exposure to Complexly Organized Electromagnetic Radiation on the Rat Behavior in the “Open Field” Test**

Kolganova OI, Panfilova VV, Izmestyeva OS *et al.* The Effect of Repeated Exposure to Complexly Organized Electromagnetic Radiation on the Rat Behavior in the “Open Field” Test. *Biol Bull Russ Acad Sci* **51**, 3467–3472 (2024). doi: 10.1134/S1062359024701826.

Abstract

The effect of threefold (1 hour a day with an interval of three days) and multiple (8 weeks, 5 days a week, 2 hours a day) pulsed-modulated electromagnetic radiation on the orienting-exploratory response was studied on males and females of Wistar rats by the “open field” method. The animals were irradiated in an anechoic chamber in the zone of the formed wave of the microwave source (a block of 10 generators carrying frequencies from 1 to 4 GHz, the total pulse power density 300 μW/cm$^2$, pulse duration 25 ms, sweep cycles 1–6 Hz, cycle turn-around time 30 s). It was shown that the exposure to

such parameters could cause a stress reaction and an impairment of long-term memory in some irradiated animals, female rats being more sensitive to the action of microwaves than males. This reaction was transient and the animal behavior was restored 1.5–2 months after cessation of irradiation. However, there is a danger that in the case of constant exposure to microwaves, which, for example, occurs in mobile users, such behavior deviations may be fixed and clinically significant.

https://link.springer.com/article/10.1134/S1062359024701826

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**Experimental Study of Stress Reactions Induced by Low-Intensity Microwave Radiation**

Izmestieva OS, Kolganova OI, Chibisova OF *et al.* Experimental Study of Stress Reactions Induced by Low-Intensity Microwave Radiation. *Biol Bull Russ Acad Sci* **51**, 3457–3466 (2024). doi: 10.1134/S1062359024701802.

Abstract

A study was made of the severity and dynamics of changes in indicators reflecting the state of the blood system (the number of myelokaryocytes in the femur, the level of CFU-S in the exo and endotest, hemolytic resistance of erythrocytes, as well as the mass and cellularity of the thymus) in mice exposed to monochromatic pulsed electromagnetic fields of the frequency range 2.27–2.78 GHz with an average power flux density of 60 μW/cm$^2$ at doses from 0.086 to 0.86 J/g. It is shown that, under repeated exposure to electromagnetic fields, the bioeffect cumulates, leading to the development of a stress-like adaptive reaction in animals.

https://link.springer.com/article/10.1134/S1062359024701802

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**Effects of 700MHz radiofrequency radiation (5G lower band) on the reproductive parameters of female Wistar rats**

Jha N, Sarsaiya P, Tomar AK, Pardhiya S, Nirala JP, Chaturvedi PK, Gupta S, Rajamani P. Effects of 700MHz radiofrequency radiation (5G lower band) on the reproductive parameters of female Wistar rats. Reprod Toxicol. 2025 Apr 10:108910. doi: 10.1016/j.reprotox.2025.108910.

Abstract

The advent of 5G technology has raised concerns about its potential biological effects, particularly reproductive health being one key area of focus. This study investigated the impact of 700MHz, a lower 5G frequency band, on the reproductive health of female Wistar rats. The experiment analyzed the effects of short-term and long-term exposure to 700MHz mobile radiation on female Wistar rats. Rats were divided into three groups (control, sham-exposed, and exposed), with sample sizes of n=6 for short-term and n=8 for long-term exposure. For short-term exposure, rats were subjected to 6 hrs of radiation daily for 10 days, while for long-term exposure, rats exposed 4 hrs daily for 60 days. Physiological parameters, including estrous cyclicity, were monitored, and histopathological and biochemical analyses were conducted on harvested ovaries. Comet assay was performed to assess DNA damage. The results indicated no changes in estrous cycles or comet assay parameters in either

exposure group. Serological hormone levels, including estradiol and progesterone, remained within normal ranges, but a slight yet significant increase in testosterone levels was observed in exposed groups. Oxidative stress markers revealed elevated malondialdehyde (MDA) levels and significant decreases in superoxide dismutase (SOD), total sulfhydryl content, and ferric reducing antioxidant power (FRAP) in exposed ovaries. Histopathological analysis showed no significant changes in ovarian morphology in short-term exposure but revealed alterations, including cystic follicles and abnormal vasculature, in long-term exposure. These findings suggest that 700MHz radiation may induce oxidative stress and tissue changes in ovarian samples over prolonged exposure

Highlights

• The length of estrous cycle remained unaffected in both short-term and long-term exposure to 700 MHz.
• Short-term exposure showed no major histoarchitectural changes. However, in long term exposure the exposed group showed abnormal structures when compared to control and sham group.
• For both short-term and long-term exposure significant changes in the testosterone level of the exposed group observed. However, the change in level remained within the normal range.
• The comet assay results indicated no DNA damage in both short-term and long-term exposure.

https://pubmed.ncbi.nlm.nih.gov/40220970/

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**Possible effects of RF EMR on contextual fear conditioning, hippocampal perivascular space, apoptosis and adrenal gland microarchitecture in rats**

Narayanan SN, Kumar RS, Kumar N, Prabhakar P, Nayak SB, Bhat PG. Possible effects of radiofrequency electromagnetic radiation on contextual fear conditioning, hippocampal perivascular space, apoptosis and adrenal gland microarchitecture in rats. Behav Brain Res. 2025 Mar 12;481:115424. doi: 10.1016/j.bbr.2025.115424.

Abstract

Whilst the world sees the tremendous growth of mobile phone technology, radiofrequency electromagnetic radiation (RF-EMR) induced possible health effects have emerged as a topic of recent day debate. The current study is designed to test the hypothesis that chronic 900 MHz radiation exposure would potentially dysregulate the stress response system (HPA axis) in vivo, via, its non-thermal mechanisms, leading to alterations in the microarchitecture of the adrenal gland, vulnerable brain regions such as the hippocampus which may results in altered behaviours in rats. Male albino Wistar rats aged four weeks, weighing 50-60 g were subjected to 900 MHz radiation from a mobile phone for four weeks at a rate of one hour per day. On the 29th day, animals from the control, sham exposed and RF-EMR exposed groups were tested for contextual fear conditioning. They were later euthanized to study hippocampal and adrenal gland cytoarchitecture. Bright and dark compartment transitions in the avoidance box were considerably elevated in the RF-EMR exposed group and they exhibited a significant decrease in the latency to enter the dark compartment during the contextual fear conditioning test. Apoptosis was apparent in the CA3 region and perivascular space was significantly increased in the hippocampus of the radiation-exposed group. In addition to lymphocytic infiltrates,

congested sinusoids, apoptotic-like changes were evident in the zona fasciculata of the adrenal gland. However, the cytoarchitecture of the adrenal medulla was comparable in all three groups. Chronic RF-EMR exposure caused changes in contextual fear conditioning, enlargement of hippocampal perivascular space, apparent CA3 apoptosis, and apoptotic-like changes in the zona fasciculata of the adrenal gland in rats.

Highlights

Chronic 900 MHz radiation-induced altered contextual fear memory.

Exposure to 900 MHz radiation resulted in increasing the hippocampal perivascular space.

Altered memory is attributed to hippocampal apoptosis induced by 900 MHz radiation.

900 MHz radiation triggered apoptosis and lymphocytic infiltration in the adrenal gland.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0166432825000105?via%3Dihub

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**Impact of a Terahertz electromagnetic field on the ion permeation of potassium and sodium channels**

Song Z, Xue L, Ouyang Q, *et al.* Impact of a Terahertz electromagnetic field on the ion permeation of potassium and sodium channels. *Commun Chem* 8, 101 (2025). doi: 10.1038/s42004-025-01503-4.

Abstract

Ion channels are essential for various physiological processes, and their defects are associated with many diseases. Previous research has revealed that a Terahertz electromagnetic field can alter the channel conductance by affecting the motion of chemical groups of ion channels, and hence regulate the electric signals of neurons. In this study, we conducted molecular dynamics simulations to systematically investigate the effects of terahertz electromagnetic fields on the ion permeation of voltage-gated potassium and sodium channels, particularly focusing on the bound ions in the selectivity filters that have not been extensively studied previously. Our results identified multiple new characteristic frequencies and showed that 1.4, 2.2, or 2.9 THz field increases the ion permeability of $K_v1.2$, and 2.5 or 48.6 THz field increases the ion permeability of $Na_v1.5$. Such effects are specific to the frequencies and directions of the electric field, which are determined by the intrinsic oscillation motions of the permeating ions in the selectivity filter or certain chemical groups of the ion channels. The amplitude of the THz field positively correlates with the change in ion permeation. This study demonstrates that THz fields can specifically regulate ion channel conductances by multiple mechanisms, which may carry great potential in biomedical applications.

Open access paper: https://www.nature.com/articles/s42004-025-01503-4

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**Residential exposure to magnetic field due to high-voltage power lines and childhood leukemia risk in mainland France - GEOCAP case-control study**

Mancini M, Hémon D, Faure L, Clavel J, Goujon S. Residential exposure to magnetic field due to high-voltage power lines and childhood leukemia risk in mainland France - GEOCAP case-control study, 2002-2010. Environ Res. 2025 Apr 16:121638. doi: 10.1016/j.envres.2025.121638.

Abstract

Background: Environmental exposure to extremely low frequency magnetic fields (ELF-MF) is suspected of being a risk factor of childhood acute leukemia (AL) and classified as possible carcinogen. Results of recent epidemiological studies remain however heterogeneous.

Objective: The present study aimed to evaluate AL risk in children exposed to ELF-MF by living close to high-voltage overhead power lines (HVOL) in France.

Methods: We included 4,117 AL cases under the age of 15 diagnosed in 2002-2010 and 44,838 contemporary controls representative of the French pediatric population, drawn from the national registry-based GEOCAP study. The distance between the geocoded address of residence and the closest 63-400kV HVOL, and the closest 225-400kV HVOL, were evaluated. ELF-MF exposure was also calculated at the geocoded addresses considering the characteristics of the neighboring HVOLs. Logistic regression models adjusted for age were used to estimate odds-ratios (OR) and 95% confidence intervals. Sensitivity analyses were carried out to account for geocoding error and potential confounders.

Results: 0.7% of the controls lived within 50 meters of HVOL and 0.3% were exposed to more than 0.3 µT. Living within 50 m of HVOL was associated with an increased risk of AL for children under 5 (OR=1.6 (1.0-2.7)), an association more marked when restricting to the high-quality geocoded addresses (OR=3.2 (1.3-7.9)). ELF-MF was not associated with AL risk (≥ 0.3 µT, OR=0.6 (0.3-1.3)). The results remained stable in all the sensitivity analyses.

Conclusion: Our study brings new evidence that ELF-MF are probably not associated with AL risk, and cannot explain an association with distance to HVOL.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0013935125008898?via%3Dihub

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**Use of Electrical Household Appliances and Risk of All Types of Tumours: A Case-Control Study**

Noori S, Aleem A, Sultan IN, Tareen AK, Ullah H, Khan MW. Use of Electrical Household Appliances and Risk of All Types of Tumours: A Case-Control Study. Med Sci (Basel). 2025 Apr 1;13(2):36. doi: 10.3390/medsci13020036.

Abstract

Introduction: The use of electrical appliances using extremely low frequency (ELF) electromagnetic fields (EMF) has increased in the past few years. These ELF MF are reported to be linked to several adverse health effects. However, only a couple of studies have been conducted on the association between risk of tumours and use of electronic devices using low frequency (LF) EMF.

Methods: We studied the use of common household electrical appliances and suspected risk of tumours in a multi-hospital-based case-control study. In total, 316 patients were included in the final analysis.

Results: The study results showed a below unity risk for most of the devices. A slight increased risk of tumour was observed for computer screen use OR: 1.13 (95% CI: 0.43-3.02) and use of microwave oven OR: 1.21 (95% CI: 0.36-4.04). We also had chance to investigate ELF MFs exposure association with tumour. Where we observed elevated odd ratios in individuals living near electricity transformer stations, with a statistically significant risk OR: 2.16 (95% CI: 1.30-3.59). However, the risk was below unity (OR: 0.98) in individuals residing close to powerlines.

Conclusion: The current study serves as a pilot study of primary data and will be helpful in future epidemiological research studies on the topic in the region.

Open access paper: https://www.mdpi.com/2076-3271/13/2/36

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**Magnetoreception and the ruling hypothesis**

Vortman Y, Fitak R, Natan E. Magnetoreception and the ruling hypothesis. J Exp Biol. 2025 Apr 1;228(7):jeb250252. doi: 10.1242/jeb.250252.

Abstract

Whereas science is written by humans and cannot escape emotions intervening with scientific thought, the scientific community should be on guard against unnoticeably adopting a favorite hypothesis. When adopting a favorite hypothesis, scientists tend to review their work in favor of this hypothesis and reject contradictory data. In 1890, Thomas Chrowder Chamberlin first described this phenomenon as when 'the search for facts, and their interpretation are dominated by affection for the favored theory until it appears to its advocate to have been overwhelmingly established'. The favorite hypothesis can then quickly transition into a ruling hypothesis, leading to an unconscious bias in favor of supporting evidence and neglect of contradictory observations. This is especially problematic when a scientific field adopts a favorite hypothesis. In this Commentary, we suggest that the field of animal magnetoreception - in particular mechanisms based on radical-pair chemistry and cryptochrome proteins - may be under the reign of a ruling hypothesis. We argue that repeatedly, conclusions are unfounded or otherwise not consistent with the results presented. We use the case of magnetoreception - the only sense that remains without a clearly described receptor - to raise general awareness of the phenomenon of a ruling hypothesis in the scientific community. We emphasize the distinction between the scientist and the scientific community suffering from a hypothesis regime, and further highlight suggestions to mitigate the risk of working under a ruling hypothesis.

https://pubmed.ncbi.nlm.nih.gov/40207401/

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**Effect of electromagnetic field radiation on transcriptomic profile and DNA methylation level in pig conceptuses during the peri-implantation period**

Franczak A, Zmijewska A, Drzewiecka EM, Kozlowska W, Wydorski P, Paukszto L, Brevini TL. Effect of electromagnetic field radiation on transcriptomic profile and DNA methylation level in pig conceptuses during the peri-implantation period. Sci Rep. 2025 Apr 23;15(1):14025. doi: 10.1038/s41598-025-98918-9.

Abstract

Extremely low-frequency electromagnetic field (ELF-EMF) radiation alters the steroidogenic activity of porcine conceptuses during the peri-implantation period. This study investigated whether short exposure (2 h) to ELF-EMF radiation may induce changes in the transcriptomic profile of conceptuses and their DNA methylation levels, with a focus on the promoter regions of differentially expressed genes of interest. Porcine conceptuses were collected on days 15-16 of pregnancy, preincubated, and then exposed in vitro to ELF-EMF at a frequency of 50 Hz. ELF-EMF treatment affected the expression of 21 protein-coding transcripts, including solute carrier family 34 member 1 (SLC34A1), hydroxysteroid 17-beta dehydrogenase 2 (HSD17B2), apolipoprotein M (APOM), regucalcin (RGN), heat shock protein family A (Hsp70) member 6 (HSPA6), fibrinogen beta chain, and fibrinogen gamma chain (FGG). There were evaluated 21 GO annotations for biological process terms, nine GO annotations for cellular component terms and two KEGG pathways. The ELF-EMF exposure increased approximately 16 times genomic DNA methylation in conceptuses. ELF-EMF-induced changes in methylation were observed in the promoter regions of APOM, HSD17B2, FGG, and SLC34A1. The results determined 116 predicted single nucleotide variant substitutions within RNA editing sites. In conclusion, ELF-EMF radiation appears to interact with DNA methylation levels and to affect the expression of genes involved mainly in cellular homeostasis, conceptuses development, and attachment, suggesting the need for further investigation to elucidate better the impact of ELF-EMF exposure on the physiology of early conceptuses.

Open access paper: https://www.nature.com/articles/s41598-025-98918-9

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**Potential influence of geomagnetic activity on blood pressure statistical fluctuations at mid-magnetic latitudes**

He P, Li C, Xu M, Guo R, Degeling AW, Pitkänen T, Bu Y, Zheng X, Zhang Y, Jia X, Tian A, Han C, Wang S, Chen T, Fang J, Sun S, Liu W, Cao J, Quan K, Cong Z, Ma D, Zong Q, Fu S, Yao S, Zhang H, Shi Q. Potential influence of geomagnetic activity on blood pressure statistical fluctuations at mid-magnetic latitudes. Commun Med (Lond). 2025 Apr 28;5(1):143. doi: 10.1038/s43856-025-00822-w.

Abstract

Background: Solar activity and the consequent geomagnetic activity (GMA) profoundly influence human biological rhythms and cardiovascular system functions. Although the response of blood pressure (BP) to GMA has attracted considerable attention, it is unclear whether the GMA can have an influence alone and how it occurs.

Methods: In this six-year time series analysis, we collated over 500,000 BP measurements from two representative cities (Qingdao and Weihai) at mid-magnetic latitudes in China. Using various statistical methods, we analyzed the correlation between BP and the GMA (represented by Ap index) and their

quasi-periodic fluctuations. Additionally, we conducted a comparative analysis of the influence of other environmental factors (air temperature and PM2.5) on BP.

Results: The statistical BP level fluctuations correlate with the GMA. Both BP and the GMA index exhibit similar annual bimodal patterns and multiple periodicities, including 12-month and 6-month cycles, and an intermittent 3-month cycle. In contrast, other known environmental factors influencing BP such as air temperature and PM2.5 do not exhibit similar periodicities, particularly they lack 3-month cycles. In years with higher GMA levels, the BP shows stronger correlations with the Ap index and responds on a shorter timescale. Additionally, BP in females appears to be more strongly correlated with GMA.

Conclusions: Our findings highlight potential risks to individuals with hypertension with elevated GMA levels, deepen our understanding of GMA's role in human health, and offer insights for healthcare policymakers on the clinical significance of the geomagnetic environment.

Plain language summary

Human blood pressure fluctuates constantly and is influenced by various factors such as hormone levels in the body and environmental conditions. Geomagnetic activity is change in the Earth’s magnetic field as a consequence of the sun’ s activity, such as the impact of solar winds. We used six years of data to investigate whether changes in geomagnetic activity have an impact on blood pressure. Our results show a relationship between geomagnetic activity and blood pressure, particularly during periods of high geomagnetic activity. Understanding this relationship could enhance our knowledge of the geomagnetic environment’s clinical significance and potentially contribute to better hypertension risk assessment and management.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC12038039/

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**Earth's magnetic field and its relationship to the origin of life, evolution and planetary habitability**

Tarduno JA, Zhou T, Huang W, Jodder J. Earth's magnetic field and its relationship to the origin of life, evolution and planetary habitability. Natl Sci Rev. 2025 Mar 3;12(5):nwaf082. doi: 10.1093/nsr/nwaf082.

Abstract

Earth's magnetic field history can provide insight into why life was able to originate and evolve on our planet, and how habitability has been maintained. The magnetism of minute magnetic inclusions in zircons indicates that the geomagnetic field is at least 4.2 billion years old, corresponding with genetic estimates for the age of the last universal common ancestor. The early establishment of the field would have provided shielding from solar and cosmic radiation, fostering environments for life to develop. The field was also likely important for preserving Earth's water, essential for life as we know it. Between 3.9 and ca. 3.4 billion years ago, zircon magnetism suggests latitudinal stasis of different ancestral terrains, and stagnant lid tectonics. These data also indicate that the solid Earth was stable with respect to the spin axis, consistent with the absence of plate tectonic driving forces. Moreover, these data point to the

existence of low-latitude continental nuclei with equable climate locales that could have supported early life. Near the end of the Precambrian (0.591 to 0.565 billion years ago), the dynamo nearly collapsed, but growth of the inner core during earliest Cambrian times renewed the magnetic field and shielding, helping to prevent drying of the planet. Before this renewal, the ultra-weak magnetic shielding may have had an unexpected effect on evolution. The extremely weak field could have allowed enhanced hydrogen escape to space, leading to increased oxygenation of the atmosphere and oceans. In this way, Earth's magnetic field may have assisted the radiation of the macroscopic and mobile animals of the Ediacara fauna. Whether the Ediacara fauna are genetically related to modern life is a matter of debate, but if so, magnetospheric control on atmospheric composition may have led to an acceleration in evolution that ultimately resulted in the emergence of intelligent life.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC11980988/

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**The effects of radiofrequency radiation on male reproductive health and potential mechanisms (Review)**

Bektas H, Dasdag S. The effects of radiofrequency radiation on male reproductive health and potential mechanisms. Electromagn Biol Med. 2025 Mar 19:1-26. doi: 10.1080/15368378.2025.2480664.

Abstract

Recent studies have demonstrated that radiofrequency (RF) radiation emanating from devices such as mobile phones and Wi-Fi may have adverse effects on male reproductive health. This radiation can elevate testicular temperature, potentially compromising sperm quality and DNA integrity, and influence the specific absorption rate (SAR) across different body regions, leading to detrimental reproductive outcomes. Furthermore, exposure to RF radiation has been linked to conditions that could affect male reproductive function, such as oxidative stress, alterations in ion transitions across cell membranes, and inflammation. The article reviews research conducted on both humans and animal models regarding the effects of electromagnetic radiation on sperm quality, DNA damage, oxidative stress, hormone levels, and testicular function, suggesting that exposure to electromagnetic radiation could have harmful implications for male reproductive health. However, further research is necessary to fully understand the mechanisms and implications of non-ionizing electromagnetic radiation on male infertility.

Plain-language Summary

In this review, the effects of RF on male reproduction and the mechanisms related to them were examined and the results were discussed. “The effects of RF on sperm, reproductive hormones and testis, occupational exposure and male reproductive health, mechanisms of RF effects on reproductive system” were discussed here. In conclusion, further research is necessary to fully understand the mechanisms and implications of non-ionizing electromagnetic radiation on male infertility.

Excerpts

A total of 90 articles were evaluated in this review.

The effects of RF radiation on sperm

In conclusion, despite an incomplete understanding of the precise mechanisms underlying the impact of non-thermal RF radiation on sperm and testicular function, research across animal and human studies consistently suggests a connection between increased levels of ROS and/or DNA damage and negative impacts on fertility factors. This indicates that the negative effects of RF radiation on sperm parameters may primarily be linked to the induction of ROS. Furthermore, the variability in study outcomes underscores the complexity of RF radiation's effects, which may be influenced by factors such as exposure duration, frequency, and individual susceptibility. Therefore, limiting mobile phone use may be advisable to mitigate the incidence of male infertility. However, further research is warranted to explore the long-term effects of mobile phone radiation on male fertility and the generalizability of these findings (). Future studies should aim to clarify the specific biological pathways affected by RF radiation and standardize experimental protocols to resolve inconsistencies in the literature.

The effects of RF radiation on DNA

In conclusion, these studies highlight the harmful effects of RF radiation on male reproductive health, including DNA damage, decreased sperm mobility and vitality, increased DNA fragmentation, and oxidative stress. The variability in the findings, driven by differences in study design, exposure parameters, and biological models, suggests that the biological impact of RF radiation may be multifactorial, involving complex interactions between ROS production, DNA repair mechanisms, and cellular apoptosis pathways. It is advisable to limit RF exposure by keeping mobile phones away from the pelvic region and minimizing the use of RF-emitting electronic devices. However, given the inconsistent outcomes across various studies, future research should focus on standardizing experimental conditions and exploring the dose-response relationship to better understand the threshold levels at which RF radiation becomes detrimental to reproductive health. Further research is necessary to fully understand the long-term implications of RF radiation on human reproductive health.

The effects of RF radiation on reproductive hormones and testis

In conclusion, the research discussed in this section indicates that RF radiation exposure could negatively affect male reproductive health, leading to changes in hormone levels, testicular morphology, and sperm count and viability (). Prolonged exposure to wireless internet and mobile phones has been associated with alterations such as increased abnormalities in sperm heads and reduced weight of reproductive organs. Additionally, RF radiation can impact testicular parenchyma in rats, resulting in irregularly shaped seminiferous tubules with epithelial cell abnormalities. The complexity of these findings suggests that RF radiation may induce a cascade of biological responses, including oxidative stress, hormonal imbalances, and apoptotic processes, which collectively contribute to testicular damage and compromised reproductive health. The observed effects appear to be dose-dependent, with longer durations and higher intensities of RF exposure correlating with more severe reproductive outcomes. These findings emphasize the importance of avoiding long-term exposure to RF radiation emissions, particularly from wireless technologies, to prevent potential harm to male reproductive health. Future research should focus on elucidating the precise mechanisms by which RF radiation affects the reproductive system and identifying potential protective strategies to mitigate these effects.

Occupational exposure and male reproductive health

In conclusion, the diverse findings from these studies shed light on the complex relationship between occupational exposure, particularly to radiofrequency radiation, and male reproductive health outcomes

(). The variability in study outcomes highlights the challenges in establishing a clear causal link, suggesting that individual susceptibility, exposure duration, and the specific characteristics of RF equipment used in different occupational settings may play significant roles. Further research is warranted to elucidate the underlying mechanisms and to inform occupational health guidelines and practices. Future studies should focus on standardizing exposure assessment methods and consider long-term monitoring of workers in high-risk occupations to better understand the cumulative effects of RF radiation. Additionally, exploring potential protective strategies, such as shielding technologies and exposure limits, could be critical in mitigating the reproductive risks associated with occupational RF exposure.

Conclusion

This study comprehensively examined the mechanisms by which RF radiation may impact male reproductive health, focusing on both thermal and non-thermal pathways. The findings indicate that RF exposure, particularly through increased oxidative stress, ionic imbalances, and inflammation, can disrupt spermatogenesis and impair sperm quality. While thermal effects highlight the role of testicular temperature elevation, non-thermal mechanisms such as ROS generation and ionic dysregulation further emphasize the multifaceted nature of RF-induced reproductive toxicity. Despite the robust body of evidence, inconsistencies across studies warrant standardized research protocols to resolve methodological discrepancies. Future investigations should prioritize long-term exposure assessments and explore protective strategies to mitigate the risks associated with RF radiation. These efforts are critical for informing public health guidelines and ensuring reproductive health safety in the era of pervasive wireless communication technologies. Findings underline the importance of revisiting current regulatory standards to better protect reproductive health.

https://pubmed.ncbi.nlm.nih.gov/40108785/

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**Use of Mobile and Cordless Phones and the Association with Prostate Cancer**

Hardell L, Carlberg M. Use of Mobile and Cordless Phones and The Association with Prostate Cancer. Fortune Journal of Health Sciences, 8 (2025): 267-273. doi: 10.26502/fjhs.273

Abstract

Exposure to radiofrequency (RF) radiation in the frequency range 30 kHz–300 GHz was in 2011 evaluated by the International Agency for Research on Cancer (IARC) at the World Health Organization (WHO) to be a 'possible' human carcinogen, Group 2B. This was based on epidemiological results on increased risk for glioma and acoustic neuroma. Results on other cancer types are sparse. An increased incidence in male rats of proliferative lesions in the prostate gland induced by RF radiation was found in the US NTP study. Thus, it was pertinent to study an association with prostate cancer in human studies. We analyzed data in two of our previous studies, one on brain tumors (only deceased subjects; those who died from prostate cancer were defined as cases) and another on prostate cancer (living subjects) that included similar questions on use of mobile phones or cordless phones. The pooled analysis gave for mobile phone use OR = 1.8, 95 % CI = 1.01-3.1, increasing in the >10 year latency group to OR = 2.8, 95 % CI = 1.5-5.3. Also, use of the cordless phone gave increased risk, although not statistically significant. Dose-response analysis gave highest risk for >2,000 h use of the mobile phone with OR = 2.4,

95 % CI = 1.2-5.1. The cordless phone yielded highest risk in the group 1001-2000 h with OR = 2.3, 95 % CI = 1.01-5.4. Lower OR was seen for use > 2,000 h but based on low numbers. Higher risk was seen in cases with more aggressive cancer based on Gleason score, PSA, and high risk profile, and among subjects with heredity for prostate cancer.

Open access paper: https://www.fortunejournals.com/articles/use-of-mobile-and-cordless-phones-and-the-association-with-prostate-cancer.html

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**Disease burden, risk factors, and trends of primary central nervous system (CNS) cancer: A global study of registries data**

My note: Because it can take up to three decades for a solid tumor to be diagnosed and reported in tumor registries, it is important to model the latency when examining tumor incidence data. Nonetheless, it is tricky trying to interpret ecological studies. Moreover, trends over time in tumor incidence can be difficult to interpret due to changes in screening, diagnostic and reporting procedures.

Huang J, Chan SC, Lok V, Zhang L, Lin X, Lucero-Prisno DE, Xu W, Zheng ZJ, Elcarte E, Withers M, Wong MCS; NCD Global Health Research Group; Association of Pacific Rim Universities (APRU). Disease burden, risk factors, and trends of primary central nervous system (CNS) cancer: A global study of registries data. Neuro Oncol. 2023 May 4;25(5):995-1005. doi: 10.1093/neuonc/noac213.

Key Points

- Brain cancer burden was higher in more developed countries and male population.
- Brain cancer was related to HDI, GDP, brain injuries, carcinogens, and phone use.
- There was an increasing trend of brain cancer in the younger male population.

Abstract

Background: This study aimed to evaluate the global incidence, mortality, associated risk factors, and temporal trends of central nervous system (CNS) cancer by sex, age, and country.

Methods: We extracted incidence and mortality of CNS cancer from the GLOBOCAN (2020), Cancer Incidence in Five Continents series I-X, WHO mortality database, the Nordic Cancer Registries, and the Surveillance, Epidemiology, and End Results Program. We searched the Global Health data exchanges for the prevalence of its associated risk factors. We tested the trends by Average Annual Percentage Change (AAPC) from Joinpoint regression analysis with 95% confidence intervals in different age groups.

Results: The age-standardized rates (ASRs) of CNS cancer incidence and mortality were 3.5 and 2.8 per 100,000 globally. Southern Europe (ASR = 6.0) and Western Asia (ASR = 4.2) had the highest incidence and mortality, respectively. The incidence was associated with Human Development Index [HDI], Gross Domestics Products per capita [GDP], prevalence of traumatic brain injuries, occupational carcinogens exposure, and mobile phone use at the country level. There was an overall stable and mixed trend in the CNS cancer burden. However, increasing incidence was observed in younger male population from five countries, with Slovakia (AAPC = 5.40; 95% CI 1.88, 9.04; P = .007) reporting the largest increase.

Conclusions: While the overall global trends of cancer have been largely stable, significant increasing trends were found in the younger male population. The presence of some higher-HDI countries with increasing mortality suggested an ample scope for further research and exploration of the reasons behind these epidemiological trends.

Excerpts

"There are inconsistent results reporting by different settings of studies regarding the associations between mobile phone use and CNS cancer. Although some studies show mobile phone use was not associated with an increased risk of brain cancer, 45–47 they may have suffered from poor exposure assessment that likely contributed to exposure mis-classification. 48 A meta-analysis of 11 studies found a significant positive association between long-term ipsilateral mobile phone use and the risk of glioma (OR = 1.46, 95% CI 1.12–1.92). 49 Another meta-analysis showed a similar significant 1.33 times increase in risk. 11 A more recent meta-analysis of 46 studies found increased CNS cancer incidence with cumulative call time of 1000 or more hours. 50"

"Higher CNS cancer incidence was associated with a higher-HDI ($\beta_{male}$ = 0.87, CI 0.66–1.08, $P$ < .001; $\beta_{female}$ = 0.59, CI 0.45–0.73, $P$ < .001), GDP per capita ($\beta_{male}$ = 0.49, CI 0.32–0.66, $P$ < .001; $\beta_{female}$ = 0.30, CI 0.18–0.42, $P$ < .001), and higher prevalence of traumatic brain injuries ($\beta_{male}$ = 2.92, CI 2.47–3.37, $P$ < .001; $\beta_{female}$ = 2.79, CI 2.35–3.24, $P$ < .001), occupational carcinogens ($\beta_{male}$ = 1.39, CI 0.13–2.66, $P$ = .031; $\beta_{female}$ = 0.78, CI 0.06–1.49, $P$ = .034), and **mobile [phone] use ($\beta_{male}$ = 2.07, CI 0.83–3.30, $P$ = .001; $\beta_{female}$ = 1.43, CI 0.61–2.24, $P$ = .001)** but not with exposure to unsafe water ($P$ > .05 for both sexes; Figure 2)."

"Higher CNS cancer mortality was associated with a higher-HDI ($\beta_{male}$ = 0.58, CI 0.41–0.74, $P$ < .001; $\beta_{female}$ = 0.37, CI 0.26–0.47, $P$ < .001), GDP per capita ($\beta_{male}$ = 0.29, CI 0.16–0.42, $P$ < .001; $\beta_{female}$ = 0.18, CI 0.09–0.26, $P$ < .001), and higher prevalence of traumatic brain injuries ($\beta_{male}$ = 1.96, CI 1.60–2.32, $P$ < .001; $\beta_{female}$ = 1.64, CI 1.28–2.00, $P$ < .001), occupational carcinogens ($\beta_{male}$ = 1.06, CI 0.12–2.00, $P$ = .027; $\beta_{female}$ = 0.63, CI 0.12–1.14, $P$ = .016), **and mobile [phone] use ($\beta_{male}$ = 1.34, CI 0.42–2.25, $P$ = .005; $\beta_{female}$ = 0.81, CI 0.22–1.39, $P$ = .007)** but not with the exposure to unsafe water ($P$ > .05 for both sexes; Figure 3)."

"The largest incidence and mortality of CNS cancer were found in populations with very high HDI. The high incidence could be attributable to the ample resources in early detection with advanced diagnostic techniques and regular health check-ups while the high mortality could be ascribed to higher exposure to its related risk factors, such as traumatic brain injuries, occupational carcinogens exposure, and mobile phone use. While the overall global trends of cancer have been largely stable, significant increasing trends were found in the younger male population. The presence of some higher-HDI countries with increasing mortality suggested an ample scope for further research and exploration of the reasons behind these epidemiological trends."

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC10158137/

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**Could electrohypersensitivity be a specific form of high sensory processing sensitivity?**

Bordarie J, Ledent M, Dieudonné M, Choisay F, De Clercq E. Could electrohypersensitivity be a specific form of high sensory processing sensitivity? Front Public Health. 2025 Feb 28;13:1550427. doi: 10.3389/fpubh.2025.1550427.

Abstract

Introduction: Electrohypersensitivity (EHS) refers to a syndrome in which individuals claim to suffer from a variety of symptoms that they attribute to electromagnetic fields. The characteristics of this specific hypersensitivity, particularly in terms of symptoms, are similar to those associated with high sensory processing sensitivity (HSPS). This article raises the question of the superposition of these two types of sensitivity and investigates the existence of a link between the two.

Methods: Participants (n = 100) completed a questionnaire measuring EHS and HSPS, as well as absorption, risk perception and avoidance strategies related to electromagnetic fields, and anxiety and depressive disorders.

Results: They showed an overrepresentation of highly sensitive people within the electrohypersensitive group. Furthermore, the results showed differences in terms of anxiety-depressive symptomatology and cognitive strategies (risk perception and avoidance strategies).

Discussion: The article discusses these results in the light of the literature and suggests avenues for future research and ways to help highly sensitive people, whether wor not this condition is considered to be caused by electromagnetic radiation.

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1550427/full

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**Self-diagnosing electromagnetic hypersensitivity—A case study**

Ashton D. Self-diagnosing electromagnetic hypersensitivity—A case study. Front Public Health 2025; 13: 1535513

No abstract

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1535513/full

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**A Novel Method for Achieving Precision and Reproducibility in a 1.8 GHz Radiofrequency Exposure System That Modulates Intracellular ROS as a Function of Signal Amplitude in Human Cell Cultures**

Dahon C, Aguida B, Lebon Y, Le Guen P, Dangremont A, Meyer O, Citerne JM, Pooam M, Raad H, Thoradit T, Jourdan N, Bertagna F, Ahmad M. A Novel Method for Achieving Precision and Reproducibility in a 1.8 GHz Radiofrequency Exposure System That Modulates Intracellular ROS as a Function of Signal Amplitude in Human Cell Cultures. Bioengineering (Basel). 2025 Mar 4;12(3):257. doi: 10.3390/bioengineering12030257.

Abstract

Radiofrequency fields in the 1-28 GHz range are ubiquitous in the modern world, giving rise to numerous studies of potential health risks such as cancer, neurological conditions, reproductive risks and electromagnetic hypersensitivity. However, results are inconsistent due to a lack of precision in exposure conditions and vastly differing experimental models, whereas measured RF effects are often indirect and occur over many hours or even days. Here, we present a simplified RF exposure protocol providing a single 1.8 GHz carrier frequency to human HEK293 cell monolayer cultures. A custom-built exposure box and antenna maintained in a fully shielded anechoic chamber emits discrete RF signals which can be precisely characterized and modelled. The chosen amplitudes are non-thermal and fall within the range of modern telecommunication devices. A critical feature of the protocol is that cell cultures are exposed to only a single, short (15 min) RF exposure period, followed by detection of immediate, rapid changes in gene expression. In this way, we show that modulation of genes implicated in oxidative stress and ROS signaling is among the earliest cellular responses to RF exposure. Moreover, these genes respond in complex ways to varying RF signal amplitudes consistent with a hormetic, receptor-driven biological mechanism. We conclude that induction of mild cellular stress and reactive oxygen species (ROS) is a primary response of human cells to RF signals, and that these responses occur at RF signal amplitudes within the range of normal telecommunications devices. We suggest that this method may help provide a guideline for greater reliability and reproducibility of research results between labs, and thereby help resolve existing controversy on underlying mechanisms and outcomes of RF exposure in the general population.

Excerpts

Concluding Remarks and Future Perspectives

We here describe an experimental RF exposure device and protocol that present fully characterized, defined RF signals to human cells in culture. Their effects are consistent with a biological receptor-driven mechanism whereby RF exposure modulates intracellular ROS and ROS signaling pathways. This provides a testable hypothesis for the many and varied effects of RF described in the literature.

These cellular responses occur at RF signal amplitudes that are orders of magnitude below those needed to achieve thermal effects, and lie within the signal range of personal electronic devices and mobile phones. Because this human cell response to RF is not linear as a function of the RF signal amplitude, the relation between RF exposure conditions and a physiological outcome is not readily deducible; indeed a robust gene expression response may occur at one amplitude but be undetected at another signal amplitude, or even undergo the opposite response entirely (e.g., opposite expression of the same gene at different signal amplitudes). It is therefore necessary to assess physiological response to RF signal exposure at multiple signal amplitudes and wavelengths, and preferably by using a readout assay that is rapid and direct. This may help explain existing confusion and contradictions in the literature, as well as stimulate future studies on the nature of the biological reception mechanisms.

Finally, although RF exposure from cell phones and telecommunications devices has not been proven harmful in any way, there is a definite physiological response in human beings to this signal range. Risk factors may therefore exist for susceptibility to RF exposure, for instance in individuals with reduced tolerance to oxidative stress and/or who are exposed to excessive stressors in their daily life. These additive or synergistic effects may contribute to certain poorly defined syndromes such as

electromagnetic hypersensitivity (EHS) that have been linked to RF exposure in rare individuals in the past [29].

Open access paper: https://www.mdpi.com/2306-5354/12/3/257

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**RF-EMF exposure assessment with add-on uplink exposure sensor in different microenvironments in seven European countries**

Bladel HV, Stroobandt B, Veludo AF, Deprez K, Röösli M, Tognola G, Parazzini M, Thuróczy G, Polańska K, Politański P, Wiart J, Guxens M, Joseph W. RF-EMF exposure assessment with add-on uplink exposure sensor in different microenvironments in seven European countries. Environment International, Volume 197, 2025, doi: 10.1016/j.envint.2025.109368.

Abstract

Introduction  Several devices have been developed to assess exposure to radiofrequency electromagnetic field (RF-EMF). Since the existing solutions to measure the personal exposure induced by emerging 5G New Radio (NR) are expensive, complex, and bulky, a new cost efficient and low-complexity sensor is developed, that aims to measure RF-EMF exposure in different scenarios of data transmission within different areas.

Methods  With this novel sensor, activity-based microenvironmental surveys were conducted across seven European countries: Belgium, Hungary, Italy, Poland, Switzerland, the Netherlands, and the United Kingdom. The device is attached to a smartphone to quantify the auto-induced uplink (a-UL) transmission component of the total exposure for a broadband frequency range from 100 MHz to 6000 MHz and is thus denoted as add-on sensor. In-situ measurements were performed for three usage scenarios, namely non-user (i.e., environmental exposure), maximum downlink (max DL), and maximum uplink (max UL) scenarios, in a large city, a secondary city, and three rural villages a priori selected within each country.

Results  Power levels were lowest in non-user scenarios (median: −2.64 dBm or 0.54mW), increasing by a factor of 5.00 dB in maximum downlink scenarios and by a factor of 14.15 dB in maximum uplink scenarios. In the maximum uplink scenarios, the highest median a-UL power of 18.68 dBm (= 73.79 mW) was recorded in The Netherlands, while the lowest median a-UL power of 4.77 dBm (= 3 mW) was observed in the UK. The analysis of the measured data showed a prominent trend of a 2.72 dB lower power in the cities compared to the villages. Further comparisons were made based on microenvironment groups, where the lowest a-UL power levels (median: 12.35 dBm) were measured in outdoor areas, with an increase of 1.78 dB and 1.91 dB in power was measured compared to public transport and public places, respectively.

Conclusion  This study compares RF-EMF power levels between different countries, urbanization settings, and usage scenarios, which is important for future epidemiological studies.

Conclusions

An add-on RF-EMF sensor was used in activity-based microenvironmental surveys. The low-cost broadband add-on sensor was used to map RF-EMF exposure in Belgium, Hungary, Italy, Poland,

Switzerland, The Netherlands and The UK in different microenvironments for three network usage scenarios, i.e., non-user, maximum downlink and maximum uplink. Median powers were used to determine any underlying general trends. When examining the measured data, the most prominent trend is found with the difference of 2.27 dB between the cities and villages and the different city areas. Lowest powers are obtained during the non-user scenarios and increase 5.00 dB and 14.15 dB for the maximum downlink and maximum uplink scenarios, respectively.

Future work entails the comparison of the measurement results obtained by this add-on sensor with the results of other measurement devices and phone applications, namely QualiPoc and the ExpoM – RF4, that were used simultaneously to verify the discussed trends. Including the GPS data creates the possibility of investigating present base stations on the different routes and locations. Furthermore, the temporal behavior will be investigated as this activity-based measurement campaign will be repeated after two years, to investigate the influence of the 5G deployment.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412025001199

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**The Effect of Proximity Sensor & Grip Sensor Use on Specific Absorption Rate (SAR) in Smartphones**

Aydin E. The Effect of Proximity Sensor & Grip Sensor Use on Specific Absorption Rate (SAR) in Smartphones. Gazi University Journal of Science Part A: Engineering and Innovation. 2025, 12(1):292-306, 26.03.2025. doi: 10.54287/gujsa.1616086.

Abstract

Today, with the contribution of the new generation of communication technologies, many smart devices are produced. Almost every electronic device, including smart phones, smart watches, wireless headphones, tablets, emits some form of radiation. While most of this electromagnetic radiation is harmless, some of it can have potential health effects, depending on the frequency of use over long periods of time and in close usage. Specific Absorption Rate is a measure of how much human body tissue absorbs energy when the body is exposed to radiation. This measurement helps determine whether a device is safe for regular use. The SAR value may vary depending on the antenna and schematic design of the smartphone. To support high band requirements for 5G smartphones, more RF antennas required to be added in PCB design. When designing smartphones, designers also need to design proximity-grip sensors that accurately meet the industry's Specific Absorption Rate (SAR) requirements. In this study, the effects of proximity and grip sensors used in smartphones on LTE and 5G NR SAR values are investigated. During these measurements, a combination of Grip and Proximity Sensors were alternately turned on and off. Although the proximity sensor and grip sensor are not mainly used to optimize SAR values, it is foreseen that they may have indirect effects on SAR. In this context, SAR measurements were made in 3D environment for different frequencies. As a result of this study, it was observed that the grip-proximity sensors used in smartphones significantly reduce the SAR value and transfer less energy to the users in close range use. The effect of using the proximity sensor on the SAR rate was measured to be approximately 8%, while the effect of using the Grip Sensor was observed to be approximately 10%.

Excerpt

In this study, the effects of the use of the grip sensor and the proximity sensor on the SAR values are realized in 4 different scenarios for different communication technologies. Both grip sensors and proximity sensors contribute indirectly to reducing SAR in mobile phones. However, their effect is primarily through optimized power management. Specifically, proximity sensing can actively reduce transmission power when the phone is near the head of the user, directly reducing SAR. Grip sensors, while helpful in managing the behavior of the phone, have a less direct impact on SAR, but they can contribute to power adjustment based on the way the device is being held. As shown in Figure 7, we achieved best case with both sensors are in ON state, provides from 5% to 11% improvement on SAR values with different frequencies. It is important to use these sensors in future smartphones as a standard hardware component.

Open access paper: https://dergipark.org.tr/en/download/article-file/4504630

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**A Decision Support System for Managing Health Symptoms of Living Near Mobile Phone Base Stations**

Parsaei H, Faraz M, Mortazavi SMJ (2024). A Decision Support System for Managing Health Symptoms of Living Near Mobile Phone Base Stations. Journal of Biomedical Physics and Engineering, (), -. doi: 10.31661/jbpe.v0i0.2310-1667.

Abstract

Background: The rapid increase in the number of Mobile Phone Base Stations (MPBS) has raised global concerns about the potential adverse health effects of exposure to Radiofrequency Electromagnetic Fields (RF-EMF). The application of machine learning techniques can enable healthcare professionals and policymakers to proactively address concerns surrounding RF-EMF exposure near MPBS.

Objective: The current study aimed to investigate the potential of machine learning models for the prediction of health symptoms associated with RF-EMF exposure in individuals residing near MPBS.

Material and Methods: This analytical study utilized Support Vector Machine (SVM) and Random Forest (RF) algorithms, incorporating 11 predictors related to participants' living conditions. A total of 699 adults participated in the study, and model performance was assessed using sensitivity, specificity, accuracy, and the Area Under Curve (AUC).

Results: The SVM-based model demonstrated strong performance, with accuracies of 85.3%, 82%, 84%, 82.4%, and 65.1% for headache, sleep disturbance, dizziness, vertigo, and fatigue, respectively. The corresponding AUC values were 0.99, 0.98, 0.920, 0.89, and 0.81. Compared to the RF model and a previously developed model, the SVM-based model exhibited higher sensitivity, particularly for fatigue, with sensitivities of 70.0%, 83.4%, 85.3%, 73.0%, and 69.0% for these five health symptoms. Particularly for predicting fatigue, sensitivity and AUC were significantly improved (70% vs. 8% and 11.1% for SVM, Multilayer Perceptron Neural Network (MLPNN), and RF, respectively, and 0.81 vs. 0.62 and 0.64, for SVM, MLPNN, and RF, respectively).

Conclusion: Machine learning methods, specifically SVM, hold promise in effectively managing health symptoms in individuals residing near or planning to settle in the vicinity of MPBS.

Excerpts

"Figure 1 highlights three variables as the most important predictors of health symptoms: the distance from the mobile base station, the age of the participant, and the duration of residence in the area."

"From a broader standpoint, our findings are in line with studies that have reported that while there is an increasing concern regarding the potential negative health consequences of RF-EMF exposures from mobile phone base stations, the health complaints of individuals living near these base stations cannot be fully explained by these concerns alone [31]. No- tably, previous large population-based studies have shown that residents who were concerned about or attributed detrimental biological effects of RF-EMF generated by mobile phone base stations, as well as those living closer to the base station (e.g., <500 m), had more health complaints compared to others [31]. Furthermore, our results support reports showing the presence of sleep disturbances, headaches, dizziness, irritability, concentration difficulties, and hypertension in the majority of people residing near mobile phone base stations [32]. Additionally, the obtained results align with reports indicating a higher risk of developing neuropsychiatric problems in individuals living in the vicinity of mobile phone base stations. Headache, memory changes, dizziness, tremors, depressive symptoms, and sleep disturbance have been reported to be significantly higher in individuals living around mobile phone base stations [33]."

Open access paper: https://jbpe.sums.ac.ir/article_49803.html

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**Brain Disease-Modifying Effects of Radiofrequency as a Non-Contact Neuronal Stimulation Technology (Review)**

Sun S, Bok J, Jang Y, Seo H. Brain Disease-Modifying Effects of Radiofrequency as a Non-Contact Neuronal Stimulation Technology. Int J Mol Sci. 2025 Mar 4;26(5):2268. doi: 10.3390/ijms26052268.

Abstract

Non-invasive, non-contact, and painless methods of electrical stimulation to enhance neural function have been widely studied in recent years, particularly in the context of neurodegenerative diseases such as Alzheimer's disease (AD) and related dementias, which cause cognitive decline and other neurological symptoms. Radiofrequency (RF), which is a rate of oscillation in the range of 3 kHz to 300 GHz (3 THz), has been suggested as one potential non-contact neuronal stimulation (NCNS) technique for improving brain function. A new type of electrical stimulation uses a radiofrequency electromagnetic field (RF-EMF). RF exposure has been shown to modulate neural stimulation and influence various brain activities in in vitro and in vivo models. Recent studies have explored the effects of RF-EMF on human physiology, particularly in areas such as brain activity, cognition, and sleep behavior. In this review, we summarize recent findings about the effects of non-contact stimulations in in vitro studies, in vivo animal models, and human clinical cases.

Conclusions

In conclusion, RF exposure has the potential to affect neural stimulation and influence various brain activities in in vitro and in vivo models. The in vitro/in vivo effects of RF-EMF exposure are summarized in Figure 1. RF-EMF exposure therapy might improve cognitive performance in optimized conditions. Cognitive dysfunction caused by increased reactive oxygen species and oxidative stress may be improved after RF-EMF exposure through cellular mechanisms such as mitochondrial restoration, gene expression regulation, and cytoskeletal trafficking, etc. Recent studies have explored the influence of EMF on human physiology, particularly brain activity, cognition, sleep, behavior, and sensory functions. Research data vary depending on the RF stimulation conditions, highlighting the need for more clinical trials to clarify its potential effects. However, research is still very limited, and conflicting results can arise depending on the exposure conditions and individual variations. Moreover, although extensive research has been conducted to assess the effects of RF exposure, current data remain insufficient to understand its biological impact. Therefore, careful consideration is needed before clinically applying RF exposure. Additionally, further investigation into the effects of RF and their mechanisms is essential, as many researchers strive to establish reliable safety and efficacy data.

Open access paper: https://www.mdpi.com/1422-0067/26/5/2268

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**Repeated Head Exposures to a 5G-3.5 GHz Signal Do Not Alter Behavior but Modify Intracortical Gene Expression in Adult Male Mice**

Lameth J, Royer J, Martin A, Marie C, Arnaud-Cormos D, Lévêque P, Poirier R, Edeline JM, Mallat M. Repeated Head Exposures to a 5G-3.5 GHz Signal Do Not Alter Behavior but Modify Intracortical Gene Expression in Adult Male Mice. Int J Mol Sci. 2025 Mar 10;26(6):2459. doi: 10.3390/ijms26062459. PMID: 40141104; PMCID: PMC11941837.

Abstract

The fifth generation (5G) of mobile communications promotes human exposure to electromagnetic fields exploiting the 3.5 GHz frequency band. We analyzed behaviors, cognitive functions, and gene expression in mice submitted to asymmetrical head exposure to a 5G-modulated 3.5 GHz signal. The exposures were applied for 1 h daily, 5 days per week over a six-week period, at a specific absorption rate (SAR) averaging 0.19 W/kg over the brain. Locomotor activities in an open field, object location, and object recognition memories were assessed repeatedly after four weeks of exposure and did not reveal any significant effect on the locomotion/exploration, anxiety level, or memory processes. mRNA profiling was performed at the end of the exposure period in two symmetrical areas of the right and left cerebral cortex, in which the SAR values were 0.43 and 0.14 W/kg, respectively. We found significant changes in the expression of less than 1% of the expressed genes, with over-representations of genes related to glutamatergic synapses. The right cortical area differed from the left one by an over-representation of responsive genes encoded by the mitochondrial genome. Our data show that repeated head exposures to a 5G-3.5 GHz signal can trigger mild transcriptome alterations without changes in memory capacities or emotional state.

Exposure System and Exposure Protocol to 5G-3.5 GHz Signals

Head-only exposures to a 5G-3.5 GHz signal were performed in awake restrained mice. Each mouse was

habituated to the exposure conditions by progressively increasing the time during which the mouse was head-fixed (from 15 min to 60 min over a week) in a red plastic tube (internal diameter: 32 mm) with the hook screwed to a small plastic post (see Figure 1A,B). Each day, a dipole antenna (SID3500, MVG, Plouzané, France) was positioned 5 mm from the animal's head in a fixed/standardized position (Figure 1B) for one hour in the vicinity of the right temporal cortex.

The exposure system was similar to the one described in a previous study [35], replacing the frequency emitted by the radiofrequency generator to generate a 5G-3.5 GHz signal corresponding to 5G NR (release 15, Digital Standards SMBVB-K444; Rohde & Schwarz, Munich, Germany) with FDD duplexing, QPSK modulation, and a 100 MHz channel bandwidth. Briefly, a radiofrequency generator emitting a 5G-3.5 GHz electromagnetic field (SMBV100B, Rohde & Schwarz) was connected to a power amplifier (ZHL-4W-422+, Mini-Circuits, Brooklin, NY, USA), a circulator (Pasternack, PE83CR1005, Irvine, CA, USA), a bidirectional coupler (Mini-circuits, ZGBDC30-372HP+, Brooklin, NY, USA) and a four-way power divider (Mini-circuits ZB4PD-462W-N+, Brooklin, NY, USA), allowing potential simultaneous exposure of four animals. A power meter (E4417A and E9323A, EPM-P Series Power Meter, Agilent, Santa Clara, CA, USA) connected to the bidirectional coupler allowed continuous measurements and monitoring of incident and reflected powers within the setup.

Each exposed mouse was matched with a PSD-exposed mouse that was in head-fixed restrained conditions next to it (at about 30 cm, Figure 1A). An antenna was also placed 5 mm from the head of the PSD-exposed mouse, but this antenna was not connected to the 5G-3.5 GHz generator.

Conclusions and Limitations

Altogether, our results show that 1h of daily head exposure to a 5G-3.5 GHz signal over a six-week period does not alter emotional state and memory performance but triggers significant modification of expression in a limited set of genes, which can potentially affect glutamatergic synapses and mitochondrial activities. We acknowledge the limitations of our study. We cannot exclude that prolongations of the head exposures beyond 6 weeks could ultimately affect the emotional state or memory abilities of the exposed mice. While the classical OF tests used in our study did not show 5G-induced change in the animals' behavior, we cannot rule out subtle alterations in emotional state that might be revealed by applying other behavioral tests, such as the elevated plus maze or emergence tests [55]. The experiments were carried out with male mice because of the impossibility of separately housing male and female mice during 5G exposure and behavioral testing. Further investigation will be required to evaluate whether female and male mice could be differentially affected by chronic exposure to 5G-3.5 GHz. In addition, our RNA-seq analyses were performed at a single time point, e.g., 24 h after the last exposure to the 5G-3.5 GHz signal. The kinetics and reversibility of the reported changes in gene expression are undetermined, and further studies are needed to assess whether and to what extent the changes in transcript levels translate into proteomic or functional alterations in mitochondria and in glutamatergic synapses. The 5G-triggered transcriptome modifications were observed in cortical areas where the average SAR levels range around 0.43 or 0.14 W/kg. These SAR levels may be considered in light of the European safety guidelines for human head exposures [56], which set the upper SAR limit to 2 W/kg. This value is higher than the corresponding SAR levels reached in the brain due to the energy absorption in the surrounding skull tissues. Recent dosimetric analyses of human exposures to downlink

RF-EMF from base stations show intracortical SAR levels attributed to environmental 5G-3.5 GHz that are much lower than the values applied in our study, being less than 1 mW/kg [9]. Further investigations are needed to specify the levels of SAR reached in the human cerebral cortex when mobile phones emitting a 5G-3.5 GHz signal are held close to the ear of the mobile-phone user.

Open access paper: https://www.mdpi.com/1422-0067/26/6/2459

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**5G Radiofrequency Exposure Reduces *PRDM16* and *C/EBP β* mRNA Expression, Two Key Biomarkers for Brown Adipogenesis**

Seewooruttun C, Bouguila B, Corona A, Delanaud S, Bodin R, Bach V, Desailloud R, Pelletier A. 5G Radiofrequency Exposure Reduces *PRDM16* and *C/EBP β* mRNA Expression, Two Key Biomarkers for Brown Adipogenesis. Int J Mol Sci. 2025 Mar 20;26(6):2792. doi: 10.3390/ijms26062792.

Abstract

The widespread use of wireless technologies has raised public health concerns about the biological effects of radiofrequency (RF) exposure. Children have a higher specific absorption rate (SAR) of radiation energy compared to adults. Furthermore, brown adipose tissue (BAT) is more prevalent in infants and tends to decrease with age. Previous animal studies demonstrated a cold sensation in rats exposed to 900 MHz (second generation, 2G). UCP1-dependent thermogenesis and BAT hyperplasia are two fundamental adaptive mechanisms initiated in response to cold. This study investigated the impact of short-term exposure to 2G and fifth generation (5G) on key thermogenic and adipogenic markers related to these mechanisms while considering age and exposure duration. Juvenile and young adult Wistar rats were randomized into three subgroups: a 5G group (3.5 GHz), 2G group (900 MHz), and a control group (SHAM). They were exposed to their respective continuous-wave RF signals for 1 or 2 weeks at an intensity of 1.5 V/m, with two exposure sessions of 1 h per day. After the exposure period, a RT-qPCR was carried out to evaluate the genetic markers involved in BAT thermogenesis and adipogenesis. Two adipogenic biomarkers were affected; a fold change reduction of 49% and 32% was detected for *PRDM16* ($p = 0.016$) and *C/EBP β* ($p = 0.0002$), respectively, after 5G exposure, regardless of age and exposure duration. No significant RF effect was found on UCP1-dependent thermogenesis at a transcriptional level. These findings suggest that exposure to a 5G radiofrequency may partially disrupt brown adipocyte differentiation and thermogenic function by downregulating *PRDM16* and *C/EBP β*, possibly leading to higher cold sensitivity.

RF Exposure System

The 5G group was exposed to a **continuous-wave RF signal** set at 3.5 GHz and the 2G group to one at 900 MHz, with an exposure period of one or two weeks. The two one-hour RF exposure sessions per day were applied at an intensity of 1.5 V/m. These sessions were scheduled randomly; one in the morning and one in the afternoon. According to the French national frequency agency (ANFR), this intensity level reflects our current environmental exposure when using wireless network technologies and mobile phones [27].

A generator (AnaPico ASPIN4010—9 kHz–4000 MHz, Glattbrugg, Switzerland), located outside the climatic chambers, was set to produce a 3.5 GHz band signal for 5G exposure. It was coupled with an

amplifier RFPA (RF26003800-4x0.5W) connected to one antenna (antenna Laird multi-band CFS60383) inside the chambers. For 2G exposure, the same generator was set to 900 MHz, paired with another amplifier RFPA (RFS7002500-6x0.5) capable of emitting this RF band, and connected to two antennas (Kathrein 800-10465, Rosenheim, Germany).

The antennas were aligned horizontally in the climatic chamber, 80 cm above the exposed rats' boxes, thus at a height larger than 2.4λ and 9λ, at 900 MHz and 3.5 GHz, respectively, with λ representing the wavelength. The position of the antennas was adjusted to minimize the variation in the field amplitude within each cage and between cages.

Using an electric field probe EP600 (Narda Safety Test Solutions, Cisano sul Neva, Italy), we measured the intensity level in five different positions in each cage. An electric field of 1.6 ± 0.4 V/m was measured under 5G exposure and 1.6 ± 0.5 V/m under 2G exposure. These data were recorded on WinEP600 (Narda Safety Test Solutions, Cisano sul Neva, Italy). The transmitting device did not generate a static magnetic field. For the non-exposed groups (controls), the antennas in the adjacent climatic chamber remained unconnected to the generator.

Using these data, the mean intensity of the RF signal per cage was used to estimate the mean whole-body SAR during the experiment. The mean whole-body SAR was calculated to be 0.07 mW/kg for the 5G exposure and 0.24 mW/kg for the 2G exposure, following the method described by Mai et al. [4].

Conclusions

Our research showed a fold change decrease of 49% for PRDM16 and 32% for C/EBP β in terms of their mRNA levels after exposure to 5G. As mentioned previously, these adipogenic markers are important in the differentiation and maturation of brown adipocytes from BAT precursors, as well as the maintenance of their thermogenic capacity. In contrast, UCP1-dependent thermogenesis was not impacted by RF exposure at the transcriptional level. Most of the studied thermogenic markers showed no age-related or exposure duration-related effects associated with RF exposure, except for PPAR α and ADRβ3. This study provides new insights into the potential impact of 5G exposure on brown adipogenesis. The disrupted differentiation and thermogenic capacity of brown adipocytes through PRDM16 and C/EBP β downregulation may affect the development and characteristics of BAT, potentially leading to increased cold sensitivity after RF exposure. These findings could partially explain the physiological events related to cold stress seen after RF exposures. However, it is important to investigate the peripheral tail temperature in rats in order to confirm our hypothesis and explain the observed biological effects. Furthermore, it may provide valuable insights to help us better understand the impact of low-intensity 2G and 5G RF signals on vasomotor responses. Most studies on low-level radiofrequency exposure have predominantly focused on "non-thermal" biological effects, such as oxidative stress, genetic instability, and reproductive health, although these findings remain heterogeneous [77]. The impact of low-intensity RFs on thermoregulation remains largely an uncharted aspect of environmental health and safety. This research addresses this gap and can help to raise public awareness about the potential health risks posed by radiofrequency electromagnetic radiation, particularly 5G, with the rise in wireless technologies.

Open access paper: https://www.mdpi.com/1422-0067/26/6/2792

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**The CB1R of mPFC is involved in anxiety-like behavior induced by 0.8/2.65 GHz dual-frequency electromagnetic radiation**

Sun B, Xue T, Gao AN, Wang XY, Wu S, Liu XM, Zhang LH, Li MH, Zou DF, Gao Y, Wang CZ. The CB1R of mPFC is involved in anxiety-like behavior induced by 0.8/2.65 GHz dual-frequency electromagnetic radiation. Front Mol Neurosci. 2025 Mar 12;18:1534324. doi: 10.3389/fnmol.2025.1534324.

Abstract

As mobile phones and communication base stations become more widespread, concerns have arisen regarding the potential risks of environmental exposure to multi-frequency electromagnetic radiation (EMR) and its effects on mental health. To address these concerns, our study established a dual-frequency EMR mouse model at 0.8/2.65 GHz to explore potential molecular mechanisms and intervention targets. Our results revealed that exposure to this dual-frequency EMR significantly induced anxiety-like behavior in mice. Molecular experiments further showed a significant decrease in cannabinoid receptor type 1 (CB1R) levels in the medial prefrontal cortex (mPFC) of the mice, along with a notable reduction in the endogenous cannabinoids 2-arachidonoylglycerol and anandamide. This led to a downregulation of the entire endocannabinoid system (ECS). Additional confirmation was obtained by overexpressing and knocking down CB1R in the mPFC. We found that increasing mPFC CB1R levels could effectively reduce anxiety-like behavior, while decreasing mPFC CB1R levels exacerbated it. Furthermore, we found dual-frequency EMR induced the change of ECS in the basolateral amygdala (BLA). Notably, female mice exhibited similar behavioral phenotypes and molecular mechanisms in response to dual-frequency EMR. In summary, our study demonstrates that anxiety induced by dual-frequency EMR is closely linked to the function of the ECS in the mPFC and BLA, and that CB1R expression in the mPFC plays a significant role in modulating emotional behavior in mice.

EMR exposure equipment

The electromagnetic reverberation chamber (RC) utilized in this experiment was developed by Wu Tongning's team at the Department of Environment and Security, China Institute of Information and Communication Technology (Li et al., 2016). Constructed with reinforced concrete, the RC is a large shielded enclosure featuring highly conductive reflective walls and multiple mechanical stirrers. The stirrers' rotation alters the chamber's boundary conditions, creating a statistically uniform, isotropic, and randomly polarized electromagnetic environment. Key components of the RC include signal generators, power amplifiers, and shielding structures. The chamber can produce electromagnetic waves within a frequency range of 0 to 3 GHz. In this study, 0.8 and 2.65 GHz frequencies were applied at a dose of 4 W/kg. The electric field intensity was calculated based on the mice's average body weight, with specific experimental parameters detailed in Table 1.

Conclusions

In summary, this study demonstrates that anxiety-like behavior induced by dual-frequency EMR is closely associated with the ECS in the mPFC and BLA. Moreover, overexpression of CB1R in the mPFC significantly alleviates anxiety-like behavior in mice, while knockdown of CB1R in the mPFC exacerbates negative emotional responses (Figure 7). This research offers new insights into potential strategies for the treatment or prevention of the effects of dual-frequency EMR.

Open access paper: https://www.frontiersin.org/journals/molecular-neuroscience/articles/10.3389/fnmol.2025.1534324/full

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**Mitigating Heat-Induced Sperm Damage and Testicular Tissue Abnormalities: The Protective Role of Radiofrequency Radiation from Wi-Fi Routers in Rodent Models**

Mahmoudi R, Karbalay-Doust S, Masoudi E, Jafari-Barmak M, Ghanbri A, Nikseresht M, Mortazavi SMJ, Mortazavi SA. (2024). Mitigating Heat-Induced Sperm Damage and Testicular Tissue Abnormalities: The Protective Role of Radiofrequency Radiation from Wi-Fi Routers in Rodent Models. *Journal of Biomedical Physics and Engineering*, (), -. doi: 10.31661/jbpe.v0i0.2405-1759

Abstract

Background: Radiofrequency electromagnetic fields (RF-EMF) have raised concerns due to their potential adverse effects on reproductive health. However, emerging evidence indicates that exposure to low-level RF-EMF may induce adaptive responses, rendering cells or organisms more resilient to subsequent stressors.

Objective: To investigate whether exposure to 2.45 GHz Wi-Fi radiation could mitigate heat-induced damage in the reproductive system of male rats.

Material and Methods: In this factorial experimental study, 32 adult male Wistar rats were divided into four groups: control, RF-EMF alone, heat stress alone, and RF-EMF combined with heat stress. Rats in the RF-EMF group were exposed to RF-EMF for 2 hours daily over 52 days, while those in the heat group experienced 10 minutes of heat stress per day over the same period. The 'RF-EMF + heat' group received both RF-EMF and heat exposure. After 52 days, the testes and sperm parameters were assessed.

Results: Animals exposed to 'RF-EMF + heat' combined with heat showed significant improvements in testis volume, tubular epithelium, interstitium, cell counts, sperm quality, and Leydig cells compared to those exposed to heat alone ($P<0.05$).

Conclusion: As far as we know, this is the first study to explore the potential protective effects of RF-EMF exposure against heat-induced structural abnormalities in the testes of male rats. Our findings suggest that RF-EMF exposure may mitigate heat-induced damage, possibly through the induction of adaptive responses. These results have implications for various fields, including reproductive biology, environmental health, and occupational safety, highlighting the need for further research to elucidate the underlying mechanisms.

Excerpts

The Wi-Fi router operated on power level of 1W and the Specific Absorption Rate at the distance of 30 cm in animals' head level, as reported in another publication by our team, was 0.091 W/kg [11]

The results suggest that RF-EMF exposure may lead to alterations in testicular weight, volume, and sperm parameters, consistent with previous research highlighting the potential negative effects on male reproductive health.

The observed decline in sperm parameters and germinal cell count in response to RF-EMF exposure and heat align with existing literature, indicating a potential link between environmental factors and male fertility. The increase in Leydig cells following exposure to heat underscores the intricate cellular responses to thermal stress.

Furthermore, the concept of adaptive response (AR) emerges as a potential mechanism through which cells may develop resistance to subsequent exposures to damaging agents. The induction of AR by RF-EMF and heat, as suggested by the study results, presents a fascinating avenue for further exploration into the protective mechanisms activated in response to low-level injuries.

Open access paper: https://jbpe.sums.ac.ir/article_50328.html

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**Histomorphometry and Sperm Quality in Male Rats Exposed to 2.45 GHz Wi-Fi**

Vijay S, Ibrahim SF, Osman K, Zulkefli AF, Mat Ros MF, Jamaludin N, Syed Taha SMA, Hairulazam A, Jaffar FHF. Histomorphometry and Sperm Quality in Male Rats Exposed to 2.45 GHz Wi-Fi. Reproduction. 2025 Apr 1:REP-25-0048. doi: 10.1530/REP-25-0048.

Abstract

Numerous studies have documented the effect of 2.45 GHz Wi-Fi exposure on the testes and sperm quality. Nevertheless, detailed histological alterations of other male reproductive organs are underexplored. Therefore, this study aimed to evaluate detailed histological alterations of the testes, epididymis, seminal vesicle, coagulating organ, and sperms parameters following 2.45GHz Wi-Fi exposure. Eighteen adult male Sprague Dawley rats (N=18) were equally divided into three groups (n=6): Control, 4-hour, and 24-hour groups. The groups were exposed to an active router daily for 4 or 24 hours, respectively. The Control group was sham-exposed using an inactive router. The exposure lasted for eight weeks at a 20cm distance, with a power density of 0.141W/m² and a specific absorption rate (SAR) of 0.41W/Kg. Histological findings revealed vacuolation in the testes and the corpus epididymis of the 4-hour and 24-hour groups. The seminal vesicle in both exposed groups exhibited multifocal atypical hyperplasia. Besides, the seminiferous tubule diameter decreased gradually in both exposed groups, with a substantial decrease in the 24-hour group. The spermatogenesis index in 4-hour and 24-hour groups also reduced significantly. The latter result was reflected in the sperm concentration, where both groups showed a significant reduction compared to the Control group. Sperm motility also decreased significantly in the 4-hour groups. Interestingly, there was a substantial increase in sperm viability in the 24-hour group. These findings indicate that 2.45 GHz Wi-Fi exposure causes changes in the histology and histomorphometry measurement and impairs important sperm parameters. This highlights the consequences following Wi-Fi exposure on male reproductive health.

Open access paper: https://rep.bioscientifica.com/view/journals/rep/aop/rep-25-0048/rep-25-0048.xml

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**The Frequency of a Magnetic Field Determines the Behavior of Tumor and Non-Tumor Nerve Cell Models**

López de Mingo I, Rivera González MX, Ramos Gómez M, Maestú Unturbe C. The Frequency of a Magnetic Field Determines the Behavior of Tumor and Non-Tumor Nerve Cell Models. Int J Mol Sci. 2025 Feb 26;26(5):2032. doi: 10.3390/ijms26052032.

Abstract

The involvement of magnetic fields in basic cellular processes has been studied for years. Most studies focus their results on a single frequency and intensity. Intensity has long been the central parameter in hypotheses of interaction between cells and magnetic fields; however, frequency has always played a secondary role. The main objective of this study was to obtain a specific frequency that allows a reduction in the viability and proliferation of glioblastoma (CT2A) and neuroblastoma (N2A) cell models. These were compared with an astrocyte cell model (C8D1A) (nontumor) to determine whether there is a specific frequency of response for each of the cell lines used. The CT2A, C8D1A, and N2A cell lines were exposed to a magnetic field of 100 µT and a variable frequency range between 20 and 100 Hz for 24, 48 and 72 h. The results fit a biological window model in which the viability and proliferation of N2A and CT2A cells decrease statistically significantly in a 50 Hz center of value window. In addition, the non-tumor cell model showed different behavior from tumor cell models depending on the applied frequency. These results are promising in the use of magnetic fields for therapeutic purposes.

Conclusions

It has been demonstrated that there are certain frequencies that can reduce the proliferation and viability of tumor cell models of nervous tissue. Exposure of cell models to different magnetic field frequency values produces a cellular response in viability and proliferation that responds to a “biological window” model centered at 50 Hz for the tumor models used. This window is cell-type specific. Astrocytes, the non-tumor cell line of comparison, show an increase in viability at 20 and 40 Hz. This allows us to consider the use of specific ’bioactive’ frequencies in therapeutic applications for different pathologies such as tumor development (with the consequent decrease in viability and proliferation) or neurodegenerative diseases (with the increase in viability and proliferation of the astrocytic network).

Open access paper: https://www.mdpi.com/1422-0067/26/5/2032

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**20 kHz Magnetic Field Emission of Induction Cooking Heaters**

Kamata K, Haga A. 20kHz Magnetic Field Emission of Induction Cooking Heaters. EMC Europe 2004, International Symposium on Electromagnetic Compatibility, Eindhoven, The Netherlands, 2004, pp. 1-6, doi: 10.23919/EMC.2004.10805977.

Abstract

The distribution of the magnetic field leakage produced by an induction cooking heater (IH) is measured and analyzed using the finite element method. First, the dependence of the amplitude of leaked magnetic fields on the distance from the IH was measured with two S-type pans, one S-type pan, and one L-type pan and compared with the ICNIRP limit of general public exposure to 20 kHz magnetic fields. Next, the validity of the analysis is confirmed by comparing with measurement. The effects of pan size, etc. on magnetic field leakage are analyzed. The analysis makes clear the reason why the measured leaked magnetic fields from the IH are different with various types of pans. The data presented in this

paper should be useful in understanding the levels of magnetic field produced by IHs, and also in estimating magnetic field exposure in homes and workplaces.

Conclusion

Four different lHs made by four manufacturers were surveyed for their magnetic field characteristics. The magnetic field levels of IH appliances as a function of distance were presented in graphical form. All sets of measurements were carried out at the fundamental frequency of 20kHz and narrow-band rms levels of magnetic flux densities expressed in µT. The magnetic field densities generated by the THs of manufacturers A, B, C and D are different. The maximum magnetic field measurement was 16 µT in the case of manufacturer A with two S-type pans at X = Z= 0, Y= -20 cm.

The analysis showed that the basic model (two S- type pans) had the most magnetic leakage followed by one S-type pan, and two L-type pans. The analysis result was in agreement with the measurement results.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10805977&isnumber=10805570

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**Extremely low frequency magnetic field distracts zebrafish from a visual cognitive task**

Ziegenbalg L, Güntürkün O, Winklhofer M. Extremely low frequency magnetic field distracts zebrafish from a visual cognitive task. Sci Rep. 2025 Mar 12;15(1):8589. doi: 10.1038/s41598-025-90194-x.

Abstract

Electromagnetic fields emitted from overhead power lines and subsea cables are widely regarded to be a disruptive factor for animals using the natural magnetic field as orientation cue for guiding their directed movements. However, it is not known if anthropogenic electromagnetic fields also have the potential to disturb animals attending to information from other sensory modalities. To find out, we trained adult zebrafish (*Danio rerio*) individually to perform avoidance behavior in response to a visual signal (green LED light spot), which in the exposure group was presented simultaneously with a sinusoidally changing magnetic field (0.3 Hz, group A: 0.015 mT, group B: 0.06 mT). Despite the salience of the visual signal, which was both sufficient and necessary to elicit conditioned avoidance responses, the 0.06 mT magnetic condition had a negative impact on learning performance and response behavior. This suggests that extremely low frequency technical magnetic fields of Earth strength amplitude can act as cross-modal distractor that diverts the attention of animals away from environmentally relevant cues based on nonmagnetic sensory modalities. Our research highlights the need to study the role of anthropogenic magnetic fields as sensory pollutant beyond the scope of magnetic orientation behavior.

Open access paper: https://www.nature.com/articles/s41598-025-90194-x

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**Learned magnetic map cues and two mechanisms of magnetoreception in turtles**

Goforth KM, Lohmann CMF, Gavin A, Henning R, Harvey A, Hinton TL, Lim DS, Lohmann KJ. Learned magnetic map cues and two mechanisms of magnetoreception in turtles. Nature. 2025 Feb;638(8052):1015-1022. doi: 10.1038/s41586-024-08554-y.

Abstract

Growing evidence indicates that migratory animals exploit the magnetic field of the Earth for navigation, both as a compass to determine direction and as a map to determine geographical position1. It has long been proposed that, to navigate using a magnetic map, animals must learn the magnetic coordinates of the destination2,3, yet the pivotal hypothesis that animals can learn magnetic signatures of geographical areas has, to our knowledge, yet to be tested. Here we report that an iconic navigating species, the loggerhead turtle (Caretta caretta), can learn such information. When fed repeatedly in magnetic fields replicating those that exist in particular oceanic locations, juvenile turtles learned to distinguish magnetic fields in which they encountered food from magnetic fields that exist elsewhere, an ability that might underlie foraging site fidelity. Conditioned responses in this new magnetic map assay were unaffected by radiofrequency oscillating magnetic fields, a treatment expected to disrupt radical-pair-based chemical magnetoreception4-6, suggesting that the magnetic map sense of the turtle does not rely on this mechanism. By contrast, orientation behaviour that required use of the magnetic compass was disrupted by radiofrequency oscillating magnetic fields. The findings provide evidence that two different mechanisms of magnetoreception underlie the magnetic map and magnetic compass in sea turtles.

Open access paper: https://www.nature.com/articles/s41586-024-08554-y

https://www.nature.com/articles/s41586-024-08554-y?linkId=12930458

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**Effects of moderate static magnetic fields on voltage-gated potassium ion channels in sympathetic neuron-like PC12 cells**

Kaneda E, Kawai T, Okamura Y, Miyagawa S. Effects of moderate static magnetic fields on voltage-gated potassium ion channels in sympathetic neuron-like PC12 cells. Physiol Rep. 2025 Mar;13(6):e70236. doi: 10.14814/phy2.70236.

Abstract

While exposure of moderate static magnetic fields (SMF) can alter neuronal excitability, the effects on sympathetic neurons remain underexplored. This study investigates the effects of moderate SMF on Kv channels in the plasma membrane of sympathetic neuron-like PC12 cells. The current density of Kv channels was significantly lower in the 18-h magnet-exposed group, with effects persisting even after the magnet was removed before patch-clamp measurements. The current density of outward current in the presence of TEA was not different between the two groups, indicating that magnetic field affects TEA-sensitive Kv channels. To further explore these changes, RNA sequencing was performed on samples from both the Sham and 18-h magnet-exposed groups, identifying 37 moderate SMF-sensitive genes. Changes in mRNA expression levels and KEGG analysis suggested that pathways involved in the inhibition of neuronal excitability, such as GABAB receptor activation and Kir3 channel opening, may be more likely to be activated. In conclusion, moderate SMF is strongly associated with reduced current density in PC12 cells, particularly affecting Kv channels. The present study provides fundamental information on the influence of long-term SMF exposure on the excitability of sympathetic neurons.

Open access paper: https://physoc.onlinelibrary.wiley.com/doi/10.14814/phy2.70236

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**Enhancement Effect of Static Magnetic Field on Bactericidal Activity**

Zhang M, Song Y, Wang J, Shi X, Chen Q, Ding R, Mou J, Fang H, Zhou Y, Chen R. Enhancement Effect of Static Magnetic Field on Bactericidal Activity. Small. 2025 Mar 22:e2412334. doi: 10.1002/smll.202412334.

Abstract

The biological effects of magnetic fields are pervasive in microorganisms, with significant attention given to alternating magnetic fields (AMFs). However, AMFs induce electrical and magnetothermal effects, which complicate the interpretation of magnetic field-induced biological effects and introduce uncertainties regarding cytotoxicity in practical applications. The static magnetic field (SMF) with few variables and high biocompatibility presents a promising alternative for both understanding biological mechanisms and ensuring safe applications, but has a remaining problem on weak interactions with microorganisms. Here we show that the combination of SMF with paramagnetic calcium-polypyrrole nanoparticles (Ca-PPy) remarkably enhances bactericidal activity. Our experiments indicate that the synergistic action of SMF and Ca-PPy significantly promotes the generation of reactive oxygen species (ROS), i.e., singlet oxygen and superoxide anion radicals, in Escherichia coli (E. coli) and Staphylococcus aureus (S. aureus), coupled with the physical disruption of bacterial membrane, exhibiting the extraordinary bactericidal performance (the bactericidal rate is over 94%). The mechanism disclosed by computations is that the singlet-to-triplet transition of radical pairs can be increased by the introduction of magnetic fields. These findings offer new insights into the biological effects of magnetic fields and pave the way for their safe, highly effective use in bactericidal applications.

https://pubmed.ncbi.nlm.nih.gov/40119825/

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**Magneto-oncology: a radical pair primer**

Hore PJ. Magneto-oncology: a radical pair primer. Front Oncol. 2025 Mar 7;15:1539718. doi: 10.3389/fonc.2025.1539718

Abstract

There are few well-established biophysical mechanisms by which external magnetic fields can influence the biochemistry of molecules in living systems. The radical pair mechanism is arguably the most promising. In this mini-review I summarize the characteristics of radical pairs in a way that may be useful to those engaged in the field of magneto-oncology. The intention is to help researchers decide whether an observed biomedical magnetic field effect could have its origin in radical pair biochemistry. Armed with a physically plausible interaction mechanism, it may be possible to devise and refine a theoretical model and thereby iteratively optimise therapeutic protocols. Such an approach may also help identify experimental artefacts.

Open access paper:
https://www.frontiersin.org/journals/oncology/articles/10.3389/fonc.2025.1539718/full

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**Perspectives on terahertz honey bee sensing**

Prokscha A, Sheikh F, Jalali M *et al.* Perspectives on terahertz honey bee sensing. *Sci Rep* 15, 10638 (2025). doi: 10.1038/s41598-025-91630-8.

Abstract

Terahertz (THz) technology provides precise monitoring capabilities in dynamic environments, offering unique insights into insect habitats. Our study focuses on environmental monitoring of European honey bees (Apis mellifera) through a combination of measurements and simulations. Initially, the dielectric material properties of honey bee body parts are characterized across the spectral range of 1–500 GHz to collect heterogeneous empirical data. To extend the study, honey bee mockups made from polyamide 12 (PA12) and epoxy resin are employed and validated as effective substitutes for real bees through comparative scattering analyses. The research further explores radar cross-section (RCS), imaging, and spectral properties using advanced THz technologies, including resonant tunneling diodes (RTDs) operating at 250 GHz and THz time-domain spectroscopy (THz-TDS) for frequencies exceeding 250 GHz. High-resolution imaging, utilizing a 450 GHz bandwidth, captures intricate anatomical features of both real and 3D-printed bees, showcasing the potential of THz technology for detailed environmental monitoring. Finally, simulations at 300 GHz assess the dosimetry and feasibility of non-invasive, continuous monitoring approaches based on the heterogeneous honey bee model.

Open access paper: https://www.nature.com/articles/s41598-025-91630-8

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**Sensation of electric fields in the Drosophila melanogaster larva**

Tadres D, Riedl J, Eden A, Bontempo AE, Lin J, Reid SF, Roehrich B, Williams K, Sepunaru L, Louis M. Sensation of electric fields in the Drosophila melanogaster larva. Curr Biol. 2025 Mar 28:S0960-9822(25)00299-4. doi: 10.1016/j.cub.2025.03.014.

Abstract

Electrosensation has emerged as a crucial sensory modality for social communication, foraging, and predation across the animal kingdom. However, its presence and functional role as well as the neural basis of electric field perception in Drosophila and other invertebrates remain unclear. In environments with controlled electric fields, we identified electrosensation as a new sense in the Drosophila melanogaster larva. We found that the Drosophila larva performs robust electrotaxis: when exposed to a uniform electric field, larvae migrate toward the cathode (negatively charged elecrode) and quickly respond to changes in the orientation of the field to maintain cathodal movement. Through a behavioral screen, we identified a subset of sensory neurons located at the tip of the larval head that are necessary for electrotaxis. Calcium imaging revealed that a pair of Gr66a-positive sensory neurons (one on each side of the head) encodes the strength and orientation of the electric field. Our results indicate that electric fields elicit robust behavioral and neural responses in the Drosophila larva, providing new evidence for the significance of electrosensation in invertebrates.

Open access paper: https://www.cell.com/current-biology/fulltext/S0960-9822(25)00299-4

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**Research of the Biomedical Effects of Electromagnetic Field in Russia over 130 Years: Main Stages of Advances in Scientific Knowledge**

Grigoriev OA, Ushakov IB, Alexseeva, VA. Research of the Biomedical Effects of Electromagnetic Field in Russia over 130 Years: Main Stages of Advances in Scientific Knowledge. Biology Bulletin, 2024, 51(12):1-13. doi: 10.1134/S1062359024701784.

Abstract

We have analyzed the key stages of advances in the scientific history of research into the biomedical effects of electromagnetic field (EMF) in Russia over 130 years and proved the continuity of this scientific knowledge and its passage from one generation of scientists to the next due to scientific schools, systematic research, and national scientific coordination. The article focuses mainly on the period in which planned EMF health research was formed, the basic methodological principles were founded, and scientific principles were established for understanding the nature of the biological effects of EMF and their impact on health. The basic concepts on the part of Russian scientists about the mechanism underlying the biological effects of EMF and principles of their hygienic regulation are summarized.

Excerpts

The data of radiobiological studies using complex irradiation modes suggest that microwave EMF with average EFD values ≤ 500 μW/cm2 (in continuous mode or in pulses) should be considered as a stimulus to the central nervous system. Therefore, it is fair to apply the laws of physiology on biological strength, adaptive response, and ways to enhance the biological significance of a weak stimulus [67, 68]....

According to current data, the Federal Statistics Agency Rosstat has recorded an increase in morbidity over 25 years for predicted disease groups in the population of adolescents aged 15–17 (malignant tumors, diseases of the nervous system, immunodefiency-related disorders, and diseases of the auditory and visual organs). Data from basic research, as well as assessment of the possible contribution of EMF from cellular communications to the increase in morbidity, performed by the IARC methodology, show that the dependence of increased morbidity on the effect of EMF indeed exists and is not a random coincidence. However, it is difficult to directly determine risk due to the uncertainty of dosimetry data, the absence of modern comparison groups, and incomplete concept of acceptable risk for mass cellular technology [70]....

Conclusion

This review of the history of research of electro- magnetic biology, radiobiology, and hygiene of non-ionizing radiation in Russia cannot be considered exhaustive: the material accumulated over more than a century is vast. It does not include issues of applied research addressed by researchers of the biomedical effects of electromagnetism during that time: physiotherapy and clinical diagnostics, agriculture, including pest control and stimulation of plant growth; the influence on ecological systems,

mitogenetic radiation, and the body's own EMF; solar–terrestrial electromagnetic coupling and problems of electromagnetic communication in nature; and anthropogenic electromagnetic pollution on the global natural background.

Continuity is evident in the evolution of scientific thought: analysis of the publications shows that many fundamental provisions on the biomedical effects of electromagnetism and their medical and environmental consequences were formulated before the 1960s, then confirmed in experiments, supplemented, and refined under different irradiation conditions in all frequency ranges from a constant EMF to EHF and modulated EMF. The fundamental results of planned research, which made it possible to predict effects, and the integration of electromagnetic topics into the system of radiobiology and hygiene made it possible to create a scientific theory and methodology for standardizing EMF in the 1970s–1980s. The continuity of knowledge is the main feature that indicates the continuous and consistent development of the scientific school in electromagnetic biology, radiobiology, and hygiene of nonionizing radiation from the first researchers in the Russian Empire to our contemporaries, scientists of the Russian Federation, over the past 130 years.

In our opinion, when discussing the problems of EMF biomedical effects, it is necessary to take into account that the discussion about the nature of electromagnetism, its physical basis, and the existence of "ether" or an equivalent physical concept has never ceased. The relativity of ideas about the nature of the electromagnetic factor allows for the relativity of knowledge about its interaction with living objects, especially since knowledge about the living cannot be considered complete either.

The scientific school of research into the biomedical effects of electromagnetism has been going on in the Russian Empire, Soviet Union, and Russian Federation for 130 years and has deep roots in national science. The number of individual publications on the subject of radiobiology and hygiene of nonionizing radiation in Russian has long exceeded 10 000, and the words of Prof. B.I. Davydov are currently becoming even more relevant: "a periodic systematization of the accumulated material, establishment of a unified terminology, and standardization of research methods and analysis of the resulting data are required."

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**A Critical Analysis of the World Health Organization (WHO) Systematic Review 2024 on Radiofrequency Radiation Exposure and Cancer Risks (Response to Karipidis et al. 2024)**

Hardell L, Nilsson M. A Critical Analysis of the World Health Organization (WHO) Systematic Review 2024 on Radiofrequency Radiation Exposure and Cancer Risks. Journal of Cancer Science and Clinical Therapeutics. 9 (2025): 09-26. doi: 10.26502/jcsct.5079261.

Abstract

Radiofrequency (RF) radiation was in 2011 classified as a possible human carcinogen by the International Agency for Research on Cancer (IARC) at the WHO. Currently the WHO undertakes a systematic review of human studies on the cancer risks. In a publication by Karipidis et al (2024), commissioned by the WHO, it was argued that based on all available studies there would be "moderate certainty evidence" that mobile phone use "likely does not increase the risk of glioma, meningioma, acoustic neuroma, pituitary tumours, and salivary gland tumours in adults, or of paediatric brain tumours." However, the

authors have overlooked results showing increased risks for brain tumours in the most exposed groups, the most exposed part of the head, and longest latency time from first exposure to tumour diagnosis. The authors also claimed that there would be “moderate certainty evidence” that transmitters and mobile phone base stations do not increase the risk of pediatric leukaemia. These conclusions are based on selective inclusion of very few and low exposure studies. This WHO evaluation is contradicted by scientific results that show increased risks of cancer from exposure to RF-radiation from mobile and cordless phones, transmitters, and base stations. Other scientists have concluded, after reviewing the available evidence, that RF-radiation may increase the risk of cancer. This article analysis the Karipidis et al review and highlights several errors, omissions, and conflicts of interests that may explain the conclusions of no cancer risk. The flawed evaluation of scientific facts should lead to retraction of the article.

Conclusion

The Karipidis group’s conclusions on no cancer risks from use of mobile and cordless phones, or exposure to RF radiation from transmitters and base stations, are based on several errors in their interpretation of scientific results, omission of facts contradicting the conclusions and inherent conflicts of interest. Further, most of the results on which the authors base their conclusions are based on very low exposure levels not representative for the public’s exposure today and the authors have excluded or ignored results based on highest exposure categories. The conclusions by the authors of various grades of “certainty” that RF-EMF exposures do not cause cancer are unscientific and unjustified in view of the available scientific evidence. Evaluations of health risks from RF radiation should be performed by scientists without ties to ICNIRP or industry. Industrial direct or indirect ties may compromise objective and sound scientific evaluation. The serious scientific malpractice by Karipidis et al [1] with fatally flawed evaluation of radiofrequency radiation and cancer risks, as outlined in this review, should lead to retraction of the article.

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**Exposure to radiofrequency electromagnetic fields and risk of cancer: Epidemiology is not enough! (Response to Karipidis et al. 2024)**

Di Ciaula A, Petronio MG, Bersani F, Belpoggi F. Exposure to radiofrequency electromagnetic fields and risk of cancer: Epidemiology is not enough! Environment International. Volume 196, 2025. doi: 10.1016/j.envint.2025.109275.

No abstract

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412025000261

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**Modern health worries and exposure perceptions of individuals reporting varying levels of sensitivity to electromagnetic fields: results of two successive surveys**

Ledent M, Vatovez B, Roelandt P, Bordarie J, Dieudonné M, De Waegeneer E, Kremer C, Boucher L, Bouland C, De Clercq EM. Modern health worries and exposure perceptions of individuals reporting varying levels of sensitivity to electromagnetic fields: results of two successive surveys. Front Public Health. 2025 Feb 19;13:1536167. doi: 10.3389/fpubh.2025.1536167.

Abstract

Introduction: Individuals who claim to be affected by idiopathic environmental intolerance attributed to electromagnetic fields (EMFs) report symptoms linked to EMF exposure. Uncertainties about the causes of these symptoms often leave them seeking their own care solutions. In our connected societies, they may limit their exposure, leading to a spiral of avoidance that negatively impacts overall health. Our objective is to gain insights into the characteristics of people who report sensitivity to EMFs in an attempt to provide care guidance. This study focuses on modern health worries (MHW), behaviours, and exposure perceptions of people reporting various sensitivity levels to EMFs during the COVID-19 lockdowns, which altered habits and increased telecommunication device use.

Methods: We conducted two surveys during relaxed lockdown periods in Belgium (June/July 2020 and February/March 2021). A total of 97 and 285 participants, respectively, answered a questionnaire on sensitivity to EMFs, MHW, exposure perception, and strategies to limit EMF exposure. We applied nonparametric descriptive and multivariate statistical analyses.

Results: Higher sensitivity to EMFs correlates with greater MHW regarding EMF sources and more strategies to limit EMF exposure. However, these strategies were inconclusive, as many still felt highly exposed to EMFs.

Discussion: Given the high distress, social isolation, and professional difficulties faced by some EMF sensitive individuals, the relevance of exposure avoidance strategies is questionable. People who perceive high sensitivity to EMFs report worries and avoidance behaviors, yet still feel highly exposed. The findings suggest exploring new care avenues.

Open access paper:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1536167/full

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**The protective effects of melatonin against electromagnetic waves of cell phones in animal models: A systematic review**

Amiri M, Khazaie H, Mohammadi M. The protective effects of melatonin against electromagnetic waves of cell phones in animal models: A systematic review. Animal Model Exp Med. 2025 Feb 24. doi: 10.1002/ame2.12552.

Abstract

Background: Due to the widespread use of cell phone devices today, numerous research studies have focused on the adverse effects of electromagnetic radiation on human neuropsychological and reproductive systems. In most studies, oxidative stress has been identified as the primary pathophysiological mechanism underlying the harmful effects of electromagnetic waves. This paper aims to provide a holistic review of the protective effects of melatonin against cell phone-induced electromagnetic waves on various organs.

Methods: This study is a systematic review of articles chosen by searching Google Scholar, PubMed, Embase, Scopus, Web of Science, and Science Direct using the keywords 'melatonin', 'cell phone radiation', and 'animal model'. The search focused on articles written in English, which were reviewed and evaluated. The PRISMA process was used to review the articles chosen for the study, and the JBI checklist was used to check the quality of the reviewed articles.

Results: In the final review of 11 valid quality-checked articles, the effects of melatonin in the intervention group, the effects of electromagnetic waves in the case group, and the amount of melatonin in the chosen organ, i.e. brain, skin, eyes, testis and the kidney were thoroughly examined. The review showed that electromagnetic waves increase cellular anti-oxidative activity in different tissues such as the brain, the skin, the eyes, the testis, and the kidneys. Melatonin can considerably augment the anti-oxidative system of cells and protect tissues; these measurements were significantly increased in control groups. Electromagnetic waves can induce tissue atrophy and cell death in various organs including the brain and the skin and this effect was highly decreased by melatonin.

Conclusion: Our review confirms that melatonin effectively protects the organs of animal models against electromagnetic waves. In light of this conclusion and the current world-wide use of melatonin, future studies should advance to the stages of human clinical trials. We also recommend that more research in the field of melatonin physiology is conducted in order to protect exposed cells from dying and that melatonin should be considered as a pharmaceutical option for treating the complications resulting from electromagnetic waves in humans.

## Conclusion

Electromagnetic radiation emitted from cell phones is proven to be harmful to various organs in animal models and the results of the current literature survey suggest that additional research should be done to achieve the best possible use of melatonin as a therapeutic agent against electromagnetic waves. Melatonin is one of the safest drugs, used for many years to help people with sleep disturbances. In order to take this research to clinical levels, it will be important to assess the primary pathophysiological theory of damage and also the mechanisms by which melatonin may protect against the specific threat, among which the most likely is by increasing the amount of antioxidants in various organs. Future reviews and interventional studies in this field should focus on determining the optimal dose and timing of melatonin administration to enhance understanding of its protective effects. Additionally, efforts should be made to develop and improve clinical trials to evaluate the benefits of melatonin in humans, enabling a deeper investigation into its potential applications and advantages in clinical settings.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/ame2.12552

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**Hypothesis: ultrasonography can document dynamic *in vivo* rouleaux formation due to mobile phone exposure**

Brown RR, Biebrich B. Hypothesis: ultrasonography can document dynamic *in vivo* rouleaux formation due to mobile phone exposure. Front. Cardiovasc. Med. 10 February 2025. Volume 12. https://doi.org/10.3389/fcvm.2025.1499499

Abstract

Carrying a cellphone against the body has become commonplace in our world replete with smartphones. Acute and chronic health effects caused by these devices emitting radiofrequency radiation from multiple antennas have not been well evaluated. In this study, the popliteal vein of a healthy volunteer was imaged with ultrasonography prior to and following the placement of an idle, but active smartphone against her knee for 5 min. Pre-exposure longitudinal sonographic images demonstrate a normal anechoic lumen to the popliteal vein. Images obtained 5 min after direct skin exposure to the smartphone demonstrate a dramatic change in the acoustic appearance of the vessel. The interior of the vessel became coarsely hypoechoic with sluggish flow seen in real-time images, a typical sonographic appearance for rouleaux formation. A follow up examination performed 5 min after the subject walked around yielded continued rouleaux formation in the popliteal vein, albeit less dramatic than that observed immediately post exposure. This revolutionary *in vivo* method to assess radiofrequency radiation induced rouleaux formation should be further pursued in the general population to determine its prevalence and if its occurrence provides a unique biomarker of exposure that may predict morbidity

Excerpt

In summary, we present a subject in whom 5 min of exposure to radiofrequency radiation emitted by a smartphone causes abnormal erythrocyte aggregation “rouleaux formation” *in vivo*. This abnormality is associated with sluggish venous flow, as documented on diagnostic ultrasound obtained in real time. Although rouleaux formation is recognized as a transient phenomenon, we hypothesize that habitual cellphone usage, common in the population, would re-expose individuals over and over again to this abnormal hematologic state. Chronic, long-term exposure to radiofrequency radiation may therefore lead to recurrent, chronic RBC aggregation and increased blood viscosity, potentially causing significant morbidity in certain patient populations, particularly diabetics and those with hypertension, ischemic heart disease, cerebrovascular insufficiency, prethrombotic states, and peripheral vascular disease. Recognizing the potential for red blood cell aggregation from radiofrequency radiation to occur in the general population is crucial. Further studies are needed to assess the incidence of this occurrence, in addition to defining which power densities and frequencies put individuals at risk.

Open access paper:

https://www.frontiersin.org/journals/cardiovascular-medicine/articles/10.3389/fcvm.2025.1499499/full

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**Three-dimensional monitoring of RBC sedimentation in external magnetic fields**

Gholampour K, Moradi AR. Three-dimensional monitoring of RBC sedimentation in external magnetic fields. Biomed Opt Express. 2025 Jan 29;16(2):736-747. doi: 10.1364/BOE.545723.

Abstract

The external magnetic fields resulting from electronic devices around humans have become more prevalent nowadays, and studying their influence on living matter is a required task. Here, we experimentally model the movement of RBCs in veins under an external magnetic field; we monitor the sedimentation of multiple RBCs at different distances from a surrounding wall. The monitoring is performed in 3D by incorporation of digital holographic microscopy (DHM). DHM not only provides a 3D quantitative phase image of an RBC but also, through its numerical refocusing feature, 3D trajectories of several cells in the field of view can be obtained. Our results show that the magnetic field facilitates the sedimentation of cells, and the effect is higher in proximity to the walls. This influence is attributed to the presence of magnetic field-sensitive materials included in RBCs.

https://pmc.ncbi.nlm.nih.gov/articles/PMC11828455/

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**Investigations Into the Impact of Static Magnetic Fields on Blood Flow**

Mayrovitz HN. Investigations Into the Impact of Static Magnetic Fields on Blood Flow. Cureus. 2025 Jan 26;17(1):e78007. doi: 10.7759/cureus.78007.

Abstract

Many claims are made regarding the impacts of static magnetic fields (SMFs) on biological and physiological processes. Some of these are based on scientific underpinnings, and others appear to have less evidence to support them. The present report focuses on the evidence regarding SMF's effects on blood flow. Fortuitously, the author has direct experimental experience in this area. The approach for this review was to search three major databases (Web of Science, PubMed, and Embase) for peer-reviewed articles written in English in which an SMF was used in humans or other animals and measurements of parameters related to blood flow or velocity before SMF application and either during or after application were reported. After screening the initial 1,954 articles, 108 studies were retrieved and evaluated for relevancy. Of these, 23 were found to satisfy the inclusion criteria and be relevant. This included 10 studies on humans and 13 studies on other animals. The methods employed in many of these studies are illustrated in this review to enhance understanding of the findings. With regard to human studies, none showed an increase in blood flow, and one showed a decrease in flow. With regard to the animal studies, one showed a transient post-exposure increase that was later explained as due to an actual reduction during SMF exposure. Four studies showed a decrease, four showed no change or difference from sham-exposed animals, and four reported an increase. Of these four, two were from the same author using a method that may not have reflected a blood flow change. Based on these findings, it is concluded that claims of an SMF providing an increase in blood flow or circulation are not supported by human studies and not well supported by animal studies. However, this does not close the door to a possible effect for at least four considerations or limitations that may have impacted the absence of a positive finding in human studies: (1) the number of subjects included is relatively small, which affects the study power; (2) the duration of the SMF application of most studies was relatively short; (3) most studies were done on healthy individuals; and (4) the SMF was delivered perpendicular to the body

surface, so the effects of tangential field directions are unknown. Although these provisos may impact the detection of a possible SMF effect, they do not alter the current findings, as no reviewed human study has demonstrated a statistically significant increase in blood circulation attributable to an SMF. Thus, the clinical use of an SMF to improve blood circulation is not supported by experimental evidence.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC11859515/

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**Central Causation of Autism/ASDs via Excessive [$Ca^{2+}$]i Impacting Six Mechanisms Controlling Synaptogenesis during the Perinatal Period: The Role of Electromagnetic Fields and Chemicals and the NO/ONOO(-) Cycle, as Well as Specific Mutations**

Pall ML. Central Causation of Autism/ASDs via Excessive [$Ca^{2+}$]i Impacting Six Mechanisms Controlling Synaptogenesis during the Perinatal Period: The Role of Electromagnetic Fields and Chemicals and the NO/ONOO(-) Cycle, as Well as Specific Mutations. *Brain Sciences*. 2024; 14(5):454. https://doi.org/10.3390/brainsci14050454

Abstract

The roles of perinatal development, intracellular calcium [$Ca^{2+}$]i, and synaptogenesis disruption are not novel in the autism/ASD literature. The focus on six mechanisms controlling synaptogenesis, each regulated by [$Ca^{2+}$]i, and each aberrant in ASDs is novel. The model presented here predicts that autism epidemic causation involves central roles of both electromagnetic fields (EMFs) and chemicals. EMFs act via voltage-gated calcium channel (VGCC) activation and [$Ca^{2+}$]i elevation. A total of 15 autism-implicated chemical classes each act to produce [$Ca^{2+}$]i elevation, 12 acting via NMDA receptor activation, and three acting via other mechanisms. The chronic nature of ASDs is explained via NO/ONOO(-) vicious cycle elevation and MeCP2 epigenetic dysfunction. Genetic causation often also involves [$Ca^{2+}$]i elevation or other impacts on synaptogenesis. The literature examining each of these steps is systematically examined and found to be consistent with predictions. Approaches that may be sed for ASD prevention or treatment are discussed in connection with this special issue: The current situation and prospects for children with ASDs. Such approaches include EMF, chemical avoidance, and using nutrients and other agents to raise the levels of Nrf2. An enriched environment, vitamin D, magnesium, and omega-3s in fish oil may also be helpful.

Open access paper: https://www.mdpi.com/2076-3425/14/5/454

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**Impact of Microwave Exposure on Cynomolgus Monkeys: EEG and ECG Analysis**

Ma L, Qiao N, Zou Y, Wang H, Wang Y, Zhi W, Zhao X, Xu X, Zhang M, Lin Z, Hu X, Wang L. Impact of Microwave Exposure on Cynomolgus Monkeys: EEG and ECG Analysis. Bioelectromagnetics. 2025 Feb;46(2):e70000. doi: 10.1002/bem.70000.

Abstract

The annual increase of microwave exposure in human environments continues to fuel debates regarding its potential health impacts. This study monitored the EEG and ECG responses of three Cynomolgus monkeys before and at 0, 3, 7, 14, and 30 days after exposure to 50 mW/cm² microwave radiation for 15

min. The findings revealed no significant differences in the power spectral densities (PSDs) of the whole brain, frontal, and temporal lobes across various frequency bands (δ, θ, α, β, low-γ, and high-γ) immediately and up to 30 days postexposure. Notable alterations were observed primarily at 14 days in the PSDs of the parietal lobe, prefrontal cortex, central zone, and occipital lobe, particularly in the θ and α bands. By Day 30, these values returned to normal ranges. ECG alterations were characterized by changes in T-wave shape and amplitude. One monkey exhibited bidirectional spikes at 7 and 14 days that normalized by Day 30. Another showed similar patterns with reduced amplitude, and a third monkey displayed a towering forward wave at 14 days that persisted at 30 days. In conclusion, the administration of L-band microwave radiation at the specified dose did not result in immediate alterations to EEG and ECG, but it induced transient modifications in brain electrical activity and normalized after 30 days, which contributed to evaluate the health implications of microwave exposure in humans.

https://pubmed.ncbi.nlm.nih.gov/39912376/

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**Evaluation of Neuronal PARP-1 and Caspase-3 Levels in the Brain Tissue of Female Rats Exposed to Electromagnetic Fields at Different Gestational Stages**

Tüfekci KK, Tatar M, Elamin AAE, Kaplan S. An Evaluation of Neuronal PARP-1 and Caspase-3 Levels in the Brain Tissue of Female Rats Exposed to Electromagnetic Fields at Different Gestational Stages. Int J Dev Neurosci. 2025 Feb;85(1):e70010. doi: 10.1002/jdn.70010.

Abstract

Fetal exposure to electromagnetic fields (EMFs) may cause marked neurocognitive impairment, although the mechanisms involved are still unclear. EMF induces region-specific neuronal and astroglial death in the rat hippocampus. Poly (ADP-ribose) polymerase-1 (PARP-1) regulates necrosis, apoptosis and other cellular processes occurring following injury. This study, therefore, investigated whether PARP-1 also regulates neuronal responses in the hippocampus of rats subjected to EMF radiation during different developmental periods. Male and female rats were first allowed to mate in separate cages. Rats identified as pregnant were then divided into four groups. A 900-MHz EMF was applied for 2 h daily on gestational days (GD) 1-7, GD 8-14 and GD 15-21. The female offspring were sacrificed at the end of the 28th postnatal day, and PARP-1 and Caspase-3 expressions in the hippocampus were then evaluated. No special treatment was applied to the control group. In the EMF-exposed group, pyramidal neurons in the cornu ammonis (CA) region appeared normal after exposure on GD 1-7 but were darkly stained and shrunken after exposure on GD 15-21, while the majority of granular cells exhibited a normal appearance during all GDs. The group exposed to EMF on GD 15-21 exhibited strong PARP-1 and Caspase-3 immune reactivity in CA and dentate gyrus (DG) cells. Higher H-scores were also observed in the EMF-exposed group following GD 15-21 irradiation. As a result, a 900-MHz EMF application at GD 15-21, which coincides with hippocampal neurogenesis, triggered hippocampal neuron cell death by activating PARP-1 and Caspase-3.

https://pubmed.ncbi.nlm.nih.gov/39964245/

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**The Behavior of a Population of Protozoan Microorganisms under Electromagnetic Radiation from Cell Phones**

Morozova, L.A., Savel'ev, S.V. The Behavior of a Population of Protozoan Microorganisms under Electromagnetic Radiation from Cell Phones. *Biophysics* 69, 955–960 (2024). doi: 10.1134/S0006350924701021.

Abstract

For the first time, the effect of a significant change in the resistance of the aquatic medium of a population of protozoan microorganisms under the influence of electromagnetic radiation from cell phones has been experimentally investigated. The results of the experiment demonstrated the biological nature of the changes occurring in the water–protozoan population system, which indicated the effect of radiation directly on the cells. This conclusion was confirmed by the same time for information exchange between individual participants of the population in the calculation and in the experiment. An extremely low concentration of protozoan cells in the experiment was established, equal to 1000 cells/L, at which the specified effect was observed. It was concluded that the method for detecting changes in the physical properties of the aquatic medium of a population of protozoa under the action of electromagnetic fields can be used to identify the mechanisms of interaction of biological systems with electromagnetic radiation.

Open access paper: https://link.springer.com/article/10.1134/S0006350924701021

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**Changes in dopamine, serotonin, their precursors and derivatives in prefrontal cortex of young male rats under chronic exposure to low-intensity Wi-Fi** (in Russian)

Chueshova NV, Shchemelev VM, Vismont FI, Cheshik IA. Changes in the content of dopamine, serotonin, their precursors and derivatives in the prefrontal cortex of young male rats under chronic exposure to a low-intensity electromagnetic field. Reports of the National Academy of Sciences of Belarus. 68:5; 2024. https://doi.org/10.29235/1561-8323-2024-68-5-381-389.

Abstract

The content of a number of biogenic amines, their precursors and derivatives in the prefrontal cortex (PFC) of the brain of male Wistar rats chronically exposed to a low-intensity electromagnetic field of a Wi-Fi device (2.45 GHz, $PPE_{max}$ – 5.83 μW/cm2 ′ $PPE_{\bar{\chi}}$ – 0.46 ± 0.37 μW/cm2 ′ 24 h/day, 7 days a week) was studied during their early postnatal development. Changes in the content of dopamine, serotonin, their precursors and metabolites in the PFC of the brain were established, which determines the development of neurotransmitter disorders in the central nervous system, and subsequently the occurrence of behavioral disorders, deterioration of social adaptation and cognitive abilities. The revealed changes in the dopaminergic system of the PFC of the brain in rats at the early stages of their postnatal development indicate the need for further hygienic assessment of the safety of long-term

exposure to electromagnetic radiation on the body, especially on the brain. Further research in this direction will allow us to determine the neurotransmitter mechanisms underlying the adverse effects of low-intensity electromagnetic fields on the central nervous system, assess their danger and correct the existing maximum permissible levels of electromagnetic radiation taking into account the reaction of the neurotransmitter systems of the brain structures to this type of exposure.

Open access paper: https://doklady.belnauka.by/jour/article/view/1213

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**A Novel Method for Achieving Precision and Reproducibility in a 1.8 GHz Radiofrequency Exposure System That Modulates Intracellular ROS as a Function of Signal Amplitude in Human Cell Cultures**

Dahon C, Aguida B, Lebon Y, Le Guen P, Dangremont A, Meyer O, Citerne J-M, Pooam M, Raad H, Thoradit T, et al. A Novel Method for Achieving Precision and Reproducibility in a 1.8 GHz Radiofrequency Exposure System That Modulates Intracellular ROS as a Function of Signal Amplitude in Human Cell Cultures. *Bioengineering*. 2025; 12(3):257. https://doi.org/10.3390/bioengineering12030257.

Abstract

Radiofrequency fields in the 1–28 GHz range are ubiquitous in the modern world, giving rise to numerous studies of potential health risks such as cancer, neurological conditions, reproductive risks and electromagnetic hypersensitivity. However, results are inconsistent due to a lack of precision in exposure conditions and vastly differing experimental models, whereas measured RF effects are often indirect and occur over many hours or even days. Here, we present a simplified RF exposure protocol providing a single 1.8 GHz carrier frequency to human HEK293 cell monolayer cultures. A custom-built exposure box and antenna maintained in a fully shielded anechoic chamber emits discrete RF signals which can be precisely characterized and modelled. The chosen amplitudes are non-thermal and fall within the range of modern telecommunication devices. A critical feature of the protocol is that cell cultures are exposed to only a single, short (15 min) RF exposure period, followed by detection of immediate, rapid changes in gene expression. In this way, we show that modulation of genes implicated in oxidative stress and ROS signaling is among the earliest cellular responses to RF exposure. Moreover, these genes respond in complex ways to varying RF signal amplitudes consistent with a hormetic, receptor-driven biological mechanism. We conclude that induction of mild cellular stress and reactive oxygen species (ROS) is a primary response of human cells to RF signals, and that these responses occur at RF signal amplitudes within the range of normal telecommunications devices. We suggest that this method may help provide a guideline for greater reliability and reproducibility of research results between labs, thereby help resolve existing controversy on underlying mechanisms and outcomes of RF exposure in the general population.

Concluding Remarks and Future Perspectives

We here describe an experimental RF exposure device and protocol that present fully characterized, defined RF signals to human cells in culture. Their effects are consistent with a biological receptor-driven mechanism whereby RF exposure modulates intracellular ROS and ROS signaling pathways. This provides a testable hypothesis for the many and varied effects of RF described in the literature.

These cellular responses occur at RF signal amplitudes that are orders of magnitude below those needed to achieve thermal effects, and lie within the signal range of personal electronic devices and mobile phones. Because this human cell response to RF is not linear as a function of the RF signal amplitude, the relation between RF exposure conditions and a physiological outcome is not readily deducible; indeed a robust gene expression response may occur at one amplitude but be undetected at another signal amplitude, or even undergo the opposite response entirely (e.g., opposite expression of the same gene at different signal amplitudes). It is therefore necessary to assess physiological response to RF signal exposure at multiple signal amplitudes and wavelengths, and preferably by using a readout assay that is rapid and direct. This may help explain existing confusion and contradictions in the literature, as well as stimulate future studies on the nature of the biological reception mechanisms.

Finally, although RF exposure from cell phones and telecommunications devices has not been proven harmful in any way, there is a definite physiological response in human beings to this signal range. Risk factors may therefore exist for susceptibility to RF exposure, for instance in individuals with reduced tolerance to oxidative stress and/or who are exposed to excessive stressors in their daily life. These additive or synergistic effects may contribute to certain poorly defined syndromes such as electromagnetic hypersensitivity (EHS) that have been linked to RF exposure in rare individuals in the past [29].

Open access paper: https://www.mdpi.com/2306-5354/12/3/257

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**Oxidative stress and energy metabolism in male reproductive damage from single and combined high-power microwave exposure at 1.5 and 4.3GHz**

Li Y, Yao B, Men J, Pang Y, Gao J, Bai Y, Wang H, Zhang J, Zhao L, Xu X, Dong J, Li C, Peng R. Oxidative stress and energy metabolism in male reproductive damage from single and combined high-power microwave exposure at 1.5 and 4.3GHz. Reprod Toxicol. 2024 Nov 29;132:108759. doi: 10.1016/j.reprotox.2024.108759.

Abstract

The effect of multi-frequency electromagnetic environments on male reproduction has attracted the medical community's interest. Studies have investigated the effects and mechanisms of single-frequency microwave exposure on male reproduction, but comparative research on high-power microwave (HPM) composite and single exposure remains scarce. This study aimed to examine the effects and mechanisms of combined 1.5 GHz and 4.3 GHz microwave exposure on male reproduction. Male Wistar rats were exposed to 1.5 GHz (L-band) and 4.3 GHz (C-band) electromagnetic radiation for 15 minutes. The four groups were: sham, 10 mW/cm² L-band, 10 mW/cm² C-band, and 5 mW/cm² L-band and 5 mW/cm² C-band compound. Assessments were made on the pathological structures of testes, sperm viability, serum sex hormones, oxidative stress, and energy metabolism levels after radiation. Exposure to 1.5 GHz and 4.3 GHz microwaves individually resulted in testicular tissue damage and reduced sperm quality. There was little difference between the damage caused by HPM composite and single exposure. The exposed groups showed histological and ultrastructural changes, with reduced spermatozoa viability, motility parameters, and serum testosterone, luteinizing hormone, follicle-stimulating hormone, and serum inhibin-B on days 1 and 7 after exposure. These tended to recover partially by day

14. Adenosine triphosphate content and lactate dehydrogenase and succinate dehydrogenase activities in the exposed testicular tissue decreased, corresponding to decreased superoxide dismutase activity and increased malondialdehyde content. Both single and combined exposure to L- and C-band HPM affect the male reproductive system. Exposure to single and compound HPM shows no significant difference in risks, with oxidative stress and energy metabolism disturbances playing key roles.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0890623824002260

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**Electromagnetic pulse exposure induces neuroinflammation and blood-brain barrier disruption by activating the NLRP3 inflammasome/NF-κB signaling pathway in mice**

Lin Y, Lang H, Gao P, Miao X, Guo Q, Hao Y, Ai T, Li J, Zhang J, Guo G. Electromagnetic pulse exposure induces neuroinflammation and blood-brain barrier disruption by activating the NLRP3 inflammasome/NF-κB signaling pathway in mice. Ecotoxicol Environ Saf. 2025 Feb 27;292:117972. doi: 10.1016/j.ecoenv.2025.117972.

Abstract

The electromagnetic pulse (EMP) is a widespread electromagnetic disturbance that can disrupt electronic systems and pose health risks to personnel in operational areas. The biological effects of EMP radiation, especially on the central nervous system (CNS), are not yet fully understood but are gaining attention. This study examines the impact of EMP on the CNS using microglial cells as a model system. We found that mice exposed to a field strength of 600 kV/m with 1000 pulses per day for two weeks exhibited increased levels of oxidative stress. This exposure induced a microglia polarization to the M1 state, leading to neuroinflammation and disruption of the blood-brain barrier (BBB) by the pro-inflammatory response of microglia. Further analysis revealed that the NLRP3 inflammasome/NF-κB signaling pathway modulates the pro-inflammatory mechanisms of EMP irradiation. In conclusion, our findings show that EMP irradiation triggers neuroinflammation and BBB damage via NLRP3 inflammasome/NF-κB activation. This research highlights the effects of EMP radiation on the CNS and offers valuable insights into the potential targets for biomedical protection against it.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0147651325003082?via%3Dihub

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**Influence of Super-Low-Intensity Microwave Radiation on Mesenchymal Stem Cells**

Artamonov MY, Pyatakovich FA, Minenko IA. Influence of Super-Low-Intensity Microwave Radiation on Mesenchymal Stem Cells. *International Journal of Molecular Sciences*. 2025; 26(4):1705. https://doi.org/10.3390/ijms26041705

Abstract

Mesenchymal stem cells (MSCs) have emerged as a promising tool for regenerative medicine due to their multipotency and immunomodulatory properties. According to recent research, exposing MSCs to super-low-intensity microwave radiation can have a significant impact on how they behave and operate. This review provides an overview of the most recent studies on the effects of microwave radiation on

MSCs with power densities that are much below thermal values. Studies repeatedly show that non-thermal mechanisms affecting calcium signaling, membrane transport, mitochondrial activity, along ion channel activation may increase MSC proliferation, differentiation along mesodermal lineages, paracrine factor secretion, and immunomodulatory capabilities during brief, regulated microwave exposures. These bioeffects greatly enhance MSC regeneration capability in preclinical models of myocardial infarction, osteoarthritis, brain damage, and other diseases. Additional study to understand microwave treatment settings, biological processes, and safety assessments will aid in the translation of this unique, non-invasive strategy of activating MSCs with microwave radiation to improve cell engraftment, survival, and tissue healing results. Microwave-enhanced MSC treatment, if shown safe and successful, might have broad relevance as a novel cell-based approach for a variety of regenerative medicine applications.

Open access paper: https://www.mdpi.com/1422-0067/26/4/1705

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**Magnetically Stimulated Myogenesis Recruits a CRY2-TRPC1 Photosensitive Signaling Axis**

Iversen JN, Tai YK, Wu KY, Wong CJK, Lim HY, Franco-Obregón A. Magnetically Stimulated Myogenesis Recruits a CRY2-TRPC1 Photosensitive Signaling Axis. Cells. 2025 Feb 6;14(3):231. doi: 10.3390/cells14030231.

Abstract

The cryptochromes are flavoproteins that either individually or synergistically respond to light and magnetic field directionality as well as are implicated in circadian rhythm entrainment and development. Single brief exposures (10 min) to low energy (1.5 mT) pulsed electromagnetic fields (PEMFs) were previously shown to enhance myogenesis by stimulating transient receptor potential canonical 1 (TRPC1)-mediated Ca2+ entry, whereby downwardly directed fields produced greater myogenic enhancement than upwardly directed fields. Here, we show that growth in the dark results in myoblasts losing their sensitivity to both magnetic field exposure and directionality. By contrast, overexpressing or silencing cryptochrome circadian regulator 2 (CRY2) in myoblasts enhances or reduces PEMF responses, respectively, under conditions of ambient light. Reducing cellular flavin adenine dinucleotide (FAD) content by silencing riboflavin kinase (RFK) attenuated responsiveness to PEMFs and inhibited selectivity for magnetic field direction. The upregulation of TRPC1 and cell cycle regulatory proteins typically observed in response to PEMF exposure was instead attenuated by upwardly directed magnetic fields, growth in the darkness, magnetic shielding, or the silencing of CRY2 or RFK. A physical interaction between CRY2 and TRPC1 was detected using coimmunoprecipitation and immunofluorescence, revealing their co-translocation into the nucleus after PEMF exposure. These results implicate CRY2 in an identified TRPC1-dependent magnetotransduction myogenic cascade.

Open access paper: https://www.mdpi.com/2073-4409/14/3/231

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**Smart Electronic Device-Based Monitoring of SAR and Temperature Variations in Indoor Human Tissue Interaction**

Laganà F, Bibbò L, Calcagno S, De Carlo D, Pullano SA, Pratticò D, Angiulli G. Smart Electronic Device-Based Monitoring of SAR and Temperature Variations in Indoor Human Tissue Interaction. *Applied Sciences*. 2025; 15(5):2439. doi:10.3390/app15052439.

Abstract

The daily use of devices generating electric and magnetic fields has led to potential human overexposure in home and work environments. This paper assesses the possible effects of electric fields on human health at low and high frequencies. It presents an electronic monitoring device that captures the incidence of specific absorption rate (SAR) and temperature variation (ΔT) on the human body. The system transmits data to a cloud platform, where a feedforward neural network (FFNN) processes the received information. SAR and surface temperature values are detected in an indoor environment, monitoring stationary and moving subjects. The results effectively assess temperature distribution due to electromagnetic fields. The prototype detected temperature peaks and high SAR values when the subjects remained motionless. Predictive analysis confirms the need for workplaces with materials shielding external electromagnetic signals and attenuating internal sources. Moderate mobile phone use could lower SAR and temperature values.

Open access paper: https://www.mdpi.com/2076-3417/15/5/2439

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**Population Density and Downlink EMF Exposure Levels by Region in Korea (3G - 5G)**

Lee AK, Jeon S, Wang S, Wiart J, Choi HD, Moon JI. Population Density and DL EMF Exposure Levels by Region in Korea*. 2024 IEEE Asia-Pacific Microwave Conference (APMC)*, Bali, Indonesia, 2024, pp. 781-783, doi: 10.1109/APMC60911.2024.10867416.

Abstract

In 2023, the electric field strength within mobile communication bands was measured in the largest city (Seoul), a small city (Gwangju, Gyeonggi province), and a rural area (Yangpyeong, Gyeonggi province) in South Korea. The three measurement regions were selected based on population density; The population densities of Seoul, Gwangju, and Yangpyeong are about 15,550/km2, 856/km2, and 133/km2, respectively. Measurements were performed by mounting the SRM3006 antenna on the roof of a vehicle and driving for approximately 40 km in each region. In this paper, the authors report the results of analyzing downlink RF-EMF levels in mobile communication networks currently in operation by frequency, time, and region.

https://ieeexplore.ieee.org/document/10867416

The median of total DL E-field strength for all generations was 1.75 V/m (Seoul), 0.75 V/m (Gwangju), and 0.61 V/m (Yangpyeong); The difference in DL EMF between the small city and rural area was not large, but that in Seoul was significantly higher.

Discussion and Conclusions

For most users, 5G terminals will spend a significant portion of time not connected to the base station. Therefore, regardless of whether the terminal is connected to the 5G network, it is necessary to

distinguish the level of radiated EMF caused by the SSB beam(s), which is (are) the only always-on signal in 5G NR, from the 5G base station.

It is impossible to distinguish between the always-on signal radiated from 5G base stations and signals generated by the use of 5G UEs using the measurement method reported in this paper. In a future study, we plan to estimate the average SSB EMF level radiated from the 5G base station with the Synchronization Signal Reference Signal Received Power (SS-RSRP) received by the terminal. We also seek to compare the total exposure level to DL EMF by all mobile networks with previously measured levels in terms of brain dose [3].

In Korea, CDMA2000 (2G) was terminated in early 2021, and WCDMA, LTE, and 5G NR are currently in service. At the time of measurement, i.e. around November 2023, the ratio of 3G subscriptions is about 2.6% of total mobile communication subscriptions, with 4G and 5G accounting for the majority; About 58.6% and 38.8% respectively. The DL EMF level by service technology generation did not match the corresponding subscription rate.

Currently, the number of 4G mobile communication base stations installed in Seoul is estimated at about 70% of the total, and those of 3G and 5G are analyzed to have similar ratios of 10 to 20% each. Compared to the ratio of subscriptions to the 5G service, the number of base stations installed is still very low. Therefore, the DL EMF exposure will continue to change in the coming years, so continuous monitoring is necessary. Additionally, since the base station installation information can be a good parameter related to the DL EMF level, it seems important to obtain data on this.

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**Progress in the study of the effects of electromagnetic radiation on the mood and rhythm (review)**

Zou DF, Li ZH, Liu YB, Wang CZ. Progress in the study of the effects of electromagnetic radiation on the mood and rhythm. Electromagn Biol Med. 2025 Feb 18:1-16. doi: 10.1080/15368378.2025.2460971.

Abstract

The ever-expanding use of a large number of electrical appliances and mobile communication systems, which outnumber the global population, emit electromagnetic radiation through mobile telephones, power stations, transmission lines, radar, microwave ovens, televisions, refrigerators, therapeutic and other electronic devices. Electromagnetic radiation has been classified by the International Agency for Research on Cancer (IARC) as possibly carcinogenic to humans (Group 2B). A large number of research results show that short-term and long-term exposure to electromagnetic radiation can lead to anxiety, depression, decreased learning ability, memory loss, sleep rhythm disorders and other adverse effects. Sleep rhythm disorders affect many people worldwide and may be associated with psychiatric disorders such as anxiety and depression. In this review, we summarise key experiments related to the effects of electric field exposure on mood and rhythms in animal and cellular studies over the past decade, describe the effects of electromagnetic radiation on emotional behaviors and circadian rhythms in humans and mammals, and explore the relationship between electromagnetic radiation, mood and rhythms as well as its underlying mechanisms of action. Most animal studies suggest that electromagnetic radiation may affect the physiological organization and functioning of the brain, influence neurotransmitters and receptors, interfere with neuronal formation and structure, or alter associated endocrine hormones and free radicals, which may lead to the unfavorable development of

psychiatric disorders and sleep rhythm disorders. This summary may provide researchers with better clues and ideas to develop therapeutic solutions with sleep disorders and depressive psychiatric disorders.

Plain Language Summary

In this paper, we summarize the effects of electromagnetic radiation on body mood and rhythm and its mechanism through the recent research status at home and abroad. Published work has investigated the effects of different substances (including neurotransmitters, neurons, endocrine hormones, and free radicals) on the body's mood and rhythm. In many studies, the thermal effects of EMR have not been fully controlled or considered, and most studies have focused on the common frequency bands used in power lines and wireless communication, while the biological effects of other frequencies and complex electromagnetic environments have been less discussed. In conclusion, our understanding of EMR's role in body mood and rhythm is quite limited, and further research is needed to answer unanswered questions.

https://pubmed.ncbi.nlm.nih.gov/39964745/

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**Modern health worries and exposure perceptions of individuals reporting varying levels of sensitivity to electromagnetic fields: results of two successive surveys**

Ledent M, Vatovez B, Roelandt P, Bordarie J, Dieudonné M, De Waegeneer E, Kremer C, Boucher L, Bouland C, De Clercq EM. Modern health worries and exposure perceptions of individuals reporting varying levels of sensitivity to electromagnetic fields: results of two successive surveys. Frontiers in Public Health, 13, 2025. doi: 10.3389/fpubh.2025.1536167,

Abstract

Introduction: Individuals who claim to be affected by idiopathic environmental intolerance attributed to electromagnetic fields (EMFs) report symptoms linked to EMF exposure. Uncertainties about the causes of these symptoms often leave them seeking their own care solutions. In our connected societies, they may limit their exposure, leading to a spiral of avoidance that negatively impacts overall health. Our objective is to gain insights into the characteristics of people who report sensitivity to EMFs in an attempt to provide care guidance. This study focuses on modern health worries (MHW), behaviours, and exposure perceptions of people reporting various sensitivity levels to EMFs during the COVID-19 lockdowns, which altered habits and increased telecommunication device use.

Methods: We conducted two surveys during relaxed lockdown periods in Belgium (June/July 2020 and February/March 2021). A total of 97 and 285 participants, respectively, answered a questionnaire on sensitivity to EMFs, MHW, exposure perception, and strategies to limit EMF exposure. We applied nonparametric descriptive and multivariate statistical analyses.

Results: Higher sensitivity to EMFs correlates with greater MHW regarding EMF sources and more strategies to limit EMF exposure. However, these strategies were inconclusive, as many still felt highly exposed to EMFs.

Discussion: Given the high distress, social isolation, and professional difficulties faced by some EMF sensitive individuals, the relevance of exposure avoidance strategies is questionable. People who perceive high sensitivity to EMFs report worries and avoidance behaviors, yet still feel highly exposed. The findings suggest exploring new care avenues.

Open access paper:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1536167

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**Wide-band metamaterial absorber for sub-6 GHz 5G applications: Reducing specific absorption rate**

Routray P, Ghosh D. Wide-band metamaterial absorber for sub-6 GHz 5G applications: Reducing specific absorption rate. AEU - International Journal of Electronics and Communications, 2025. doi: 10.1016/j.aeue.2025.155709.

Abstract

Wide coverage area, less sensitivity to noise, high data transceiving, low latency, IOT-based mass application, and increased connectivity make sub-6 GHz, a popularly used frequency band for 5G. However, the health issues due to the high amount of harmful electromagnetic radiation generated from the growing usage of the sub-6 GHz band have drawn the attention of researchers. This article presents a wide-band, polarization, and oblique angle insensitive metamaterial absorber with an absorption bandwidth of 1.9 GHz stretching from 3.1 to 5 GHz, covering bands of n77, n78, and n79 allocated for 5G. The design consists of combination of rings, split rings, and meander-crossed dipoles loaded with lumped resistors. The equivalent circuit is designed using a quasi-static approach and the design is fabricated and measured. The proposed absorber is demonstrated for the reduction of electromagnetic radiation and specific absorption rate in the entire 5G band allocated in the sub-6 GHz range.

Conclusion

The growing demands of 5G, especially in the sub-6 GHz band, can generate a large amount of EM radiation, which is harmful to living beings. This article presents a resistive loaded wideband metamaterial absorber based on the combination of rings, split rings, and meander dipoles. The absorption bandwidth of the absorber is 1.9 GHz ranging from 3.1 to 5 GHz, which includes the bands of n77 (3.3 to 4.2 GHz), n78 (3.3 to 3.8 GHz), and n79 (4.4 to 5 GHz). The absorber is independent of polarization angle and exhibits an absorptivity of over 80% up to an oblique angle of 60◦. The equivalence of the circuit is confirmed by comparing the absorptivity plots obtained from EM simulation and circuit simulation. The agreement between measured and simulation results veri fies that the structure can be used in a practical environment. The demonstration of the proposed absorber for the reduction of EM radiation and SAR generated in the 5G band is demonstrated to be up to 95%. Hence, the proposed absorber can be used to protect living beings and also can help to solve the concerns regarding health hazards due to the widespread use of 5G in the sub-6 GHz band.

https://www.sciencedirect.com/science/article/pii/S1434841125000500

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**Network-Scale Impact of Vegetation Loss on Coverage and Exposure for 5G Networks**

Schampheleer J, Huss A, Deruyck M. Network-Scale Impact of Vegetation Loss on Coverage and Exposure for 5G Networks. *IEEE Access*, vol. 13: 23902-23912, 2025, doi: 10.1109/ACCESS.2025.3538054.

Abstract

This study investigates the effects of vegetation on 5G network performance, with a particular focus on coverage, user exposure, and base station deployment strategies in an urban environment (Utrecht, The Netherlands). This is the first study to perform network planning simulations that account for vegetation and building-induced propagation challenges on a city-wide scale, providing understanding of their effects on 5G network performance and exposure. The study also explores the influence of user height, examining how vegetation's blocking and shielding effects vary with user height. By evaluating both sub-6 GHz and mmWave networks under various simulated scenarios, the research qualifies the dual role of vegetation as both a coverage barrier and a mitigator of user exposure. Key findings include a significant 14.71% reduction in coverage for sub-6 GHz networks in the presence of vegetation and a 42.98% decrease in downlink whole-body SAR in mmWave networks due to vegetation's shielding effects. Flexible base station placement is shown to effectively counteract coverage losses while maintaining stable exposure metrics, but mmWave networks remain highly sensitive to environmental obstructions. These findings emphasize the importance of incorporating vegetation and other environmental factors into network planning, especially for high-frequency 5G networks, to ensure optimal performance and limit user exposure.

Open access paper: https://ieeexplore.ieee.org/document/10870177

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**Study on field strength prediction using different models on time series from urban continuous RF-EMF monitoring**

Song X, Feng W, Yang C, Djuric N, Kljajic D, Djuric S. Study on field strength prediction using different models on time series from urban continuous RF-EMF monitoring. Expert Systems with Applications. 2025. doi: 10.1016/j.eswa.2025.126963.

Abstract

State-of-the-art electromagnetic field (EMF) monitoring networks, such as the latest one – the Serbian EMF RATEL system, are able to provide continuous and daily monitoring of radio-frequency (RF) EMF levels, which is especially important for urban areas where people may spend many hours and, consequently, experience increased sensitivity to RF-EMF exposure. By generating considerable time series sets of RF-EMF data, these monitoring networks are initiating a new research topic – near-future RF-EMF prediction, which is valuable for a number of public health activities, from supplementing EMF monitoring in high-risk areas, to proactively reducing exposure times, and towards advancing pre-testing of EMF compliance. This paper investigates the impact of different models on the prediction of field strength in urban environments, where Seasonal Auto-Regressive Integrated Moving Average (SARIMA), Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), Extreme Learning Machine

(ELM), Partial Least Squares Regression (PLS) and Transformer models are considered. The prediction performance of each model is analyzed on a case study of EMF-sensitive areas in the Serbian city of Novi Sad, i.e., two kindergartens and an elementary school; however, the established framework has strong potential for generalization to other urban environments. Based on two-year long monitoring data sets, a comprehensive comparison of the six models on prediction accuracy, performance degradation rate, extreme value prediction accuracy, and training time is made, showing that the PLS model outperforms other models in predicting EMF exposure. This preliminary study may be a valuable reference for large-scale deployment in real-time monitoring systems for public health protection and may trigger additional research on this ultimate EMF topic.

https://www.sciencedirect.com/science/article/pii/S0957417425005858

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**A Survey of IEEE 802.11ax WLAN Temporal Duty Cycle for the Assessment of RF Electromagnetic Exposure** (Wi-Fi 6)

Yang Y, Vermeeren G, Verloock L, Guxens M, Joseph W. A Survey of IEEE 802.11ax WLAN Temporal Duty Cycle for the Assessment of RF Electromagnetic Exposure. *Applied Sciences*. 2025; 15(5):2858. https://doi.org/10.3390/app15052858

Abstract

The increasing deployment of IEEE 802.11ax (Wi-Fi 6) networks necessitates an accurate assessment of radiofrequency electromagnetic field (RF-EMF) exposure under realistic usage scenarios. This study investigates the duty cycle (DC) and corresponding exposure levels of Wi-Fi 6 in controlled laboratory conditions, focusing on bandwidth variations, multi-user scenarios, and application types. DC measurements reveal significant variability across internet services, with FTP upload exhibiting the highest mean DC (94.3%) under 20 MHz bandwidth, while YouTube 4K video streaming showed bursts with a maximum DC of 89.2%. Under poor radio conditions, DC increased by up to 5× for certain applications, emphasizing the influence of degraded signal-to-noise ratio (SNR) on retransmissions and modulation. Weighted exposure results indicate a reduction in average electric-field strength by up to 10× when incorporating DC, with maximum weighted exposure at 4.2 V/m (6.9% of ICNIRP limits) during multi-user scenarios. These findings highlight the critical role of realistic DC assessments in refining exposure evaluations, ensuring regulatory compliance, and advancing the understanding of Wi-Fi 6's EMF exposure implications.

Open access paper: https://www.mdpi.com/2076-3417/15/5/2858

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**The Numerical Assessment of RF Human Exposure to Microwave Ovens with Contact-Type Doors**

Tian R, Wei J-C, Lu M. The Numerical Assessment of RF Human Exposure to Microwave Ovens with Contact-Type Doors. *Electronics*. 2025; 14(5):873. https://doi.org/10.3390/electronics14050873

Abstract

In complex electromagnetic environments, cardiac pacemakers may be interfered with easily. Microwave ovens, as common household appliances, may display electromagnetic leakage, which may

pose risks to pacemaker wearers. This work evaluates the electromagnetic exposure of pacemaker wearers under various conditions. One involves different distances from the microwave oven to the human body, and the other involves a distinct oven door gap. This work uses COMSOL Multiphysics to establish a human thoracic cavity model with a heart and unipolar pacemaker, as well as a model of a microwave oven with contact-type doors. The results show that the specific absorption rate ($SAR_{10g}$) and temperature increase in the thoracic cavity and heart tissue are inversely proportional to the distance from the microwave source. They are directly proportional to the oven door gap size. The induced electric field intensity, the temperature increase, and the induced voltage in the pacemaker show the same trend. When the human body is closest to the microwave oven with the largest door gap (D = 100 mm, d = 0.3 mm), the $SAR_{10g}$ and temperature increase of the thoracic cavity and heart tissue reach their maximum values, which are significantly below the safety standards recommended by ICNIRP. Similarly, the maximum value of the temperature increase and the induced electric field intensity in the pacemaker are below the safety standard recommended by ISO 14708-3 (+2 °C) and IEC 60601-1-2 (28 V/m). The maximum induced voltage at the pacemaker electrode is 5.322 mV, which exceeds the sensing sensitivity setting recommended by ISO 14117 (2 mV) for unipolar pacemakers. These findings demonstrate that microwave ovens with contact-type doors electromagnetic radiation do not threaten human health under normal usage conditions. However, the maximum value of the induced voltage exceeds the sensing sensitivity of some unipolar pacemakers, which may affect the operation of the unipolar pacemaker. This phenomenon requires attention from clinicians and patients. We still recommend that pacemaker wearers keep a distance from microwave ovens when using them.

## Conclusions

Through the simulation of the induced electric field intensity, the $SAR_{10g}$ distribution, the temperature increase after 30 min of exposure of the human thoracic cavity, the heart tissue, and the cardiac pacemaker, and the induced voltage at the electrode under different distances and oven door gap sizes, the following conclusions were drawn:

- Human thoracic tissue: The $SAR_{10g}$ and temperature increase in the thoracic cavity gradually decreased as the distance between the human thoracic cavity and the microwave source increased, and they increased with the size of the oven door gap. Under a condition of a 100 mm distance from the microwave source and a 0.3 mm oven door gap, the $SAR_{10g}$ and temperature increase in the thoracic cavity reached their maximum values, which were 0.295 W/kg and 0.008687 °C, respectively. Nevertheless, the $SAR_{10g}$ value and temperature increase remained below the safety standard recommended by ICNIRP.
- Heart tissue: The $SAR_{10g}$ value and temperature increase in the heart tissue were lower than those of the thoracic tissue, and the change trends in the heart tissue were similar to those in the thoracic tissue. Under the most unfavorable conditions (distance of 100 mm and a 0.3 mm oven door gap), the maximum $SAR_{10g}$ value and temperature increase in the heart tissue were 0.000789 W/kg and 0.00001156 °C, respectively, which were far below the safety standard recommended by ICNIRP. Although the $SAR_{10g}$ of the human thoracic cavity and heart tissue for a single exposure was below the safety standard recommended by ICNIRP, long-term exposure could have led to electromagnetic energy accumulation in the tissue, potentially causing health risks [31].

- Electromagnetic compatibility of cardiac pacemaker: The temperature increase, the induced electric field intensity, and the induced voltage of the cardiac pacemaker were also inversely proportional to the distance between the human thoracic cavity and the microwave source, and directly proportional to the size of the microwave oven door gap. The induced electric field intensity, temperature increase, and induced voltage of the cardiac pacemaker reached their highest values when the distance was 100 mm and the oven door gap was 0.3 mm, which were 27.7 V/m, 0.000892 °C and 5.322 mV, respectively. However, the induced electric field intensity and temperature increase remained below the immunity recommended by IEC 60601-1-2 (28 V/m) and the temperature rise standard recommended by the ISO 14708-3 standard (+2 °C). ISO 14117 recommends setting the sensing sensitivity of the unipolar pacemaker to 2 mV. Some manufacturers set the sensing sensitivity according to the characteristics of their products at the factory. For example, Medtronic's unipolar pacemaker is set to 2.8 mV [32], and Biotronik's unipolar pacemaker is set to 2.5 mV [33]. The maximum induced voltage used in this work was 5.322 mV. This value already exceeded the sensitivity of the aforementioned pacemakers. We hope that this conclusion is helpful to those involved in research.

To sum up, under the conditions set in this work, the electromagnetic radiation of the microwave oven with contact-type doors had a minimal impact on the human body, remaining within the safe range. However, when the human body is within 300 mm of the microwave oven, it may affect the operation of the unipolar pacemaker. It was recommended that patients implanted with medical devices, especially those with pacemakers, maintain a safe distance or replace aging microwave ovens, while also minimizing the time spent near an operating microwave. In addition, patients are advised to opt for bipolar pacemakers whenever possible to reduce potential electromagnetic exposure risks.

Open access paper: https://www.mdpi.com/2079-9292/14/5/873

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**Bio-Electromagnetic Safety Assessment of Wireless Charging Environment for Electric Vehicles**

Zheng H, Zhao X. Bio-Electromagnetic Safety Assessment of Wireless Charging Environment for Electric Vehicles. *Progress In Electromagnetics Research Letters*, Vol. 122, 87-92, 2024. doi:10.2528/PIERL24081306.

Abstract

Wireless power charging technology has been developed rapidly and is extensively utilized for electric vehicle wireless charging due to its numerous over plug-in charging. The electromagnetic bio-safety of the human body in charging environment has become a significant public concern. To address this issue, this paper employs the finite element analysis method to assess the electromagnetic safety of crucial organs in a typical charging environment. Firstly, human-vehicle models in various typical postures were constructed in COMSOL, and the spatial distribution of electromagnetic fields in the critical organs was calculated in a 7.7 kW, 85 kHz charging environment. Subsequently, the electromagnetic radiation dose of each organ was calculated and compared with the ICNIRP standards. The results indicated that the electromagnetic radiation dose received by different organs is influenced by both the electromagnetic parameters and position of the organs. When the human body is positioned flat in the car, the electromagnetic radiation exposure to various organs is at its highest. Additionally, the maximum

radiation dose for each organ is significantly below ICNIRP standard in a low-power wireless charging environment, supporting the commercial adoption of wireless charging technology for electric vehicles.

Open access paper: https://www.jpier.org/issues/volume.html?paper=24081306

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**Electromagnetic exposure level of pure electric vehicle inverter to human body in different seating positions**

Dong X, Ren Y, Lu M. Electromagnetic exposure level of pure electric vehicle inverter to human body in different seating positions. *Radiation Protection Dosimetry*, 2025. https://doi.org/10.1093/rpd/ncaf013

The market share of pure electric vehicle (PEV) as a green transportation steadily increases as the global demand for renewable energy sources and environmentally friendly mobility continues to increase. However, during PEV operation, the inverter system, as the key power conversion device, generates strong electromagnetic field in the local space. Long-term exposure to such electromagnetic environments may have potential effects on human body. In this study, the electromagnetic environment model of the PEV body, human body and simplified inverter is established. The finite element software, COMSOL Multiphysics, is used to calculate and analyse the variations in the induction field in different tissues of the driver and rear passenger, caused by the electromagnetic field generated by the inverter system operating at maximum power. The electromagnetic exposure level of the driver and rear passenger is assessed. Results show significant differences in the electromagnetic exposure levels of different seating positions in the vehicles. The electromagnetic exposure level in the driver's body is higher than that of the rear passenger, but it does not exceed the exposure limits defined by the International Commission for Non-ionizing Radiation Protection. This finding effectively complements the study on evaluating the safety of the electromagnetic environment of PEV and improves public awareness.

https://doi.org/10.1093/rpd/ncaf013

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**Brain Disease-Modifying Effects of Radiofrequency as a Non-Contact Neuronal Stimulation Technology**

Sun S, Bok J, Jang Y, Seo H. Brain Disease-Modifying Effects of Radiofrequency as a Non-Contact Neuronal Stimulation Technology. *International Journal of Molecular Sciences*. 2025; 26(5):2268. https://doi.org/10.3390/ijms26052268

Abstract

Non-invasive, non-contact, and painless methods of electrical stimulation to enhance neural function have been widely studied in recent years, particularly in the context of neurodegenerative diseases such as Alzheimer's disease (AD) and related dementias, which cause cognitive decline and other neurological symptoms. Radiofrequency (RF), which is a rate of oscillation in the range of 3 kHz to 300 GHz (3 THz), has been suggested as one potential non-contact neuronal stimulation (NCNS) technique for improving brain function. A new type of electrical stimulation uses a radiofrequency electromagnetic field (RF-EMF). RF exposure has been shown to modulate neural stimulation and influence various brain activities in in vitro and in vivo models. Recent studies have explored the effects of RF-EMF on human physiology,

particularly in areas such as brain activity, cognition, and sleep behavior. In this review, we summarize recent findings about the effects of non-contact stimulations in in vitro studies, in vivo animal models, and human clinical cases.

Open access paper: https://www.mdpi.com/1422-0067/26/5/2268

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**Learned magnetic map cues and two mechanisms of magnetoreception in turtles**

Goforth KM, Lohmann CMF, Gavin A, Henning R, Harvey A, Hinton TL, Lim DS, Lohmann KJ. Learned magnetic map cues and two mechanisms of magnetoreception in turtles. Nature. 2025 Feb 12. doi: 10.1038/s41586-024-08554-y.

Abstract

Growing evidence indicates that migratory animals exploit the magnetic field of the Earth for navigation, both as a compass to determine direction and as a map to determine geographical position[1]. It has long been proposed that, to navigate using a magnetic map, animals must learn the magnetic coordinates of the destination[2,3], yet the pivotal hypothesis that animals can learn magnetic signatures of geographical areas has, to our knowledge, yet to be tested. Here we report that an iconic navigating species, the loggerhead turtle (Caretta caretta), can learn such information. When fed repeatedly in magnetic fields replicating those that exist in particular oceanic locations, juvenile turtles learned to distinguish magnetic fields in which they encountered food from magnetic fields that exist elsewhere, an ability that might underlie foraging site fidelity. Conditioned responses in this new magnetic map assay were unaffected by radiofrequency oscillating magnetic fields, a treatment expected to disrupt radical-pair-based chemical magnetoreception[4-6], suggesting that the magnetic map sense of the turtle does not rely on this mechanism. By contrast, orientation behaviour that required use of the magnetic compass was disrupted by radiofrequency oscillating magnetic fields. The findings provide evidence that two different mechanisms of magnetoreception underlie the magnetic map and magnetic compass in sea turtles.

https://pubmed.ncbi.nlm.nih.gov/39939776/

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**Effects of electromagnetic radiation from offshore wind power on the physiology and behavior of two marine fishes**

Xu P, Wang B, Wang Z, Jin R, Ahmad M, Shang Y, Hu M, Chen F, Khalil MF, Huang W, Wang Y. Effects of electromagnetic radiation from offshore wind power on the physiology and behavior of two marine fishes. Mar Pollut Bull. 2025 Feb 7;213:117633. doi: 10.1016/j.marpolbul.2025.117633.

Abstract

With the widespread promotion of wind power, its potential ecological impacts on marine ecosystems have raised concerns, among which electromagnetic radiation is one of the significant impacts. It is well known that the effects of electromagnetic fields on different marine organisms vary greatly, but little is known about their effects on commercially important fish species. We studied the toxicity differences between the large yellow croaker (Larimichthys crocea) and the black sea bream (Acanthopagrus schlegelii) when exposed to magnetic field strengths of 0mT, 0.5mT, 1.0mT, 1.5mT and 2.0mT. We found

that under the 1.5mT and 2.0mT, the swimming velocity of L. crocea and A. schlegelii was reduced and the antioxidant enzymes in the body had a protective function on the body. Under the 2.0mT, the stress response of A. schlegelii was higher and the immune systems of both fish species were activated. The electromagnetic intensity below 2.0mT was more sensitive to L. crocea and A. schlegelii. However, electromagnetic radiation seems to have no significant effect on the nutrient absorption capacity of the organisms. After several days of recovery, all affected markers showed signs of reversibility. In summary, the experiment could provide valuable data for developing early warning systems and preventive measures to mitigate potential threats to marine life from offshore wind farms.

https://pubmed.ncbi.nlm.nih.gov/39921984/

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**The Collision between Wireless and Biology**

Héroux P. The Collision between Wireless and Biology. *Heliyon*, 2025. doi: 10.1016/j.heliyon.2025.e42267.

Abstract

This article examines the historical development of the concept of energy of activation, which has been used in the past to frame the belief that non-ionizing electromagnetic radiation is harmless at non-thermal levels. The power and telecommunications industries have used two arguments to support their view that human exposures to non-thermal non-ionizing radiation is inoffensive. First, the radiation is non-ionizing. Second, the energy quanta of the radiation are too weak to overcome the competing energy of thermal motion. Those arguments rest on the Arrhenius equation (1889) and on the concept of energy of activation. Later scientific developments such as the Eyring equation (1935) and the Bennett-Chandler (1977-1978) equation on reaction rates, and the Second Law of Thermodynamics, recognized in living systems by Schrödinger as “negentropy”, all undermine these arguments. The Second Law of Thermodynamics supplies the ionization claimed to be lacking, while some biological processes are independent of thermal motion. We contribute a new view of the physics and biology of non-ionizing electromagnetic radiation hygiene which explains many epidemiological, toxicological and scientific observations. The health effects of non-thermal non-ionizing radiation presently observed are in fact completely supported by physics. Furthermore, the expansion of wireless data rates is in direct conflict with preservation of a healthy environment.

Conclusion

Modeling living tissues as sugar/water/salt, or as separate bio-molecular components such as protein, biopolymers and solvated biomolecules excludes the most essential element of the living process, which is the continuous traffic of electrons and protons maintained by metabolism.

These currents are required by the Second Law of Thermodynamics, and their vulnerability to NTER [non-thermal electromagnetic radiation] is enhanced by the anatomy of OXPHOS [oxidative phosphorylation].

In a more complete model, and from the principle of superposition, oscillating electric or magnetic fields penetrating from the environment will alter the tissue's electron and proton currents. These can be far more easily disturbed by external electromagnetic fields than ionic species. To be biologically active, NTER does not need to produce ionized targets or electronic currents itself, but only to disturb those already provided by biology.

The present environmental perspective is sad given that a substantial engineering toolbox is available to mitigate NTER exposures: optical fiber, wire twisting, earthing practices, DC power. But a reversal of exposure tendencies will be difficult, as industry has long enjoyed the support of a critical actor, the military.

The same wireless communication techniques used to enable maneuverability in war theaters can also be used for high data rate access in civilian environments. Innovations such as 5G are useful to the military. Consequently, the military supports these developments with the goal of achieving superiority over their adversaries in a theater of war (Department of Defense 2020).

The alliance between industry and the military certainly has some practical advantages, but it has one major drawback.

If your environment is made to mimic a theater of war, it will not be a theater of health.

This paper addresses aspects of electron and proton dynamics in living systems. While it raises the subject of telecommunications signals crest factors, it ignores characteristics of common carrier modulations such as GSM and LTE, believed to be of importance in determining health impacts (NTP 2019). Refinement of modulations may minimize biological impacts, with the ultimate goal of controlling enough of those impacts to uncover new modulation schemes capable of reducing major health effects.

Open access paper: https://www.sciencedirect.com/science/article/pii/S2405844025006474

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**Two letters attacking WHO-sponsored Systematic Review on RF-EMF Exposure and Cancer by Karipidis et al. (2024) and Authors' (Inadequate) Responses**

Karipidis K, Baaken D, Loney T, Blettner M, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies - Part I: Most researched outcomes. Environ Int. 2024 Sep;191:108983. doi: 10.1016/j.envint.2024.108983. https://www.sciencedirect.com/science/article/pii/S0160412024005695

Frank JW, Moskowitz JM, Melnick RL, Hardell L, Philips A, Héroux P, Kelley E. The Systematic Review on RF-EMF Exposure and Cancer by Karipidis et al. (2024) has Serious Flaws that Undermine the Validity of the Study's Conclusions. Environment International, 2024. doi: 10.1016/j.envint.2024.109200. Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024007876

Karipidis K, Baaken D, Loney T, Blettner M, Mate R, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. Response to the letter from members of the ICBE-EMF. Environment International, 2024. doi: 10.1016/j.envint.2024.109201. Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024007888

ICBE-EMF. Scientific rebuttal to the misleading responses from Karipidis et al. on the ICBE-EMF critique of their systematic review on exposure to RF-EMF and human cancer. Jan. 15, 2025. Open access response: https://icbe-emf.org/scientific-response-to-the-rebuttal-of-karipidis-et-al-to-the-icbe-emfs-criticisms-of-the-who-cell-phone-radiation-cancer-review.

Di Ciaula A, Petronio MG, Bersani F, Belpoggi F. Exposure to radiofrequency electromagnetic fields and risk of cancer: Epidemiology is not enough! Environment International, 2025. doi: 10.1016/j.envint.2025.109275. Open access response: https://www.sciencedirect.com/science/article/pii/S0160412025000261

Karipidis K, Baaken D, Loney T, Blettner M, Mate R, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. Response to the letter from Di Ciaula et al. Environment International, 2025. doi: 10.1016/j.envint.2025.109276. https://www.sciencedirect.com/science/article/pii/S0160412025000273

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**The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part II: Less researched outcomes**

Karipidis K, Baaken D, Loney T, Blettner M, Mate R, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part II: Less researched outcomes. Environment International, 2025. doi: 10.1016/j.envint.2025.109274.

Abstract

Background

In the framework of the World Health Organization assessment of health effects of exposure to radiofrequency electromagnetic fields (RF-EMF), we have conducted a systematic review of human observational studies on the association between exposure to RF-EMF and risk of neoplastic diseases. Due to the extremely large number of included exposure types/settings and neoplasm combinations, we decided to present the review findings in two separate papers. In the first one we addressed the most investigated exposure-outcome pairs (e.g. glioma, meningioma, acoustic neuroma in relation to mobile phone use, or risk childhood leukemia in relation to environmental exposure from fixed-site transmitters) (Karipidis et al., 2024). Here, we report on less researched neoplasms, which include lymphohematopoietic system tumours, thyroid cancer and oral cavity/pharynx cancer, in relation to wireless phone use, or occupational RF exposure.

Methods

Eligibility criteria: We included cohort and case-control studies of neoplasia risks in relation to three types of exposure to RF-EMF: 1. exposure from wireless phone use; 2. environmental exposure from fixed-site transmitters; 3. occupational exposures. In the current paper, we focus on less researched neoplasms including leukaemia, non-Hodgkin's lymphoma and thyroid cancer in mobile phone users; lymphohematopoietic system tumours and oral cavity/pharynx cancer in exposed workers. We focussed on investigations of specific neoplasms in relation to specific exposure sources (termed exposure-outcome pair, abbreviated E-O pairs), noting that a single article may address multiple E-O pairs. Information sources: Eligible studies were identified by predefined literature searches through Medline,

Embase, and EMF-Portal. Risk-of-bias (RoB) assessment: We used a tailored version of the Office of Health Assessment and Translation (OHAT) RoB tool to evaluate each study's internal validity. Then, the studies were classified into three tiers according to their overall potential for bias (low, moderate and high) in selected, predefined and relevant bias domains. Data synthesis: We synthesized the study results using random effects restricted maximum likelihood (REML) models. Evidence assessment: Confidence in evidence was assessed according to the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach.

Results

We included 26 articles, which were published between 1988 and 2019, with participants from 10 countries, reporting on 143 different E-O pairs, including 65 different types of neoplasms. Of these, 19 E-O pairs satisfied the criteria for inclusion in quantitative syntheses of the evidence regarding the risks of leukaemia, non-Hodgkin's lymphoma or thyroid cancer in relation to mobile phone use, and the risks of lymphohematopoietic system tumours or oral cavity/pharynx cancer following occupational exposure to RF-EMF. RF-EMF exposure from mobile phones (ever or regular use vs no or non-regular use) was not associated with an increased risk of leukaemia [meta-estimate of the relative risk (mRR) = 0.99, 95 % CI 0.91–1.07, 4 studies), non-Hodgkin's lymphoma (mRR = 0.99, 95 % CI = 0.92–1.06, 5 studies), or thyroid cancer (mRR = 1.05, 95 % CI = 0.88–1.26, 3 studies). Long-term (10 + years) mobile phone use was also not associated with risk of leukaemia (mRR = 1.03, 95 % CI 0.85–1.24, 3 studies), non-Hodgkin lymphoma (mRR = 0.99, 95 % CI 0.86–1.15, 3 studies), or thyroid cancer (no pooled estimate given the small number of studies). There were not sufficient studies of any specific neoplasms to perform dose–response meta-analyses for either cumulative call time or cumulative number of calls; individual studies did not show statistically significant associations between lifetime intensity of mobile phone use and any specific neoplasm. Occupational RF-EMF exposure (exposed vs unexposed) was not associated with an increased risk of lymphohematopoietic system tumours (mRR = 1.03, 95 % CI = 0.87–1.28, 4 studies) or oral cavity/pharynx cancer (mRR = 0.68, 95 % CI 0.42–1.11, 3 studies). There were not sufficient studies of any specific neoplasms to perform meta-analysis on the intensity or duration of occupational RF-EMF exposure; individual studies did not show statistically significant associations with either of those exposure metrics and any specific neoplasms. The small number of studies, and of exposed cases in some instances, hampered the assessment of the statistical heterogeneity in findings across studies in the meta-analyses. Based on the summary risk of bias, most studies included in the quantitative evidence syntheses were classified at moderate risk of bias. The most critical issue was exposure information bias, especially for occupational studies where the exposure characterization was rated at high risk of bias for all included studies. Outcome information bias was an issue in mortality-based occupational cohort studies investigating non-rapidly fatal neoplasms. Further, the healthy subscriber effect, and (at a lesser extent) the healthy worker effect, were identified as plausible explanations of the decreased risks observed in some studies. The association of RF-EMF exposure from wireless phone use, or workplace equipment/devices, with other important neoplasms was reported by only one or two studies per tumour, so no quantitative evidence syntheses were conducted on these outcomes. It is noted that there were generally no statistically significant exposure-outcome associations for any combinations, independently of the exposure metric and level, with a few studies reporting decreased risks (especially for smoking-related cancers). There was only one study which assessed the effect of RF-EMF exposure from fixed-site transmitters on less researched neoplasms and it reported no statistically

significant associations between exposure from base stations and risk of lymphomas overall, lymphoma subtypes, or chronic lymphatic leukaemia in adults.

Conclusions

For near field RF-EMF exposure to the head from mobile phones, there was low certainty of evidence that it does not increase the risk of leukaemia, non-Hodgkin's lymphoma or thyroid cancer. For occupational RF-EMF exposure, there was very low certainty of evidence that it does not increase the risk of lymphohematopoietic system tumours or oral cavity/pharynx cancer. There was not sufficient evidence to assess the effect of whole-body far-field RF-EMF exposure from fixed-site transmitters (broadcasting antennas or base stations), or the effect of RF-EMF from any source on any other important neoplasms.

Other

This project was commissioned and partially funded by the World Health Organization (WHO). Co-financing was provided by the New Zealand Ministry of Health; the Istituto Superiore di Sanità in its capacity as a WHO Collaborating Centre for Radiation and Health; and ARPANSA as a WHO Collaborating Centre for Radiation Protection. Registration: PROSPERO CRD42021236798. Published protocol: [(Lagorio et al., 2021) DOI https://doi.org/10.1016/j.envint.2021.106828].

Excerpts

"Our conclusive statements, formulated in accordance with the GRADE guidelines 26 (Santesso et al., 2020), are provided below.

- For near field RF-EMF exposure to the head from mobile phones, there was low certainty of evidence that it does not increase the risk of leukaemia, non-Hodgkin's lymphoma or thyroid cancer.
- For occupational RF-EMF exposure, there was very low certainty of evidence that it does not increase the risk of lymphohematopoietic system tumours or risk of oral cavity/pharynx cancer.
- There was not sufficient evidence to assess whole-body far-field RF-EMF exposure from fixed-site transmitters (broadcasting antennas or base stations) or the effect of exposure to RF-EMF (from any source) on any other *important* neoplasms."

"The main limitation in this second paper on findings from our systematic review was the small number of studies per tumour type (which in some ways is inherent to this paper, that is dedicated to less researched neoplasms). A formal synthesis of the evidence was only possible for a few types of neoplasms, mainly different types of lymphohematopoietic system tumours, as well as thyroid and oral cavity/pharynx cancers. There were 54 types of neoplasms which were investigated in only one or two studies and did not satisfy the criteria for a quantitative synthesis of the evidence, but none of these showed evidence of an effect of RF EMF."

"Looking at specific sources of RF-EMF exposure, the majority of the evidence was on mobile phone use. There was only sufficient evidence to assess the effect of ever (or regular) use *vs* no (or non-regular) use, as well as of long-term (10 + years) use. There was not sufficient evidence on lifetime intensity of mobile

phone use, including cumulative call time and cumulative number of calls, so we could not conduct a dose–response analysis."

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Mark Elwood has given expert advice on topics in electromagnetic fields and health, and on the objective interpretation of epidemiological and other scientific information, over many years to individuals and groups, including government ministries, environmental regulators, community groups, commercial organisations, and formal inquiries by government and professional groups including parliamentary and legal proceedings. Some of this work has been financially supported, by universities, health care organisations, research bodies, or by government, professional or commercial groups. Some work has been reported 'blind', with the client being unidentified. Susanna Lagorio was principal investigator (April 2019 – March 2020) of the research project "BRiC 2018/06 − Systematic reviews of exposure to radiofrequency fields and cancer", supported by the Italian Workers' Compensation Authority, a public no-profit entity (grant code I85B19000120005). Her employment duties involved provision of advice on health hazards from exposure to RF-EMF to the Italian Ministry of Health and Higher Health Council (she retired on August 1st, 2023). Martin Röösli's research is entirely funded by public entities or not for profit foundations. He has served as advisor on potential health effects of exposure to non-ionizing radiation to several national and international public advisory and research steering groups, including the World Health Organization, the International Agency for Research on Cancer, the International Commission on Non-Ionizing Radiation Protection, the Swiss Government (member of the working group "Mobile phone and radiation" and chair of the expert group BERENIS), the German Radiation Protection Commission (member of the committee Non-ionizing Radiation (A6) and member of the working group 5G (A630)) and the Independent Expert Group of the Swedish Radiation Safety Authority. From 2011 to 2018, M.R. was an unpaid member of the foundation board of the Swiss Research Foundation for Electricity and Mobile Communication, a non-profit research foundation at ETH Zurich. Neither industry nor nongovernmental organizations are represented on the scientific board of the foundation. Chris Brzozek and Rohan Mate as part of their employment are involved in the provision of advice to the Australian Commonwealth Government, Australian States and Territories and the general public on the risks and health effects of exposure to ionising and non-ionising radiation.

The other authors declare that they have no known conflicts of interest.

Open access paper: https://www.sciencedirect.com/science/article/pii/S016041202500025X

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**Histopathologic effects of mobile phone radiation exposure on the testes and sperm parameters: a systematic literature review of animal studies**

Assefa EM, Abdu SM. Histopathologic effects of mobile phone radiation exposure on the testes and sperm parameters: a systematic literature review of animal studies. Front Reprod Health. 2025 Jan 17;6:1515166. doi: 10.3389/frph.2024.1515166.

Abstract

Introduction: Male infertility, often attributed to insufficient production of healthy and active sperm, can be exacerbated by electromagnetic radiation emitted from mobile phones, which disrupts normal spermatogenesis and leads to a notable decline in sperm quality. The main targets of mobile phone-induced damage in the testes are Leydig cells, seminiferous tubules, and sperm cells. The aim of this systematic literature review is to identify histopathological changes in the testes due to mobile phone radiation exposure and to examine its effects on sperm parameters in experimental animals.

Methods: In this systematic review, an extensive literature search was conducted across databases such as PubMed, ScienceDirect, Hinari, and Google scholar.

Results: A total of 752 studies were identified for screening, and 18 studies were deemed eligible for data extraction. Studies have identified histopathological alterations in testicular tissue caused by mobile phone radiation, such as reduced seminiferous tubule diameter, tunica albuginea and germinal epithelial thickness, Leydig cell hypoplasia, and increased intertubular space. Consistent exposure to mobile phone radiation has been shown to significantly reduce sperm count, motility, and viability, while also increasing abnormal sperm morphology in male rats, mice, and rabbits.

Conclusion: Animal studies indicate that electromagnetic radiation from mobile phones can negatively impact testicular tissue and sperm parameters, including sperm count, motility, viability, and morphology. As a precaution, preventive measures are recommended to minimize potential risks from mobile phone exposure, and further research is needed to fully understand its effects on human reproductive health.

Open access paper: https://www.frontiersin.org/journals/reproductive-health/articles/10.3389/frph.2024.1515166

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**Laptop and tablet use and their influence on total motile sperm count parameters: are laptops linked to infertility in Jamaican men?**

Sterling L, Carroll K, Harris LR. Laptop and tablet use and their influence on total motile sperm count parameters: are laptops linked to infertility in Jamaican men? Rev Int Androl. 2024 Dec;22(4):25-32. doi: 10.22514/j.androl.2024.027.

Abstract

Background: This study aims to determine the impact of laptop and tablet use on total motile sperm count (TMSC) in men being investigated for assisted reproduction.

Methods: A cross-sectional study was conducted on 156 men attending a fertility clinic in Jamaica. Routine semen analyses were performed and parameters specific to TMSC assessed. All data analyses were performed using SPSS Version 26. Logistic regression analyses were performed to independently predict the impact of quantifiable measures of laptop and tablet use. The main outcome measures were the parameters associated with TMSC.

Results: Overall, 64% of the participants reported using laptops and 36% reported using tablets. There was a significant relationship seen with time spent on laptops and time trying to conceive (p = 0.015). Regression analyses showed that persons who used their laptops for 2 to 5 h daily were approximately 16 times (adjusted Odds Ratio (aOR) = 15.9; 95% Confidence Interval (CI), 2.5-103.3, p = 0.004) more likely to be diagnosed with low semen volume (hypospermia). Although no significant association was found between total motile sperm count (TMSC) and laptop use, a trend towards significance was observed with high laptop use (p = 0.052), suggesting potential implications for TMSC as a predictor of pregnancy outcomes.

Conclusions: Our findings highlight the need for clinicians to take into consideration wireless device usage in men undergoing fertility investigations.

Open access paper: https://files.intandro.com/files/article/20241230-28/pdf/RIA20240615001.pdf

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**A review of effects of electromagnetic fields on ageing and ageing dependent bioeffects of electromagnetic fields**

Wei X, Huang Y, Sun C. A review of effects of electromagnetic fields on ageing and ageing dependent bioeffects of electromagnetic fields. Sci Total Environ. 2025 Jan 15;963:178491. doi: 10.1016/j.scitotenv.2025.178491.

Abstract

Thanks to the progress of science and technology, human life expectancy has dramatically increased in the past few decades, but accompanied by rapid ageing of population, resulting in increased burden on society. At the same time, the living environment, especially the electromagnetic environment, has also greatly changed due to science and technology advances. The effect of artificial electromagnetic fields (EMFs) emitted from power lines, mobile phones, wireless equipment, and other devices on ageing and ageing-related diseases are receiving increasing attention. However, the information on the relationship between EMFs and ageing and ageing related susceptibility to EMFs is fragmentary, a review is needed. Only few studies directly investigate the effect of EMFs on ageing, and we reviewed the impact of EMFs on lifespan and cellular senescence to pry whether EMFs have an effect on ageing, and reviewed the age-dependent bioeffects and health impacts of EMFs to see whether ageing would affect biological susceptibility to EMFs. The results indicated that EMFs may have an effect on longevity and cellular senescence, but the results were inconsistent which may depend on EMF types (frequency, intensity, wave shape, etc.), species, and cell lines. Ageing has an impact on the biological or health effects of EMFs; however, the results differ depending on the EMF type and the endpoint or health outcome. Age-dependent changes in free radical metabolism, ion homeostasis, gene expression, enzyme activity, and tissue biophysical properties may be the reason; however, the underlying mechanisms are not fully elucidated.

Highlights

- Electromagnetic fields (EMF) exposure has an effect on lifespan, but the effect may vary with type of EMF and animal model.
- Extremely-low-frequency EMFs exposure can affect cellular senescence in a wave shape- and/or magnetic density-dependent manner.
- Radio-frequency EMFs promotes cellular senescence in a frequency- and intensity-dependent manner.
- The influence of EMFs on cellular, animal, and human health exhibits a degree of age-dependency.

https://pubmed.ncbi.nlm.nih.gov/39818160/

Conclusion

With the intensification of ageing and the variety of EMFs in the environment continues to increase, the effects of EMFs on ageing and ageing-dependent effects of EMFs will get constant attention. Although current research is insufficient to answer this question, some important information can be gleaned. The ageing state of the cell or body plays a role in determining the biological or health effects of EMF exposure, but the exact effect depends on the specific conditions, and further investigation of the underlying mechanism is needed.

6.1. The effect of EMFs on ageing

Ageing is a complex and expanding concept (López-Otín et al., 2023); therefore, understanding the effects of EMFs on ageing is not to be done in a short time, but we can gain insights into this mystery from the study of lifespan and cellular senescence. SMFs have an effect on delaying cellular senescence (Fig. 3) and extending the lifespan of C. elegans and mice (Fig. 2); however, SMFs at high flux intensity had negative effects on C. elegans (Fig. 2). RMFs have both beneficial effects on anti-cellular senescence and prolong the lifespan of C. elegans (Fig. 2, Fig. 3). The impact of ELF-EMFs on lifespan and cellular senescence had been found to be inconsistent, potentially dependent on wave shape and/or magnetic flux density (Fig. 2, Fig. 3). Exposure to RF-EMFs in the wireless communication bands (1800 MHz–2480 MHz) appears to have no significant impact on lifespan (Fig. 2). However, these RF-EMFs may influence cellular senescence in a frequency- and intensity-dependent manner (Fig. 3).

6.2. Ageing-dependent effect of EMFs

With the global ageing of the population, it is very meaningful to understand the age-dependent health effects of EMFs. Although the current research is still in the preliminary stage, the biological effects of SMFs, ELF-EMFs, and RF-EMFs have been reported to be age dependent (Fig. 4). SMFs have an age-dependent effect on cell apoptosis, calcium signalling and tissue hydration. ELF-EMFs have an age-dependent effect on human-derived primary cells and brain oxidative stress in animals, and epidemiological studies have shown that the relationship between ELF-EMFs and the risk of neurodegenerative disease is greater in older individuals and that the risk of carcinogenesis is greater in young individuals. RF-EMFs have an age-dependent effect on immune cells, tissue development, and brain activity but do not interfere with sleep. Importantly, RF-EMFs are more strongly related to the risk

of carcinogenesis in younger age groups.

6.3. Possible mechanisms for the age-dependent effect of EMFs

Cellular senescence is the basis of ageing, so the age-dependent effect may be fundamentally due to cellular senescence (van Deursen, 2014). A deeper understanding of the molecular mechanism underlying the interactions between EMFs and cells may lead to new findings. Free radical metabolism and calcium signalling have mostly been studied for their ability to mediate the bioeffects of EMFs; thus, age-related functional changes in these two aspects might be the cause of age-dependent effects (Falone et al., 2008; Selakovic et al., 2013). Existing studies have shown that other possible mechanisms, such as age-dependent Na+/K+ pump dysfunction (Deghoyan et al., 2014) and decreased expression levels of high-affinity ouabain receptors (Narinyan et al., 2013), play important roles in the age-dependent effect of SMFs on tissue hydration. The effect of EMFs is also dependent on the biophysical properties of tissues or cells, and ageing-related differences in the biophysical properties that result in different responses to EMFs may also be the cause of age-dependent effects.

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**Effects of radiofrequency electromagnetic radiation with a focus on hematology parameters: a brief review and future research needs**

N. Žura, I. Žura Žaja*, P. Perić, K. Malarić, S. Milinković Tur, N. Poljičak Milas, V. Rimac, J. Pejaković Hlede, S. Kunštek, M. Pećin, M. Vili. Effects of radiofrequency electromagnetic radiation with a focus on haematology parameters: a brief review and future research needs. Veterinarska Stanica, 56(3):375-387. 2025. doi: 10.46419/vs.56.3.6.

Abstract

The use of radiofrequency electromagnetic radiation (RF-EMR) has steadily increased since the 1950s. RF-EMR is used in medicine, industry, household appliances, security and navigation, and especially in wireless tele- communications and animal husbandry. The widespread use of RF-EMR, especially with the introduction of 5G networks, raises concerns about potential adverse effects on human and animal health. The effects and mechanisms of RF-EMR impacts of 5G network frequencies on human and animal health are still unknown or poorly understood. Current research findings include the biological effects of RF-EMR on genotoxicity, cell proliferation, gene expression, cell signalling, cell membrane function, and the function of immune, hematopoietic, and reproductive systems. Exposure of humans and laboratory animals to RF-EMR emitted from cell phones and many other electronic devices of 4G and older technologies has been shown to have detrimental effects on blood cells and to cause changes in the complete blood count. This depends on the type of organisms exposed, sources, frequency, electric field level and duration of exposure. There is sparse data in the available literature on the effects of RF-EMR on haematology indicators and erythrocyte morphometry in domestic animals. Therefore, the aim of this scientific review is to highlight the effects of RF-EMR on haematology indicators, erythrocyte morphometry, and platelet activation in humans and animals, taking into account the findings on the effects of 5G electromagnetic radiation on these indicators. Considering the ubiquitous electromagnetic pollution, it is important to gain knowledge about the effects of RF-EMR on human and animal health. In addition, it is necessary to determine the effects following in vitro exposure of blood to RF-EMR, especially due to the storage and use of blood and blood products in transfusion medicine.

Open access paper: https://hrcak.srce.hr/file/462530

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**Waveforms of 4G and 5G Radiofrequency Signals: Are Differences Relevant to Biology or Health?**

My note: Studies of **4G** and **5G** exposure have found adverse effects as well as exposure to **millimeter waves**.

Foster KR, Maxson D, Zollman PM. Waveforms of 4G and 5G Radiofrequency Signals: Are Differences Relevant to Biology or Health?. Health Physics. November 20, 2024. doi: 10.1097/HP.0000000000001895.

Abstract

This Note briefly reviews, at a level that is intended to be accessible to non-specialists, the similarities and differences between waveforms of 4G Long-Term Evolution (4G LTE) and 5G New Radio (5G NR) transmitted by cellular base stations, as a resource for health physicists and others who are engaged in public communication about cellular telephone technologies. Despite the difference in levels of controversy presently existing between 4G LTE (introduced in 2008) and 5G NR (introduced in 2019), the differences in waveform as represented by the baseband waveform are minimal, although 5G NR offers system designers a much wider choice of parameters. Transmitted radiofrequency signals in both technologies appear noise-like, in a frequency range that is narrowly contained in the assigned channel. It is concluded that the modulation differences between 4G LTE and 5G NR are unlikely to have any biological relevance, but the greater range of accessible frequencies in 5G NR suggests the need for further health research, particularly in the 5G FR2 millimeter-wave band.

Conclusion

In closing, it is noted that the topic of 5G NR and health extends beyond the technical considerations concerning modulation, waveform, and frequency, to include population exposure assessment, risk perception and risk communication, and other topics. One factor contributing to public concerns about 5G NR cell sites is the use of small wireless facilities ("small cells") along city streets, sometimes close to residences (network operators have deployed 4G LTE and 5G NR small cells in some localities). To address this broader range of issues, in 2022, the European Union funded a large set of studies called CLUE-H that combines efforts of "more than 70 European research organizations in four research consortia" (https://emf-health-cluster.eu) to study the risks and perceived risks of 5G technology.

As communications technology continues to develop, the authors hope that high-quality targeted research will resolve the remaining gaps in our knowledge.

https://journals.lww.com/health-physics/abstract/9900/waveforms_of_4g_and_5g_radiofrequency_signals__are.200.aspx

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**Auto-induced uplink 4G and 5G RF-EMF exposure assessment using a network monitoring application in different microenvironments across seven European countries**

Stroobandt B, Van Bladel H, Veludo AF, Deprez K, Aerts S, Verloock L, Thuróczy G, Politanski P, Polanska K, Tognola G, Parazzini M, Wiart J, Guxens M, Röösli M, Joseph W. Auto-induced uplink 4G and 5G RF-EMF exposure assessment using a network monitoring application in different microenvironments across seven European countries. Environmental Research, 2025, doi: 10.1016/j.envres.2025.121029.

Highlights

Assessment of uplink 4G and 5G microenvironmental RF-EMF exposure in Europe

Novel methodology using network monitoring application QualiPoc for 4G and 5G

Transmit powers were higher in villages than in big cities, with 5G lower than 4G

Base station density was suggested as key predictor of auto-induced uplink exposure

Transmit powers are related to uplink duty cycles and frequency band usage

Abstract

The auto-induced uplink (a-UL) radio-frequency electromagnetic field (RF-EMF), often the dominant part of the total RF-EMF exposure, has not been included in previous microenvironmental studies. As 5G exposure depends more on mobile phone usage, monitoring typical transmit power levels is crucial towards more accurate personal exposure assessment. This study describes spatial differences in average mobile phone transmit power and investigates the influence of uplink duty cycles and frequency band usage. A novel methodology using the network monitoring application QualiPoc in fourth-generation (4G) and non-standalone fifth-generation (5G) networks was presented. For the first time, the assessment of 4G and 5G a-UL RF-EMF exposure was conducted simultaneously in a large-scale microenvironmental study in Europe. Measurements were performed along predefined routes in 282 different microenvironments (e.g., parks, residential areas) across seven European countries, during a maximum uplink usage scenario. The Netherlands had the highest average transmit powers per microenvironment (median 20.6 dBm). Transmit powers in villages were 0.6 to 2.1 dB higher than in big cities. The study suggested that base station density is a key predictor of a-UL exposure. Comparing technologies and frequency bands, average transmit powers for 5G were about 3.3 dB lower than for 4G and lowest for frequency bands with a time division duplexing (TDD) scheme due to the low uplink duty cycle (below 20%). This study provides crucial measurement data for epidemiologists and governments to enhance the understanding of the a-UL component of personal RF-EMF exposure.

https://www.sciencedirect.com/science/article/pii/S0013935125002804

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**Electromagnetic Field-Aware Radio Resource Management for 5G and Beyond: A Survey (Review)**

Salem MA, Lim HS, Diong KS, Alaghbari KA, Zarakovitis CC, Chien SF. Electromagnetic Field-Aware Radio Resource Management for 5G and Beyond: A Survey. *Computers*. 2025; 14(2):51. doi: 10.3390/computers14020051.

Abstract

The expansion of 5G infrastructure and the deployment of large antenna arrays are set to substantially influence electromagnetic field (EMF) exposure levels within mobile networks. As a result, the accurate measurement of EMF exposure and the integration of EMF exposure constraints into radio resource management are expected to become increasingly important in future mobile communication systems. This paper provides a comprehensive review of EMF exposure evaluation frameworks for 5G networks, considering the impacts of high-energy beams, the millimeter wave spectrum, network densification and reconfigurable intelligent surfaces (RISs), while also examining EMF-aware radio resource management strategies for 5G networks and beyond, with RIS technology as an assistive factor. Furthermore, challenges and open research topics in the EMF evaluation framework and EMF-aware resource management for 5G mobile networks and beyond are highlighted. Despite the growing importance of RIS technology in enhancing mobile networks, a research gap remains in addressing specific EMF exposure considerations associated with RIS deployments. Additionally, the impact of EMF-aware radio resource allocation approaches on RIS-assisted 5G networks is still not fully understood.

Open access paper: https://www.mdpi.com/2073-431X/14/2/51

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**Measurement of Ambient Millimeter Wave Exposure Levels around Small Base Stations**

My note: Averaging exposure over time, 30 minutes in this study, ensures very low power densities for 5G millimeter waves (MMW) especially when few (or no) 5G cell phones are downloading files using the MMW band. Assessing MMW exposure from a 5G base station is both a costly and tricky endeavor especially if one is concerned about peak exposures: "... when a UE was used to attract the beam toward the measurement location, the maximum instantaneous exposure measured was -60 dBm (0.8% public MPE)." This was 381 times the 30-min average maximum exposure at that location.

Bushberg JT, Butcher MJ. Measurement of Ambient Millimeter Wave Exposure Levels around Small Base Stations. Health Phys. 2025 Jan 13. doi: 10.1097/HP.0000000000001935.

Abstract

This study investigated the implementation and impact of fifth-generation (5G) wireless millimeter wave (mmW) technology. 5G offers significant advancements over previous generations and supports additional frequency bands, including mmW, to enhance mobile broadband with ultra-reliable, low-latency communications, supporting a high volume of diverse communications. This technology is expected to enable billions of new connections in the Internet of Things (IoT), fostering innovations in various sectors including healthcare, manufacturing, and education. This research contributes to the understanding and safe implementation of this transformative technology. Global adoption of 5G is rapidly increasing, with over 1.5 billion subscriptions as of 2024, projected to reach 58% of all wireless subscriptions by 2029. Despite its benefits, 5G mmW installations have raised concerns regarding exposure to electromagnetic fields. This study was conducted using a dual-polarized horn antenna and relatively inexpensive spectrum analyzers to measure typical ambient mmW radiofrequency field power densities near operational radio base stations (RBS) in urban and suburban environments. The measurements were taken at various times of the day and in different weather conditions to ensure a comprehensive understanding of the ambient mmW exposure. The study's results provide reassuring evidence that the ambient mmW exposure from RBSs is significantly lower than the safety limits set by

the Federal Communications Commission (FCC) and other international standards. The exposure levels ranged from 0.0003% to 0.0082% of the public maximum permissible exposure (MPE), with the highest levels being more than 25,000 times lower than the allowed continuous public exposure. This study concludes that typical mmW exposure from 5G RBSs is minimal and substantially below established safety limits.

https://pubmed.ncbi.nlm.nih.gov/39804717/

Excerpts

Table 1 - RF hardware.

| **Device** | **Description** | **Manufacturer/Part Number** |
|---|---|---|
| Spectrum Analyzer #1 | Spectrum Analyzer 24-43 GHz v.2 | SAF/J0GSAP541B |
| Spectrum Analyzer #2 | Spectrum Compact 24-40 GHz v.2 | SAF/J0GSAP741B |
| Antenna | 18.0-40.0GHz Dual Polarization Horn Antenna | A-Info/LB-SJ-180400-KF |
| RF Cable Assembly (x2) | Sucoflex 102 500 mm Cable with 2.92 mm Connectors | HUBER+SUHNER/SF102/11SK/11SK/500 mm |
| Right Angle Adapter (x2) | 2.92 mm Plug to 2.92 mm Jack Right Angle Adapter | Dynawave/1101-9495-6200 |

Thirty-minute (30 min) measurements were made at three distance intervals (3-15, 15-30, and 35+ m) from the base of the RBS support structure as measured with a laser rangefinder (Fig. 3). These distance intervals were selected to highlight the fact that exposure levels can vary with distance and angle relative to the BTS. Locations were selected for alignment with the RBS antenna panels, line of sight to the antenna, and critically in a location that allowed for 30-min uninterrupted measurements. All the criteria could not be met for all locations. As seen in Fig. 4, the middle and far locations were selected off-boresight to avoid vehicle traffic and achieve line-of-sight. Following the 30-min measurement at each location, four additional 2-min measurements were made with the horn oriented at 0°, 90°, 180°, and 270° relative to the direction of the 30-min measurement to assess the presence of reflections and mmW signals from other RBSs in the area. An example is shown in Fig. 5. The first 2 min are oriented at the RBS, and the remaining time is at the other azimuths before returning to the RBS.

At most of the measured RBSs, a 1-min sample acquisition was obtained with a mobile phone (UE) behind the horn antenna assembly. High-definition/large file-size video downloads were performed to attract the beam toward the measurement location. The increase in signal strength over the RBS signal bandwidth was used to confirm that the measurement equipment and RBS were operating as expected and to estimate the maximum exposure corresponding to the RBS operating close to full capacity. It was noted that some RBS operated at 800, 400, and 300 MHz, corresponding to eight, four, and three 100-MHz channels.

The spectrum analyzers display and record received signal power in units of decibels relative to a milliwatt (dBm). The analyzers required a little over 10 s to scan the entire 1 GHz spectrum, using overlapping 100 kHz bins spaced every 30 kHz. SAF settings are listed in Table 2. Before measurements, the spectrum analyzers, the horn antenna, and the feedlines were checked with an RF source at mmW frequencies and found to agree with the expected levels. Each frequency bin was averaged throughout the measurement, and the bin with the highest received averaged power was selected to represent the highest time-average exposure at the base station. Extrapolating from the highest received averaged power bin provides a very conservative assessment of power over the entire spectrum based on the measurements. The highest received averaged power bin was converted to power received over the operating bandwidth, considering the ratio of the bin bandwidth to the observed bandwidth of the signal and the loss of the transmission lines.

The power density for both polarizations was summed to determine the time-averaged total exposure and compared with the exposure limit. This result is presented for three distances for each RBS. RBSs in four geographic areas—Los Angeles, CA; Arlington, VA; Washington, DC; and Providence, RI—were selected. All have deployed different manufacturers' equipment by different operators, including T-Mobile and AT&T. Locations included urban commercial and residential areas.

Table 3 shows data of 30-min measurement results at different distance intervals, indicating the maximum average bin over that 30-min expressed as a percent of the General Public exposure limit. The ambient mmW measurements ranged from −77 dBm down to −94 dBm, which, when polarizations are combined, correspond to total exposure levels of 0.0082% to 0.0003% of the public maximum permissible exposure (MPE). The noise floor adjacent to the measured signal was −98 dBm (Fig. 6). By comparison, **when a UE was used to attract the beam toward the measurement location, the maximum instantaneous exposure measured was -60 dBm (0.8% public MPE) (Fig. 7)**. At the same location, the 30-min average maximum 100 kHz bin is −83 dBm (0.0021% GP). The figures show only one polarization at RBS CYLA4-7 and include the 100 MHz channel average.

Conclusions

One of the distinguishing characteristics of 5G mmW base stations is dynamic beamforming using a multi-element antenna. When the scanning beams detect a UE in its service environment, the RBS creates a narrow beam directed toward UEs requesting service. Even when an obstacle in its direct path blocks the beam, the system will use multiple directed beams for spatial multiplexing. Spectral analysis of mmW signals typically requires expensive portable spectrum analyzer equipment, costing upwards of $70,000. Substantially less expensive equipment (approximately $20,000) can be used. This report demonstrates that a cross-polarized horn and two spectrum analyzers can make power density measurements of orthogonal polarization and capture the total mmW exposure from an RBS.

RF surveys were conducted in the United States in various urban environments, using different frequency bands, operators, and equipment manufacturers. Measurements at several distances from operational radio base stations (RBS) indicate that the typical exposure from an mmW RBS at ground level was an exceedingly small fraction of the FCC public safety limit. The overall measurements of ambient mmW exposure ranged from 0.0003% to 0.0044% of the FCC public MPE. Even the highest exposure level was more than 25,000 times lower than allowed for continuous public exposure.

This work is made possible through the funding provided by the Mobile & Wireless Forum under the project grant number TBD. The authors alone are responsible for the content of this paper.

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**Explainable Machine Learning-Based Electric Field Strength Mapping for Urban Environmental Monitoring**

Kiouvrekis Y, Psomadakis I, Vavouranakis K, Zikas S, Katis I, Tsilikas I, Panagiotakopoulos T, Filippopoulos I. Explainable Machine Learning-Based Electric Field Strength Mapping for Urban Environmental Monitoring: A Case Study in Paris Integrating Geographical Features and Explainable AI. *Electronics*. 2025; 14(2):254. https://doi.org/10.3390/electronics14020254

Abstract

The objective of this study is to determine the optimal machine learning model for constructing electric field strength maps across urban areas, advancing the field of environmental monitoring. These models are unique because they use a detailed dataset that goes beyond electromagnetic readings, incorporating information like population density, urbanization levels, and building characteristics. This novel approach, combined with explainable AI, helps identify the key factors affecting electromagnetic exposure. The models enable the creation of highly detailed and dynamic maps of electromagnetic pollution. These maps are not just static snapshots, they can track changes over time, evaluate the success of mitigation efforts, and provide deeper insights into how electromagnetic fields are distributed in urban areas. To construct a detailed electric field strength map, we conducted an extensive analysis using 410 machine learning models across the urban area of Paris, incorporating three fundamental approaches: k-nearest neighbors, neural networks, and decision trees. This comprehensive exploration allowed us to evaluate and optimize various model configurations, ensuring robust and accurate predictions of electric field strength across diverse urban environments. The kNN model exhibited the most consistent performance, with an RMSE of 1.63 and an SD of 0.20. The analysis indicates that kNN outperforms simple neural networks and decision trees in terms of both RMSE and performance stability. From the SHAP analysis, we conclude that the feature representing the total volume of buildings in the area around each antenna (V) is the most significant in predicting electromagnetic field strength in the kNN regression model, consistently showing a high impact across predictions. The population density feature (POP) also demonstrates considerable influence.

Open access paper: https://www.mdpi.com/2079-9292/14/2/254

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**Effects of 5G mobile phone network electromagnetic field exposure on testicular endoplasmic reticulum stress and the protective role of coenzyme Q10 (CoQ10)**

Yilmaz H, Tümkaya L, Mercantepe T, Yılmaz A, Gül F, Suzan ZT. Effects of 5G mobile phone network electromagnetic field exposure on testicular endoplasmic reticulum stress and the protective role of coenzyme Q10. Arch Med Res. 2025 Jan 6;56(4):103157. doi: 10.1016/j.arcmed.2024.103157.

Abstract

Aim: Nowadays, the electromagnetic field (EMF) has become an issue of electromagnetic pollution. This study aimed to determine the effect of 5 G Fr1 frequency band EMF waves on endoplasmic reticulum (ER) stress in testicular tissue and to demonstrate the efficacy of coenzyme Q10 (CoQ10) in suppressing the potential situation.

Materials and methods: Three groups of eight male Sprague-Dawley rats were established. In group I (control) received only saline solution by oral gavage. In group II (EMF), saline solution was administered by oral gavage and the rats were exposed to 5.9 GHz EMF for 2 h/d (09:00-11:00). In group III (EMF+ CoQ10), the EMF exposure was created in the same way as in group II and CoQ10 was given daily at 10 mg/kg (CoQ10), 2 mg/kg dissolved in corn oil and administered by oral gavage for the experimental period (30 days).

Results: Histopathological damage, including edematous regions, vascular congestion, and neutrophil inflammation accompanied by loss of spermatogenic cells, particularly spermatozoa, and spermatids, increased thiobarbituric acid (TBARS) and decreased total thiol (TT) levels were observed in the seminiferous tubules in the EMF group. Furthermore, germinal epithelial cells showing intense GRP-78 immunopositivity and spermatogenic cells indicating C/EBP homologous protein (CHOP) immunopositivity were increased in the seminiferous tubules. On the other hand, in the EMF+CoQ10 group, both histopathological and biochemical findings were observed in the opposite direction.

Conclusion: Due to its antioxidant properties and its ability to suppress oxidative stress and apoptosis, CoQ10 may be a promising candidate against 5 G EMF-induced testicular ER damage.

https://pubmed.ncbi.nlm.nih.gov/39765017/

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**Short-term exposure of 2.4 GHz electromagnetic radiation on cellular ROS generation and apoptosis in SH-SY5Y cell line and impact on developing chick embryo brain tissue**

Deena K, Maadurshni GB, Manivannan J, Sivasamy R. Short-term exposure of 2.4 GHz electromagnetic radiation on cellular ROS generation and apoptosis in SH-SY5Y cell line and impact on developing chick embryo brain tissue. Mol Biol Rep. 2025 Jan 21;52(1):144. doi: 10.1007/s11033-025-10217-8.

Abstract

Background: Electromagnetic radiation (EMR) from wireless technology and mobile phones, operates at various frequencies. The present study analyses the major impact of short-term exposure to 2.4 GHz frequency EMR, using the two model systems chick embryos and SH-SY5Y cell lines. We hypothesized that exposure to this frequency would induce oxidative stress and apoptosis in neurons.

Methods and results: Chick embryos were exposed continuously to 2.4 GHz EMR for 4 h each day over a 5-day period, and comparisons were made with a control group. At the end of the exposure, brain tissues were dissected for histopathological analysis, antioxidant assays, and reactive oxygen species (ROS) detection. Additionally, SH-SY5Y cells were exposed to 2.4 GHz EMR to assess cell viability, DNA damage, and apoptosis. Our results showed that exposure to 2.4 GHz EMR induces oxidative stress in both chick embryos and the SH-SY5Y cells, though no significant tissue-level impact was observed. In SH-

SY5Y cells, ROS production increased after 4 h of exposure, accompanied by moderate DNA damage and early markers of apoptosis, such as upregulation of the Bax gene. Furthermore, we observed that antioxidants, such as NAC and Mito-TEMPO, helped mitigate the cytotoxic effects of EMR in both the study models.

Conclusion: In conclusion, short-term exposure (4 h) to 2.4 GHz EMR induced moderate cellular and molecular changes, primarily oxidative stress. The oxidative stress was reduced by antioxidants, which suggests potential benefits in preventing EMR-induced cytotoxicity. Extended exposure to EMR beyond 4 h may pose adverse health risks to humans, endorsing further investigation.

https://pubmed.ncbi.nlm.nih.gov/39836269/

Conclusion

This study demonstrates the intricacy of the influential impacts of short-term exposure to 2.4 GHz electromagnetic radiation (EMR) at the cellular and tissue levels, thus shedding light on its potential biological implications. Even though there were no significant structural changes detected in histopathological studies of chick embryo brain tissues, results of scanning electron microscopy revealed micro-impacts after short-term exposure of 2.4 GHz, which induced moderate surface modifications. Similarly, antioxidant enzyme activities displayed differential responses where the levels of SOD increased, and on the other hand, CAT activity remained the same. These observations thus emphasise the tight regulation of oxidative stress responses to EMR exposure. In neuronal cell, SH-SY5Y, a marked increase in ROS generation was accompanied by DNA damage and upregulation of apoptotic markers, especially the Bax gene. These findings show that EMR causes oxidative stress and triggers the activation of apoptosis-related pathways stating that mitochondria have a role in these events. Interestingly, the antioxidant protection by NAC and Mito-TEMPO shows a potential area of intervention for the abrogation of oxidative stress due to EMR.

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**Compound exposure of 2.8 GHz and 9.3 GHz microwave causes learning and memory impairment in rats**

Sun L, Wang X, Ren K, Yao C, Wang H, Xu X, Wang H, Dong J, Zhang J, Yao B, Wei X, Peng R, Zhao L. Compound exposure of 2.8 GHz and 9.3 GHz microwave causes learning and memory impairment in rats. Heliyon. 2025 Jan 3;11(1):e41626. doi: 10.1016/j.heliyon.2025.e41626.

Abstract

The anxieties and concerns about health hazards caused by microwave has been growing recently. Previous studies have reported microwave induced structural and functional injuries to brain. However, the biological effects caused by compound microwave were largely unexplored. In this study, we investigated the biological effects on rat's hippocampus after sequentially exposure to 2.8 GHz and 9.3 GHz at **average power density of 10 mW/cm$^2$**. Morris water maze (MWM) navigation tests showed that microwave exposure significantly extended the average escape latency (AEL) at 1d and 3d after exposure, suggesting reduced learning and memory ability. Importantly, compound microwave produced strongest responses at 3 d after exposure. Moreover, microwave also could induce abnormal electroencephalogram (EEG), such as increasing the power of θ wave and δ wave, suggesting brain

damage or dysfunction. Histopathological analysis suggested that microwave resulted in obvious structural injuries in hippocampus at 7 d after exposure, and most serious injuries were observed in compound microwave exposed rats. Moreover, disorder of mitochondria and reduced Nissl bodies in hippocampus might contribute to the decrease of cognitive function. However, both the cognitive function and hippocampal structure restored to normal at 28 d after exposure, which might be attributed to self-recovery mechanisms. Gene ontology (GO) and Protein-protein interaction (PPI) analyses of differential expressed genes (DEGs) in peripheral blood suggested that Htt and Bdnf might be potential indicators to predict microwave. In conclusion, compound microwave of 2.8 GHz and 9.3 GHz could elicit reversible structural injuries to hippocampus, which could decrease the cognitive function of rats.

Conclusion

The composite microwave of 2.8 GHz and 9.3 GHz can cause damage to rat hippocampal tissue, inhibit brain activity, and reduce the metabolism of hippocampal neurons through inducing mitochondrial disorder and decreasing Nissl bodies, and ultimately impaired the learning and memory abilities of rats. Notably, compound microwave can reduce the learning and memory ability of rats more than single frequency microwave. Through a combination of GO and PPI analyses, we have also identified Htt, Htra, Psen1, Tp73, and Bdnf as potential predictive indicators of microwave-induced neuronal damage in the nervous system.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC11760294/

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**Measurement of non-ionizing radiation (NIR) from Wi-Fi access points and microwave ovens in residential environments**

Silva, J. da L. A., Rodrigues, M. E. C., Pinheiro, F. S. R., Silva, G. S. da, Mendonça, H. B., Silva, R. Q. de F. H., … Sousa, V. A. de, Jr. (2025). Measurement of non-ionizing radiation (NIR) from Wi-Fi access points and microwave ovens in residential environments. *Journal of Electromagnetic Waves and Applications*, 1–22. doi: 10.1080/09205071.2024.2449120.

Abstract

It is essential to monitor the radiation levels to which the general population may be exposed and compare them to limits established by national and international standards. This is especially true in residential environments, where there is a consolidated use of microwave ovens and Wi-Fi access points, in addition to the short distances devices can be from the user, as well as prolonged periods of user exposure. The objective of this work is to measure the exposure levels for daily Wi-Fi and microwave oven use scenarios in residential environments, to compare measured levels with the standards and to verify possible relation with the characteristics of the equipment under analysis. We use the Narda NBM-520 to support our measurements, the same equipment the National Telecommunication Agency (ANATEL) uses for Brazil's Non-ionizing Radiation (NIR) inspection. This work presents measurements in 40 Wi-Fi access points in which the highest exposure level was 4.66V/m (7.64 % of the limit), verified for the 2.4 GHz network (the so-called Situation 1). This work also presents measurements in 50 microwave ovens. It was observed that 72% of them had the highest level of exposure for the position in front of the door.

Conclusion

This work evaluates the level of exposure to NIR in homes, mainly from technologies commonly found in residences: Wi-Fi and microwave ovens. For this, measurements were performed on 40 Wi-Fi access points and 50 microwave ovens following measurement methodologies from suitable governmental agencies.

For Wi-Fi case study, the influence of electric field levels was investigated in four measurement situations, by equipment brand, and by time of use. The highest level of exposure was verified for the 2.4 GHz loaded network (Situation 1), at a value of 4.66V/m (7.64% of limit). As for the influence of the brand, the variation of the equipment model between the samples impacts the dispersion of the data; so Brand 4, which has the highest dispersion, has four different models and only two samples of identical models, while Brands 1 and 2 had the lowest dispersion and contain most of the samples belonging to the same model. Thus, no clear relation was observed regarding the year of acquisition of Wi-FI APs and the NIR leakage.

The microwave oven case study targets the relation between power density level and position, brand, time of use, and conservation. We observe that 72% of the samples had the highest level of exposure in front of the door, followed by 18% on the left side (considering the observer facing the microwave oven as a reference). We speculate that the ventilation outlet located at the left side is responsible for some NIR leakage, since 2 of 3 samples that presented the worst point at the top of the oven, the ventilation outlet is located in this local

Our results do not show the influence of the brand on the power density levels. However, regarding the time of use, there is a tendency for microwave ovens to reach higher levels of power density with age, since microwave ovens with year of acquisition <2016 (oldest) present the highest levels. Likewise, the state of conservation of the equipment restrained the levels of power density so that all microwave ovens that reached an average power density above 0.6W/m2 showed signs of use. In addition, only two of the nine ovens that obtained peak power above 1W/m2 did not show signs of use.

https://www.tandfonline.com/doi/full/10.1080/09205071.2024.2449120

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**Evaluation of Population Exposure to Radiofrequency Fields in Microenvironments in the Cities of Lima, Cusco and Pucallpa in Perú, Using a Personal Exposimeter**

Cruz V, Quispe M. Evaluation of Population Exposure to Radiofrequency Fields in Microenvironments in the Cities of Lima, Cusco and Pucallpa in Perú, Using a Personal Exposimeter. 2024 IEEE XXXI International Conference on Electronics, Electrical Engineering and Computing (INTERCON), Lima, Peru, 2024, pp. 1-8, doi: 10.1109/INTERCON63140.2024.10833492.

Abstract

The objective of this study was to make an evaluation of radiofrequency fields in microenvironments of Cuzco, Lima and Pucallpa using personal exposimeters. To carried it out a literature review was first made, then the urban environ-ments were defined, and 95 microenvironments were selected in the

three cities. Subsequently, the exposimeter including the proprietary software for data processing was tested. In total, 1900 measurements of the main telecommunications services were carried out. The electric field was measured for each environment, with a maximum of 2.531 V/m, a minimum of 0.063 V/m and an average of 0.521 V/m for all measurements combined. Based on the ICNIRP 1998 limits, exposure quotients were also obtained for all the measurements combined and for the measurements in each city considering outdoor and indoor measurements, different types of environments and by main frequency bands. For all measurements combined, the maximum exposure quotient was 0.747% and the average was 0.033%. All measurements made were well below international limits, the largest contributors to total exposure were mobile phone base stations, the second largest were broadcasting services, and mobile phone handsets exposure was well below that of mobile phone base stations.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10833492&isnumber=10833229

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**Wireless radiation and health: making the case for proteomics research of individual sensitivity**

Leszczynski D. Wireless radiation and health: making the case for proteomics research of individual sensitivity. Front. Public Health. Volume 12 doi: 10.3389/fpubh.2024.1543818.

No abstract

Excerpts

"According to the WHO definition of health, just a belief in having EHS and experiencing non-specific symptoms, physiological and/or psychological, is experiencing the health effects of wireless technology. Hence, it is correct to claim that wireless radiation causes health effects."

"Puzzlingly, the frequent observation that the self-declared EHS person can't feel the wireless radiation and can't recognize when the wireless transmitter emits radiation and when it is not transmitting, is considered ultimate proof that the form of individual sensitivity to wireless radiation called EHS is not caused by wireless radiation exposures. This is questionable as no person, sensitive or not, could feel the ionizing radiation or other non-ionizing radiation like ultraviolet in their environment."

"...logically and per analogiam with other environmental factors, individual sensitivity to wireless radiation, which includes EHS, exists as indicated below, and should be studied using biochemical methods."

"Search for sensitive individuals, most commonly using provocation studies where experimentally controlled exposures are followed by inquiries about acutely occurring symptoms and feelings, has failed to detect any sensitivity to wireless radiation. The reason might be that provocation exposures combined with psychological inquiries might be not sensitive enough to detect individual sensitivity to a single agent present in a mix of other environmental agents..."

"There is a need for human volunteer studies where the already proposed, and other potentially useful biomarkers, would be examined in groups of sensitive and non-sensitive persons, ethically exposed to wireless radiation."

"The way forward in EHS research is to discover biomarkers of EHS, molecules that are affected by wireless radiation exposure, by research using high-throughput screening techniques of proteomics,

transcriptomics, and metabolomics [...]. For the start, proteomics might be the most promising of these methods."

"The reasons why proteomics is not used to study the physiological effects of wireless radiation exposures in humans are difficult to understand and comprehend. Despite the advantages of research using proteomics methodology, over the last 20 years, only a few proteomics studies have examined proteome changes in response to wireless radiation exposures."

"In conclusion, it is logical to conclude that the individual sensitivity to wireless radiation emitted by wireless communication devices and networks exists and impacts the health of sensitive persons. Clearly, the to-date unsuccessfully used methods of provocation studies were either too crude or too much affected by the perceptions and preexisting opinions of study volunteers."

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1543818/full

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**Amelioration and Immuno-modulation by Ashwagandha on Wi-fi Induced Oxidative Stress in Regulating Reproduction Via Estrogen Receptor Alpha in Male Japanese Quail**

Gupta V, Srivastava R. Amelioration and Immuno-modulation by Ashwagandha on Wi-fi Induced Oxidative Stress in Regulating Reproduction Via Estrogen Receptor Alpha in Male Japanese Quail. Reprod Sci. 2025 Jan 13. doi: 10.1007/s43032-024-01774-7.

Abstract

As global change threatens avian biodiversity, understanding species responses to environmental perturbations due to radiation emitted by enormous increase in the application of wireless communication is very urgent. The study investigates the effect of MW radiation on redox balance, stress level, male fertility and the efficacy of Withania somnifera (WS) root extract (100 mg/kg body weight) orally administered in 8 weeks old mature male Japanese quail exposed to 2.4 GHz MW radiation for 2 h/day for 30 days with power density = 0.1264 mw/cm$^2$ and SAR = 0.9978 W/Kg. Wi-fi exposure induces a decrease in testicular weight, volume, density and gonado-somatic index (GSI) while Ashwagandha increases them. Oxidative stress parameters increased and activity of SOD, catalase, GSH was reduced in testes of exposed quail while Ashwagandha treatment reinstates the redox balance. Exposure to Wi-fi alters quail reproduction by increase in corticosterone and decreased testosterone with reduced expression of estrogen receptor alpha (ERα) in testis. Wi-fi exposure increases IL1β and reduces IL10 in testis. IL-1β inhibits testicular cell function and promotes apoptosis by increasing NF-κB and decreasing sperm count in exposed quails. Ashwagandha increases expression of ERα, sperm count and immunity in quail testis. Further, decrease in IL1β, NF-κB and increase in IL-10 after administration of Ashwagandha in Wi-fi exposed quail prevents inflammatory damages and enhances gonadal function. Thus, exposure to Wi-fi increases oxidative stress, activates apoptosis, modulates immunity in testis while Ashwagandha reverses them via enhanced ERα expression, increase in sperm count thereby enhancing fertility in male Japanese quail.

https://pubmed.ncbi.nlm.nih.gov/39806168/

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**The Development of a Reverberation Chamber for the Assessment of Biological Effects of Electromagnetic Energy Absorption in Mice**

Iskra S, McIntosh RL, McKenzie RJ, Frankland JV, Deng C, Sylvester E, Wood AW, Croft RJ. The Development of a Reverberation Chamber for the Assessment of Biological Effects of Electromagnetic Energy Absorption in Mice. Bioelectromagnetics. 2025 Jan;46(1):e22539. doi: 10.1002/bem.22539.

Abstract

In this paper, we present the design, RF-EMF performance, and a comprehensive uncertainty analysis of the reverberation chamber (RC) exposure systems that have been developed for the use of researchers at the University of Wollongong Bioelectromagnetics Laboratory, Australia, for the purpose of investigating the biological effects of RF-EMF in rodents. Initial studies, at 1950 MHz, have focused on investigating thermophysiological effects of RF exposure, and replication studies related to RF-EMF exposure and progression of Alzheimer's disease (AD) in mice predisposed to AD. The RC exposure system was chosen as it allows relatively unconstrained movement of animals during exposures which can have the beneficial effect of minimizing stress-related, non-RF-induced biological and behavioral changes in the animals. The performance of the RCs was evaluated in terms of the uniformity of the Whole-Body Average-Specific Absorption Rate (WBA-SAR) in mice for a given RF input power level. The expanded uncertainty in WBA-SAR estimates was found to be 3.89 dB. Validation of WBA-SAR estimates based on a selected number of temperature measurements in phantom mice found that the maximum ratio of the temperature-derived WBA-SAR to the computed WBA-SAR was 1.1 dB, suggesting that actual WBA-SAR is likely to be well within the expanded uncertainties.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22539

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**Continuous exposure to 60 Hz extremely low frequency magnetic field at 10-14 mT promotes various human cell proliferation by activating extracellular-signal-regulated kinase**

Goh J, Suh D, Um DY, Chae SA, Park GS, Song K. Continuous exposure to 60 Hz extremely low frequency magnetic field at 10-14 mT promotes various human cell proliferation by activating extracellular-signal-regulated kinase. Biochem Biophys Res Commun. 2025 Jan 28;751:151414. doi: 10.1016/j.bbrc.2025.151414.

Abstract

We previously showed that 60 Hz extremely low-frequency magnetic fields (ELF-MF) at 6 mT promote various humancell proliferation. This study investigated the effects of 60 Hz ELF-MF at 10-16 mT on various mammalian cells, including human cervical carcinoma, rat neuroblastoma, liver cancer stem cells, immortalized normal hepatic cells, and normal fibroblasts. Using a revised ELF-MF-generating device that increases magnetic flux density stably without thermal effects, we exposed cells to 10 and 16 mT ELF-MF for 72 h. All cell types exhibited an approximately 20 % or greater increase in proliferation compared to the sham exposure group at 14 mT, with no further increase observed at 16 mT. In cells with activated proliferation at 14 mT, we observed activation of the MEK-ERK pathway and NF-κB, but not Akt, and a slight increase in S phase population. Intracellular and mitochondrial ROS levels remained unchanged, and the proliferation-activating effects persisted when oxidative phosphorylation was

interrupted. No changes in intracellular calcium levels were observed, and the proliferation-activating effects were maintained in the presence of a calcium chelator. These findings suggest that ROS and intracellular calcium do not mediate ELF-MF's proliferation-activating physiological effect. In conclusion, exposure to 60 Hz ELF-MF at 10-14 mT promotes cell proliferation by activating ERK1/2 without affecting intracellular ROS and calcium levels.

https://pubmed.ncbi.nlm.nih.gov/39903967/

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**An amplification mechanism for weak ELF magnetic fields quantum-bio effects in cancer cells**

Zandieh A, Shariatpanahi SP, Ravassipour AA, Azadipour J, Nezamtaheri MS, Habibi-Kelishomi Z, Ghanizadeh M, Same-Majandeh A, Majidzadeh-A K, Taheri A, Ansari AM, Javidi MA, Pirnia MM, Goliaei B. An amplification mechanism for weak ELF magnetic fields quantum-bio effects in cancer cells. Sci Rep. 2025 Jan 23;15(1):2964. doi: 10.1038/s41598-025-87235-w.

Abstract

Observing quantum mechanical characteristics in biological processes is a surprising and important discovery. One example, which is gaining more experimental evidence and practical applications, is the effect of weak magnetic fields with extremely low frequencies on cells, especially cancerous ones. In this study, we use a mathematical model of ROS dynamics in cancer cells to show how ROS oscillatory patterns can act as a resonator to amplify the small effects of the magnetic fields on the radical pair dynamics in mitochondrial Complex III. We suggest such a resonator can act in two modes for distinct states in cancer cells: (1) cells at the edge of mitochondrial oscillation and (2) cells with local oscillatory patches. When exposed to magnetic fields, the first group exhibits high-amplitude oscillations, while the second group synchronizes to reach a whole-cell oscillation. Both types of amplification are frequency-dependent in the range of hertz and sub-hertz. We use UV radiation as a positive control to observe the two states of cells in DU and HELA cell lines. Application of magnetic fields shows frequency-dependent results on both the ROS and mitochondrial potential which agree with the model for both type of cells. We also observe the oscillatory behavior in the time-lapse fluorescence microscopy for 0.02 and 0.04 Hz magnetic fields. Finally, we investigate the dependence of the results on the field strength and propose a quantum spin-forbidden mechanism for the effect of magnetic fields on superoxide production in $Q_O$ site of mitochondrial Complex III.

Excerpts

In a nutshell, our proposed scheme acts in two distinct levels: [I] At the level of superoxide production in mitochondrial ETC where the applied magnetic field can alter production rate of superoxide by closing the energy gap between singlet and triplet state of a radical pair in Complex III. Here the applied magnetic field effectively acts as a static field. And [II] at the level of mitochondrial network, where oscillation of the applied magnetic field (and thus oscillation in the production rate of superoxide) can resonate with the intrinsic frequency of RIRR in cancer cells. At this level, the minor effect of underlying RPM is amplified to affect the physiology of the cell in a frequency-dependent manner....

Conclusion

Our study proposed a quantum biological mechanism for the effect of varying small magnetic fields on cancer cells. The frequency dependent effect of magnetic field is here postulated to be the result of interaction of alternating field with the intrinsically oscillatory system of coupled mitochondria via a novel radical pair phenomenon.

Here the site of action of the field is suggested to be the semiquinone/FeS radical pair in Complex III of ETC. A magnetic field of the order of few hundreds of millitesla is predicted to populate the triplet state of the radical pair whose electron transfer onto oxygen molecule is restricted by a spin forbidden reaction in half of the cases. This leads to a mild decrease in superoxide production in the presence of such a magnetic field. An oscillatory field can amplify such an effect via a resonance phenomenon in a network of coupled mitochondria in many cell lines. This substantial change in ROS balance can potentially cause physiological effect in the cells, including apoptosis. Our simulations show the mentioned effect can be manifested in two resonance modes: Either triggering the oscillation in network or synchronizing the out of phase oscillatory mitochondria. Our experimental results confirm the suggested model which can explain the previous observations for the first time. The hypothesis was validated by the observation of the synchronization when cells were exposed to sudden UV irradiation.

Moreover, we observed a frequency-dependent variation of the ROS concentration and mitochondrial membrane potential under the effect of oscillatory magnetic field in frequencies and intensities suggested by our model.

Further in vitro investigation with higher resolution of microscopy and more extensive profile of magnetic field frequencies and intensities can shed light on the detailed components of the involved mechanism.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC11757740/

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**Effect of terahertz radiation on cells and cellular structures (Review)**

Rytik AP, Tuchin VV. Effect of terahertz radiation on cells and cellular structures. Front Optoelectron. 2025 Jan 27;18(1):2. doi: 10.1007/s12200-024-00146-y.

Abstract

The paper presents the results of modern research on the effects of electromagnetic terahertz radiation in the frequency range 0.5-100 THz at different levels of power density and exposure time on the viability of normal and cancer cells. As an accompanying tool for monitoring the effect of radiation on biological cells and tissues, spectroscopic research methods in the terahertz frequency range are described, and attention is focused on the possibility of using the spectra of interstitial water as a marker of pathological processes. The problem of the safety of terahertz radiation for the human body from the point of view of its effect on the structures and systems of biological cells is also considered.

Conclusion

The presented data show that THz radiation has a variety of effects on cells, which are manifested in the disruption of the properties of cell membranes, the formation of pores, the activation of ion channels,

and changes in their proliferation and viability [110]. Possible mechanisms that determine the reaction of cells to THz radiation may be the following:

- a change in the conformation of membrane proteins, which triggers an intracellular cascade of regulators of the genetic and enzymatic systems and the permeability of cell membranes for various substances;
- a change in the conformation of membrane proteins that perceive external regulatory signals;
- change in the conformation of membrane proteins that are pumps or channels for the transport of various substances into and out of the cell;
- redistribution of the electric charge on the cell membrane;
- excitation of resonant oscillations of macromolecules that make up the cell membrane and the cytoskeleton as a whole.

Thus, fundamentally, THz radiation does not cause the breaking or restoration of chemical covalent bonds, since the quantum energy is insufficient for this, 1 THz − 4.1 meV. However, this radiation, in its frequencies, falls into the region of vibrational–rotational movements of biological molecules and water and can excite energy levels of vibrational–rotational transitions of proteins and water, and thereby change the spatial conformation of proteins, which can affect various interactions between proteins, protein and water molecules.

It is generally accepted that there are several mechanisms that determine the effect of the response of living cells to THz radiation, in particular [1]:

- redistribution of electrical charge on the cell membrane, changing the ratio of concentrations of bound and free water;
- excitation of resonant vibrations of macromolecules that make up the cell membrane and the cytoskeleton as a whole;
- change in the conformation of membrane proteins.

Water molecules themselves can be considered as a universal marker in the THz frequency range, which is sensitive to various vital processes occurring in living tissues and cells. Compared to what is traditionally described in dielectric spectroscopy, in the THz frequency range water as a marker allows one to obtain new information about biological systems. Moving from the gigahertz (GHz) to the THz range, we are gradually approaching various vibrational–rotational processes that are determined by the interaction of water molecules with surrounding molecular systems [23]. Biomacromolecules, being excited, absorb part or all of the energy of electromagnetic waves, depending on the frequency of the incident radiation [26]. Since the generalized terahertz range (0.1–100 THz) partially overlaps with the vibration spectrum of biomolecules, terahertz waves can greatly enhance vibrations of biomolecule bonds such as twisting, stretching, and bending through resonant excitation [111]. However, early studies of the biological effects induced by optical stimulation focused on the infrared region, which promotes the strong absorption of incoming energy by water and its conversion into heat [112, 113]. While heat alters transmembrane capacitance or ion channel activity and hence induces biological responses, it inevitably also causes a transient increase in local temperature. On the other hand,

terahertz wave modulation is seen as a promising approach for interfering with biophysical processes without being damaged by electromagnetic radiation. The study of non-thermal biological effects of infrared radiation has attracted close attention from both opticians and biologists. In addition, THz waves with low photon energy are unlikely to cause ionizing effects, thus will not damage genome integrity as other radiation intervention approaches might [112].

It can be concluded that currently there is no full consensus in the scientific community as to whether THz radiation has a damaging effect on biological objects at various levels of organization [83, 114]. Therefore, an increase in studies using THz radiation to monitor the activity of uncontrolled dividing cells is expected in the near future. The development of new high-resolution THz diagnostic methods in combination with AI technologies will take cancer diagnosis and therapy to a new level. It is obvious that more and more new data will appear soon for THz diagnostics and therapy of tumor oncological processes. In addition, theranostics technologies, where THz radiation from the same source is used first for diagnosis and then at increased energy parameters for therapy within a single protocol, have not yet received proper development, but are undoubtedly promising.

Open access paper: https://link.springer.com/article/10.1007/s12200-024-00146-y

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**Metabolomic and gene networks approaches reveal the role of mitochondrial membrane proteins in response of human melanoma cells to THz radiation**

Butikova EA, Basov NV, Rogachev AD, Gaisler EV, Ivanisenko VA, Demenkov PS, Makarova AA, Ivanisenko TV, Razumov IA, Kolomeyets DA, Cheresiz SV, Solovieva OI, Larionov KP, Sotnikova YS, Patrushev YV, Kolchanov NA, Pokrovsky AG, Vinokurov NA, Kanygin VV, Popik VM, Shevchenko OA. Metabolomic and gene networks approaches reveal the role of mitochondrial membrane proteins in response of human melanoma cells to THz radiation. Biochim Biophys Acta Mol Cell Biol Lipids. 2025 Jan 20:159595. doi: 10.1016/j.bbalip.2025.159595.

This paper presents a study on the biological effects of terahertz irradiation with a frequency of 2.3 THz and a power of 0.056 W/cm$^2$ on SK-MEL-28 cells, using targeted metabolomic screening by liquid chromatography and tandem mass spectrometry (LC-MS/MS) and gene network analysis.

Highlights

• THz radiation exposure induced significant changes in the levels of 40 metabolites, especially those related to purine and pyrimidine pathways. Lipids, such as ceramides and phosphatidylcholines, were also affected by this exposure.
• Gene network reconstruction identified mitochondrial membrane proteins, including components of the respiratory chain complex, ATP synthase, and lipid rafts, as key regulators of the enzymes involved in biosynthesis and degradation of the significantly altered metabolites.
• THz radiation induces reversible disruption of lipid raft macromolecular structure, altering mitochondrial molecule transport while maintaining protein integrity.
• Importantly, the metabolic effects observed were specific to THz radiation and were not due to heating, as evidenced by the distinct responses in control cells exposed to infrared radiation.

Abstract

Terahertz (THz) radiation has gained attention due to technological advancements, but its biological effects remain unclear. We investigated the impact of 2.3 THz radiation on SK-MEL-28 cells using metabolomic and gene network analysis. Forty metabolites, primarily related to purine, pyrimidine synthesis and breakdown pathways, were significantly altered post-irradiation. Lipids, such as ceramides and phosphatidylcholines, were also affected. Gene network reconstruction and analysis identified key regulators of the enzymes involved in biosynthesis and degradation of significantly altered metabolites. Mitochondrial membrane components, such as the respiratory chain complex, the proton-transporting ATP synthase complex, and components of lipid rafts, reacted to THz radiation. We propose that THz radiation induces reversible disruption of the lipid raft macromolecular structure, thereby altering mitochondrial molecule transport while maintaining protein integrity, which explains the high cell survival rate. Our findings enhance the understanding of THz biological effects and emphasize the role of membrane components in the cellular response to THz radiation.

https://www.sciencedirect.com/science/article/abs/pii/S1388198125000034

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**Hidden route of protein damage through oxygen-confined photooxidation**

Kim S, Kim E, Park M, Kim SH, Kim BG, Na S, Sadongo VW, Wijesinghe WCB, Eom YG, Yoon G, Jeong H, Hwang E, Lee C, Myung K, Kim CU, Choi JM, Min SK, Kwon TH, Min D. Hidden route of protein damage through oxygen-confined photooxidation. Nat Commun. 2024 Dec 30;15(1):10873. doi: 10.1038/s41467-024-55168-z.

Abstract

Oxidative modifications can disrupt protein folds and functions, and are strongly associated with human aging and diseases. Conventional oxidation pathways typically involve the free diffusion of reactive oxygen species (ROS), which primarily attack the protein surface. Yet, it remains unclear whether and how internal protein folds capable of trapping oxygen ($O_2$) contribute to oxidative damage. Here, we report a hidden pathway of protein damage, which we refer to as $O_2$-confined photooxidation. In this process, $O_2$ is captured in protein cavities and subsequently converted into multiple ROS, primarily mediated by tryptophan residues under blue light irradiation. The generated ROS then attack the protein interior through constrained diffusion, causing protein damage. The effects of this photooxidative reaction appear to be extensive, impacting a wide range of cellular proteins, as supported by whole-cell proteomic analysis. This photooxidative mechanism may represent a latent oxidation pathway in human tissues directly exposed to visible light, such as skin and eyes.

Open access paper: https://www.nature.com/articles/s41467-024-55168-z

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**Structural Analysis of Plasma-Induced Oxidation and Electric Field Effect on the Heat Shock Protein (Hsp60) Structure**

Attri P, Okumura T, Koga K, Shiratani M. Structural Analysis of Plasma-Induced Oxidation and Electric Field Effect on the Heat Shock Protein (Hsp60) Structure: A Computational Viewpoint. Chem Biodivers. 2025 Jan 5:e202401243. doi: 10.1002/cbdv.202401243.

Abstract

In recent years, there has been an increase in the study of the mechanisms behind plasma oncology. For this, many wet lab experiments and computational studies were conducted. Computational studies give an advantage in examining protein structures that are costly to extract in enough amounts to analyze the biophysical properties following plasma treatment. Therefore, in this work, we studied the effect of plasma oxidation and electric field on the human mitochondrial heat shock protein (mHsp60). Hsp60, alias chaperonin, is one of the most conserved proteins expressed across all species. Hence, we performed molecular dynamic simulations to calculate the root-mean-square deviation, root-mean-square fluctuation, and solvent-accessible surface area of mHsp60 with and without oxidation. In addition to the oxidation state, we also applied an electric field (0.003 and 2.0 V/nm) to check the changes in the mHsp60 protein. Through simulations, we observed that the electric field strongly affects the structure of mHsp60 protein compared with the oxidation. The combination of oxidation and electric field effect increases the destabilization of the mHsp60 structure compared with their respective control states.

https://pubmed.ncbi.nlm.nih.gov/39756028/

Conclusion

We can conclude that the mHsp60 structure is modified by possible plasma-assisted oxidation, particularly involving Trp, Try, and Met amino acids, resulting in noticeable structural changes. RMSD values reflect that mHsp60 structure flexibility slightly increases in OXID-2, whereas the structure becomes rigid in OXID-1. This suggests that the oxidation of Met amino acids plays a significant role in enhancing mHsp60 flexibility. On the other hand, applying an electric field (EF1 and EF2) to the control mHsp60 increases the RMSD value more than for oxidized mHsp60 (OXID-1 and OXID-2), indicating that the electric field has a more substantial effect on the mHsp60 structure than oxida- tion alone. Additionally, the RMSD values of OXID-1 and OXID-2 increased after electric field treatment (0.003 V/nm from the x, y, and z axes), demonstrating that the small electric field generated by DBD plasma can significantly influence protein conforma- tional changes in both native and oxidized states. HSPs, including Hsp60, play a vital role in maintaining protein homeostasis, which is crucial for cell integrity, survival, and metabolism. However, when chaperone-assisted protein quality control is compromised due to oxidation or exposure to electric effect, it may trigger the onset and progression of numerous diseases.

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**World Health Organization's EMF Project's Systemic Reviews on the Association Between RF Exposure and Health Effects Encounter Challenges**

In a newly-published paper, one of the world's most renowned scientists who has studied the effects of radio frequency (RF) radiation, Dr. James C. Lin, Professor Emeritus at the University of Illinois, Chicago

and a former ICNIRP Commissioner, attacks the World Health Organization's systematic reviews of the research on RF radiation that dismiss the substantial evidence for adverse biological and health effects.

He concludes:

"The criticisms and challenges encountered by the published WHO-EMF systematic reviews are brutal, including calls for retraction. Rigorous examinations of the reviews reveal major concerns. In addition to the scientific quality, they appear to have a strong conviction of nothing but heat to worry about with RF radiation. The unsubtle message that cellular mobile phones do not pose a cancer risk is clear. The reviews exhibit a lack of serious concerns for conflicts of interest and display unequivocal support for the recently promulgated ICNIRP RF exposure guidelines for human safety.

From its inception, WHO-EMF had close ties with ICNIRP, a private organization, frequently referred to as the WHO-EMF project's scientific secretariat [18]. What may not be as apparent for the WHO-EMF systematic reviews is the lack of diversity of views. A large number of ICNIRP commissioners and committee members are listed as authors for the WHO-EMF systematic reviews; some also served as lead authors. These concerns advance issues of reviewer independence and potential for conflicts of interest."

Lin JC. World Health Organization's EMF Project's Systemic Reviews on the Association Between RF Exposure and Health Effects Encounter Challenges [Health Matters]. *IEEE Microwave Magazine*, 26(1): 13-15, Jan. 2025, doi: 10.1109/MMM.2024.3476748.

No abstract

Excerpts

1) Regarding "The WHO-EMF systematic review on the association between RF exposure and adverse health effects pertaining to reproductive health (pregnancy and birth outcome.... While the WHO-EMF systematic review presents itself as thorough, scientific, and relevant to human health, numerous issues were identified, suggesting the WHO-EMF review was severely flawed. The found flaws skewed the results in support of the review's conclusion that there is no conclusive evidence for effects other than RF-induced tissue heating. It showed that the underlying data, when relevant studies are cited correctly, support the opposite conclusion: "There are clear indications of detrimental nonthermal effects" from RF exposure. The authors identified a multitude of flaws in the methodology. To those scientists, the methodology and low quality of the systematic review were highly concerning "as it threatens to undermine the trustworthiness and professionalism of the WHO-EMF project in the area of human health hazards from man-made RF radiation."

2) Regarding "The WHO-EMF systematic review of human observational studies on the occurrence of migraine, headaches, tinnitus, sleep disturbances, and nonspecific symptoms in the general and working population .... An ensuing critical appraisal by three accomplished senior researchers documented major problems with the WHO-EMF-commissioned review and called for its retraction [8]. The meta-analysis for the handful of very heterogeneous primary studies identified for each of the analyzed exposure and outcome combinations appeared fundamentally inappropriate. The number is very small, and the methodological quality of the relevant primary studies is low. In contrast, this peer-reviewed publication concluded that the body of evidence reviewed is inadequate to either support or refute the safety of

current exposure limits.

3) "Some skepticism has been expressed regarding a third WHO-EMF systematic review on RF-induced oxidative stress [9]. The study identified 11,599 studies on oxidative stress in the frequency range 800–2,450 MHz and then eliminated 11,543 of them as not meeting the criteria for inclusion. Of the remaining 56 papers, there were 45 animal studies and 11 in vitro cellular studies....For many years, Henry Lai, a leading researcher in RF oxidative responses and professor emeritus at the University of Washington, Seattle, has maintained a bibliography of RF-oxidative stress papers. As of mid-August, his list includes 367 studies, published between 1997 and 2024. By his count, 89% showed significant effects. Lai's assessment of the WHO-EMF review is that it left out a large portion of RF-oxidative effect studies and appears to have only considered oxidative molecular reactions among the possible oxidative effects [10]. As reported, others have opined that "this systematic review methodically excluded most of the relevant research."'

4) Regarding the WHO systematic review to assess the evidence provided by human epidemiological studies for the cancer risk from radiofrequency (RF): " This WHO-EMF review was picked up and reported on by many Western media outlets. Actually, there are truly few data that are new in this review. For sure, the assessment of scientific evidence in this subject has been controversial and less than uniform. The question is, "Is this review really the definitive word on the long-standing issue of whether cell phone radiations pose a cancer risk?" My answer is, far from it!"

"Microwave News [12] published a meticulously researched investigative report in the historical context of the latest WHO-EMF cancer review. Five years ago, the lead author [13] with some members of the same team made similar efforts to terminate the RF–cancer debate with basically the same no-risk message. However, "it was not well received" by the scientific community, since the analysis excluded some people older than 59 years of age, the largest segment of the brain cancer population."

"The WHO-IARC, NIH-NTP, and Ramazzini outcomes, under normal circumstances, would likely have provided the justification for raising WHO-IARC's current possible cancer risk designation to the probable cancer-causing classification, if not higher.

https://ieeexplore.ieee.org/document/10795296

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**A mechanistic understanding of human magnetoreception validates the phenomenon of electromagnetic hypersensitivity (EHS)**

Henshaw DL, Philips A. (2024). A mechanistic understanding of human magnetoreception validates the phenomenon of electromagnetic hypersensitivity (EHS). *International Journal of Radiation Biology*, 1–19. doi: 10.1080/09553002.2024.2435329.

Abstract

Background Human electromagnetic hypersensitivity (EHS) or electrosensitivity (ES) symptoms in response to anthropogenic electromagnetic fields (EMFs) at levels below current international safety standards are generally considered to be nocebo effects by conventional medical science. In the wider field of magnetoreception in biology, our understanding of mechanisms and processes of magnetic field

(MF) interactions is more advanced.

Methods  We consulted a range of publication databases to identify the key advances in understanding of magnetoreception across the wide animal kingdom of life.

Results  We examined primary MF/EMF sensing and subsequent coupling to the nervous system and the brain. Magnetite particles in our brains and other tissues can transduce MFs/EMFs, including at microwave frequencies. The radical pair mechanism (RPM) is accepted as the main basis of the magnetic compass in birds and other species, acting via cryptochrome protein molecules in the eye. In some cases, extraordinary sensitivity is observed, several thousand times below that of the geomagnetic field. Bird compass disorientation by radio frequency (RF) EMFs is known.

Conclusions  Interdisciplinary research has established that all forms of life can respond to MFs. Research shows that human cryptochromes exhibit magnetosensitivity. Most existing provocation studies have failed to confirm EHS as an environmental illness. We attribute this to a fundamental lack of understanding of the mechanisms and processes involved, which have resulted in the design of inappropriate and inadequate tests. We conclude that future research into EHS needs a quantum mechanistic approach on the basis of existing biological knowledge of the magnetosensitivity of living organisms.

Conclusions and recommendations

1. At the scientific level, researchers working in the field of *magnetoreception in biology* should be made aware of EHS as a human public health concern and funded to address the issue as part of their scientific research.
2. All interested parties, especially EHS sufferers and medical professionals, should be made aware of the considerable growth in understanding in recent decades of the mechanisms by which all forms of life sense MFs/EMFs, even at extremely low levels. EHS research to date has been significantly hindered by a fundamental lack of knowledge among many medical scientists and EHS researchers regarding the current scientific understanding of quantum biology mechanisms and processes. This has resulted in the design and analysis of inappropriate provocation tests.
3. Almost all existing epidemiological and provocation studies have failed adequately to determine and measure the necessary dependent and independent variables. In particular:
    1. to characterize in proper technical detail the EMF/RF exposures (including electric and MF levels; average and peak power-density levels; frequencies involved; and modulation characteristics).
    2. to triage participants effectively to remove ‘electrophobic’ and other volunteers self-reporting apparent EHS-related problems.
    3. in provocation studies, to fail to recognize the nonlinear nature of EHS responses and the extremely low levels of exposure (<100 nT) that have effects and, instead, use relatively high exposures fairly close to the ICNIRP and IEEE guidance levels.

    4. in provocation studies, to provide a participant-comfortable extremely low EMF/RF test location, screened from anthropogenic sources and allow adequate time (days rather than hours) for adverse effects to washout between exposures.

4. EHS studies should move away from current, nonforensic epidemiological approaches and human subjective provocation studies (Leszczynski 2022; Röösli et al. 2024). Instead, objective measurements of biological parameters, such as heart rate variability, brain wave activity (e.g. fMRI and wide-bandwidth EEG), and the immune response to oxidative stress should be investigated (Caswell et al. 2016; Gurfinkel et al. 2018; Pishchalnikova et al. 2019; Wang et al. 2019; Thoradit et al. 2024). We caution that these approaches require sophisticated design and analysis and advanced design personal exposure meters.

5. We recommend that the WHO properly reevaluates its understanding of EHS to align it with the substantial body of available scientific literature showing mechanistic evidence of interactions of all forms of life, including humans, with low levels of electric and magnetic fields.

Open access paper: https://www.tandfonline.com/doi/full/10.1080/09553002.2024.2435329

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**Gaps in Knowledge Relevant to the "ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (100 kHz TO 300 GHz)"**

International Commission on Non-Ionizing Radiation Protection (ICNIRP). Gaps in Knowledge Relevant to the "ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (100 kHz TO 300 GHz)". Health Phys. 2025 Feb 1;128(2):190-202. doi: 10.1097/HP.0000000000001944.

Abstract

In the last 30 y, observational as well as experimental studies have addressed possible health effects of exposure to radiofrequency electromagnetic fields (EMF) and investigated potential interaction mechanisms. The main goal of ICNIRP is to protect people and the environment from detrimental exposure to all forms of non-ionizing radiation (NIR), providing advice and guidance by developing and disseminating exposure guidelines based on the available scientific research on specific parts of the electromagnetic spectrum. During the development of International Commission on Non-Ionizing Radiation Protection's (ICNIRP's) 2020 radiofrequency EMF guidelines some gaps in the available data were identified. To encourage further research into knowledge gaps in research that would, if addressed, assist ICNIRP in further developing guidelines and setting revised recommendations on limiting exposure, data gaps that were identified during the development of the 2020 radiofrequency EMF guidelines, in conjunction with subsequent consideration of the literature, are described in this Statement. Note that this process and resultant recommendations were not intended to duplicate more traditional research agendas, whose focus is on extending knowledge in this area more generally but was tightly focused on identifying the highest data gap priorities for guidelines development more specifically. The result of this distinction is that the present data gap recommendations do not include some gaps in the literature that in principle could be relevant to radiofrequency EMF health, but which were excluded because either the link between exposure and endpoint, or the link between endpoint and health, was not supported sufficiently by the literature. The evaluation of these research areas

identified the following data gaps: (1) Issues concerning relations between radiofrequency EMF exposure and heat-induced pain; (2) Clarification of the relation between whole-body exposure and core temperature rise from 100 kHz to 300 GHz, as a function of exposure duration and combined EMF exposures; (3) Adverse effect thresholds and thermal dosimetry for a range of ocular structures; (4) Pain thresholds for contact currents under a range of exposure scenarios, including associated dosimetry; and (5) A range of additional dosimetry studies to both support future research, and also to improve the application of radiofrequency EMF exposure restrictions in future guidelines.

Open access paper:https://journals.lww.com/health-physics/fulltext/2025/02000/gaps_in_knowledge_relevant_to_the__icnirp.8.aspx

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**Sensory Processing Sensitivity, and Not Gender, Drives Electromagnetic Hypersensitivity and Nature Connection**

Watten RG, Volden F, Visnes H. Sensory Processing Sensitivity, and Not Gender, Drives Electromagnetic Hypersensitivity and Nature Connection. Ecopsychology. Nov 28, 2024. doi: 10.1089/eco.2024.0027

Abstract

Electromagnetic hypersensitivity (EHS) is a biomedical condition associated with exposure to man-made radio-frequency electromagnetic fields. Common sources are devices like mobile phones, wireless networks, base stations, computers, TVs, and more. Identifying individuals at risk of developing EHS is important. Those with heightened sensory processing sensitivity (SPS; the ability to perceive, process, and react to environmental stimuli, approximately 25% to 30% of the population) are of special interest. SPS could also be associated with connectedness to nature (CNS) and EHS. In the current gender-matched cross-sectional study (*n* = 450; 225 men and 225 women) we assessed gender differences in environmental sensitivity assessed as SPS, EHS, and CNS. Women had higher general EHS prevalence than men (13.3% vs. 5.3%), higher mean values on perceived sensitivity for 5 out of 9 categories of electromagnetic equipment (computers, electrical appliances, fluorescent lighting, mobile phones, and television) and they had higher scores on the three EHS Scales EHS General, EHS Scale, and EHS Index, in addition to higher SPS and CNS scores. The gender differences vanished when adjusting for SPS in the multivariate analyses of variance (MANOVA) analyses, suggesting that the differences in these scales were associated with SPS. The statistical equation modeling (SEM) results showed a significant positive direct effect of SPS on CNS, and a significant indirect effect mediated by EHS. The present study provides the first empirical evidence that highly sensitive individuals are capable of perceiving electromagnetic radiation. The results indicate that perceived EHS and CNS are driven by SPS and not by gender.

https://www.liebertpub.com/doi/10.1089/eco.2024.0027

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**Effect of Exposure to Mobile Phones on Electrical Cardiac Measurements: Multivariate Analysis & Variable Selection Algorithm to Detect Relationship With Mean Changes**

Alharbi N, Alassiri M. The Effect of Exposure to Mobile Phones on Electrical Cardiac Measurements: A Multivariate Analysis and a Variable Selection Algorithm to Detect the Relationship With Mean Changes. Int J Cell Biol. 2024 Oct 3;2024:7093771. doi: 10.1155/2024/7093771.

Abstract

Background: The exponential growth in mobile phone usage has raised concerns about electromagnetic field (EMF) exposure and its health risks. Blood pressure and BMI, which impair heart function due to decreased adrenoreceptor responsiveness, parasympathetic tone withdrawal, and increased sympathetic activity, may further exacerbate these risks. However, the effects of radiofrequency electromagnetic (RF-EM) exposure from mobile phones on electrocardiograms (ECGs) and heart rate variability (HRV) in individuals remain unclear.

Purpose: Building upon our previous findings on HRV changes due to mobile phone proximity, this study is aimed at significantly enhancing the analytical approach used to assess the effects of mobile phones on cardiac parameters. This study exploits data from a previous study but with a different purpose. The aim of this study is twofold: (a) to examine whether exposure to mobile phones changes the five variables (P-R, QRS, QT, ST, and HR) in a multivariate manner and (b) to examine whether the blood pressure and/or the body mass index (BMI), which acts as a proxy for obesity, have an effect on the change of these five variables. For both aspects of the study, four cycles are performed.

Method: We conducted multivariate analysis on previously collected electrical cardiac measurement data from 20 healthy male subjects exposed to mobile phone EMF, with the mobile phones placed at four different body locations. The one-sample Hotelling $T^2$ test on the mean vector of differences was utilised instead of multiple paired t-tests. This multivariate method comprehensively analyzes data features and accounts for variable correlations, unlike multiple univariate analyses. Given our small sample size, we employed the MMPC variable selection algorithm to identify predictor variables significantly related to mean changes.

Results: Significant alterations in ECG intervals and heart rate were noted in the subjects before and after the first EMF exposure cycle, independent of their BMI. Notably, heart rate, P-R, and QRS intervals fell postexposure while QT and ST intervals increased. These changes were influenced by variations in systolic blood pressure, with BMI showing no significant effect.

Conclusion: The observed modifications in cardiac electrical measurements due to mobile phone EMF exposure are attributed to the effects of EMF itself, with no impact from BMI on the extent of these changes.

Note: iPhone 5 Plus was used.

Conclusion

Given the evidence linking EMFs from mobile phones to adverse effects on heart health, it is crucial for regular users of such devices, especially those at risk of CVDs, to take steps towards reducing their overall exposure. This can be achieved through measures such as limiting talk time or using hands-free headsets during calls. Additionally, ongoing research in this area is essential to deepen our understanding of how these potentially harmful frequencies impact our bodies over both short- and long-term periods.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1155/2024/7093771

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**The Role of Excess Charge Mitigation in Electromagnetic Hygiene: An Integrative review**

Jamieson IA, Bell JNB, Holdstock P. The Role of Excess Charge Mitigation in Electromagnetic Hygiene: An Integrative review. Biomedical Journal. 2024, doi: 10.1016/j.bj.2024.100801.

Abstract

The electromagnetic characteristics of many environments have changed significantly in recent decades. This is in large part due to the increased presence of equipment that emits electromagnetic radiation and materials that may often readily gain excess charge. The presence of excess charge can often increase risk of infection from pathogens, and likelihood of individuals experiencing compromised performance, respiratory problems and other adverse health issues from increased uptake of particulate matter. It is proposed that adopting improved electromagnetic hygiene measures, including optimized humidity levels, to reduce the presence of inappropriate levels of electric charge can help reduce the likelihood of ill health, infection and poor performance arising from contaminant inhalation and deposition, plus reduce the likelihood of medical devices and other electronic devices getting damaged and/or having their data compromised. It is suggested that such measures should be more widely adopted within clinical practice guidelines and water, sanitation and hygiene programs.

Highlights

Electric fields can increase localized deposition of pathogens.

High charge of either polarity increases contaminant deposition.

40-60% relative humidity reduces likelihood of infection.

Proper specification of materials reduces infection risks.

Electromagnetic hygiene can reduce risk of infection.

Open access paper: https://www.sciencedirect.com/science/article/pii/S2319417024001045

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**5G RF-EMF Effects on the Human Sleep Electroencephalogram: A Randomized Controlled Study in Healthy Volunteers (pre-print, not peer-reviewed)**

My note: Most studies to date that claim to evaluate the effects of 5G exposure did not employ a 5G signal generator. This study, however, used an exposure system (sXh5G) developed by the IT'IS Foundation that provides a controlled and well-characterized 5G EMF exposure at two different carrier frequencies.

Sousouri G, Eicher C, D'Angelo RM, Billecocq M, Fussinger T, Studler M, Capstick M, Kuster N, Achermann P, Huber R, Landolt H-P. 5G Radio-Frequency-Electromagnetic-Field Effects on the Human Sleep Electroencephalogram: A Randomized Controlled Study in CACNA1C Genotyped Healthy Volunteers. MedRxiv. Dec 26, 2024. doi: 10.1101/2024.12.16.24319082.

Abstract

Background: The introduction of 5G technology as the latest standard in mobile telecommunications has raised concerns about its potential health effects. Prior studies of earlier generations of radiofrequency electromagnetic fields (RF-EMF) demonstrated narrowband spectral increases in the electroencephalographic (EEG) spindle frequency range (11-16 Hz) in non-rapid-eye-movement (NREM) sleep. However, the impact of 5G RF-EMF on sleep remains unexplored. Additionally, RF-EMF can activate L-type voltage-gated calcium channels (LTCC), which have been linked to sleep quality and EEG oscillatory activity.

Objective: This study investigates whether the allelic variant rs7304986 in the CACNA1C gene, encoding the α1C subunit of LTCC, modulates 5G RF-EMF effects on EEG spindle activity during NREM sleep.

Methods: Thirty-four healthy, matched participants, genotyped for rs7304986 (15 T/C and 19 T/T carriers), underwent a double-blind, sham-controlled study with standardized left-hemisphere exposure to two 5G RF-EMF signals (3.6 GHz and 700 MHz) for 30 min before sleep. Sleep spindle activity was analyzed using high-density EEG and the Fitting Oscillations & One Over f (FOOOF) algorithm.

Results: T/C carriers reported longer sleep latency compared to T/T carriers. A significant interaction between RF-EMF exposure and rs7304986 genotype was observed, with 3.6 GHz exposure in T/C carriers inducing a faster spindle center frequency in the central, parietal, and occipital cortex compared to sham.

Conclusion: These findings suggest 3.6 GHz 5G RF-EMF modulates spindle center frequency during NREM sleep in a CACNA1C genotype-dependent manner, implicating LTCC in the physiological response to RF-EMF and underscoring the need for further research into 5G effects on brain health.

Excerpts

All participants completed three experimental nights with different, standardized exposure conditions according to a randomized, double-blind, cross-over design: 1) 30-min, pre-sleep exposure to an active 5G EMF at a carrier frequency of 700 MHz, 20 MHz bandwidth, and 12.5 Hz applied power control, 2) 30-min, pre-sleep exposure to an active 5G EMF at a carrier frequency of 3.6 GHz, 100 MHz bandwidth, and 12.5 Hz applied power control, and 3) a 30-min sham exposure without an active field....

All exposure conditions were administered with the same exposure system (sXh5G), provided by the IT’IS Foundation for Research on Information Technologies in Society (IT'IS Foundation, Zurich, Switzerland), which ensures controlled and well-characterized 5G EMF exposure. Following detailed simulated dosimetry (Figure 1), the signal intensity was calibrated to ensure the specific absorption rate (SAR) for the head (averaged over 10 g of tissue) did not exceed 2 W/kg. The active field remained within the SAR limit for the general population established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and posed no known health risks. The two active fields administered are 5G uplink signals generated in the 5G frequency range. The lower frequency signal has a carrier frequency of 700 MHz, 20 MHz bandwidth, Frequency Division Duplexing/Orthogonal Frequency-Division Multiplexing (FDD/OFDM) with 24 resource blocks, 16 time slots, 60 kHz sub-carrier spacing and Quadrature Phase Shift Keying (QPSK) modulation, with an output power of 4.28 W. The higher frequency signal has a carrier frequency of 3.6 GHz, 100 MHz bandwidth, Time Division Duplexing (TDD)/QPSK OFDM with 135 resource blocks, 16 time slots, 60 kHz sub-carrier spacing and QPSK modulation, with an output power of 1.63 W. In the signals used, only uplink communication is

implemented, and all frames are identical with 16 time slots. Both signals have identical power control applied that introduces low frequency amplitude modulation at 12.5 Hz on top of the modulation due to the occupied time slots which have a dominant power modulation frequency of 200 Hz resulting in a 14.2 dB peak to average power ratio (PAPR) (Supp. Figure 1, 2 & 3). The exposure levels in grey and white matter, thalamus and all tissues in the brain averaged over 0.125 g which is a cube of side length ~5 mm are reported in Table 1 for both 700 MHz and 3.6 GHz....

... we found a significant interaction between exposure and the genetic variant in the center frequency of sleep spindles. Specifically, we demonstrated a topographically widespread acceleration of spindle center frequency in the T/C carriers after exposure to the 3.6 GHz RF-EMF in comparison to sham....

By leveraging the strengths of spectral parameterization, we demonstrated a widespread shift in the center frequency of sleep spindles towards faster oscillatory activity in T/C allele carriers after exposure to a 5G RF-EMF with a carrier frequency of 3.6 GHz. This effect was evident in central, parietal, and occipital cortical areas coinciding with areas that predominantly express faster spindles. A number of previous studies also reported enhanced EEG spectral power in the upper spindle range after exposure to RF-EMF of earlier generation (Huber et al., 2000, 2002; Schmid, Loughran, et al., 2012; Schmid, Murbach, et al., 2012)....

The discrepancy between the deeper penetration of the 700 MHz signal revealed by the simulated SAR distribution in the brain and the more pronounced effects on the EEG sleep spindles observed following exposure to the 3.6 GHz signal remains unclear. Notably, the pulse modulation, which has been identified as critical for the biological effects of RF-EMF (Huber et al., 2002), was identical at 12.5 Hz in both fields and the psSAR10gr was consistently set at 2 W/kg. The findings underscore the necessity for a comprehensive investigation into the complex characteristics of the new 5G signals. Furthermore, they may suggest that the dielectric and conductive properties of the tissues associated with the minor allele may not be adequately represented by the current simulation parameters. Alternatively, the observed effects may indicate a distinct mode of action that is unrelated to SAR distribution....

The differential effects observed between the 700 MHz and 3.6 GHz exposures highlight the importance of considering signal characteristics and tissue properties in understanding RF-EMF interactions. Overall, our results provide new insights into the genetic and biophysical factors underlying RF-EMF effects on sleep, emphasizing the need for more targeted studies to elucidate these mechanisms.

Open access pre-print: https://www.medrxiv.org/content/10.1101/2024.12.16.24319082v1

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**RF-EMF Exposure near 5G NR Small Cells**

Aerts S, Deprez K, Verloock L, Olsen RG, Martens L, Tran P, Joseph W. RF-EMF Exposure near 5G NR Small Cells. *Sensors*. 2023; 23(6):3145. doi: 10.3390/s23063145.

Abstract

Of particular interest within fifth generation (5G) cellular networks are the typical levels of radiofrequency (RF) electromagnetic fields (EMFs) emitted by ‘small cells’, low-power base stations, which are installed such that both workers and members of the general public can come in close proximity with them. In this study, RF-EMF measurements were performed near two 5G New Radio (NR)

base stations, one with an Advanced Antenna System (AAS) capable of beamforming and the other a traditional microcell. At various positions near the base stations, with distances ranging between 0.5 m and 100 m, both the worst-case and time-averaged field levels under maximized downlink traffic load were assessed. Moreover, from these measurements, estimates were made of the typical exposures for various cases involving users and non-users. Comparison to the maximum permissible exposure limits issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) resulted in maximum exposure ratios of 0.15 (occupational, at 0.5 m) and 0.68 (general public, at 1.3 m). The exposure of non-users was potentially much lower, depending on the activity of other users serviced by the base station and its beamforming capabilities: 5 to 30 times lower in the case of an AAS base station compared to barely lower to 30 times lower for a traditional antenna.

Excerpt

Scaled to small-cell powers, the measured exposure levels in this study were below the MPE limits for both occupational (at distances between 0.5 m and 1 m from the base station) and general public exposure (>1 m) issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [17]: the maximum exposure ratios were 0.15 (occupational) and 0.68 (general public). These theoretical worst-case exposures were higher than the actual maxima measured in situ by maximizing the downlink traffic load, and both types of worst-case exposures were much higher (3–12 times) than the exposures of a typical user, which in turn were much higher (4–9 times) than the exposures without any users. Finally, the exposure of a non-user within a mature 5G NR network depends on the distribution of users, their usage, and the AAS capabilities of the base station radio.

Although adverse health effects at non-thermal exposure levels cannot be ruled out [20], the ICNIRP reference levels are still relevant to calculate exposure ratios against. The measurement values obtained in this study and reported in this paper can be directly compared to other reference or limit levels (e.g., from legislation or scientific literature), depending on the scope of the study.

For a 5G NR AAS base station, the actual exposure of a given user will generally be less than the theoretical maximum exposure $E_{max}$ for several reasons. First, other users (the number may vary) may be in beams other than the one the given user is using. Hence, the RF energy directed toward these users will not add (much) to the exposure of the given user. Second, the usage by the given user will generally be less than the maximum assumed for which $E_{max}$ was defined. Third, there may be dynamic power control to reduce base station power to the minimum needed for communication. This was not taken into account in this study. Finally, the base station beam may be narrower or wider than that used to measure $E_{max}$. Hence, the problem of determining actual RF exposure becomes a statistical one that depends on several different variables. However, the exposure will almost always be less than $E_{max}$.

Similarly, for the non-user, the difference lies in whether they are in a beam or not. Generally, the RF exposure from the base station for the non-user will be smaller than that for a user (here by at least a factor of 5 for an AAS), unless there are many users around and the MaMIMO capabilities of the base station are limited (Table 4) [19].

Open access paper: https://www.mdpi.com/1424-8220/23/6/3145

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**Improving Monitoring of Indoor RF-EMF Exposure Using IoT-Embedded Sensors and Kriging Techniques**

Jabeur R, Alaerjan A. Improving Monitoring of Indoor RF-EMF Exposure Using IoT-Embedded Sensors and Kriging Techniques. *Sensors*. 2024; 24(23):7849. https://doi.org/10.3390/s24237849

Abstract

Distributed wireless sensor networks (WSNs) are widely used to enhance the quality and safety of various applications. These networks consist of numerous sensor nodes, often deployed in challenging terrains where maintenance is difficult. Efficient monitoring approaches are essential to maximize the functionality and lifespan of each sensor node, thereby improving the overall performance of the WSN. In this study, we propose a method to efficiently monitor radiofrequency electromagnetic fields (RF-EMF) exposure using WSNs. Our approach leverages sensor nodes to provide real-time measurements, ensuring accurate and timely data collection. With the increasing prevalence of wireless communication systems, assessing RF-EMF exposure has become crucial due to public health concerns. Since individuals spend over 70% of their time indoors, it is vital to evaluate indoor RF-EMF exposure. However, this task is complicated by the complex indoor environments, furniture arrangements, temporal variability of exposure, numerous obstructions with unknown dielectric properties, and uncontrolled factors such as people's movements and the random positioning of furniture and doors. To address these challenges, we employ a sensor network to monitor RF-EMF exposure limits using embedded sensors. By integrating Internet of Things-embedded sensors with advanced modeling techniques, such as kriging, we characterize and model indoor RF-EMF downlink (DL) exposure effectively. Measurements taken in several buildings within a few hundred meters of base stations equipped with multiple cellular antennas (2G, 3G, 4G, and 5G) demonstrate that the kriging technique using the spherical model provides superior RF-EMF prediction compared with the exponential model. Using the spherical model, we constructed a high-resolution coverage map for the entire corridor, showcasing the effectiveness of our approach.

Conclusions

This study proposes the use of WSN to monitor the indoor RF-EMF exposure induced by cellular networks. To this end, we first proposed a measurement system based on the Narda NBM-550 and Nucleo-F401RE microcontroller board. The aim is to characterize and model indoor RF-EMF DL exposure using the collected measurements and kriging technique. First, several indoor measurements are conducted in an area covered by various frequency bands, including those used for 5G. By comparing the spherical and exponential models, we demonstrated that the spherical model provides a superior fit for predicting RF-EMF exposure levels. The high-resolution coverage map constructed using the spherical model revealed that the maximum average RF-EMF DL exposure levels within the corridor are well below the limits established by the ICNIRP. These findings underscore the effectiveness of the kriging technique in accurately modeling and predicting RF-EMF exposure in complex indoor environments.

For future work, several avenues can be explored to enhance the understanding and assessment of indoor RF-EMF exposure. Firstly, expanding the measurement campaign to include a wider variety of indoor environments, such as residential buildings, offices, and public transport, would provide a more comprehensive dataset. Additionally, incorporating temporal variations by conducting long-term

measurements could offer insights into the fluctuations of RF-EMF exposure over time. Furthermore, integrating advanced machine learning algorithms with the kriging technique could improve the accuracy and efficiency of exposure predictions. Another important research axis involves the analysis of measurement uncertainty, which is planned for future investigation. For large-scale deployments, the Narda NBM-550 can be replaced with frequency-selective equipment such as the ExpoM-RF4, MVG EME Spy Evolution, or Narda SRM-3006. This substitution ensures that only downlink bands are considered and enables the reconstruction of RF-EMF exposure maps for each frequency band, facilitating a more detailed assessment by frequency band. Finally, investigating the impact of emerging wireless technologies, such as beyond 5G, on indoor RF-EMF exposure will be crucial as these technologies become more widespread. These future directions will contribute to a more thorough understanding of indoor RF-EMF exposure and help address public concerns regarding wireless communication systems.

Open access paper: https://www.mdpi.com/1424-8220/24/23/7849

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**AI-based optimization of EM radiation estimates from GSM base stations using traffic data**

Lal R, Singh RK, Nishad DK, *et al.* AI-based optimization of EM radiation estimates from GSM base stations using traffic data. *Discov Appl Sci* 6, 655 (2024). doi: 10.1007/s42452-024-06395-y

Abstract

The fast expansion of mobile networks has sparked worries regarding base station EM radiation's health impacts. Traffic load is commonly ignored when evaluating EM radiation levels using maximum power output. This study proposes utilizing AI and ML on real network traffic data to optimize GSM base station EM radiation estimations. We obtained EM radiation measurements and traffic data from selecting GSM base stations by location and configuration. To predict EM radiation levels, traffic patterns were used to train linear regression, random forests, and neural networks. Base stations were clustered by radiation profile using unsupervised learning. Considering regulatory restrictions and measurement feasibility, an optimization methodology was created to minimize EM radiation estimate inaccuracy. The results show better prediction accuracy than power-based estimations and high generalisability across base station types. Site-specific factors influenced daily EM radiation patterns after clustering. EM radiation levels can be monitored using traffic data and the optimized AI/ML model. This research helps telecom operators and regulators analyze EM radiation more accurately and efficiently. Future projects should include 5G and small cell network extensions and intelligent city platform integration. The suggested method develops data-driven, AI-powered Public Safety and mobile network trust solutions.

Open access paper: https://link.springer.com/article/10.1007/s42452-024-06395-y

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**Advancements in electromagnetic microwave absorbers: Ferrites and carbonaceous materials**

Mohapatra PP, Singh HK, Dobbidi P. Advancements in electromagnetic microwave absorbers: Ferrites and carbonaceous materials. Adv Colloid Interface Sci. 2024 Dec 14;337:103381. doi: 10.1016/j.cis.2024.103381.

Abstract

Heightened levels of electromagnetic (EM) radiation emitted by electronic devices, communication equipment, and information processing technologies have become a significant concern recently. So, substantial efforts have been devoted for developing novel materials having high EM absorption properties. This critical review article provides an overview of the advancements in understanding and developing such materials. It delves into the interaction between EM radiation and absorbing materials, focusing on phenomena like multiple reflections, scattering, and polarization. Additionally, the study discusses various types of losses that impact microwave absorber performance, like magnetic loss, and dielectric loss. Each of these losses has distinct implications for microwave absorbers' effectiveness. Furthermore, the review offers detailed insights into different microwave-absorbing materials, such as metal composites, magnetic materials, conducting polymers, and carbonaceous materials (composites with carbon fiber, porous carbon, carbon nanotube, graphene oxide, etc.). Overall, it highlights the progress achieved in microwave-absorbing materials and emphasizes optimizing various loss mechanisms for enhanced performance.

Conclusions

This study provides a comprehensive overview of recent advancements in magnetic and carbon-based dielectric composites, showcasing their potential as promising materials for microwave absorption. The examples underscore that a single dielectric or magnetic system alone cannot consistently achieve optimal microwave absorption performance, necessitating the formulation of composite mixtures that incorporate dielectric and magnetic fillers. These composites' exceptional microwave absorption capabilities can be attributed to several key factors: optimizing intrinsic properties: The amalgamation of a carbon-based material with dielectric components yields distinctive complementary responses in their intrinsic properties, resulting in optimized impedance matching. Inducing Interfacial Polarization: Ample heterogeneous interfaces between different components effectively induce strong interfacial polarization, enhancing the overall microwave absorption performance. Facilitating Conductive Networks: Integrating multiple components facilitates the formation of a conductive network, hopping electrons and fostering the migration and fortifying conductivity loss. Precision in Microstructure Design: Meticulously designed microstructures offer additional propagation paths for incident electromagnetic waves, stimulating multiple reflections and scatterings that efficiently consume electromagnetic energy.

Despite remarkable progress in carbon-based dielectric systems, persistent challenges warrant a strategic approach: In-Depth Exploration of EM Loss Characteristics: A meticulous exploration of the electromagnetic loss characteristics of each component is crucial. It emphasizes the need for a rational combination of elements rather than arbitrarily preparing multicomponent composites. Defect Engineering: While defects like grain boundaries, atom vacancies, and heteroatoms positively affect polarization and conductivity losses, the intricate relationship between defect sites and microwave absorption performance necessitates further exploration. Defect engineering is pivotal in guiding the fabrication of high-performance magnetic and carbon-based dielectric composites. Expanding the Effective Frequency Range: The effective frequency range of most composites is confined to 8.0–18.0 GHz, limiting their applicability in the electronics industry, where many devices operate at frequencies lower than 8.0 GHz. A rational construction approach for multicomponent composites with well-designed microstructures holds the potential to overcome this limitation and enhance low-frequency attenuation capabilities. Simplified Preparation Methods: The preparation methods,

especially for multicomponent composites, are often complicated, posing challenges for large-scale production. Streamlining these methods is crucial for overcoming production difficulties.

In conclusion, the future outlook for high-performance materials against electromagnetic pollution lies in developing novel carbon-based dielectric systems, magnetic fillers with well-balanced compositions, and intricate microstructures. Addressing the outlined challenges will contribute to realizing these materials' potential to mitigate electromagnetic interference.

https://pubmed.ncbi.nlm.nih.gov/39700971/

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**Effect of radiation emitted from mobile phone on innate immunity in mice**

Pei, Y., Gao, H., Zhang, M., Zhou, F., Zhu, Y., Wang, X., & Sun, J. (2024). Effect of radiation emitted from mobile phone on innate immunity in mice. *Radiation Effects and Defects in Solids*, *179*(11–12), 1585–1596. doi: 10.1080/10420150.2024.2352845

Abstract

This present study aims to explore the potential impact of cell phone radiation on innate immunity in mice. Ninety-six male BALB/C mice aged 2–3 weeks were randomly distributed into 4 groups as blank control, control, TD-SCDMA and LTE-Advanced respectively, with 32 mice in each group. Mice were designed to be exposed to cell phone radiation for 4–8 weeks. Eight mice in each group were taken out for measurement given exposure periods were 4, 6 and 8 weeks respectively. Cell biological technique was conducted to assess the chemotaxis of neutrophils, and a morphological method was performed for the detection of phagocytosis of neutrophil and macrophage, while microbiological means was carried out to test the relative activity of lysozyme in serum of mice. As a result, the chemotaxis ratio of neutrophils was with little statistical difference among the four groups given a shorter exposure period. However, the ratios in TD-SCDMA and LTE-Advanced groups were decreased significantly on the condition that the exposure period was more than 6 weeks. No statistical difference was observed among the four groups during the entire exposure period in terms of the chemotaxis index. Phagocytosis of the innate cells as neutrophil and macrophage showed little change in the two control groups during the whole experimental stages, while the percentage in the two treated groups decreased statistically, and this kind of reduction was prone to feature time dependence. The activities of lysozyme in TD-SCDMA and LTE-Advanced groups declined significantly, further to that, the impact was climbing paralleled with the prolonged duration. It could be deduced that radiation from cell phones could weaken innate immunity in experimental mice; moreover, this adverse effect was seemingly more severe as the radiation exposure continued.

https://www.tandfonline.com/doi/full/10.1080/10420150.2024.2352845

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**Numerical dosimetry of specific absorption rate of insects exposed to far-field radiofrequency electromagnetic fields**

Jeladze V, Nozadze T, Partsvania B, Thielens A, Shoshiashvili L, Gogoladze T (2025). Numerical dosimetry of specific absorption rate of insects exposed to far-field radiofrequency electromagnetic fields. *International Journal of Radiation Biology*, 1–14. doi: 10.1080/09553002.2024.2442693.

Abstract

Purpose  This paper reports a study of electromagnetic field (EMF) exposure of several adult insects: a ladybug, a honey bee worker, a wasp, and a mantis at frequencies ranging from 2.5 to 100 GHz. The purpose was to estimate the specific absorption rate (SAR) in insect tissues, including the brain, in order to predict the possible biological effects caused by EMF energy absorption.

Method  Numerical dosimetry was executed using the finite-difference time-domain (FDTD) method. Insects were modeled as 3-tissue heterogeneous dielectric objects, including the cuticle, the inner tissue, and the brain tissue. The EMF source was modeled as sinusoidal plane waves at a single frequency (far-field exposure).

Results  The whole-body averaged, tissue averaged, and 1 milligram SAR values were determined in insects for all considered frequencies for 10 different incident plane waves. SAR values were normalized to the incident power density of 1 mW/cm2. Maximal EMF absorption in the inner and brain tissues was observed at 6, 12, and 25 GHz for the considered insects, except the brain tissue of a ladybug (max at 60 GHz).

Conclusion  The paper presented the first estimation of the SAR for multiple insects over a wide range of RF frequencies using 3-tissue heterogenous insect 3D models created for this specific research. The selection of tissues' dielectric properties was validated. The obtained results showed that EMF energy absorption in insects highly depends on frequency, polarization, and insect morphology.

Conclusion

The paper presented a study of RF-EMF dosimetry of honeybee worker, wasp, mantis, and ladybug from 2.5 to 100 GHz, including frequencies that will be utilized in future 5 G technologies.

Discrete, 3-tissue heterogenous insect 3D models were created and used for FDTD modeling.

The whole-body averaged SAR values and tissue-averaged SAR values were estimated in insects' tissues for 9 considered frequencies and 10 polarizations of incident plane wave. For the first time, 1 mg SAR values were determined in insect tissues.

The obtained results showed SAR values in honeybee, wasp, ladybug, and mantis body tissues, which depend on the direction of the incident plane wave and polarization, frequency, and the insects' body sizes and peculiarities.

The highest values of the peak 1 mg SAR for the honeybee and wasp − 39.2 W/kg and 169.2 W/kg for an incident field strength of 1 mW/cm$^2$, were observed when E-field polarization was directed along the insect's length (pol. E3, E5, E9).

The obtained results showed maximal tissue-specific SAR values in the brain at 25 GHz for the honeybee (3.6 W/kg), 12 GHz for the wasp (5.4 W/kg), 25 GHz for the mantis (5.2 W/kg), and 60 GHz for the

ladybug (10 W/kg), all for an incident power density of 1 mW/cm$^2$. Maximal EMF absorption in the inner tissue was observed at 12 GHz, 4.3 W/kg, 5.9 W/kg, 4.8 W/kg for the honey bee, wasp, and ladybug, respectively, and for the mantis 3.3 W/kg at 6 GHz for an incident power density of 1 mW/cm$^2$. The absorption in insects' cuticles increased proportionally with frequency. For example, for the ladybug, the tissue-specific SAR in the cuticle was 0.1 W/kg at 2.5 Ghz and 11.9 W/kg at 100 GHz for the same incident power density of 1 mW/cm$^2$.

Future studies will consider introducing insect models that will be obtained using micro-CT scanning, examining the effects of high-frequency electromagnetic fields on other insects of different forms and sizes, conducting thermal simulations along with EM simulations, and evaluating temperature rise in insect tissues.

Based on the present results, we expect this research to have an impact on (environmental) policymaking and standardization and regulation regarding RF-EMF emissions. We expect to contribute to the harmonization of 5G EMF safety and compliance doses and to the development of future recommendations about safe frequencies and doses of 5G-EMF on the organisms studied in the present research.

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**Emerging cancer therapies: targeting physiological networks and cellular bioelectrical differences with non-thermal systemic electromagnetic fields in the human body – a comprehensive review**

Costa FP, Wiedenmann B, Schöll E, Tuszynski J. Emerging cancer therapies: targeting physiological networks and cellular bioelectrical differences with non-thermal systemic electromagnetic fields in the human body – a comprehensive review. Frontiers in Network Physiology. Vol. 4, 2024. doi: 10.3389/fnetp.2024.1483401.

Abstract

A steadily increasing number of publications support the concept of physiological networks, and how cellular bioelectrical properties drive cell proliferation and cell synchronization. All cells, especially cancer cells, are known to possess characteristic electrical properties critical for physiological behavior, with major differences between normal and cancer cell counterparts. This opportunity can be explored as a novel treatment modality in Oncology. Cancer cells exhibit autonomous oscillations, deviating from normal rhythms. In this context, a shift from a static view of cellular processes is required for a better understanding of the dynamic connections between cellular metabolism, gene expression, cell signaling and membrane polarization as states in constant flux in realistic human models. In oncology, radiofrequency electromagnetic fields have produced sustained responses and improved quality of life in cancer patients with minimal side effects. This review aims to show how non-thermal systemic radiofrequency electromagnetic fields leads to promising therapeutic responses at cellular and tissue levels in humans, supporting this newly emerging cancer treatment modality with early favorable clinical experience specifically in advanced cancer.

Open access paper:

https://www.frontiersin.org/journals/network-physiology/articles/10.3389/fnetp.2024.1483401

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**Effect of 6 GHz radiofrequency electromagnetic field on the development of fetal bones**

Karamazı Y, Emre M, Uçar S, Aksoy G, Emre T, Tokuş M. (2024). Effect of 6 GHz radiofrequency electromagnetic field on the development of fetal bones. *Electromagnetic Biology and Medicine*, 1–9. doi: 10.1080/15368378.2024.2438608.

Abstract

This study examined the impact of 6 GHz (0.054 W/kg SAR) Radiofrequency-Electromagnetic Field (RF-EMF) on prenatal bone development. In this study, 20 female and 20 male Wistar Albino rats divided into four groups. The Control group received no treatment, while in Group-I, only male rats were exposed to RF-EMF, female rats had no exposure. Group-II, both male and female rats received RF-EMF treatment. While in Group-III, only female rats were exposed to RF-EMF, male rats had no exposure. The exposure lasted 4 hours per day for 6 weeks. The rats were then allowed to mate within the group. After pregnancy, pregnant rats (Group-II and III) were exposed 4 hours per day for 18 days. On the 18th day of gestation, fetuses were removed and their weight and various lengths were measured. The skeletal system development of fetuses was examined with double skeletal staining method and assessed ossification in the extremities. In the study, fetal weights, head-tail length, occipital-frontal and parietal-parietal lengths significantly increased in all exposure groups when compared to the control group ($p < 0.001$). Although occipital-frontal length was smallest in Group-I, Group-II and Group-III were more higher than the control group ($p < 0.001$). The bones of the anterior and posterior extremities showed significant increases in length, ossification zone length, and ossification percentage in all experimental groups compared to the control group ($p < 0.001$). Our study showed that rats exposed to 6 GHz (0.054 W/kg) RF-EMF during the prenatal period had significant increases in bone development.

Plain-Language Summary

Radiofrequency Electromagnetic Field (RF-EMF) sources are one of the most widely used technology systems in daily life. This study examined the impact of 6 GHz RF-EMF on prenatal bone development. In this study, 20 female and 20 male Wistar Albino rats divided into four groups. The control group rats received no treatment, while in Group-I, only male rats, Group-II, both male and female rats, while in Group-III, only female rats were exposed to RF-EMF. The exposure lasted 4 hours/day for 6 weeks. The rats were then allowed to mate within the group. After pregnancy, pregnant rats (Group-II and III) were exposed 4 hours/day for 18 days. On the 18th day of gestation, fetuses were removed 10 fetuses each group were randomly selected in each group and their weight and various lengths were measured. The skeletal system development of fetuses was examined with double skeletal staining method. The ImageJ program was used assess ossification in the extremities.

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**Effects of 4G Long-Term Evolution Electromagnetic Fields on Thyroid Hormone Dysfunction and Behavioral Changes in Adolescent Male Mice**

Kim H-Y, Son Y, Jeong YJ, Lee S-H, Kim N, Ahn YH, Jeon SB, Choi H-D, Lee H-J. Effects of 4G Long-Term Evolution Electromagnetic Fields on Thyroid Hormone Dysfunction and Behavioral Changes in Adolescent Male Mice. *International Journal of Molecular Sciences*. 2024; 25(20):10875. doi: 10.3390/ijms252010875.

Abstract

Radiofrequency electromagnetic fields (RF-EMFs) can penetrate tissues and potentially influence endocrine and brain development. Despite increased mobile phone use among children and adolescents, the long-term effects of RF-EMF exposure on brain and endocrine development remain unclear. This study investigated the effects of long-term evolution band (LTE) EMF exposure on thyroid hormone levels, crucial for metabolism, growth, and development. Four-week-old male mice (C57BL/6) were exposed to LTE EMF (whole-body average specific absorption rate [SAR] 4 W/kg) or a positive control (lead; Pb, 300 ppm in drinking water) for 4 weeks. Subsequently, the mice underwent behavioral tests including open field, marble burying, and nest building. Blood pituitary and thyroid hormone levels, and thyroid hormone-regulating genes within the hypothalamus–pituitary–thyroid (HPT) axis were analyzed. LTE exposure increased T3 levels, while Pb exposure elevated T3 and T4 and decreased ACTH levels. The LTE EMF group showed no gene expression alterations in the thyroid and pituitary glands, but hypothalamic Dio2 and Dio3 expressions were significantly reduced compared to that in the sham-exposed group. Pb exposure altered the hypothalamic mRNA levels of Oatp1c1 and Trh, pituitary mRNA of Trhr, and Tpo and Tg expression in the thyroid. In conclusion, LTE EMF exposure altered hypothalamic Dio2 and Dio3 expression, potentially impacting the HPT axis function. Further research is needed to explore RF-EMF's impacts on the endocrine system.

Open access paper: https://www.mdpi.com/1422-0067/25/20/10875

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**Evaluation of the Thyroids of Offsprings Exposed to 2450 MHz Radiofrequency Radiation During Pregnancy: A Sixth Month Data**

Ozyilmaz C, Oktay MF, Dasdag S, Ulukaya E, Genel ME, Tansuker HD, Emre F, Yeğin K. Evaluation of the Thyroids of Offsprings Exposed to 2450 MHz Radiofrequency Radiation During Pregnancy: A Sixth Month Data. Journal of International Dental & Medical Research, 2024, 17(2): 925-930.

Abstract

This study aimed to determine whether the exposure to radiofrequency emitted by wireless internet providers (2450 MHz) throughout the day during rats' pregnancy causes a problem in the thyroid tissues of their offspring.

The pregnant rats in the experimental group were exposed to radiofrequency radiation (RFR) (24 hours/day) at a 2450 MHz frequency in pulse wave mode with 1 W output strength by a generator simulating Wi-Fi waves. The offspring in the control and experimental groups were randomized selected (n:8). At the end of the sixth month, the thyroid tissues were removed and evaluated histopathologically and biochemically. Mann–Whitney U-tests and T-tests were used for statistical analysis. The threshold for statistical significance was $p < 0.05$.

There was a significant difference in mononuclear cell infiltration (p=0.03) and vascular increase in congestion (p<0.001). There was no difference in the TUNEL-positive cell percentage (p=0.62) and H2A.X antibody levels (p=0.68) between the rats in the control and experimental groups. In this study, 2450 MHz RFR exposure during the prenatal period did not cause a statistically significant difference in terms of H2A.X levels and TUNEL-positive cell percentages in the thyroid tissue of rats.

Open access paper: http://www.jidmr.com/journal/wp-content/uploads/2024/06/71-M24_3112_Suleyman_DASDAG_Turkey-Exp-2.pdf

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**Effects of extremely low frequency magnetic fields on animal cancer and DNA damage: a systematic review and meta-analysis**

Brabant C, Honvo G, Demonceau C, Tirelli E, Léonard F, Bruyère O. Effects of extremely low frequency magnetic fields on animal cancer and DNA damage: a systematic review and meta-analysis. Prog Biophys Mol Biol. 2024 Dec 31:S0079-6107(24)00116-0. doi: 10.1016/j.pbiomolbio.2024.12.005.

Abstract

The objective of this systematic review and meta-analysis is to assess the carcinogenic effects of extremely low frequency magnetic fields (ELF-MF) by analyzing animal and comet assay studies. We have performed a global meta-analysis on all the animal studies on the relation between ELF-MF and cancer incidence and separate meta-analyses on the incidence of cancer, leukemia, lymphoma, breast cancer, brain cancer and DNA damage assessed with the comet assay. Of the 5145 references identified, 71 studies have been included in our systematic review and 22 studies in our meta-analyses. Our global meta-analysis indicated that ELF-MF exposure had no significant impact on the incidence of cancers in rodents (19 studies, OR = 1.10; 95% CI 0.91-1.32). However, our separate meta-analyses showed that ELF-MF increased the odds of developing leukemia in mice (4 studies, OR = 4.45; 95% CI 1.90-10.38) but not in rats. Our systematic review also suggests that ELF-MF can damage DNA in certain cell types like brain cells. Nevertheless, a meta-analysis on three comet assay studies indicated that ELF-MF did not increase DNA damage in neuroblastoma cells (SMD = -0.08; 95% CI -0.18-0.01). Overall, our results suggest that exposure to ELF-MF does not represent a major hazard for mammals and the carcinogenic effects of these magnetic fields could be limited to leukemia.

Highlights

ELF-MF do not affect the odds of lymphoma, brain cancer and breast cancer in rodents

ELF-MF could increase the odds of developing leukemia in mice but not in rats

ELF-MF have no influence on survival and body weight in rodents

ELF-MF do not increase DNA damage in neuroblastoma cells

ELF-MF could damage DNA of certain cell types like brain cells in rodents

https://pubmed.ncbi.nlm.nih.gov/39746455/

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**Effects of extremely low-frequency (50 Hz) electromagnetic fields on vital organs of adult Wistar rats and viability of mouse fibroblast cells**

Tekam CKS, Majumdar S, Kumari P, Prajapati SK, Sahi AK, Singh R, Krishnamurthy S, Mahto SK. Effects of extremely low-frequency (50 Hz) electromagnetic fields on vital organs of adult Wistar rats and viability of mouse fibroblast cells. Radiat Prot Dosimetry. 2024 Dec 4:ncae220. doi: 10.1093/rpd/ncae220.

Abstract

In recent years, scientific communities have been concerned about the potential health effects of periodic electromagnetic field exposure (≤1 h/d). The objective of our study is to determine the impact of extremely low-frequency pulsed electromagnetic fields (ELF-PEMF) (1-3 mT, 50 Hz) on mouse fibroblast (red fluorescent protein (RFP)-L929) cells and adult Wistar rats to gain a comprehensive understanding of biological effects. We observed that RFP-L929 exhibits no significant changes in cell proliferation and morphology but mild elevation in aspartate aminotransferases, alanine aminotransferases, total bilirubin, serum creatinine, and creatine kinase-myocardial band levels in ELF-PEMF exposed groups under in vitro and in vivo conditions. However, the histological examination showed no significant alterations in tissue structure and morphologies. Our result suggests that 50-Hz ELF-PEMF exposure (1-3 mT, 50 Hz) with duration (<1 h/d) can trigger mild changes in biochemical parameters, but it is insufficient to induce any pathological alterations.

Conclusions

The present study demonstrates the effects of 50-Hz ELF-PEMF (1–3 mT) using *in vitro* (RFP-L929 mouse fibroblast cells) and *in vivo* (adult male Wistar rats) models. The results reveal that exposure duration of 20 min (each) with a 4-h gap is non-destructive for RFP-L929 cells and causes mild alterations in biochemical parameters but not in organ coefficient, tissue structure, and morphology of adult Wistar rats. The results demonstrated that 50-Hz ELF-PEMF exposure did not cause significant cellular fragmentation and changes in the morphology of mouse fibroblast cells. We observed mild alterations in the biochemical parameters of rats among MF exposed and control groups. Conversely, histological analysis of the selected liver, kidney, and heart sections following ELF-PEMF exposure revealed no significant changes in tissue structure and morphology. Our efforts provide conceptual and experimental support to establish a link between 50-Hz ELF-PEMF exposure and biological systems/tissues in residential and occupational environments.

https://pubmed.ncbi.nlm.nih.gov/39656829/

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**Extremely Low-Frequency Electromagnetic Field (ELF-EMF) Increases Mitochondrial Electron Transport Chain Activities and Ameliorates Depressive Behaviors in Mice**

Teranishi M, Ito M, Huang Z, Nishiyama Y, Masuda A, Mino H, Tachibana M, Inada T, Ohno K. Extremely Low-Frequency Electromagnetic Field (ELF-EMF) Increases Mitochondrial Electron Transport Chain Activities and Ameliorates Depressive Behaviors in Mice. *International Journal of Molecular Sciences*. 2024; 25(20):11315. https://doi.org/10.3390/ijms252011315

Abstract

Compromised mitochondrial electron transport chain (ETC) activities are associated with depression in humans and rodents. However, the effects of the enhancement of mitochondrial ETC activities on depression remain elusive. We recently reported that an extremely low-frequency electromagnetic field (ELF-EMF) of as low as 10 μT induced hormetic activation of mitochondrial ETC complexes in human/mouse cultured cells and mouse livers. Chronic social defeat stress (CSDS) for 10 consecutive days caused behavioral defects mimicking depression in mice, and using an ELF-EMF for two to six weeks ameliorated them. CSDS variably decreased the mitochondrial ETC proteins in the prefrontal cortex (PFC) in 10 days, which were increased by an ELF-EMF in six weeks. CSDS had no effect on the mitochondrial oxygen consumption rate in the PFC in 10 days, but using an ELF-EMF for six weeks enhanced it. CSDS inactivated SOD2 by enhancing its acetylation and increased lipid peroxidation in the PFC. In contrast, the ELF-EMF activated the Sirt3-FoxO3a-SOD2 pathway and suppressed lipid peroxidation. Furthermore, CSDS increased markers for mitophagy, which was suppressed by the ELF-EMF in six weeks. The ELF-EMF exerted beneficial hormetic effects on mitochondrial energy production, mitochondrial antioxidation, and mitochondrial dynamics in a mouse model of depression. We envisage that an ELF-EMF is a promising therapeutic option for depression.

Open access paper: https://www.mdpi.com/1422-0067/25/20/11315

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**Effects of light, electromagnetic fields and water on biological rhythms**

Martel J, Rouleau N, Murugan NJ, Chin WC, Ojcius DM, Young JD. Effects of light, electromagnetic fields and water on biological rhythms. Biomed J. 2024 Dec 11:100824. doi: 10.1016/j.bj.2024.100824.

Abstract

The circadian rhythm controls a wide range of functions in the human body and is required for optimal health. Disruption of the circadian rhythm can produce inflammation and initiate or aggravate chronic diseases. The modern lifestyle involves long indoor hours under artificial lighting conditions as well as eating, working, and sleeping at irregular times, which can disrupt the circadian rhythm and lead to poor health outcomes. Seasonal solar variations, the sunspot cycle and anthropogenic electromagnetic fields can also influence biological rhythms. The possible mechanisms underlying these effects are discussed, which include resonance, radical-pair formation in retina cryptochromes, ion cyclotron resonance, and interference, ultimately leading to variations in melatonin and cortisol. Intracellular water, which represents a coherent, ordered phase that is sensitive to infrared light and electromagnetic fields, may also respond to solar variations and man-made electromagnetic fields. We describe here various factors and underlying mechanisms that affect the regulation of biological rhythms, with the aim of providing practical measures to improve human health.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S2319417024001276?via%3Dihub

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**The origins of light-independent magnetoreception in humans**

Shibata T, Hattori N, Nishijo H, Kuroda S, Takakusaki K. The origins of light-independent magnetoreception in humans. Front Hum Neurosci. 2024 Nov 29;18:1482872. doi: 10.3389/fnhum.2024.1482872.

Abstract

The Earth's abundance of iron has played a crucial role in both generating its geomagnetic field and contributing to the development of early life. In ancient oceans, iron ions, particularly around deep-sea hydrothermal vents, might have catalyzed the formation of macromolecules, leading to the emergence of life and the Last Universal Common Ancestor. Iron continued to influence catalysis, metabolism, and molecular evolution, resulting in the creation of magnetosome gene clusters in magnetotactic bacteria, which enabled these unicellular organisms to detect geomagnetic field. Although humans lack a clearly identified organ for geomagnetic sensing, many life forms have adapted to geomagnetic field-even in deep-sea environments-through mechanisms beyond the conventional five senses. Research indicates that zebrafish hindbrains are sensitive to magnetic fields, the semicircular canals of pigeons respond to weak potential changes through electromagnetic induction, and human brainwaves respond to magnetic fields in darkness. This suggests that the trigeminal brainstem nucleus and vestibular nuclei, which integrate multimodal magnetic information, might play a role in geomagnetic processing. From iron-based metabolic systems to magnetic sensing in neurons, the evolution of life reflects ongoing adaptation to geomagnetic field. However, since magnetite-activated, torque-based ion channels within cell membranes have not yet been identified, specialized sensory structures like the semicircular canals might still be necessary for detecting geomagnetic orientation. This mini-review explores the evolution of life from Earth's formation to light-independent human magnetoreception, examining both the magnetite hypothesis and the electromagnetic induction hypothesis as potential mechanisms for human geomagnetic detection.

Conclusion

Eukaryotic cells, and vertebrates have developed magnetoreception systems to adapt to the geomagnetic field. Numerous studies on magnetoreception in birds, particularly concerning the upper beak and inner ear, suggest that in humans, the trigeminal nerve, vestibular nerve, and hindbrain might be involved in light-independent magnetoreception pathways. However, the specific sensory organ in humans that detects the geomagnetic field has not yet been identified. Unlike traditional senses, geomagnetic information is transmitted without attenuation through the scalp, bones, and cerebrospinal fluid, similar to gravity. It also generates eddy currents and lorentz forces accompanying the relative movement of the geomagnetic field (Arago and Flourens, 1856). Considering these unique properties, vertebrates might have evolved to detect the geomagnetic field in a light-independent manner, not only through direct detection using torque-based magnetic particles but also through indirect detection of electric potentials using electromagnetic induction. Further research into this evolutionary adaptation could help unravel the mystery of geomagnetic field detection in humans.

Open access paper: https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2024.1482872/full

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**Effects of anthropogenic electromagnetic fields used for subsurface oil and gas exploration (controlled-source electromagnetics, CSEM) on the early development of Atlantic haddock**

Guillebon C, Perrichon P, Browman HI, Cresci A, Sivle LD, Skiftesvik AB, Zhang G, Durif CMF. Effects of anthropogenic electromagnetic fields used for subsurface oil and gas exploration (controlled-source electromagnetics, CSEM) on the early development of Atlantic haddock (Melanogrammus aeglefinus). Mar Pollut Bull. 2024 Dec 12;211:117425. doi: 10.1016/j.marpolbul.2024.117425.

Abstract

Controlled source electromagnetics (CSEM) uses electromagnetic fields (EMF) to detect oil reservoirs. Atlantic haddock, Melanogrammus aeglefinus, is a commercially important demersal fish species that can potentially be impacted by such surveys due to potential overlap with egg distribution. In this study, haddock eggs were exposed to EMF, replicating CSEM survey conditions in a laboratory. Three different EMF intensities were used to replicate different distances between the EMF source and the organism. Exposures lasted for 15 min. A worst-case scenario, i.e. 1 h exposure at the highest EMF level was also carried out. None of the treatments caused malformations, mortality or affected hatching of eggs. However, EMF exposure induced tachycardia in newly hatched larvae and reduced the size of their yolk sac reserve. The effect was significant at the lowest EMF intensity (corresponding to 1000 m between the EMF source and the exposed subject) and increased with exposure time and intensity

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0025326X24014024?via%3Dihub

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**The effect of mobile phone electromagnetic fields on the human resting state wake EEG and event-related potential: A systematic review and meta-analysis**

Prins AC, Baas K, van der Meer JN, Jacobs M, Nederveen AJ. The effect of mobile phone electromagnetic fields on the human resting state wake EEG and event-related potential: A systematic review and meta-analysis. Bioelectromagnetics. 2024 Nov 22. doi: 10.1002/bem.22531.

Abstract

The rapid growth of mobile phone usage and its use of radiofrequency electromagnetic fields (RF-EMF) have raised concerns about potential health risks. Researchers have conducted studies to examine the effects of RF-EMF on the brain using electroencephalography (EEG). We conducted a systematic quality assessment and meta-analysis of published research in this field to establish high-quality studies as references for future protocols. The electronic search yielded 244 records from which a total of 51 studies were included in the review after excluding studies based on study design, and data or report availability. Of these 51 studies, 31 (61%) focused on resting state wake EEG and 20 (39%) on event-related potentials (ERP). None of the 51 studies were free from risk of bias. From the 51 included studies, we were able to use seven studies to create three different groups for meta-analysis for resting state wake EEG and five studies to create 10 different groups for meta-analysis for ERP. Per group the number of studies varies from 1 to 5. Our procedure is the first systematic quality assessment in this field and revealed three important findings. First, there is evidence of an effect on the EEG of a 2G protocol using an eyes-open condition. Second, we did not find evidence for EEG effects during task

performance. This suggests that the impact of EMF during task performance is less pronounced compared to the resting state condition. Third, this meta-analysis shows that the field is unable to create an evidence base for most comparisons due to heterogeneity. We therefore advise that all future studies are double-blind in nature, adhere to the methodological standard of randomized experiments, and publish their protocols first.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22531

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**Electromagnetic fields exposure on fetal and childhood abnormalities: Systematic review and meta-analysis**

Kashani ZA, Pakzad R, Fakari FR, Haghparast MS, Abdi F, Kiani Z, Talebi A, Haghgoo SM. Electromagnetic fields exposure on fetal and childhood abnormalities: Systematic review and meta-analysis. Open Med (Wars). 2023 May 12;18(1):20230697. doi: 10.1515/med-2023-0697

Abstract

Today, in the modern world, people are often exposed to electromagnetic waves, which can have undesirable effects on cell components that lead to differentiation and abnormalities in cell proliferation, deoxyribonucleic acid (DNA) damage, chromosomal abnormalities, cancers, and birth defects. This study aimed to investigate the effect of electromagnetic waves on fetal and childhood abnormalities. PubMed, Scopus, Web of Science, ProQuest, Cochrane Library, and Google Scholar were searched on 1 January 2023. The Cochran's *Q*-test and $I^2$ statistics were applied to assess heterogeneity, a random-effects model was used to estimate the pooled odds ratio (OR), standardized mean difference (SMD), and mean difference for different outcomes, and a meta-regression method was utilized to investigate the factors affecting heterogeneity between studies. A total of 14 studies were included in the analysis, and the outcomes investigated were: change in gene expression, oxidant parameters, antioxidant parameters, and DNA damage parameters in the umbilical cord blood of the fetus and fetal developmental disorders, cancers, and childhood development disorders. Totally, the events of fetal and childhood abnormalities were more common in parents who have been exposed to EMFs compared to those who have not (SMD and 95% confidence interval [CI], 0.25 [0.15-0.35]; $I^2$, 91%). Moreover, fetal developmental disorders (OR, 1.34; CI, 1.17-1.52; $I^2$, 0%); cancer (OR, 1.14; CI, 1.05-1.23; $I^2$, 60.1%); childhood development disorders (OR, 2.10; CI, 1.00-3.21; $I^2$, 0%); changes in gene expression (mean difference [MD], 1.02; CI, 0.67-1.37; $I^2$, 93%); oxidant parameters (MD, 0.94; CI, 0.70-1.18; $I^2$, 61.3%); and DNA damage parameters (MD, 1.01; CI, 0.17-1.86; $I^2$, 91.6%) in parents who have been exposed to EMFs were more than those in parents who have not. According to meta-regression, publication year has a significant effect on heterogeneity (coefficient: 0.033; 0.009-0.057). Maternal exposure to electromagnetic fields, especially in the first trimester of pregnancy, due to the high level of stem cells and their high sensitivity to this radiation, the biochemical parameters of the umbilical cord blood examined was shown increased oxidative stress reactions, changes in protein gene expression, DNA damage, and increased embryonic abnormalities. In addition, parental exposure to ionizing and non-ionizing radiation can lead to the enhancement of different cell-based cancers and developmental disorders such as speech problems in childhood.

Conclusions

Studies are associated with mothers' exposure to EMFs during pregnancy and non-ionizing radiation (RF and ELF-EMFs) with fetal complications such as significant enhancement of oxidant factors, decrease of antioxidant factors, and increase in DNA damage parameters, as well as changes in expression proteins in cord blood genes. On the other hand, close maternal exposure in prenatal and postnatal (residence or occupational exposure) with EMFs of high voltages power lines more than 1 mG or 50 Hz with congenital anomalies (CNS defect, spina bifida) and fetal developmental disorders (such as reduced embryonic bud length) and neurodevelopmental disorders in childhood (e.g., speech problems in children) are associated. Moreover, parents' exposure to ionizing and non-ionizing radiation (X-ray, ELF-EMF, and RF examinations) before and after birth is also associated with enhancement of the risk of cancers (such as rhabdomyosarcoma, ALL, brain tumors, and neuroectoderm) in childhood and adolescence. However, due to the limitations of studies, such as inaccurate measurement of exposure to ELF-EMF (e.g., interviews based on participants' reminders) or inaccurate measure of the actual rate of exposure to EMF or case–control model of most studies, the effects of EMF on fetal and childhood abnormalities should be interpreted with caution. Considering the widespread exposure to non-ionizing radiation, a little enhancement of exposure to EMF could lead to unacceptable health consequences for future generations. Although the number of epidemiological studies examining the undesirable effects of EMF exposure in humans is limited, the findings of this study should prompt further research on this significant environmental danger for pregnant women.

Open access paper: https://www.degruyter.com/document/doi/10.1515/med-2023-0697/html?lang=en

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**Systematic Review of Exposure Studies to Radiofrequency Electromagnetic Fields: Spot Measurements and Mixed Methodologies**

Ramirez-Vazquez R, Escobar I, Arribas E, Vandenbosch GAE. Systematic Review of Exposure Studies to Radiofrequency Electromagnetic Fields: Spot Measurements and Mixed Methodologies. *Applied Sciences*. 2024; 14(23):11161. https://doi.org/10.3390/app142311161

Abstract

This work presents a review and evaluation of studies measuring exposure to Radiofrequency Electromagnetic Fields (RF-EMF). The review meets the basic quality criteria and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines after the eligibility criteria of the PECO (Population, Exposure, Comparator, and Outcome) methodology and the instrument Critical Appraisal Skills Programme Español (CASPe). A total of 86 papers published between 1 January 1998 and 31 December 2023 are included: 61 studies with spot measurements and 25 studies with mixed methodologies (spot measurements, personal measurements with volunteers or with a trained researcher and prediction models) are highlighted. Forty-three percent of the studies use Spectrum Analyzers in the spot measurements, mainly the Narda SRM–3006, followed by the Narda SRM-3000, highlighting the introduction and use of Sensors for this kind of study. The minimum mean value was measured in Palestine at 0.0600 $\mu W/m^2$, and the maximum mean value was measured in Norway at 200,000 $\mu W/m^2$. The RF-EMF exposure levels measured in the different microenvironments are minimal and far from the maximum levels established by the ICNIRP guidelines.

Conclusions

This study reviewed 86 scientific works on personal exposure to RF-EMF that conducted measurements through spot measurements and/or using different methods (mixed method) combining spot measurements, personal measurements with volunteers or with trained researchers, spatiotemporal exposure measurements and in some cases using model predictions.

In addition to the exposure measurement studies, we want to refer to a study recently published by McKenzie [143] in which electromagnetic fields produced by “smart” devices used daily in a modern “smart” home are measured. It is interesting to see the activity of these EMFs in different periods of time while they are used. This study has not been included in this review because although specific measures have been taken, exposure to these fields has not been measured.

As far as we know, today, despite the different methodologies used, the results are comparable with international reference levels and comparable between microenvironments and countries; although it is true that some values are higher than others, they are still lower than these reference levels. The minimum average was measured in Palestine at 0.0600 μW/m2 in 2017, and the maximum average was measured in Norway at 200,000 μW/m2 in 2022, equivalent to 0.200 W/m2, far below the permitted international reference levels. During the development of this work, we have seen that the statistical data confirm that the exposure levels to RF-EMF are much lower than the maximum levels allowed in the ICNIRP guidelines, both for the general public scenario (10 W/m2) and for the occupational scenario (50 W/m2). However, these values can change over time, considering the new 5G technologies introduced everywhere right at this moment, so it is recommended to stay vigilant and continue expanding research in this field.

As previously indicated, with this work, we want to help researchers scrutinize this field with a review that classifies, orders, and synthesizes, thus making a reference for future research and comparisons. We believe that in the future, some research areas may be prioritized in the field of radiofrequency electromagnetic exposure fields: exploring new measurement devices, such as the use of sensors that have already begun to be used to monitor RF-EMF [111], as well as carrying out longitudinal studies to evaluate possible long-term effects.

We want to highlight that in this society in which we currently live, in which we are always immersed in a sea of electromagnetic waves, the importance of clear and effective communication of the possible risks associated with RF-EMF exposure, as well as the need to educate the public on how to minimize exposure in everyday environments.

Open access paper: https://www.mdpi.com/2076-3417/14/23/11161

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**Causal associations between mobile phone usage and glaucoma risk: A Mendelian randomization study**

Song R, Wang Y, Kong Y, Fan X, Yuan C, Zha X. Causal associations between mobile phone usage and glaucoma risk: A Mendelian randomization study. Medicine (Baltimore). 2024 Nov 29;103(48):e40666. doi: 10.1097/MD.0000000000040666.

Abstract

Previous research has indicated a possible link between mobile phone usage and the incidence of glaucoma. This study employs a 2-sample Mendelian randomization (MR) analysis to examine the causal relationship between mobile phone use and glaucoma risk. We used single nucleotide polymorphisms (SNPs) from publicly accessible genome-wide association study (GWAS) datasets as instrumental variables (IVs). The primary analytical method was the inverse variance weighted (IVW) approach, with MR-Egger and weighted median analyses serving as complementary methods. Sensitivity was evaluated using Cochran's Q test and MR-Egger regression. The results demonstrate a causal effect of mobile phone usage on an increased risk of glaucoma (OR IVW = 1.358, 95% CI: 1.052-1.752, P = .019; OR MR-Egger = 1.882, 95% CI: 0.53-6.682, P = .337; OR Weighted median = 1.387, 95% CI: 1.012-1.900, P = .042; OR MR-PRESSO = 1.358, 95% CI: 1.052-1.752, P = .026). Sensitivity analyses confirmed the robustness and reliability of these findings. The study identifies mobile phone usage as a potentially modifiable risk factor for glaucoma, providing new avenues for exploring the specific mechanisms underlying these ocular disorders.

Open access paper: https://journals.lww.com/md-journal/fulltext/2024/11290/causal_associations_between_mobile_phone_usage_and.12.aspx

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**Association between mobile phone use and incidence of dementia: A prospective cohort study using the UK Biobank**

Zhao H, Wen Q, Zhuo L, Wang S, Zhan S. Association between mobile phone use and incidence of dementia: A prospective cohort study using the UK Biobank. Gerontology. 2023 Jul 26. doi: 10.1159/000531847.

Abstract

Introduction: The rapid growth in mobile phone use has led to public concern about its potential effects on the risk of dementia. This study aimed to investigate the association between mobile phone use in daily life and the risk of dementia incidence in community-dwelling adults based on the data from the UK Biobank.

Methods: Participants in the UK Biobank aged 60 years or older with no diagnosis of dementia at the time of recruitment were included in this prospective cohort study. A Cox regression model adjusted for sociodemographic characteristics, general health factors, mental health, lifestyle factors, comorbidities, and medication use was used to estimate the hazard ratio (HR) and confidence interval (CI) of the association between mobile phone use and dementia risk.

Results: The final analyses included 213,181 participants. During a median follow-up period of 12.4 years, 6,344 cases of incident dementia occurred. Mobile phone use displayed a modest association with lower risk of dementia incidence, with HRs of 0.85 (95% CI: 0.79-0.91), 0.85 (95% CI: 0.80-0.91), 0.78 (95% C: 0.71-0.86), 0.86 (95% CI: 0.77-0.96), and 0.83 (95% CI: 0.70-0.98) for participants who reported phone call usage of fewer than 5 minutes, 5-29 minutes, 30-59 minutes, 1-3 hours, and more than 3 hours per week, respectively, compared with non-users. In addition, the proportions of the association medicated by family/friend visits and other leisure/social activities were 2.62% (95% CI: -0.64-6.51) and 2.22% (95% CI: 1.12-4.12), respectively.

Conclusions: Daily mobile phone use is significantly associated with a reduced risk of incident dementia in community-dwelling adults in the UK Biobank population. This association seems to be mediated by improved social and mental activities.

https://pubmed.ncbi.nlm.nih.gov/37494916/

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**Protective Properties of Botanical Extracts against 5G Radiation-induced Damage to Human Skin, as Demonstrated in Preliminary Data from a Keratinocyte Cell Culture Model**

Havas F, Cohen M, Krispin S, Attia-Vigneau J. Protective Properties of Botanical Extracts against 5G Radiation-induced Damage to Human Skin, as Demonstrated in Preliminary Data from a Keratinocyte Cell Culture Model. *Front. Biosci. (Landmark Ed)* 2024, 29(1). doi: 10.31083/j.fbl2901031.

Abstract

Background: Next-generation 5G communication technology involves increasing use of 3–100 GHz wireless bands in population centers. Though still non-ionizing, this implies higher radiation energy vs. existing bands. The range is also shorter, needing more numerous emitters, closer to the user—resulting in higher electromagnetic energy exposure. With no universal consensus regarding exposure risks, there is some concern among the public and the scientific community, following indications that 5G radiation can impact immune function, trigger inflammatory responses, and influence expression of genes affecting protein folding, oxidative stress, tissue/extracellular matrix (ECM) matrix turnover, and more. This work aims at identifying botanical extracts for protection of human skin from these impacts, based on a preliminary cell culture-based model.

Methods: We irradiated human epidermal keratinocytes at 6 GHz, evaluating effects on Interleukin1-α (IL1-α), a key inflammatory cytokine; TIMP metallopeptidase inhibitor 1 (TIMP1), shown to inhibit collagenase; Angiopoietin-like protein 4 (ANGPLT4), which plays a role in wound healing and epidermal differentiation; and S100 calcium-binding protein A9 (S100A9), involved in immune recruitment during injury, by enzyme-linked immunosorbent assay (ELISA) and immunostaining. We next used this model to identify substances able to mitigate the effects of 5G irradiation, through the evaluation of the influence of treatment by one of several botanical extracts on the observed effects of 5G irradiation.

Results: After a remarkably short 1-h exposure, clear effects on keratinocyte function were observed: increased inflammatory cytokine IL1-α; reduced collagenase inhibitor TIMP1; increased wound healing/differentiation facilitator ANGPLT4; and increased SA100A9, involved in immune recruitment during injury. On this basis, we then showed the protective effects of selected botanical extracts, capable of reducing the increase in IL1-α induced by 5G exposure, possibly in part due to anti-inflammatory and antioxidant properties of compounds present in these extracts.

Conclusions: Our results show a clear influence of 5G irradiation on the keratinocytes, possibly indicating injury and damage responses. What's more, we showed how these preliminary data can be used to identify botanical extracts capable of offering some protection against these effects for users of 5G technology, e.g., when employed as active ingredients in protective cosmetic applications.

Open access paper: https://doi.org/10.31083/j.fbl2901031

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**Preliminary Study on the Impact of 900MHz Radiation on Human Sperm: An In Vitro Molecular Approach**

Keskin I, Karabulut S, Kaplan AA, Alagöz M, Akdeniz M, Tüfekci KK, Davis DL, Kaplan S. Preliminary Study on the Impact of 900MHz Radiation on Human Sperm: An In Vitro Molecular Approach. Reprod Toxicol. 2024 Nov 4:108744. doi: 10.1016/j.reprotox.2024.108744.

Abstract

The use of technologies that produce and emit electromagnetic fields (EMF) is growing exponentially worldwide. The biological effects of EMF-emitting equipment, such as mobile phones and other wireless devices, have been studied in the last decade using in vitro and in vivo methods. Infertility is a growing health problem, and nearly half of cases are because of male-factor. This study investigated the direct in vitro effects of 900 MHz radiation exposure on sperm parameters, genetic status, apoptotic markers, and the PI3K/AKT signaling pathway in healthy normozoospermic men. Semen samples were divided into four groups, two control (30 min and 1 h) and two EMF exposure (30 min and 1 h). Sperm parameters (motility, progressive motility, acrosomal index, morphology), genetic status (DNA fragmentation and chromatin integrity), apoptotic markers (cytokine-c and caspase-3 expression) and the PI3K/AKT signaling pathway (phosphoinoitide 3-kinase-PI3K- and phosphorylated AKT- p-AKT-) were analysed. Sperm motility were significantly reduced in 30 min EMF exposure while a significant increase in the expression of p-AKT were observed in 1 h EMF exposure group. An increased vacuolisation, acrosomal defect, extension of subacrosomal space, uncondensed chromatin structure, apoptotic signs and disrupted axoneme were observed in both EMF groups which were not observed in the control group. Other sperm parameters (morphology and acrosomal index), genetic status, apoptotic markers and the PI3K expression rates had no significant change.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0890623824002119

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**Sensory Processing Sensitivity, and Not Gender, Drives Electromagnetic Hypersensitivity and Nature Connection**

Watten RG, Volden F, Visnes H. Sensory Processing Sensitivity, and Not Gender, Drives Electromagnetic Hypersensitivity and Nature Connection. Ecopsychology. Nov 28, 2024. https://doi.org/10.1089/eco.2024.0027

Abstract

Electromagnetic hypersensitivity (EHS) is a biomedical condition associated with exposure to man-made radio-frequency electromagnetic fields. Common sources are devices like mobile phones, wireless networks, base stations, computers, TVs, and more. Identifying individuals at risk of developing EHS is important. Those with heightened sensory processing sensitivity (SPS; the ability to perceive, process, and react to environmental stimuli, approximately 25% to 30% of the population) are of special interest.

SPS could also be associated with connectedness to nature (CNS) and EHS. In the current gender-matched cross-sectional study (*n* = 450; 225 men and 225 women) we assessed gender differences in environmental sensitivity assessed as SPS, EHS, and CNS. Women had higher general EHS prevalence than men (13.3% vs. 5.3%), higher mean values on perceived sensitivity for 5 out of 9 categories of electromagnetic equipment (computers, electrical appliances, fluorescent lighting, mobile phones, and television) and they had higher scores on the three EHS Scales EHS General, EHS Scale, and EHS Index, in addition to higher SPS and CNS scores. The gender differences vanished when adjusting for SPS in the multivariate analyses of variance (MANOVA) analyses, suggesting that the differences in these scales were associated with SPS. The statistical equation modeling (SEM) results showed a significant positive direct effect of SPS on CNS, and a significant indirect effect mediated by EHS. The present study provides the first empirical evidence that highly sensitive individuals are capable of perceiving electromagnetic radiation. The results indicate that perceived EHS and CNS are driven by SPS and not by gender.

https://www.liebertpub.com/doi/10.1089/eco.2024.0027

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**Exploring RF-EMF levels in Swiss microenvironments: An evaluation of environmental and auto-induced downlink and uplink exposure in the era of 5G**

Veludo AF, Stroobandt B, Van Bladel H, Sandoval-Diez N, Guxens M, Joseph W, Röösli M. Exploring RF-EMF levels in Swiss microenvironments: An evaluation of environmental and auto-induced downlink and uplink exposure in the era of 5G. Environmental Research, 2024, doi: 10.1016/j.envres.2024.120550.

Highlights

A new protocol was created to measure environmental and auto-induced RF-EMF levels.

Environmental RF-EMF was mainly attributed to downlink frequency bands

Inducing downlink and uplink traffic increased RF-EMF exposure levels notably

Auto-induced downlink exposure was mainly attributed to the 5G band at 3.5 GHz

The main contributor to auto-induced uplink exposure was the band at 2.1 GHz

Abstract

The advancement of cellular networks requires updating measurement protocols to better study radiofrequency electromagnetic field (RF-EMF) exposure emitted from devices and base stations. This paper aims to present a novel activity-based microenvironmental survey protocol to measure environmental, auto-induced downlink (DL), and uplink (UL) RF-EMF exposure in the era of 5G. We present results when applying the protocol in Switzerland. Five study areas with different degrees of urbanization were selected, in which microenvironments were defined to assess RF-EMF exposure in the population. Three scenarios of data transmission were performed using a user equipment in flight mode (non-user), inducing DL traffic (max DL), or UL traffic (max UL). The exposimeter ExpoM-RF 4, continuously measuring 35 frequency bands ranging from broadcasting to Wi-Fi sources, was carried in a backpack and placed 30cm apart from the user equipment. The highest median RF-EMF levels during the non-user scenario were measured in an urban business area (1.02 mW/m2). Here, DL and broadcasting

bands contributed the most to total RF-EMF levels. Compared to the non-user scenario, exposure levels increased substantially during max DL due to the 5G band at 3.5 GHz with 50% of the median levels between 3.20-12.13 mW/m2, mostly in urban areas. Note that the time-division nature of this band prevents distinguishing between exposure contribution from DL beamforming or UL signals emitted at this frequency. The highest levels were measured during max UL, especially in rural microenvironments, with 50% of the median levels between 12.08-37.50 mW/m2. Mobile UL 2.1 GHz band was the primary contributor to exposure during this scenario. The protocol was successfully applied in Switzerland and used in nine additional countries. Inducing DL and UL traffic resulted in a substantial increase in exposure, whereas environmental exposure levels remained similar to previous studies. This data is important for epidemiological research and risk communication/management.

Conclusion

A novel activity-based microenvironmental survey protocol was developed and successfully carried out to disentangle environmental from auto-induced downlink and uplink exposure in the era of 5G. The measurements conducted in Switzerland demonstrate that higher RF-EMF exposure levels were measured when inducing maximum downlink and uplink traffic using a user equipment, with the 5G band at 3.5 GHz and the UL band at 2.1 GHz the main contributors to exposure, respectively. This data is important for epidemiological research, risk communication and risk management, but also for future dosimetry and modelling studies. Future research understanding auto-induced DL and UL exposure from more realistic case scenarios remains necessary for a better characterization of the exposure levels. Future research will consist of the application of the proposed protocol in various countries and the comparison of the exposure values.

Open access paper: https://www.sciencedirect.com/science/article/pii/S001393512402454X

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**Electromagnetic intensity investigation of emitted non-ionizing radiation from base transcriptive stations in the urban region of southern Iran**

Abbasi F, Badeenezhad A, Abouee E, Shademanpour Z, Janghorban F, Janatshoar H, Naserpour M, Mohammadpour A. Electromagnetic intensity investigation of emitted non-ionizing radiation from base transcriptive stations in the urban region of southern Iran. Int J Environ Health Res. 2024 Dec 2:1-12. doi: 10.1080/09603123.2024.2435484. Epub ahead of print. PMID: 39620927.

Abstract

Their monitoring in urban regions is essential for policymakers and the population. In this study, the electromagnetic intensity (EMI) was measured around 30 stations of base transcriptive stations (BTS) at both distances lower than 20m and higher than 200m using real-time equipment SMP2-dual in summer and winter. Results have shown that EMI in summer (range: 2-6500 mW/m2) was more than in winter (1.5-5000), and the intensity of about 93% of samples exceeded WHO standards. EMI has consistently decreased with the increasing distance from BTS. There was a negative correlation between the temperature and EMI in summer and humidity and EMI for both distances. The mapping of EMI depicted the highest value of EMI across the central region from south to eastern north at a distance lower than 20 m in winter. The clustering of the EMI in this region was influenced by the geographical location of BTS.

https://pubmed.ncbi.nlm.nih.gov/39620927/

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**Effect of microwave radiation on adult neurogenesis and behavior of prenatally exposed rats**

Popovičová A, Račeková E, Martončíková M, Fabianová K, Raček A, Žideková M. Effect of microwave radiation on adult neurogenesis and behavior of prenatally exposed rats. IBRO Neuroscience Reports, 17:234-244, 2024. doi: 10.1016/j.ibneur.2024.08.007.

Abstract

Postnatal neurogenesis appears to be highly sensitive to environmental factors, including microwave electromagnetic radiation (MWR). Here, we investigated the impact of MWR during intrauterine development on juvenile and adult neurogenesis in the rostral migratory stream (RMS) and the dentate gyrus of the hippocampus in the rat brain, as well as its effect on animal behavior. Female rats were exposed to MWR at a frequency of 2.45 GHz for 2 hours daily throughout pregnancy. The offspring of irradiated mothers survived to either juvenile age or adulthood. The brains of the rats were subjected to morphological analysis, assessing cell proliferation and death in both neurogenic regions. In the RMS, the differentiation of nitrergic neurons was also investigated. The effect of MWR on behavior was evaluated in rats surviving to adulthood. Prenatal MWR exposure caused significant changes in the number of proliferating and dying cells, depending on the age of the animals and the observed neurogenic region. In addition, MWR attenuated the maturation of nitrergic neurons in the RMS in both juvenile and adult rats. Morphological alterations in neurogenesis were accompanied by changes in animals' behavior. Affected neurogenesis and changes in animal behavior suggest a high sensitivity of the developing brain to MWR.

Open access paper: https://www.sciencedirect.com/science/article/pii/S2667242124000782

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**The histological investigation of the effects of electromagnetic radiation on rat ovaries**

Kartal B, Alimoğulları E, Akkurt G, Alimogulları M, Çaylı S. The histological investigation of the effects of electromagnetic radiation on rat ovaries. J Mol Histol. 2024 Dec 4;56(1):29. doi: 10.1007/s10735-024-10319-w.

Abstract

People are now exposed to higher levels of electromagnetic radiation (EMR) due to the widespread use of mobile phones in recent years. The possible effects of this exposure on human health are related to EMR. It has been suggested that exposure to EMR has serious effects on reproduction. The study aimed to investigate the impact of exposure to EMR (4.5 GB; 2600 MHz) emitted by mobile phones on rat ovaries. 18 adult female Wistar albino rats were used in the study, and the animals were divided into three groups (n = 6): control, stand-by, and dialing. For 8 weeks, the experimental groups were subjected to 4.5 GB EMR at 2600 MHz while on standby and making 10-min calls every hour. The rats in the control group received no exposure. Hematoxylin-eosin (H&E) staining of ovarian tissues was performed for histomorphological examinations. Additionally, immunoexpression of autophagy-related

protein Beclin-1, apoptosis marker Caspase-3, ovarian reserve marker FSH, and oxidative stress marker iNOS were investigated in the rat ovaries. Microscopic examinations showed follicular degeneration in the ovaries of the rats in the stand-by and dialing groups. The immunoexpression of Beclin-1, Caspase-3, FSH, and iNOS was detected in granulosa cells and the corpus luteum in ovarian tissues obtained from the two EMR-exposed groups. There was a significant increase in the immunoexpression of Beclin-1 and Caspase-3 in the dialing group compared to the other two groups. Additionally, the iNOS and FSH expressions were increased in both EMR exposure groups compared to the control. Our results suggest that EMR exposure harms the ovaries, and autophagy and apoptosis are involved in this process.

https://pubmed.ncbi.nlm.nih.gov/39630206/

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**Exposure to a 0.9-GHz electromagnetic field on postnatal days 21-45 may trigger the renin-angiotensin system in male rat: a histological and biochemical study**

Keleş Aİ, Kaya H, Keleş G, Erol HS, Mercantepe T, Odaci E. Exposure to a 0.9-GHz electromagnetic field on postnatal days 21-45 may trigger the renin-angiotensin system in male rat: a histological and biochemical study. J Mol Histol. 2024 Dec 4;56(1):22. doi: 10.1007/s10735-024-10317-y.

Abstract

The aim of this study was to examine the relationship between the renin-angiotensin system (RAS) and histological and biochemical changes occurring in the kidney tissue of male rats exposed to a 0.9 GHz electromagnetic field (EMF). Twelve male rats aged 21 days were randomly assigned to control (C-Gr) and EMF (EMF-Gr) groups. No procedure was performed on C-Gr, while the EMF-Gr rats were exposed to a 0.9 GHz EMF on postnatal days 21-45 (one hour a day for 25 days). Tissues were removed at the end of the experiment and evaluated using biochemical, and histopathological methods. Increased kidney tissue volume and weight and total body weight were determined in the group exposed to EMF. Lipid peroxidation, glutathione, catalase, and superoxide dismutase also increased in the kidney tissue of the EMF-Gr rats. Histopathological evaluation revealed cortical/medullary bleeding/obstruction and widespread fibrosis, dilatation, vacuolization, and degeneration in distal and proximal tubules, decreased and atypical parietal cells, and degeneration in epithelial cells. Additionally, dilated and degenerated glomeruli in the Malpighian body, Bowman's membrane degeneration and degeneration in the vascular pole, podocyte, pedicel and mesangial cells were also observed. As a result of exposure to EMF, oxidative stress, tissue volume and weight increased, and histopathological changes caused the formation of a pathway that triggers RAS in kidney tissues. In conclusion, long-term exposure to 0.9 GHz EMF can activate the renin-angiotensin system in the rat kidney, and we think that such activation may be associated with structural, histopathological, and biochemical changes occurring in renal tissue.

https://pubmed.ncbi.nlm.nih.gov/39627484/

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**Oxidative Stress and Energy Metabolism in Male Reproductive Damage from Single and Combined High-Power Microwave Exposure at 1.5 and 4.3Ghz**

Li Y, Yao B, Men J, Pang Y, Gao J, Bai Y, Wang H, Zhang J, Zhao L, Xu X, Dong J, Li C, Peng R. Oxidative Stress and Energy Metabolism in Male Reproductive Damage from Single and Combined High-Power

Microwave Exposure at 1.5 and 4.3Ghz. Reprod Toxicol. 2024 Nov 29:108759. doi: 10.1016/j.reprotox.2024.108759.

Abstract

The effect of multi-frequency electromagnetic environments on male reproduction has attracted the medical community's interest. Studies have investigated the effects and mechanisms of single-frequency microwave exposure on male reproduction, but comparative research on high-power microwave (HPM) composite and single exposure remains scarce. This study aimed to examine the effects and mechanisms of combined 1.5GHz and 4.3GHz microwave exposure on male reproduction. Male Wistar rats were exposed to 1.5GHz (L-band) and 4.3GHz (C-band) electromagnetic radiation for 15minutes. The four groups were: sham, 10mW/cm² L-band, 10mW/cm² C-band, and 5mW/cm² L-band and 5mW/cm² C-band compound. Assessments were made on the pathological structures of testes, sperm viability, serum sex hormones, oxidative stress, and energy metabolism levels after radiation. Exposure to 1.5GHz and 4.3GHz microwaves individually resulted in testicular tissue damage and reduced sperm quality. There was little difference between the damage caused by HPM composite and single exposure. The exposed groups showed histological and ultrastructural changes, with reduced spermatozoa viability, motility parameters, and serum testosterone, luteinizing hormone, follicle-stimulating hormone, and serum inhibin-B on days 1 and 7 after exposure. These tended to recover partially by day 14. Adenosine triphosphate content and lactate dehydrogenase and succinate dehydrogenase activities in the exposed testicular tissue decreased, corresponding to decreased superoxide dismutase activity and increased malondialdehyde content. Both single and combined exposure to L- and C-band HPM affect the male reproductive system. Exposure to single and compound HPM shows no significant difference in risks, with oxidative stress and energy metabolism disturbances playing key roles.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0890623824002260?via%3Dihub

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**Impact of exposure to extremely low-frequency magnetic fields on blood pressure, heart rate variation and disturbance to quality of sleep on industrial workers in Korea**

Amila Madhushanka Weerasinghe SDNAM, Liyanage S, Rajitha Kawshalya MAD, Hong SC. Impact of exposure to extremely low-frequency magnetic fields on blood pressure, heart rate variation and disturbance to quality of sleep on industrial workers in Korea. Int J Occup Saf Ergon. 2024 Nov 23:1-8. doi: 10.1080/10803548.2024.2413816.

Abstract

Objectives: This study investigates the potential health risks associated with exposure to extremely low-frequency magnetic fields (ELF-MFs), focusing on the impact on sleep quality. The hypothesis is that increasing ELF-MF exposure will correlate with elevated blood pressure (BP), altered heart rate (HR) dynamics and poorer sleep quality among occupational workers in Korea.

Methods: The study involved 85 participants. Assessment of ELF-MF exposure was carried out continuously for 24 h in the two groups. Measurements of BP parameters, HR and sleep quality were conducted accordingly.

Results: The study found significant ELF-MF exposure levels in both working and sleeping times for industrial factory workers (0.19 ± 0.38 and 0.17 ± 0.23 μT, $p < 0.05$). Long-term exposure among industrial workers may contribute to a significant difference in systolic blood pressure (SBP) (125.61 ± 9.60 mm Hg, $p < 0.05$). Additionally, a significant difference in deep sleep analysis was observed between the high-exposure and low-exposure groups (67.13 ± 31.15 min, $p < 0.05$).

Conclusion: The hypothesis was confirmed, indicating possible effects of high ELF-MF exposure on SBP and deep sleep. However, further research on long-term exposure and its association with sleep quality disturbances is needed for validation

Open access paper: https://www.tandfonline.com/doi/full/10.1080/10803548.2024.2413816

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**Biological issue of electromagnetic fields and waves**

Koyama S. Biological issue of electromagnetic fields and waves. Chapter 12 in Shinohara N. Wireless Power Transfer Technologies: Theory and Technologies (2nd edition). Aug 6, 2024.

Abstract

In the past few decades, the use of electromagnetic fields (EMF) has become prevalent throughout the world, and we no longer intend to stop using this technology. The widespread use of electromagnetic sources in daily life has induced an inevitable exposure to EMF. Recently, the rapid introduction of EMF has witnessed an upsurge in the use of EMF for telecommunication. Mobile phone use has become ubiquitous. Wireless communication devices emit nonionizing electromagnetic radiofrequency (RF) fields in the range of 300 MHz to 300 GHz, raising public concern regarding the increasing use of mobile phones and their potential health-related risks. The intermediate frequency (IF) EMF (300 Hz to 10 MHz) is also now widely used for wireless power transmission (WPT) or domestic kitchen appliances such as induction heating (IH) cooking. Unfortunately, although plenty of research has been conducted on RF, little information exists on the potential health effects associated with the exposure to IF magnetic fields. With growing concerns regarding the potential health hazards, it has become necessary to investigate the risks of IF magnetic fields in more detail.

12.5 Conclusions on IF and RF studies

A handful of cellular studies exist on IF exposure. The usage of IF is now spreading all over the world, and more devices are using this frequency. Although the research on IF is urgent, so far it seems that the low-power intensity of IF might not induce any adverse effects on the cellular response. However, no general conclusions can be drawn on this frequency range.

There are still contradictory results about the effects of exposure to RF on the cellular response. However, RF energy does not directly cleave intercellular DNA since most genotoxicity studies have indicated negative results. Some positive data at high SARs seem to relate mainly thermal effect by exposure to RF. Several interesting results of HSP and apoptosis should be validated shortly. Further studies on RF effects using improved biotechnological methods are warranted for precise conclusions.

https://doi.org/10.1049/PBPO256E_ch12

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**Fifty-hertz magnetic fields induce DNA damage through activating mPTP associated mitochondrial permeability transition in senescent human fetal lung fibroblasts**

Sun C, Wang S, Zhang J, Zhou X, Zhu T, Mao G. Fifty-hertz magnetic fields induce DNA damage through activating mPTP associated mitochondrial permeability transition in senescent human fetal lung fibroblasts. Biophysical Chemistry. Volume 318, 2025, doi: 10.1016/j.bpc.2024.107367.

Abstract

With the rapid development and using of electromagnetic technology, artificial electromagnetic fields (EMFs) have become an emerging environmental factor in our daily life. Extremely-low-frequency (ELF) magnetic fields (MFs), generally generated by power lines and various electric equipment, is one of the most common EMFs in the environment which were concerned for the potential impact on human health. Base on limited evidence, ELF-MFs have been classified as possible carcinogen to human by International Agency for Research on Cancer (IARC), but the mechanisms have not been fully elucidated. Senescent cells are a group of special cells, characterized by cell cycle arrest, senescence-associated secretory phenotype (SASP), accumulation of macromolecular damage, and metabolic disturbance, play important role in fetal development, tissue aging, and even carcinogenesis. Thus, EMFs may promote carcinogenesis by affecting senescent cells, however, there are few studies. In this study, we found that exposure to 50 Hz MFs at 1.0 mT for 24 h could induce significant DNA damage in senescent but not non-senescent human fetal lung fibroblast suggested that senescent cells are more sensitive to 50 Hz MFs on DNA damage, and further results revealed that reactive oxygen species (ROS) generation mediated by mitochondrial permeability transition pore (mPTP) activation play critical role in this process. Our results indicated that cellular senescence can lead to cell sensitivity to the DNA damage effect of 50 Hz MFs, however, whether this play important role in mediating the carcinogenesis of EMFs await further study.

https://www.sciencedirect.com/science/article/pii/S0301462224001960

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**Effects of electric fields on the release and content of extracellular vesicles**

Wang Y, Worrell GA, Wang HL. Effects of electric fields on the release and content of extracellular vesicles. J Extracell Biol. 2024 Nov 29;3(11):e70018. doi: 10.1002/jex2.70018.

Abstract

Extracellular vesicles (EVs) are small membrane-bound structures that originate from various cell types and carry molecular cargos to influence the behaviour of recipient cells. The use of EVs as biomarkers for diagnosis and as delivery vehicles for treatment in a wide range of human disease is a rapidly growing field in research and clinical practice. We hypothesized that electric fields (EFs) could influence the release and content of EVs. To examine this hypothesis, we developed a specialized bioreactor enabling cells to thrive in a three-dimensional setting, replicating in-vivo conditions amidst programmable EF environments. We established a three-step EV purification protocol to achieve high-density production

of EVs. We also performed mass spectrometry-based proteomics analysis on EV-carrying proteins and used high-resolution nanoparticle flowcytometry for single-vesicle analysis. Findings from this report suggest that electrical stimulation, employing physiologically relevant amplitudes typical in therapeutic deep brain stimulation, influences the release of EVs and their cargo content in a frequency-dependent fashion. This conclusion could carry significant implications for both fundamental biological understanding and medical advancements. First, it raises an intriguing question about how the endogenous electrical activity of neuronal and other cellular assemblies influence the production and composition of EVs. Second, it reveals a novel underlying mechanism of how therapeutic electrical stimulations can modulate EVs and treat human brain disorders. Third, it provides a novel approach to utilize electrical stimulation for generating desired EV cargos in a programmable setting.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC11605478/

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**Extremely low frequency magnetic fields (ELF-MF) in Switzerland: From exposure monitoring to daily exposure scenarios**

Loizeau N, Haas D, Zahner M, Stephan C, Schindler J, Gugler M, Fröhlich J, Ziegler T, Röösli M. Extremely low frequency magnetic fields (ELF-MF) in Switzerland: From exposure monitoring to daily exposure scenarios. Environment International. 2024. doi: 10.1016/j.envint.2024.109181.

Abstract

Exposure to extremely low frequency magnetic fields (ELF-MF) is ubiquitous in our daily environment. This study aims to provide a comprehensive overview of the ambient ELF-MF exposure in Switzerland and presents a novel environmental exposure matrix for exposure assessment and risk communication. Magnetic flux density levels (μT) were measured using a portable exposimeter carried in a backpack for the main ELF sources: railway power (16.7 Hz), domestic power (50 Hz), and tram ripple current (300 Hz). We collected ELF-MF levels between 2022 and 2024 in various environments representative of the Swiss population: 300 outdoor areas (e.g. city centres, residential areas), 245 public spaces (e.g. train stations, schools), 348 transport journeys (e.g. train, cars), and in 59 homes (e.g. bedrooms, living rooms). Over all environments, the highest ELF-MF exposure levels were measured in train stations (median: 0.48 μT), trains (median: 0.40 μT), and in living rooms near (<200 m) highest voltage lines of 220 kV and 380 kV (median: 0.37 μT). ELF-MF median levels measured two years apart showed high Pearson correlation coefficients in the same 150 outdoor areas (r = 0.88) and 86 public spaces (r = 0.87), without any significant changes. All measurements are well below the Swiss ambient regulatory limit based on the ICNIRP 1998 guidelines (median: 0.2 %). Finally, we derived an environmental exposure matrix and modelled 27 daily time-weighted average ELF-MF exposure scenarios by combining typical time spent at home, work and transport environments. People who do not live near highest voltage lines or work in highly exposed environments are typically exposed to less than 0.3 μT on average, while those who do are likely to exceed this level. This novel environmental exposure matrix is a useful tool for public communication and agent-based exposure modelling for future epidemiological research.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024007670

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**Biophysical mechanism of animal magnetoreception, orientation and navigation**

Panagopoulos DJ, Karabarbounis A, Chrousos GP. Biophysical mechanism of animal magnetoreception, orientation and navigation. Sci Rep. 2024 Dec 3;14(1):30053. doi: 10.1038/s41598-024-77883-9.

Abstract

We describe a biophysical mechanism for animal magnetoreception, orientation and navigation in the geomagnetic field (GMF), based on the ion forced oscillation (IFO) mechanism in animal cell membrane voltage-gated ion channels (VGICs) (IFO-VGIC mechanism). We review previously suggested hypotheses. We describe the structure and function of VGICs and argue that they are the most sensitive electromagnetic sensors in all animals. We consider the magnetic force exerted by the GMF on a mobile ion within a VGIC of an animal with periodic velocity variation. We apply this force in the IFO equation resulting in solution connecting the GMF intensity with the velocity variation rate. We show that animals with periodic velocity variations, receive oscillating forces on their mobile ions within VGICs, which are forced to oscillate exerting forces on the voltage sensors of the channels, similar or greater to the forces from membrane voltage changes that normally induce gating. Thus, the GMF in combination with the varying animal velocity can gate VGICs and alter cell homeostasis in a degree depending, for a given velocity and velocity variation rate, on GMF intensity (unique in each latitude) and the angle between velocity and GMF axis, which determine animal position and orientation.

Open access paper: https://www.nature.com/articles/s41598-024-77883-9

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**Relationship between radiofrequency-electromagnetic radiation from cellular phones and brain tumor: meta-analyses using various proxies for RF-EMR exposure-outcome assessment**

**My Note:** The journal *Environmental Health* published a systematic review and meta-analytic study on cell phone use and brain tumor risk by Moon et al. (2024). The study found significantly elevated risks for three types of brain tumors when examining tumors on the side of the head where cell phones were held and for heavy, long-term cell phone use.

Six other systematic reviews and meta-analyses of case-control studies published in peer-reviewed journals since 2016 have also found significant associations between heavy, long-term cellphone use and brain tumor risk (Wang & Guo, 2016; Bortkiewicz et al., 2017; Carlberg & Hardell, 2017; Prasad et al., 2017, Yang et al., 2017; Choi et al., 2020).

**These seven peer-reviewed meta-analytic studies contradict the conclusion of the recent WHO systematic review conducted by Karipidis et al. (2024) that there is no evidence cell phone use causes brain cancer. To learn about serious problems with the WHO systematic reviews on the health effects of radiofrequency radiation see:**

**Biased WHO-commissioned review claims no cancer link to cellphone use**

**WHO Radiofrequency EMF Health Risk Assessment Monograph (EHC series)**

References

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Yang et al (2017). Mobile phone use and glioma risk: A systematic review and meta-analysis. *PLOS One*. https://bit.ly/3U0kafd

Choi, Moskowitz, et al (2020). Cellular phone use and risk of tumors: Systematic review and meta-analysis. *Int J Envir Res Public Health*. https://doi.org/10.3390/ijerph17218079.

Karipidis et al. (2020). The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies - Part I: Most researched outcomes. *Environ Int.* https://doi.org/10.1016/j.envint.2024.108983

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Moon J, Kwon J, Mun Y. Relationship between radiofrequency-electromagnetic radiation from cellular phones and brain tumor: meta-analyses using various proxies for RF-EMR exposure-outcome assessment. *Environ Health* **23**, 82 (2024). https://doi.org/10.1186/s12940-024-01117-8.

Abstract

Introduction

The authors conducted meta-analyses regarding the association between cellular and mobile phone use and brain tumor development by applying various radiofrequency-electromagnetic radiation (RF-EMR) exposure subcategories. With changing patterns of mobile phone use and rapidly developing Wireless Personal Area Network (WPAN) technology (such as Bluetooth), this study will provide insight into the importance of more precise exposure subcategories for RF-EMR.

Methods

The medical librarian searched MEDLINE (PubMed), EMBASE, and the Cochrane Library until 16 December 2020.

Results

In these meta-analyses, 19 case-control studies and five cohort studies were included. Ipsilateral users reported a pooled odds ratio (OR) of 1.40 (95% CI 1.21–1.62) compared to non-regular users. Users with years of use over 10 years reported a pooled OR of 1.27 (95% CI 1.08–1.48). When stratified by each type of brain tumor, only meningioma (OR 1.20 (95% CI 1.04–1.39)), glioma (OR 1.45 (95% CI 1.16–1.82)), and malignant brain tumors (OR 1.93 (95% CI 1.55–2.39)) showed an increased OR with statistical significance for ipsilateral users. For users with years of use over 10 years, only glioma (OR 1.32 (95% CI 1.01–1.71)) showed an increased OR with statistical significance. When 11 studies with an OR with cumulative hours of use over 896 h were synthesized, the pooled OR was 1.59 (95% CI 1.25–2.02). When stratified by each type of brain tumor, glioma, meningioma, and acoustic neuroma reported the pooled

OR of 1.66 (95% CI 1.13–2.44), 1.29 (95% CI 1.08–1.54), and 1.84 (95% CI 0.78–4.37), respectively. For each individual study that considered cumulative hours of use, the highest OR for glioma, meningioma, and acoustic neuroma was 2.89 (1.41–5.93) (both side use, > 896 h), 2.57 (1.02–6.44) (both side use, > 896 h), and 3.53 (1.59–7.82) (ipsilateral use, > 1640 h), respectively. For five cohort studies, the pooled risk ratios (RRs) for all CNS tumors, glioma, meningioma, and acoustic neuroma, were statistically equivocal, respectively. However, the point estimates for acoustic neuroma showed a rather increased pooled RR for ever-use (1.26) and over 10 years of use (1.61) compared to never-use, respectively.

Excerpts

“In consideration of these rapidly changing mobile phone technologies, the currently used proxies for RF-EMR exposure assessment are crude and insufficient to clarify the relationship between RF-EMR exposure from cell phones and brain tumor incidence.... The usual exposure measures, such as the years of mobile phone use, the cumulative duration of calls, and the number of calls per week, are rough indicators of mobile phone use.... the authors conducted a series of meta-analyses and subgroup analyses using various exposure measuring categories, from crude to more precise ones. In consideration of crude exposure classifications used in previous meta-analyses, this study will give insight into the importance of more precise exposure subcategories in investigating this topic."

"... the authors analyzed the risk of bias regarding selection and recall bias for the amount of cell phone use and misclassification and recall bias for ipsilateral/contralateral use. A major reason was that typical risk of bias rating tools such as the National Toxicology Program Office of Health Assessment and Translation Risk of Bias rating tool (NTP OHAT RoB rating tool, Supplementary material B) were not appropriate for assessing individual studies regarding this topic." [Note: The WHO systematic reviews relied on this rating tool.]

"With the conversion from 2G cellular phones through 3G and 4G mobile phones to current 5G mobile phones, transmission of large data became possible. With the introduction of 3G technology, all aspects of our society and daily lives have changed drastically. Currently, we are using mobile phones nearly continuously and putting mobile phones near our bodies even when we are not using them. For example, if people use their mobile phone for morning-alarming purposes, they might put their mobile phone near the bed, sometimes even beside their head, all night. These changed patterns of mobile phone use could increase exposure to RF-EMR from cellular and mobile phones. Therefore, precise exposure assessment for RF-EMR from mobile phones would become more complex in future studies."

"The results of cumulative meta-analyses according to precision indicated that the pooled OR was biased downwards with the addition of studies with lower precision. This indicates that the results of studies with a lower precision should be interpreted cautiously."

"Because brain tumors require a latency period to develop [29], an accurate assessment of brain tumor risk associated with RF-EMR exposure requires a long observation span. However, each included study did not consider a sufficient latency period in their study design. This could have led to a possible underestimation of brain tumor risk. Future studies with long observation spans might resolve this problem.”

"In this meta-analysis, as the applied exposure subcategories became more concrete, the pooled ORs showed more increased values with statistical significance. Even though the meta-analysis of cohort

studies showed statistically equivocal pooled effect estimates, (i) as the number of included studies increases and (ii) as the applied exposure subcategory becomes more concrete, the pooled RRs could show a different aspect in future studies. Furthermore, changing patterns of mobile phone use and increasing use of earphones or headphones with WPAN technology should be sufficiently considered in future studies. Relatively short observation spans for brain tumor incidence and age of starting exposure and brain tumor diagnosis should also be considered in future studies. Previous studies that adjusted for selection and recall bias for the amount of cellphone use and misclassification and recall bias for ipsilateral/contralateral use showed possible underestimations of previous risk estimates. Future studies should try to adjust for these biases in their study design."

Open access paper: https://ehjournal.biomedcentral.com/articles/10.1186/s12940-024-01117-8

Supplementary material: https://static-content.springer.com/esm/art%3A10.1186%2Fs12940-024-01117-8/MediaObjects/12940_2024_1117_MOESM1_ESM.docx

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**Electromagnetic fields of cellular communication as risk factors able to produce negative effects on the central nervous system of children and adolescents (review)**

Khorseva NI, Grigoriev PE. Electromagnetic fields of cellular communication as risk factors able to produce negative effects on the central nervous system of children and adolescents (review). Part 1. Modeling. Parameters of electroencephalography and sensorimotor reactions. Health Risk Analysis, 2024, no. 2, pp. 162–169. doi: 10.21668/health.risk/2024.2.15.eng.

Abstract

It is quite relevant to investigate possible outcomes of exposure to radio frequency electromagnetic fields (RF EMF) since contemporary children and adolescents have become active users of the most advanced technologies. They are especially susceptible to electromagnetic factors; therefore, it is necessary to have a proper insight into outcomes of such exposures for the body.

The central nervous system (CNS) is one of the main targets under exposure to RF EMF. In most cases, users hold mobile phones close to their heads thereby directly exposing their brains to RF EMF.

As the analysis of literature data has shown, there are few studies in this area; however, proposed options for assessing the impact of RF EMF on children and adolescents are very diverse.

This part of the review focuses on various types of modeling. These are not only phantom, voxel models or the finite difference method but also new approaches such as distribution matrices, Monte Carlo simulations and an integrated radio frequency model based on the results of magnetic resonance imaging of the brain and other methods.

The review provides the results obtained by investigating encephalography under exposure to RF EMF created by mobile communication devices. They are rather contradictory; however, changes in the bioelectrical activity of the brain are detected in most cases, in particular, a decrease in the alpha rhyme.

Since the characteristics of sensorimotor reactions quite clearly reflect the power relations in the cerebral cortex, we analyzed changes in the parameters of simple auditory-motor and visual-motor reactions in children and adolescents who were mobile communication users. In addition, the review covers the results of changes in working capacity, fatigue, the duration of an individual minute and the reproduction of a given rhythm.

Open access paper: health-risk-analysis-2024-2-15.pdf

**Assessing the risk of negative effects produced by electromagnetic fields of cellular communication on the central nervous system of children and adolescents (review). Part 2. Indicators of cognitive processes**

Khorseva NI, Grigoriev PE. Assessing the risk of negative effects produced by electromagnetic fields of cellular communication on the central nervous system of children and adolescents (review). Part 2. Indicators of cognitive processes. Health Risk Analysis, 2024, no. 3, pp. 146–154. doi: 10.21668/health.risk/2024.3.15.eng

Abstract

This paper continues the authors' review that dwells on modeling radiofrequency electromagnetic fields (RF EMF) and results obtained by measuring electroencephalography indicators, sensorimotor reactions, fatigue, work capacity, duration of an individual minute and the reproduction of a given rhythm in children and adolescents.

Health risk assessment is always based on data obtained by either laboratory tests or epidemiological studies. This paper analyses publications that describe effects of RF EMF exposure, including Wi-Fi, on cognitive processes in children and adolescents as well as methodical approaches to investigating this exposure. However, there are few such studies; in particular, effects produced by Wi-Fi exposure on cognitive indicators of adolescents aged 14–17 years, were found only in two publications.

Literature analysis has established that research findings do not always give an unambiguous estimation of RF EMF effects. The review covers the reasons for ambiguous interpretation of research results: a variable range of test-systems used for investigating indicators of cognitive processes; simultaneous analysis of single exposures including descriptions of 'effect of improvement' in indicators; changes in cognitive indicators registered for a group of children and adolescents in a wide age range.

Nevertheless, most results give evidence of negative changes in attention and memory of children and adolescents. Given that, longitudinal studies are becoming especially relevant since they estimate changes in various indicators in dynamics, including those induced by changes in mobile phone use. The review highlights the relevance of comprehensive investigations with their focus on health outcomes of RF EMF exposure intrinsic to 5G technologies considering their global implementation.

Open access paper: https://journal.fcrisk.ru/eng/2024/3/15

Russian version: https://journal.fcrisk.ru/sites/journal.fcrisk.ru/files/upload/article/787/health-risk-analysis-2024-3-15.pdf

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**Autonomous nervous system responses to environmental-level exposure to 5G's first deployed band (3.5 GHz) in healthy human volunteers**

Jamal L, Michelant L, Delanaud S, Hugueville L, Mazet P, Lévêque P, Baz T, Bach V, Selmaoui B. Autonomous nervous system responses to environmental-level exposure to 5G's first deployed band (3.5 GHz) in healthy human volunteers. Exp Physiol. 2024 Oct 15. doi: 10.1113/EP092083.

Abstract

Following the global progressive deployment of 5G networks, considerable attention has focused on assessing their potential impact on human health. This study aims to investigate autonomous nervous system changes by exploring skin temperature and electrodermal activity (EDA) among 44 healthy young individuals of both sexes during and after exposure to 3.5 GHz antenna-emitted signals, with an electrical field intensity ranging from 1 to 2 V/m. The study employed a randomized, cross-over design with triple-blinding, encompassing both 'real' and 'sham' exposure sessions, separated by a maximum interval of 1 week. Each session comprised baseline, exposure and postexposure phases, resulting in the acquisition of seven runs. Each run initiated with a 150 s segment of EDA recordings stimulated by 10 repeated beeps. Subsequently, the collected data underwent continuous decomposition analysis, generating specific indicators assessed alongside standard metrics such as trough-to-peak measurements, global skin conductance and maximum positive peak deflection. Additionally, non-invasive, real-time skin temperature measurements were conducted to evaluate specific anatomical points (hand, head and neck). The study suggests that exposure to 3.5 GHz signals may potentially affect head and neck temperature, indicating a slight increase in this parameter. Furthermore, there was a minimal modulation of certain electrodermal metrics after the exposure, suggesting a potentially faster physiological response to auditory stimulation. However, while the results are significant, they remain within the normal physiological range and could be a consequence of an uncontrolled variable. Given the preliminary nature of this pilot study, further research is needed to confirm the effects of 5G exposure.

Open access paper: https://physoc.onlinelibrary.wiley.com/doi/10.1113/EP092083

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**Does radiofrequency radiation impact sleep? A double-blind, randomised, placebo-controlled, crossover pilot study**

Bijlsma N, Conduit R, Kennedy G, Cohen M. Does radiofrequency radiation impact sleep? A double-blind, randomised, placebo-controlled, crossover pilot study. Front Public Health. 2024 Oct 29;12:1481537. doi: 10.3389/fpubh.2024.1481537.

Abstract

The most common source of Radiofrequency Electromagnetic Field (RF-EMF) exposures during sleep includes digital devices, yet there are no studies investigating the impact of multi-night exposure to electromagnetic fields emitted from a baby monitor on sleep under real-world conditions in healthy adults. Given the rise in the number of people reporting to be sensitive to man-made electromagnetic fields, the ubiquitous use of Wi-Fi enabled digital devices and the lack of real-world data, we investigated the effect of 2.45 GHz radiofrequency exposure during sleep on subjective sleep quality, and objective sleep measures, heart rate variability and actigraphy in healthy adults. This pilot study was

a 4-week randomised, double-blind, crossover trial of 12 healthy adults. After a one-week run-in period, participants were randomised to exposure from either an active or inactive (sham) baby monitor for 7 nights and then crossed over to the alternate intervention after a one-week washout period. Subjective and objective assessments of sleep included the Pittsburgh Insomnia Rating Scale (PIRS-20), electroencephalography (EEG), actigraphy and heart rate variability (HRV) derived from electrocardiogram. Sleep quality was reduced significantly ($p < 0.05$) and clinically meaningful during RF-EMF exposure compared to sham-exposure as indicated by the PIRS-20 scores. Furthermore, at higher frequencies (gamma, beta and theta bands), EEG power density significantly increased during the Non-Rapid Eye Movement sleep ($p < 0.05$). No statistically significant differences in HRV or actigraphy were detected. Our findings suggest that exposure to a 2.45 GHz radiofrequency device (baby monitor) may impact sleep in some people under real-world conditions; however, further large-scale real-world investigations with specified dosimetry are required to confirm these findings.

Open access paper:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1481537/full

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**A review on the consequences of molecular & genomic alterations following exposure to EMF: Remodeling of neuronal network & cognitive changes**

Abtin S, Seyedaghamiri F, Aalidaeijavadi Z, Farrokhi AM, Moshrefi F, Ziveh T, Zibaii MI, Aliakbarian H, Rezaei-Tavirani M, Haghparast A. A review on the consequences of molecular and genomic alterations following exposure to electromagnetic fields: Remodeling of neuronal network and cognitive changes. Brain Research Bulletin, Volume 217, 2024. doi: 10.1016/j.brainresbull.2024.111090.

Abstract

The use of electromagnetic fields (EMFs) is essential in daily life. Since 1970, concerns have grown about potential health hazards from EMF. Exposure to EMF can stimulate nerves and affect the central nervous system, leading to neurological and cognitive changes. However, current research results are often vague and contradictory. These effects include changes in memory and learning through changes in neuronal plasticity in the hippocampus, synapses and hippocampal neuritis, and changes in metabolism and neurotransmitter levels. Prenatal exposure to EMFs has negative effects on memory and learning, as well as changes in hippocampal neuron density and histomorphology of hippocampus. EMF exposure also affects the structure and function of glial cells, affecting gate dynamics, ion conduction, membrane concentration, and protein expression. EMF exposure affects gene expression and may change epigenetic regulation through effects on DNA methylation, histone modification, and microRNA biogenesis, and potentially leading to biological changes. Therefore, exposure to EMFs possibly leads to changes in cellular and molecular mechanisms in central nervous system and alter cognitive function.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0361923024002247

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**Impact of non-ionising radiation of male fertility: a systematic review**

Motchidlover L, Sari-Minodier I, Sunyach C, Metzler-Guillemain C, Perrin J. Impact of non-ionising radiation of male fertility: a systematic review. French Journal of Urology. 35(1), 2025, doi: 10.1016/j.fjurol.2024.102800.

Abstract

Exposure to non-ionizing radiation has become inevitable because people cannot escape sources of electromagnetic fields, such as Wi-Fi or cell phones. Among the mechanisms mentioned, the energy emitted by this non-ionizing radiation could cause heating which would have harmful effects on semen quality. The objective of our study was to carry out a systematic review of the literature concerning the impact of exposure to non-ionizing radiation from mobile phones (or other sources) on sperm parameters. We selected 12 studies: the majority of in vivo studies in humans and in vitro studies in animals report a significant impact on sperm count, mobility and vitality. Mobility and vitality seem to be the parameters most regularly impacted by exposure to non-ionizing radiation. Additional studies are necessary to complete this study in order to deepen knowledge with new generations of mobile phones which can raise health concerns.

https://www.sciencedirect.com/science/article/pii/S2950393024002675

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**Exposure to Radiofrequency Electromagnetic Fields Enhances Melanin Synthesis by Activating the P53 Signaling Pathway in Mel-Ab Melanocytes**

Kim JH, Kang D-J, Seok JY, Kim M-H, Kim D-S, Jeon S-B, Choi H-D, Moon JI, Kim N, Kim HR. Exposure to Radiofrequency Electromagnetic Fields Enhances Melanin Synthesis by Activating the P53 Signaling Pathway in Mel-Ab Melanocytes. *International Journal of Molecular Sciences*. 2024; 25(22):12457. https://doi.org/10.3390/ijms252212457

Abstract

The skin is the largest body organ that can be physiologically affected by exposure to radiofrequency electromagnetic fields (RF-EMFs). We investigated the effect of RF-EMFs on melanogenesis; Mel-Ab melanocytes were exposed to 1760 MHz radiation with a specific absorption rate of 4.0 W/kg for 4 h/day over 4 days. Exposure to the RF-EMF led to skin pigmentation, with a significant increase in melanin production in Mel-Ab melanocytes. The phosphorylation level of cAMP response element binding protein (CREB) and the expression of microphthalmia-associated transcription factor (MITF), which regulate the expression of tyrosinase, were significantly increased in Mel-Ab after RF-EMF exposure. Interestingly, the expression of tyrosinase was significantly increased, but tyrosinase activity was unchanged in the RF-EMF-exposed Mel-Ab cells. Additionally, the expression of p53 and melanocortin 1 receptor (MC1R), which regulate MITF expression, was significantly increased. These results suggest that the RF-EMF induces melanogenesis by increasing phospho-CREB and MITF activity. Importantly, when Mel-Ab cells were incubated at 38 °C, the melanin production and the levels of tyrosinase significantly decreased, indicating that the increase in melanin synthesis by RF-EMF exposure is not due to a thermal effect. In conclusion, RF-EMF exposure induces melanogenesis in Mel-Ab cells

through the increased expression of tyrosinase via the activation of MITF or the phosphorylation of CREB, which are initiated by the activation of p53 and MC1R.

Conclusion: In summary, we have shown that 1760 MHz RF-EMF exposure (SAR of 4.0 W/kg for 4 h/d over 4 d) could induce hyperpigmentation by activating the melanin synthesis pathway in Mel-Ab melanocytes, suggesting that skin pigmentation could be affected by RF-EMF exposure in a way that is distinct from simple thermal effects.

Open access paper: https://www.mdpi.com/1422-0067/25/22/12457

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**Genotoxicity of radiofrequency electromagnetic fields on mammalian cells in vitro: A systematic review with narrative synthesis**

My note: This is not one the ten systematic reviews commissioned by the WHO. Nonetheless, this review of *in vitro* studies dismisses most evidence of adverse effects from RF-EMF.

"Genotoxicity, a key characteristic of human carcinogens (Smith et al. 2016), is one of the most investigated outcomes in experimental studies on the effects of RF-EMF (SCHEER 2023). However, none of the ten systematic reviews commissioned by the World Health Organization (WHO) in the framework of an updated RF-EMF hazard and risk assessment, deals with this topic (Verbeek et al. 2021)."

Romeo S, Sannino A, Scarfì MR, Lagorio S, Zeni O. Genotoxicity of radiofrequency electromagnetic fields on mammalian cells in vitro: A systematic review with narrative synthesis. Environment International, 2024, doi: 10.1016/j.envint.2024.109104.

Abstract

Background: Over the last decades, great concern has been raised about possible adverse effects to human health due to exposures to radiofrequency electromagnetic fields (RF-EMF, 100 kHz – 300 GHz) emitted by wireless communication technologies. In 2011 the International Agency for Research on Cancer classified RF-EMF as possibly carcinogenic to humans, highlighting that the evidence was weak and far from conclusive. Updated systematic reviews of the scientific literature on this topic are lacking, especially for mechanistic studies.

Objectives: To perform a systematic review of the scientific literature on genotoxic effects induced by RF-EMF in in vitro experimental models. The overall aim is to assess the confidence and level of evidence of the induced effects in mammalian cell cultures.

Methods: Full details regarding the eligibility criteria, information sources, and methods developed to assess risk of bias in the included study, are reported in our published protocol (Romeo et al. 2021). The databases NCBI PubMed, Web of Science, and EMF-Portal were used as information sources (last searched on 31st December 2022). In developing the systematic review, we followed the guidelines provided by the National Toxicology Program-Office of Health Assessment and Translation (NTP-OHAT), adapted to the evaluation of in vitro studies. A narrative synthesis of the body of evidence was performed by tabulating data classified according to meaningful groups (endpoints) and sub-groups (exposure parameters). This report, abstract included, conforms to the PRISMA 2020 (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines.

Results: Out of 7750 unique records identified, 159 articles were eligible for inclusion. From the extracted data, we identified 1111 experiments (defined as independent specific combinations of diverse biological and electromagnetic parameters). The large majority (80%) of experiments reviewed did not show statistically significant genotoxic effects of RF-EMF exposures, and most "positive" studies were rated as of moderate to low quality, with negative ratings in the key bias domains. A qualitative evidence appraisal was conducted at the endpoint level, and then integrated across endpoints.

Discussion: To the best of our knowledge, this is the first systematic review of the scientific literature on genotoxic effects in mammalian cell cultures in relation to RF-EMF exposure, which confirms and strengthens conclusions from previous syntheses of this specific topic thanks to the use of transparently reported methods, pre-defined inclusion criteria, and formal assessment of susceptibility to bias. Limitations of the evidence included were the frequent reporting of findings in graphical display only, and the large heterogeneity of experimental data, which precluded a meta-analysis.

Conclusions: In the assessment restricted to studies reporting a significant effect of the exposure on the outcome, we reached an overall assessment of "low" confidence in the level of evidence that RF-EMF induce genotoxic effects in mammalian cells However, 80% of experiments reviewed showed no effect of RF exposure on the large majority of endpoints, especially the irreversible ones, independently of the exposure features, level, and duration (moderate evidence of no effect). Therefore, we conclude that the analysis of the papers included in this review, although only qualitative, suggests that RF exposure does not increase the occurrence of genotoxic effects in vitro.

Framework and funding: This systematic review addresses one of the evidence streams considered in a larger systematic review of the scientific literature on the potential carcinogenicity of RF-EMF, performed by scientists from several Italian public research agencies. The project is supported by the Italian Workers' Compensation Authority (INAIL) in the framework of the CRA with the Istituto Superiore di Sanità "BRiC 2018/06 – Scientific evidence on the carcinogenicity of electromagnetic fields".

Excerpt

Conclusions

The main conclusion of our systematic analysis is that the certainty of evidence for genotoxic effects of RF-EMF in mammalian cell cultures is weak. No genotoxic effects of RF exposure were observed in most experiments, especially those concerning irreversible endpoints, independently of the exposure features, level, and duration (moderate evidence of no effect). In the whole, we conclude that the analysis of the papers included in this review, although only qualitative, suggests that RF exposure does not increase the occurrence of genotoxic effects *in vitro*, also considering that the absence of significant effects prevails among the studies classified in tier-1 and tier-2 categories, whereas for the tier-3 studies the trend is reversed, highlighting how methodological quality affects the studies outcome (Simko et al. 2016).

This systematic review may provide support to panels of experts involved in policy making regarding safety of exposure to RF-EMF.

Furthermore, it is possible to state that, although the number of publications on this topic has considerably increased in recent years, this has not translated into an improvement of the experimental quality. Only a small number of the reviewed studies qualified for inclusion in the tier 1 category, while most of them, including those of moderate quality, still present considerable criticalities in key experimental features (use of sham samples, adequate dosimetry, exposure to a uniformly distributed electromagnetic field, appropriateness of biological methods, presence of positive control and outcome analysis blind to the exposure). It is evident that methodological quality is demanded for future research into this field, which will aim at producing sufficiently similar and unbiased data to be aggregated in meaningful categories.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024006901?via%3Dihub

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**The role of digital device use on the risk of migraine: a univariable and multivariable Mendelian randomization study**

He Z, Qiu F, Yang J, Zhao M. The role of digital device use on the risk of migraine: a univariable and multivariable Mendelian randomization study. Front Neurol. 2024 Oct 30;15:1462414. doi: 10.3389/fneur.2024.1462414.

Abstract

Background: The pervasive integration of digital devices into daily life has raised concerns about their potential health impacts. This study aimed to explore the causal relationships between digital device use and the risk of migraine using Mendelian randomization (MR).

Methods: Genetic data on digital device use and migraines were sourced from large-scale genome-wide association studies conducted by the UK Biobank, the FinnGen study, and the International Headache Genetics Consortium. Univariable MR (UVMR), meta-analysis, and multivariable MR (MVMR) approaches were conducted to explore and verify the causal effects of digital device use (including mobile phone use, computer use, playing computer games, and watching television) on migraine risk. Sensitivity analyses were conducted using Cochran's Q, MR-Egger intercept test, MR pleiotropy residual sum and outlier, MR Radial, MR Steiger, and leave-one-out methods.

Results: UVMR analyses revealed that genetically predicted mobile phone use was significantly associated with an increased risk of overall migraine (odds ratio [OR] = 2.39, $p$ = 9.78e-5) and migraine without aura (MO) (OR = 2.25, $p$ = 0.024). Additionally, there were significant positive associations between genetically predicted television watching and the risk of overall migraine (OR = 1.63, $p$ = 2.12e-5) and MO (OR = 2.10, $p$ = 4.98e-5). These results were further supported by the meta-analysis and MVMR analysis. Sensitivity analysis indicated no heterogeneity or pleiotropy.

Conclusion: This comprehensive MR study provides preliminary evidence for the causal impact of mobile phone use and television watching on the risk of migraines. Further studies are needed to explore these associations across different populations.

Open access paper:
https://www.frontiersin.org/journals/neurology/articles/10.3389/fneur.2024.1462414/full

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**The Effect of Exposure to Mobile Phones on Electrical Cardiac Measurements: A Multivariate Analysis and a Variable Selection Algorithm to Detect the Relationship With Mean Changes**

Alharbi N, Alassiri M. The Effect of Exposure to Mobile Phones on Electrical Cardiac Measurements: A Multivariate Analysis and a Variable Selection Algorithm to Detect the Relationship With Mean Changes. Int J Cell Biol. 2024 Oct 3;2024:7093771. doi: 10.1155/2024/7093771.

Background: The exponential growth in mobile phone usage has raised concerns about electromagnetic field (EMF) exposure and its health risks. Blood pressure and BMI, which impair heart function due to decreased adrenoreceptor responsiveness, parasympathetic tone withdrawal, and increased sympathetic activity, may further exacerbate these risks. However, the effects of radiofrequency electromagnetic (RF-EM) exposure from mobile phones on electrocardiograms (ECGs) and heart rate variability (HRV) in individuals remain unclear.

Purpose: Building upon our previous findings on HRV changes due to mobile phone proximity, this study is aimed at significantly enhancing the analytical approach used to assess the effects of mobile phones on cardiac parameters. This study exploits data from a previous study but with a different purpose. The aim of this study is twofold: (a) to examine whether exposure to mobile phones changes the five variables (P-R, QRS, QT, ST, and HR) in a multivariate manner and (b) to examine whether the blood pressure and/or the body mass index (BMI), which acts as a proxy for obesity, have an effect on the change of these five variables. For both aspects of the study, four cycles are performed.

Method: We conducted multivariate analysis on previously collected electrical cardiac measurement data from 20 healthy male subjects exposed to mobile phone EMF, with the mobile phones placed at four different body locations. The one-sample Hotelling T 2 test on the mean vector of differences was utilised instead of multiple paired t-tests. This multivariate method comprehensively analyzes data features and accounts for variable correlations, unlike multiple univariate analyses. Given our small sample size, we employed the MMPC variable selection algorithm to identify predictor variables significantly related to mean changes.

Results: Significant alterations in ECG intervals and heart rate were noted in the subjects before and after the first EMF exposure cycle, independent of their BMI. Notably, heart rate, P-R, and QRS intervals fell postexposure while QT and ST intervals increased. These changes were influenced by variations in systolic blood pressure, with BMI showing no significant effect.

Conclusion: The observed modifications in cardiac electrical measurements due to mobile phone EMF exposure are attributed to the effects of EMF itself, with no impact from BMI on the extent of these changes.

https://regulatoryinfo.apple.com/rfexposure/iphone5,1/en

Open access paper: https://onlinelibrary.wiley.com/doi/10.1155/2024/7093771

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**Use of Mobile Phones and Radiofrequency-Emitting Devices in the COSMOS-France Cohort**

Deltour I, Guida F, Ribet C, Zins M, Goldberg M, Schüz J. Use of Mobile Phones and Radiofrequency-Emitting Devices in the COSMOS-France Cohort. *International Journal of Environmental Research and Public Health*. 2024; 21(11):1514. doi: 10.3390/ijerph21111514.

Abstract

COSMOS-France is the French part of the COSMOS project, an international prospective cohort study that investigates whether the use of mobile phones and other wireless technologies is associated with health effects and symptoms (cancers, cardiovascular diseases, neurologic pathologies, tinnitus, headaches, or sleep and mood disturbances). Here, we provide the first descriptive results of COSMOS-France, a cohort nested in the general population-based cohort of adults named Constances.

Methods: A total of 39,284 Constances volunteers were invited to participate in the COSMOS-France study during the pilot (2017) and main recruitment phase (2019). Participants were asked to complete detailed questionnaires on their mobile phone use, health conditions, and personal characteristics. We examined the association between mobile phone use, including usage for calls and Voice over Internet Protocol (VoIP), cordless phone use, and Wi-Fi usage with age, sex, education, smoking status, body mass index (BMI), and handedness.

Results: The participation rate was 48.4%, resulting in 18,502 questionnaires in the analyzed dataset. Mobile phone use was reported by 96.1% (N = 17,782). Users reported typically calling 5–29 min per week (37.1%, N = 6600), making one to four calls per day (52.9%, N = 9408), using one phone (83.9%, N = 14,921) and not sharing it (80.4% N = 14,295), mostly using the phone on the side of the head of their dominant hand (59.1%, N = 10,300), not using loudspeakers or hands-free kits, and not using VoIP (84.9% N = 15,088). Individuals' age and sex modified this picture, sometimes markedly. Education and smoking status were associated with ever use and call duration, but neither BMI nor handedness was. Cordless phone use was reported by 66.0% of the population, and Wi-Fi use was reported by 88.4%.

Conclusion: In this cross-sectional presentation of contemporary mobile phone usage in France, age and sex were important determinants of use patterns.

Open access paper: https://www.mdpi.com/1660-4601/21/11/1514

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**Effects of 1800 MHz and 2100 MHz mobile phone radiation on the blood-brain barrier of New Zealand rabbits**

Kizilçay AO, Tütüncü B, Koçarslan M, Gözel MA. Effects of 1800 MHz and 2100 MHz mobile phone radiation on the blood-brain barrier of New Zealand rabbits. Med Biol Eng Comput. 2024 Nov 16. doi: 10.1007/s11517-024-03238-1.

Abstract

In this study, the impact of mobile phone radiation on blood-brain barrier (BBB) permeability was investigated. A total of 21 New Zealand rabbits were used for the experiments, divided into three groups, each consisting of 7 rabbits. One group served as the control, while the other two were exposed to electromagnetic radiation at frequencies of 1800 MHz with a distance of 14.5 cm and 2100 MHz with a distance of 17 cm, maintaining a constant power intensity of 15 dBm, for a duration equivalent to the current average daily conversation time of 38 min. The exposure was conducted under non-thermal conditions, with RF radiation levels approximately ten times lower than normal values. Evans blue (EB) dye was used as a marker to assess BBB permeability. EB binds to plasma proteins, and its presence in brain tissue indicates a disruption in BBB integrity, allowing for a quantitative evaluation of radiation-induced permeability changes. Left and right brain tissue samples were analyzed using trichloroacetic acid (TCA) and phosphate-buffered solution (PBS) solutions to measure EB amounts at 620 nm via spectrophotometry. After the experiments, BBB tissue samples were collected from the right and left brains of all rabbits in the three groups and subjected to a series of medical procedures. Samples from Group 1 were compared with those from Group 2 and Group 3 using statistical methods to determine if there were any significant differences. As a result, it was found that there was no statistically significant difference in the BBB of rabbits exposed to 1800 MHz radiation, whereas there was a statistically significant difference at a 95% confidence level in the BBB of rabbits exposed to 2100 MHz radiation. A decrease in EB values was observed upon the arithmetic examination of the BBB.

https://pubmed.ncbi.nlm.nih.gov/39548043/

Excerpts

When compromised, the BBB is linked to neurological disorders such as Alzheimer's disease, stroke, and multiple sclerosis, leading researchers to develop models for in vitro studies of its mechanisms [9, 10]. However, BBB permeability can be influenced by various factors, including pathological conditions, multiple sclerosis, stroke, and diabetes, as well as exposure to ionizing and non-ionizing radiation [11]. For instance, radiofrequency (RF) radiation has been shown to increase BBB permeability, allowing normally excluded substances to penetrate the brain, potentially impacting neurological health [5]. Furthermore, ultra-wideband electromagnetic pulses have demonstrated the ability to disrupt BBB integrity in animal models [8]....

The two primary frequencies utilized in contemporary mobile telecommunications, 1800 MHz and 2100 MHz, have garnered substantial attention due to their widespread application in cellular networks worldwide [13, 14]. For example, in ref. [15], it has been demonstrated that radiation from mobile phones at 900, 1800, and 2100 MHz frequencies can increase oxidative damage in the frontal lobes of rat brain tissues, an increase in lipid peroxidation, and oxidative DNA damage. Additionally, exposure to 2100 MHz radiofrequency radiation has been shown to induce single-strand breaks in DNA. In ref. [16], it was observed and presented that exposure to 900–1800 MHz radiation caused oxidative stress in the tissues of pregnant mothers and their offspring. In ref. [17], it has been observed that radiofrequency radiation at 2100 MHz can damage the nasal septal mucosa and disrupt mucociliary clearance in rats. While numerous studies have explored the biological effects of radiofrequency radiation, the specific impact of these frequencies on BBB permeability remains an area of ongoing investigation [18,19,20]....

Our research was conducted with three distinct groups, each consisting of seven female rabbits with an average weight ranging from 2 to 5 kg. These groups were categorized as follows: with "N" signifying the

number of subjects in each group: Group I, control female group (N = 7); Group II, 1800 MHz GSM group (N = 7); and Group III, 2100 MHz GSM group (N = 7)....

The exposure duration of rabbits to RF radiation was determined to be 38 min, taking into account the current average daily talk time of 19 min for mobile phone users [29]....

It is evident that various studies have investigated the impact of electromagnetic radiation at different frequencies on brain tissue. The analysis of these studies indicates that while lower frequencies may affect brain structure over a longer time frame, higher frequencies like 2.1 GHz have more immediate, statistically significant impacts, suchas compromising BBB integrity. This comparison underscores the importance of further investigating the threshold effects of different frequencies, especially those commonly used in mobile telecommunications.

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**Effects of 4G Long-Term Evolution Electromagnetic Fields on Thyroid Hormone Dysfunction and Behavioral Changes in Adolescent Male Mice**

Kim HY, Son Y, Jeong YJ, Lee SH, Kim N, Ahn YH, Jeon SB, Choi HD, Lee HJ. Effects of 4G Long-Term Evolution Electromagnetic Fields on Thyroid Hormone Dysfunction and Behavioral Changes in Adolescent Male Mice. Int J Mol Sci. 2024 Oct 10;25(20):10875. doi: 10.3390/ijms252010875.

Abstract

Radiofrequency electromagnetic fields (RF-EMFs) can penetrate tissues and potentially influence endocrine and brain development. Despite increased mobile phone use among children and adolescents, the long-term effects of RF-EMF exposure on brain and endocrine development remain unclear. This study investigated the effects of long-term evolution band (LTE) EMF exposure on thyroid hormone levels, crucial for metabolism, growth, and development. Four-week-old male mice (C57BL/6) were exposed to LTE EMF (whole-body average specific absorption rate [SAR] 4 W/kg) or a positive control (lead; Pb, 300 ppm in drinking water) for 4 weeks. Subsequently, the mice underwent behavioral tests including open field, marble burying, and nest building. Blood pituitary and thyroid hormone levels, and thyroid hormone-regulating genes within the hypothalamus-pituitary-thyroid (HPT) axis were analyzed. LTE exposure increased T3 levels, while Pb exposure elevated T3 and T4 and decreased ACTH levels. The LTE EMF group showed no gene expression alterations in the thyroid and pituitary glands, but hypothalamic *Dio2* and *Dio3* expressions were significantly reduced compared to that in the sham-exposed group. Pb exposure altered the hypothalamic mRNA levels of *Oatp1c1* and *Trh*, pituitary mRNA of *Trhr*, and *Tpo* and *Tg* expression in the thyroid. In conclusion, LTE EMF exposure altered hypothalamic *Dio2* and *Dio3* expression, potentially impacting the HPT axis function. Further research is needed to explore RF-EMF's impacts on the endocrine system.

Open access paper: https://www.mdpi.com/1422-0067/25/20/10875

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**Characterising core body temperature response of free-moving C57BL/6 mice to 1.95 GHz whole-body radiofrequency-electromagnetic fields**

Sylvester E, Deng C, McIntosh R, Iskra S, Frankland J, McKenzie R, Croft RJ. Characterising core body temperature response of free-moving C57BL/6 mice to 1.95 GHz whole-body radiofrequency-electromagnetic fields. Bioelectromagnetics. 2024 Oct 14. doi: 10.1002/bem.22527.

Highlights

- Exposure of 1.95 GHz electromagnetic fields at 5 W/kg whole-body average specific absorption rate increases core body temperature by 0.4°C.
- The increased thermal energy at 3.75 W/kg is effectively managed by thermoregulation (max increase = 0.24°C).
- An extended habituation period prior to RF-EMF exposure is necessary to account for the large effect of handling on mice core body temperature.

Abstract

The present study investigated the core body temperature (CBT) response of free-moving adult male and female C57BL/6 mice, during and following a 2-h exposure to 1.95 GHz RF-EMF within custom-built reverberation chambers, using temperature capsules implanted within the intraperitoneal cavity and data continuously logged and transmitted via radiotelemetry postexposure. Comparing RF-EMF exposures (WBA-SAR of 1.25, 2.5, 3.75, and 5 W/kg) to the sham-exposed condition, we identified a peak in CBT within the first 16 min of RF-EMF exposure (+0.15, +0.31, +0.24, +0.37°C at 1.25, 2.5, 3.75, and 5 W/kg respectively; statistically significant at WBA-SAR ≥ 2.5 W/kg only), which largely dissipated for the remainder of the exposure period. Immediately before the end of exposure, only the CBT of the 5 W/kg condition was statistically differentiable from sham. Based on our findings, it is apparent that mice are able to effectively compensate for the increased thermal load at RF-EMF strengths up to 5 W/kg. In addition, the elevated CBT at the end of the exposure period in the 5 W/kg condition was statistically significantly reduced compared to the sham condition immediately after RF-EMF exposure ceased. This would indicate that measures of CBT following the end of an RF-EMF exposure period may not reflect the actual change in the CBT of mice caused by RF-EMF exposure in mice.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22527

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**Effects of radiofrequency electromagnetic radiation emitted by mobile phones on rat parotid gland histology - an experimental study**

Matei LI, Neag MA, Mocan LP, Sufleţel RT, Cuţaş A, Onofrei MM, Gherman LM, Armencea G, Mihu C, Ilea A, Mihu CM, Bordea IR, Inchingolo F, Dipalma G, Melincovici CS. The effects of radiofrequency electromagnetic radiation emitted by mobile phones on rat parotid gland histology - an experimental study. Eur Rev Med Pharmacol Sci. 2024 Oct;28(20):4405-4419. doi: 10.26355/eurrev_202410_36864.

Abstract

Objective: The advancement of telecommunication technology and devices promptly transformed mobile phones into indispensable objects in our day-to-day lives, but their biological effects remain unclear. Therefore, this study aimed to investigate the potential histopathological changes induced by mobile phone radiation in the parotid gland and the nearby tissues.

Materials and methods: Thirty female Rattus Norvegicus rats were divided into three groups: group 1 (exposed for 30 days), group 2 (exposed for 60 days), and control group (non-exposed). Each subject was exposed to mobile phone radiation in the form of a phone call for two hours every day for their subsequent exposure time. The exposure was always directed towards the same side of the face throughout the whole exposure period. At the end of the exposure period, a comprehensive examination was conducted, including inspection of the orofacial structures, tissue sections of the parotid glands, overlying skin, oral mucosa, and cervical lymph nodes, as well as obtaining smears from the oral cavity. To highlight the presence of micronuclei within the exfoliated squamous cells of the oral epithelium, Feulgen stain was performed.

Results: The results showed a significant activation of the fibroblasts in the parotid gland septa, in both exposed experimental groups, compared to the control group. We also detected significant cervical lymph node reactive changes, hyperkeratosis of the oral epithelium, and activated fibroblasts in the dermis and oral mucosa lamina propria in both experimental groups. Dermal fibrosis and lamina propria fibrosis were significantly increased in the second experimental group, compared to the control group. Moreover, vascular congestion in the parotid gland, dermal, and lamina propria fibrosis were significantly increased in the second study group compared to the first one.

Conclusions: These findings suggest that exposure to mobile phone radiation may lead to pathological changes in the parotid gland and nearby tissues of experimental rats.

Open access paper: https://www.europeanreview.org/article/36864

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**Frequency-Dependent Antioxidant Responses in HT-1080 Human Fibrosarcoma Cells Exposed to Weak Radio Frequency Fields**

Gurhan H, Barnes F. Frequency-Dependent Antioxidant Responses in HT-1080 Human Fibrosarcoma Cells Exposed to Weak Radio Frequency Fields. *Antioxidants*. 2024; 13(10):1237. doi: 10.3390/antiox13101237.

Abstract

This study explores the complex relationship between radio frequency (RF) exposure and cancer cells, focusing on the HT-1080 human fibrosarcoma cell line. We investigated the modulation of reactive oxygen species (ROS) and key antioxidant enzymes, including superoxide dismutase (SOD), peroxidase, and glutathione (GSH), as well as mitochondrial superoxide levels and cell viability. Exposure to RF fields in the 2–5 MHz range at very weak intensities (20 nT) over 4 days resulted in distinct, frequency-specific cellular effects. Significant increases in SOD and GSH levels were observed at 4 and 4.5 MHz, accompanied by reduced mitochondrial superoxide levels and enhanced cell viability, suggesting improved mitochondrial function. In contrast, lower frequencies like 2.5 MHz induced oxidative stress, evidenced by GSH depletion and increased mitochondrial superoxide levels. The findings demonstrate that cancer cells exhibit frequency-specific sensitivity to RF fields even at intensities significantly below current safety standards, highlighting the need to reassess exposure limits. Additionally, our analysis of

the radical pair mechanism (RPM) offers deeper insight into RF-induced cellular responses. The modulation of ROS and antioxidant enzyme activities is significant for cancer treatment and has broader implications for age-related diseases, where oxidative stress is a central factor in cellular degeneration. The findings propose that RF fields may serve as a therapeutic tool to selectively modulate oxidative stress and mitochondrial function in cancer cells, with antioxidants playing a key role in mitigating potential adverse effects.

Open access paper: https://www.mdpi.com/2076-3921/13/10/1237

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**The influence of eyelashes on electric field distribution and absorbed power density in the cornea under millimeter-wave exposure**

Foroughimehr N, Vilagosh Z, Yavari A, Wood A. The influence of eyelashes on electric field distribution and absorbed power density in the cornea under millimeter-wave exposure. Bioelectromagnetics. 2024 Oct 14. doi: 10.1002/bem.22526.

Abstract

As millimeter wave (MMW) technology, particularly in fifth-generation (5G) devices, gains prominence, there is a crucial need for comprehensive electromagnetic (EM) models of ocular tissues to understand and characterize EM exposure conditions accurately. This study employs numerical modeling to investigate the interaction between MMW and the cornea, aiming to characterize EM field distributions and absorption within an anatomically accurate eye model while considering the influence of eyelashes. Using the finite-difference time-domain (FDTD) method, we conduct simulations of EM radiation interactions from 20.0 to 100.0 GHz with a human eye model. Moreover, we analyze the temperature distribution increase within the eye model using a thermal sensor in XFdtd, employing a scheme based on the finite difference (FD) method. Our findings reveal a nonuniform distribution of the EM field, particularly intensified in corneal regions adjacent to eyelashes and eyelids. Despite similar EM field patterns, the presence or absence of eyelashes has minimal impact on temperature differences. However, the study highlights increased radiation absorption by the eyelid's epidermis at 100.0 GHz, reducing the rise in the cornea's temperature.

https://pubmed.ncbi.nlm.nih.gov/39402869/

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**Exploring the potential link between prostate cancer and magnetic fields**

Dart DA, Koushyar S, Uysal-Onganer P. Exploring the potential link between prostate cancer and magnetic fields. Medical Hypotheses. Volume 189, 2024. doi: 10.1016/j.mehy.2024.111384.

Abstract

Prostate cancer is the most common solid cancer in men worldwide. Various lifestyle factors have been established as contributors to cancer risk, and prostate cancer is no exception. Elements such as

advanced age, diet, obesity, smoking, alcohol consumption, circadian rhythm disruptions, Afro-Caribbean ethnicity, and sexual activity have all been linked to an increased risk of prostate cancer. Notably, famous male guitarists from bands spanning the last few decades are now entering the age demographic most closely associated with prostate cancer. It is not surprising that they may fall into the 'at-risk' category. Media speculation has hinted at a potentially higher incidence of prostate cancer among guitarists compared to their bandmates, although no tangible correlation has been established. This speculation piqued our curiosity and prompted an exploration into potential reasons why musicians, particularly guitarists, might be at an elevated risk of developing prostate cancer. We hypothesise the electromagnetic fields generated by the electric guitar may in part explain the possible increase in prostate cancer risk among electric guitarists. This study delves into these intriguing possibilities, shedding light on an area of research that remains speculative but warrants further investigation.

Highlights

Prostate cancer is the most common solid cancer in men globally.
Age, diet, ethnicity, sexual activity and circadian rhythm disruptions, are identified as contributors to prostate cancer risk.
Magnetic fields (MF) and electromagnetic fields (EMF) may amplify prostate cancer risks.
Magnetic fields may potentially affect the behaviour of quantum systems within biological molecules.

https://www.sciencedirect.com/science/article/pii/S0306987724001270

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**Electromagnetic Field Exposure in the Public Space of the Slovakian City**

Trnka M, Gálik P, Kráľová E, Važan R. Electromagnetic Field Exposure in the Public Space of the Slovakian City. Scientific Letters of the University of Zilina 2023, 25(1):G1-G6. doi: 10.26552/com.C.2023.014

The main objective of our research was to map the exposure to electromagnetic smog in the frequented space of shopping centres in the city of Bratislava and to compare our results to the actual hygienic limits. The measurements of the low- and high-frequency electromagnetic fields were performed at different places in shopping centres. Our results did not exceed the Slovak current limits in any of the measurements. However, almost all of them markedly exceed new permitted limits according to EUROPAEM. Based on our results, stricter limits in many European countries and increasing evidence on possible harmfulness of long-term exposures to artificial electromagnetic fields, preventive carefulness can be recommended - to support the research in this field, to prepare professional public education and possibly to prepare the stricter Slovak exposure limits.

Open access paper: https://komunikacie.uniza.sk/pdfs/csl/2023/01/08.pdf

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**Development of electromagnetic pollution maps utilizing Gaussian process spatial models**

Kiouvrekis Y, Zikas S, Katis I, Tsilikas I, Filippopoulos I. Development of electromagnetic pollution maps utilizing Gaussian process spatial models. Sci Total Environ. 2024 Oct 21;955:176907. doi: 10.1016/j.scitotenv.2024.176907.

Abstract

The rapid proliferation of wireless technologies in everyday environments demands the quick and precise estimation of electromagnetic field distribution. This distribution is commonly depicted through the electric field strength across various geographical areas. The objective of this research is to determine the most effective geospatial model for generating a national-level electric field strength map within the 30 MHz-6 GHz frequency range. To achieve this, we employed five different methodologies for constructing the electric field strength map. Four of these methodologies are based on Gaussian process regression, while the fifth utilizes the classical weighted-average method of the nearest neighbor. Our study focused on a country with a total area of 9251 $km^2$, using a dataset comprising 3621 measurements. The findings reveal that Gaussian process spatial models, also known as Kriging models, generally outperform other methods when applied to spatial data. However, it was observed that, after excluding some outlier data points, the performance of the classical nearest neighbor models becomes comparable to that of the Gaussian process models. This indicates the potential for both approaches to be effective, depending on the data quality and the presence of outliers.

Excerpts

For the Total (Fig. 4 and Table 2), the mean stands at 4.78 V/m, with a maximum value of 37.99 V/m, a minimum of 0.28 V/m, and a median of 3.42 V/m....

The present research constitutes the first step of many that can be implemented in the future regarding the construction of systems for mapping EMR exposure. Initially, future research should be conducted in cities, exploring characteristics related to urban infrastructure, such as building materials, density, and height. This novel approach regards not only improving the model's performance but also developing models that consider these characteristics between measurement points to better capture the spatial distribution of EMR within urban and semi-urban areas. Additionally, it would be interesting to incorporate temporal patterns to account for the various varieties of EMR over time, considering factors such as daily, seasonal, and yearly variations. In a subsequent stage, the inclusion of data from environmental sources, such as weather conditions, levels of atmospheric pollution, and population density, could be beneficial to enhance the predictive capability of the models. Furthermore, research into improving the interpretability of the models should be conducted to provide meaningful insights into the factors influencing EMR levels in different environments (urban, semi-urban, and rural). All of the above should be combined with conducting validation studies in collaboration with stakeholders for the effectiveness of the developed models in real-world scenarios.

https://pubmed.ncbi.nlm.nih.gov/39442732/

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**An Analysis of Radio Frequency Radiation Emitted by Smartphones**

Manoharan S, Mahalakshmi B, Ananthi K, Sindhu MP. An Analysis of Radio Frequency Radiation Emitted by Smartphones. 2024 8th International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), Kirtipur, Nepal, 2024, pp. 301-307, doi: 10.1109/I-SMAC61858.2024.10714888.

Abstract

The introduction of smartphones has transformed how we interact, access information, and entertains ourselves. Nevertheless, as the usage of smartphones continues to rise, there has been greater concern over the possible health implications of Radio Frequency radiation released by these devices. RF radiation, also known as radiofrequency radiation, is a kind of electromagnetic radiation utilized for wireless communication in devices like smartphones. This study seeks to offer a thorough analysis of RF radiation and its emissions from smartphones, as well as the potential health implications associated with their use and strategies to minimize exposure. This research study also explores the importance of Specific Absorption Rate (SAR) testing in the context of 5G technologies, including testing methodologies, regulatory frameworks, and the implications of 5G frequency bands on SAR measurements.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10714888&isnumber=10714582

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**The 5G-FR1 Signals: Beams of the Phased Antennas Array and Time-Recurrence of Emissions with Consequences on Human Exposure**

Deaconescu DB, Miclaus S. The 5G-FR1 Signals: Beams of the Phased Antennas Array and Time-Recurrence of Emissions with Consequences on Human Exposure. *Electronics*. 2023; 12(2):297. doi: 10.3390/electronics12020297.

Abstract

The fifth generation (5G) of mobile communication technology poses lots of questions while introducing significant improvements compared with previous generations. The most sensitive question is related to the safety of human exposure. The aim of present work was to analyze, with a few chosen examples, two of the most significant features of 5G emissions: the extreme spatial variability of the exposure and the nonlinear dynamics characteristics of the temporal variability of the exposure. Two models of patch antenna arrays operating at 3.7 GHz with varying beam forming and beam steering capabilities were considered for an analysis of the specific absorption rate of electromagnetic energy deposition in tissues of a head model. This allowed clear emphasis on the influence of the antenna geometry and feeding peculiarities on the spatial variability of exposure. The second approach implemented the original idea of following the nonlinear recurrence behavior of exposure in time, and underlined the time variability characteristics of emissions with a real-life mobile phone running different 5G applications. Time series of the emitted electric-field strengths were recorded by means a real-time spectrum analyzer and two near-field probes differently positioned in the beam. The presence of laminar emissions, chaotic emissions, determinism and recurrence in the exposures prove the potential for recurrence quantification in predicting time variability features of 5G exposure. Overall, the impact of 5G signals on living bodies, with the highest possible man-made spatial and temporal variability, may have very unpredictable bio-medical consequences.

Open access paper: https://www.mdpi.com/2079-9292/12/2/297

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**Preliminary Study on the Impact of 900MHz Radiation on Human Sperm: An In Vitro Molecular Approach**

Keskin I, Karabulut S, Kaplan AA, Alagöz M, Akdeniz M, Tüfekci KK, Davis DL, Kaplan S. Preliminary Study on the Impact of 900MHz Radiation on Human Sperm: An In Vitro Molecular Approach. Reprod Toxicol. 2024 Nov 4:108744. doi: 10.1016/j.reprotox.2024.108744.

Abstract

The use of technologies that produce and emit electromagnetic fields (EMF) is growing exponentially worldwide. The biological effects of EMF-emitting equipment, such as mobile phones and other wireless devices, have been studied in the last decade using in vitro and in vivo methods. Infertility is a growing health problem, and nearly half of cases are because of male-factor. This study investigated the direct in vitro effects of 900MHz radiation exposure on sperm parameters, genetic status, apoptotic markers, and the PI3K/AKT signaling pathway in healthy normozoospermic men. Semen samples were divided into four groups, two control (30min and 1h) and two EMF exposure (30min and 1h). Sperm parameters (motility, progressive motility, acrosomal index, morphology), genetic status (DNA fragmentation and chromatin integrity), apoptotic markers (cytokine-c and caspase-3 expression) and the PI3K/AKT signaling pathway (phosphoinoitide 3-kinase-PI3K- and phosphorylated AKT- p-AKT-) were analysed. Sperm motility were significantly reduced in 30min EMF exposure while a significant increase in the expression of p-AKT were observed in 1h EMF exposure group. An increased vacuolisation, acrosomal defect, extension of subacrosomal space, uncondensed chromatin structure, apoptotic signs and disrupted axoneme were observed in both EMF groups which were not observed in the control group. Other sperm parameters (morphology and acrosomal index), genetic status, apoptotic markers and the PI3K expression rates had no significant change.

https://pubmed.ncbi.nlm.nih.gov/39505052/

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**Quantitative Assessment of Thermal Effects on the Auricle Region Caused by Mobile Phones Operating in Different Modes**

Rok T, Kacprzyk A, Rokita E, Kantor D, and Taton G. Quantitative Assessment of Thermal Effects on the Auricle Region Caused by Mobile Phones Operating in Different Modes. *AIMS Biophys* 11, no. 4 (2024): 427–44. https://doi.org/10.3934/biophy.2024023.

Abstract

To analyze thermal effects caused by mobile phones on the human auricle region, we performed an experiment with controlled exposure to mobile phones operating in different modes for a group of 40 men. Temperature changes were measured with the use of infrared thermography. Thermograms were taken before and after a standardized 15-minute phone call when the mobile phone was placed lightly against the skin surface in the auricle region. The measurements were performed in three modes: OFF,

ON, and FLIGHT. Statistically significant differences (p = 0.03) were observed between the experimental temperature increase of the auricle region in OFF mode (average temperature rise = 1.1 °C ± 0.2 °C) and in ON mode (average temperature rise = 1.9 °C ± 0.3 °C), while between FLIGHT (average temperature rise = 1.4 °C ± 0.2 °C) and ON modes, no statistical differences were observed (p = 0.20). Based on thermographic measurements and the model of heat transfer between the ear and the phone, it was shown that the human ear is the largest heat source in the system and that the increase in skin temperature is mainly caused by the handheld mobile phone restricting heat dissipation from the skin surface.

Excerpt for the assessment of near-field exposure, Received Signal Strength Indicator (RSSI) and Specific Absorption Rate (SAR) were used. During exposure sessions RSSI values were continuously measured and retrospectively controlled. All the participants received exposure at an arbitrary mean value of RSSI between −90 and −80 dBm. The SAR quantifies the absorption of RF-EMF in tissues, and for the human body, it depends on the dielectric properties of tissues due to the complexity of the human head anatomy its estimation is a subject of great challenge [21],[22] and for the phone used (Huawei P20 Lite), it was reported as 0.75 W/kg in the manual.

For the far-field exposure a personal exposure meter (ExpoM-RF, Zurich, Switzerland) performing a spectral analysis of RF-EMF within 16 different frequency bands from 87.5 MHz up to 5.875 GHz was used. Based on electric field strength, the power density was calculated as 45 µW. The uplink and downlink radiation remained on a comparable level throughout a simulated phone call.

In OFF mode, the smartphone was switched off, while in FLIGHT mode, there was no connection with the GSM network, so music was constantly playing. In ON mode, the mobile phone was fully connected to the GSM network and the smartphone was operating at a frequency of 1800 MHz.

Open access paper: http://www.aimspress.com/article/doi/10.3934/biophy.2024023

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**Rat brain and testicular tissue effects of radiofrequency radiation exposure: Histopathological, DNA damage of brain and qRT-PCR analysis**

Yavas MC, Kilitci A, Çelik E, Yegin K, Sirav B, Varol S. Rat brain and testicular tissue effects of radiofrequency radiation exposure: Histopathological, DNA damage of brain and qRT-PCR analysis. INTERNATIONAL JOURNAL OF RADIATION RESEARCH. JUL 2024. 22(3):529-536. doi: 10.61186/ijrr.22.3.529

Abstract

We evaluate the effects of radiofrequency electromagnetic field (RF-EMF) on rat brain and testicular tissue using histopathology, comet assay, and real-time quantitative PCR techniques.

Materials and Methods: Two equal groups of fourteen rats one for sham-control and the other for exposure (n = seven) were created. For a duration of 14 days, the exposure group (2100 MHz, testicular tissue SAR values of 163 mW/kg for 10 g, brain tissue SAR values of 292 mW/ kg on average) was subjected to five hours of exposure per day. Evaluations were conducted on tissue gene expression levels, histopathology, and DNA damage to brain tissue.

Results: The histological examination of brain tissue from the exposed group revealed vascular alterations and significant edema ($p < 0.05$). It was determined that RF radiation-induced much more cellular damage in the exposed group (18.26% tail DNA) than in the control group (4.06% tail DNA). Signs of deterioration in spermatogenic cells in the testicular tissue of the exposed group also changed significantly ($p < 0.05$). The Bax and bcl-2 genes showed a significant difference ($p < 0.05$) in the mRNA level data, whereas the p53 genes showed no significant change ($p > 0.05$).

Conclusion: These findings suggest that it may cause some histopathological and cellular damage in brain and testis tissue.

Open access paper: https://ijrr.com/article-1-5507-en.html

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**Does Radiofrequency Radiation From Mobile Phones Affect the Formation of Parotid Gland Malignancy? An Experimental Study**

Ozergin Coskun Z, Tumkaya L, Yilmaz A, Dursun E, Mercantepe T, Kalkan Y, Ersoz S. Does Radiofrequency Radiation From Mobile Phones Affect the Formation of Parotid Gland Malignancy? An Experimental Study. Ear Nose Throat J. 2024 Sep 27:1455613241287295. doi: 10.1177/01455613241287295.

Abstract

Objectives: The use of mobile phone is increasing around the world. Although it is beneficial in terms of communication, the electromagnetic radiations emitted by mobile phones may cause undesirable biological effects on the human body. In practical use, the tissue with which mobile phones come into most and are closest is the parotid gland. This study investigated the effects of the 1800 MHz electromagnetic field created by a generator on the parotid gland in rats.

Methods: A total of 21 Sprague-Dawley Albino rats were included in the study. The rats were randomly divided into three equal groups. To simulate a mobile phone in conversation mode, the first study group was exposed to an 1800-MHz electromagnetic field for 6 hours a day for 30 days, and the second study group was exposed to an 1800-MHz electromagnetic field for 12 hours a day for 30 days. After 30 days, rats were sacrificed, and histopathological and immunohistochemical methods were used to evaluate the effects on the parotid gland. The total antioxidant level and the total oxidant level were measured biochemically in homogenized parotid tissue.

Results: Histopathological results showed an increase in degeneration in rats exposed to electromagnetic fields for 6 and 12 hours a day, and immunohistochemical analysis showed an increase in the apoptotic index in both study groups ($P = .001$, $P < .001$). Intranuclear inclusions was observed during histopathological examination performed by electron microscopy.

Conclusions: This study observed that the 1800 MHz electromagnetic field caused undesirable adverse histopathological and biochemical effects on the parotid gland of rats. Histopathological and biochemical findings were detected with increasing contact and exposure time. This study will lead to other studies on this topic and contribute to the literature by completing other studies.

Excerpts

This study used a generator (Anritsu MG3670 B type, Japan) that produces microwave radiation at 1800 MHz radiofrequency to create exposure in mobile communion. The generator peak power was fixed at 2 W during exposure. In the digital signal generator used in this study, the carrier frequency was 1800 MHz, the modulation frequency was 217 Hz, there was a pulse of 577 µseconds, and the maximum peak power was 2 W. The average specific absorption rate (SAR) of the whole body was 0.117 W/kg. The study was carried out on a total of 21 rats divided in 3 groups (n = 7).

Groups 1, 2, and 3 were exposed to microwave radiation for 0 (control group), 6, and 12 hours, respectively. A generator with an external antenna was placed in the lower middle part of the cages.[5] The rats in the study group were exposed to microwave radiation for the specified hours in the mobile phone conversation mode....

The parotid tissue has been reported to absorb 40% of the electromagnetic energy emitted by mobile phones on phones held in place. This absorbed energy can cause thermal and nonthermal effects in the parotid tissue.[14] ....

Conclusion

In light of our knowledge of the literature, this is the first study to investigate the effects of an 1800-MHz electromagnetic field on the parotid gland of rats with biochemical tests, immunohistochemically in light microscopy and histopathologically in electron microscopy. This study observed that an 1800-MHz electromagnetic field causes undesirable adverse histopathological and biochemical effects on the parotid gland of rats. Histopathological and biochemical findings were detected with increasing contact and exposure time. This study will lead other studies on this topic and contribute to the literature in this area.

Open access paper: https://journals.sagepub.com/doi/10.1177/01455613241287295

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**Blueberry anthocyanins regulate SIRT1/FoxO1 pathway to inhibit oxidative stress and reduce testicular tissue damage induced by microwave radiation in rats**

Pang Y, Men J, Li Y, Zhang J, Zhao L, et al. Blueberry anthocyanins regulate SIRT1/FoxO1 pathway to inhibit oxidative stress and reduce testicular tissue damage induced by microwave radiation in rats. Journal of Functional Foods. Vol. 122, 2024. doi: 10.1016/j.jff.2024.106523.

Abstract

Researches have shown that microwave radiation could cause oxidative stress injury in male reproductive system, and blueberry anthocyanins had excellent oxidation resistance. Our study aimed to investigate the protective effect of blueberry anthocyanins (100, 200 and 400 mg/kg/d) on testicular tissue damage in Wistar rats exposed to 2.856 GHz microwave and the optimal dose. We found that blueberry anthocyanins could ameliorate the decrease of sperm motility and sex hormone levels and testicular tissue structure damage caused by microwave radiation, increase SIRT1 expression and decrease FoxO1 expression, increase GSH/GSSG, SOD and inhibit MDA. The LDH, SDH and ATP synthase

were increased, and Caspase-3 expression was decreased, and the high-dose of blueberry anthocyanins (400 mg/kg/d) had the best protective effect. These results suggested that blueberry anthocyanins could inhibit oxidative stress injury induced by 2.856 GHz microwave radiation in rat testicular tissue by regulating SIRT1/FoxO1 pathway, enhance energy metabolism and reduce cell apoptosis.

Open access paper: https://www.sciencedirect.com/science/article/pii/S1756464624005255

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**Effects of 4.9 GHz Radiofrequency Field Exposure on Brain Metabolomic and Proteomic Characterization in Mice**

Wang X, Zhou G, Lin J, Zhang Z, Qin T, Guo L, Wang H, Huang Z, Ding G. Effects of 4.9 GHz Radiofrequency Field Exposure on Brain Metabolomic and Proteomic Characterization in Mice. Biology (Basel). 2024 Oct 10;13(10):806. doi: 10.3390/biology13100806.

Abstract

Electromagnetic exposure has become increasingly widespread, and its biological effects have received extensive attention. The purpose of this study was to explore changes in the metabolism profile of the brain and serum and to identify differentially expressed proteins in the brain after exposure to the 4.9 GHz radiofrequency (RF) field. C57BL/6 mice were randomly divided into a Sham group and an RF group, which were sham-exposed and continuously exposed to a 4.9 RF field for 35 d, 1 h/d, at an **average power density (PD) of 50 W/m$^2$**. After exposure, untargeted metabolomics and Tandem Mass Tags (TMT) quantitative proteomics were performed. We found 104 and 153 up- and down-regulated differentially expressed metabolites (DEMs) in the RF_Brain group and RF_Serum group, and the DEMs were significantly enriched in glycerophospholipid metabolism. Moreover, 10 up-regulated and 51 down-regulated differentially expressed proteins (DEPs) were discovered in the RF group. Functional correlation analysis showed that most DEMs and DEPs showed a significant correlation. These results suggested that 4.9 GHz exposure induced disturbance of metabolism in the brain and serum, and caused deregulation of proteins in the brain.

Simple Summary

The brain, as the central nervous system that controls the body's sensory, behavior, and mental symptoms, is sensitive to RF exposure, and lots of studies have explored the potential health hazards of RF-EMR with different frequencies to the brain. Our previous study found that 4.9 GHz radiofrequency radiation induced depression-like behavior in mice, but the mechanism of the behavioral changes was unclear. Studies have shown that changes in peripheral energy metabolism might affect brain lipid levels, and thereby cortical excitability, and a deregulated hippocampus proteome might influence the healthy functioning of the brain. Here, we provide evidence that 4.9 GHz RF exposure altered metabolite expression patterns in brain tissue and serum, especially glycerophospholipid metabolism. In addition, 4.9 GHz RF exposure induced an imbalance in the protein profile of brain tissue and may alter gap junction communication. Our results initially revealed the biological effects of 5G communication frequency exposure and provided a possible mechanism for electromagnetic radiation-induced behavioral changes from the perspective of metabolome and proteome.

Open access paper: https://www.mdpi.com/2079-7737/13/10/806

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**Cellular signaling pathways in the nervous system activated by various mechanical and electromagnetic stimuli**

Kazuhito M, Ferguson AR, Aboubacar W, Youngjae R. Cellular signaling pathways in the nervous system activated by various mechanical and electromagnetic stimuli. Frontiers in Molecular Neuroscience. Vol. 17. 2024. doi: 10.3389/fnmol.2024.1427070.

Abstract

Mechanical stimuli, such as stretch, shear stress, or compression, activate a range of biomolecular responses through cellular mechanotransduction. In the nervous system, studies on mechanical stress have highlighted key pathophysiological mechanisms underlying traumatic injury and neurodegenerative diseases. However, the biomolecular pathways triggered by mechanical stimuli in the nervous system has not been fully explored, especially compared to other body systems. This gap in knowledge may be due to the wide variety of methods and definitions used in research. Additionally, as mechanical stimulation techniques such as ultrasound and electromagnetic stimulation are increasingly utilized in psychological and neurorehabilitation treatments, it is vital to understand the underlying biological mechanisms in order to develop accurate pathophysiological models and enhance therapeutic interventions. This review aims to summarize the cellular signaling pathways activated by various mechanical and electromagnetic stimuli with a particular focus on the mammalian nervous system. Furthermore, we briefly discuss potential cellular mechanosensors involved in these processes

Open access paper: https://www.frontiersin.org/journals/molecular-neuroscience/articles/10.3389/fnmol.2024.1427070

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**Neurobiological effects and mechanisms of magnetic fields: a review from 2000 to 2023**

Wang X, Ye Y, Zuo H, Li Y. Neurobiological effects and mechanisms of magnetic fields: a review from 2000 to 2023. BMC Public Health. 2024 Nov 8;24(1):3094. doi: 10.1186/s12889-024-18987-9.

Abstract

Magnetic fields are widely used in medical diagnostics because of their superior non-invasive properties. In addition, with the widespread use of magnetic fields in transportation and other areas, their potential hazards to human health and the assessment of their safety have attracted considerable attention. The effects of magnetic fields on living organisms have a long history. The biological effects of magnetic field exposure in mice and rats depend on the magnetic field strength, exposure time, and direction; depending on these and potentially other factors, magnetic fields can cause a series of neurobiological effects. We reviewed global research on the neurobiological effects of magnetic fields from recent years to provide an overview and insights into the underlying mechanisms. This review focuses on the

biological effects of static and dynamic magnetic fields of different frequencies and intensities on animals and nerve cells and their mechanisms of action.

Conclusion

In summary, this article reviews the progress in research on the neural effects of SMF and DMF at the level of animal models and nerve cells in recent years. The number of studies on the effects of MFs on learning memory, emotional behavior, nerve cells, and neurotransmitters is gradually increasing, but owing to the diversity of MF parameters, experimental subjects, and conditions, the conclusions are inconsistent. Certain conditions of MF exposure can lead to changes in emotional behavior and learning memory and cause or relieve anxiety-like and depressive behaviors, with or without significant effects. The biological effects of MFs on neurons and glial cells include alterations in cell proliferation, cell cycle distribution, and apoptosis. However, some problems remain unclear. Due to the unspecific nature of MFs, their neurobiological effects are difficult to target experimentally. Urgent problems to be solved by future research include how to establish proper experimental animal and neural cell models, and how to select the appropriate MF exposure intensity and time.

Open access paper: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-024-18987-9

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**Cellular and Molecular Effects of Magnetic Fields**

Tota M, Jonderko L, Witek J, Novickij V, Kulbacka J. Cellular and Molecular Effects of Magnetic Fields. Int J Mol Sci. 2024 Aug 17;25(16):8973. doi: 10.3390/ijms25168973.

Abstract

Recently, magnetic fields (MFs) have received major attention due to their potential therapeutic applications and biological effects. This review provides a comprehensive analysis of the cellular and molecular impacts of MFs, with a focus on both in vitro and in vivo studies. We investigate the mechanisms by which MFs influence cell behavior, including modifications in gene expression, protein synthesis, and cellular signaling pathways. The interaction of MFs with cellular components such as ion channels, membranes, and the cytoskeleton is analyzed, along with their effects on cellular processes like proliferation, differentiation, and apoptosis. Molecular insights are offered into how MFs modulate oxidative stress and inflammatory responses, which are pivotal in various pathological conditions. Furthermore, we explore the therapeutic potential of MFs in regenerative medicine, cancer treatment, and neurodegenerative diseases. By synthesizing current findings, this article aims to elucidate the complex bioeffects of MFs, thereby facilitating their optimized application in medical and biotechnological fields.

Open access paper: https://www.mdpi.com/1422-0067/25/16/8973

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**Morphological, biochemical and genotoxic effects of non-ionizing radiation at 1800 MHz and 2400 MHz frequencies in Allium cepa L**

Sharma A, Bahel S, Katnoria JK. Morphological, biochemical and genotoxic effects of non-ionizing radiation at 1800 MHz and 2400 MHz frequencies in Allium cepa L. Environ Sci Pollut Res Int. 2024 Oct 30. doi: 10.1007/s11356-024-35414-z.

Abstract

The frequent use of electronic devices in daily lives, predominantly reliant on non-ionizing radiation, has increased the prevalence of electromagnetic radiation (EMR) in natural environment. In light of this, effects of EMR at frequencies of 1800 MHz and 2400 MHz characterized by a power of 10.0 dBm (0.01 W), across varying exposure durations of 1 h/day, 2 h/day, 4 h/day, 6 h/day, and 8 h/day for 7 days, in Allium cepa L. were studied. The effects of the treatment on the morphological features (root length, fresh weight, and dry weight of roots) and biochemical characteristics (protein content and antioxidative enzymes, namely, ascorbate peroxidase (APX), glutathione reductase (GR), superoxide dismutase (SOD), glutathione-S-transferase (GST), guaiacol peroxidase (POD), catalase (CAT), and dehydroascorbate (DHAR)) were studied in roots and bulbs of Allium cepa L. Further genotoxicity for different exposure periods at both frequencies was also conducted. Prolonged exposure to electromagnetic radiation (EMR) at both frequencies was found to reduce root length, fresh weight, and dry weight of plant. Furthermore, significant effects were observed on protein content, indicating a reduction with prolonged exposure duration. Investigation into the activities of antioxidative enzymes such as APX, GR, GST, DHAR, CAT, SOD, and POD at a frequency of 1800 MHz and 2400 MHz in roots and bulbs demonstrated a significant enhancement in enzyme activity during 6 h/day and 8 h/day exposure periods. Additional investigation during genotoxicity studies demonstrated the induction of chromosomal aberrations in the root tip cells of the Allium cepa L. plant test system. The current study revealed the initiation of oxidative stress and genotoxicity resulting from long-term exposure to electromagnetic radiation in the studied plant test systems.

https://pubmed.ncbi.nlm.nih.gov/39472374/

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**Representations of 5G in the Chinese and British press: a corpus-assisted critical discourse analysis**

Pei, J., Cheng, L. Representations of 5G in the Chinese and British press: a corpus-assisted critical discourse analysis. *Humanit Soc Sci Commun* **11**, 400 (2024). https://doi.org/10.1057/s41599-024-02896-8

Abstract

This study employs a corpus-assisted critical discourse analysis to demystify the dominant patterns of representations around 5G in the Chinese and British press. Keyword analyses identify four thematic categories around the representation of 5G: the nature of 5G, social actors in 5G discourse, actions around 5G and timing in 5G discourse. Findings suggest that the Chinese press tends to use positive evaluative expressions to depict 5G as a trustworthy and beneficial issue and stress China's strong support for 5G development. In contrast, the British press prefers to frame 5G as a product of geopolitical rivalry and an issue with scientific uncertainties and controversies by repeatedly employing negative language patterns related to 5G risks and conspiracy theories. Besides, a subtle but varying "self versus other" schema is constructed by the two presses. The Chinese press is inclined to use positive predication strategies to construct a positive self-representation, whereas the British press

tends to adopt negative predication strategies to portray China as an outgroup and meanwhile use scapegoating strategies to profile Britain as a positive self by using recurrent patterns denoting the pressure exerted on Britain by the United States. Such differences could result from their journalistic ideologies and values and the contrasting socio-political contexts where the two presses are situated.

Open access paper: https://www.nature.com/articles/s41599-024-02896-8

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Magnetic fields from indoor transformer stations and risk of cancer in adults: a cohort study

Juutilainen J, Khan MW, Naarala J, Roivainen P. Magnetic fields from indoor transformer stations and risk of cancer in adults: a cohort study. Occup Environ Med. 2024 Nov 18:oemed-2024-109466. doi: 10.1136/oemed-2024-109466.

Abstract

Objectives: Studies assessing the association of adult cancers with extremely low frequency (ELF) magnetic fields (MF) have provided inconclusive results, probably affected by limitations such as low exposure levels, confounding and various forms of bias. This study investigated the association between residential ELF MF exposure and adult cancer using a design that avoids the main limitations of previous studies.

Methods: Persons who have lived in buildings with indoor transformer stations during the period 1971-2016 formed the study cohort. Their MF exposure was assessed based on the location of their apartment in relation to the transformer room. Information on their cancer diagnoses was obtained from the Finnish Cancer Registry. SIR with 95% CI was calculated to investigate the association of MF exposure with overall cancer and specific cancers.

Results: The SIR for all primary sites was 1.01 (95% CI 0.93 to 1.09). An increased risk of digestive organ cancers was observed among the exposed persons, with a SIR of 1.23 (95% CI 1.03 to 1.46). The highest SIR was observed for gallbladder cancer (3.92, 95% CI 1.44 to 8.69). Increased risk of testicular cancer was observed among men exposed to MF during childhood, but this is likely to be due to confounding associated with living on the lowest floors. No other significant associations were observed for other primary cancer sites studied.

Conclusions: Overall cancer risk was not affected by residential MF exposure. The increased risk of digestive organ cancers among MF-exposed persons is a novel finding requiring confirmation in further studies.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- Extremely low frequency magnetic fields (ELF MFs) have been classified as possibly carcinogenic. The evidence is strongest for increased risk of childhood leukaemia and more inconsistent for risks of adult cancers.

WHAT THIS STUDY ADDS

- This study was carried out using a unique database of residential buildings with indoor transformer stations. Many limitations of previous studies could be avoided. The study suggested an association between residential MF exposure and digestive organ cancers. The overall cancer risk was not affected by MF exposure.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- As there is little previous evidence of an association between digestive organ cancers and MF exposure, further research on this topic is required. Compared with previous studies, this study included higher exposure levels and thus provides a useful addition to the data available for health risk assessment and risk communication.

https://pubmed.ncbi.nlm.nih.gov/39557565/

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**Exploring Non-Thermal Mechanisms of Biological Reactions to Extremely Low-Frequency Magnetic Field Exposure**

Radil R, Carnecka L, Judakova Z, Pobocikova I, Bajtos M, Janousek L. Exploring Non-Thermal Mechanisms of Biological Reactions to Extremely Low-Frequency Magnetic Field Exposure. *Applied Sciences*. 2024; 14(20):9409. https://doi.org/10.3390/app14209409

Abstract

The increasing evidence regarding biological effects of exposure to an extremely low frequency magnetic field is of utmost interest not only to the scientific community, but also to legislative bodies and the public. However, the research in this field is full of controversial and inconsistent results, originated from a lack of widely acceptable physical mechanisms that could sufficiently describe the principle of such a field's action. This experimental study addresses and points to possible sources of ambiguities via investigation of the ion parametric resonance mechanism at 50 Hz frequency. The chosen methodology incorporates exposure of the Saccharomyces cerevisiae yeast strain based on an established exposure protocol with special attention to the measurement of an applied time-varying magnetic field corresponding to the ion parametric resonance requirements. Subsequently, the differences in cell growth as a reaction to changes in magnetic flux density are evaluated and statistically analyzed. It is found that fluctuations in the magnetic field within the exposure setup need to be addressed properly, since this could have an impact on replication of the experiments and reliability of the results. Furthermore, comparison of two independently performed sets of 10 experiments showed statistically significant effects even in conditions that did not fulfill the requirements of the resonance theory, putting the validity and practical application of the ion parametric resonance model into question.

Open access paper: https://www.mdpi.com/2076-3417/14/20/9409

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**Migratory birds can extract positional information from magnetic inclination and magnetic declination alone**

Packmor F, Kishkinev D, Zechmeister T, Mouritsen H, Holland RA. Migratory birds can extract positional information from magnetic inclination and magnetic declination alone. Proc Biol Sci. 2024 Nov;291(2034):rspb20241363. doi: 10.1098/rspb.2024.1363.

Abstract

Migratory birds are able to navigate over great distances with remarkable accuracy. The mechanism they use to achieve this feat is thought to involve two distinct steps: locating their position (the 'map') and heading towards the direction determined (the 'compass'). For decades, this map-and-compass concept has shaped our perception of navigation in animals, although the nature of the map remains debated. However, some recent studies suggest the involvement of the Earth's magnetic field in the map step. Here, we tested whether migratory songbirds, Eurasian reed warblers (*Acrocephalus scirpaceus*), can determine their position based on two magnetic field components that are also associated with direction finding, i.e. magnetic inclination and magnetic declination. During a virtual magnetic displacement experiment, the birds were exposed to altered magnetic inclination and magnetic declination values that would indicate a displacement from their natural migratory corridor, but the total intensity of the field remained unchanged, creating a spatial mismatch between these components. The response was a change in the birds' migratory direction consistent with a compensatory re-orientation. This suggests that birds can extract positional as well as directional information from these cues, even when they are in conflict with another component of the magnetic field. It remains to be seen whether birds use the total intensity of Earth's magnetic field for navigation.

Open access paper: https://royalsocietypublishing.org/doi/10.1098/rspb.2024.1363

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**Indoor & outdoor artificial light-at-night (ALAN) & cancer risk: A systematic review & meta-analysis of multiple cancer sites with a critical appraisal of exposure assessment**

Palomar-Cros A, Deprato A, Papantoniou K, Straif K, Lacy P, Maidstone R, Adan A, Haldar P, Moitra S, Navarro JF, Durrington H, Moitra S, Kogevinas M, Harding BN. Indoor and outdoor artificial light-at-night (ALAN) and cancer risk: A systematic review and meta-analysis of multiple cancer sites and with a critical appraisal of exposure assessment. Science of The Total Environment, Vol 955, 2024. doi: 10.1016/j.scitotenv.2024.177059.

Abstract

Exposure to artificial light-at-night (ALAN) has been linked to cancer risk. Few meta-analyses on this topic have reviewed only breast cancer. This study aimed to systematically review and meta-analyze existing studies on ALAN exposure and cancer incidence, thoroughly evaluating exposure assessment quality. We considered observational studies (cohort, case-control, cross-sectional) on ALAN exposure (indoor and outdoor) and cancer incidence, measured by relative risk, hazard ratio, and odds ratio. We searched six databases, two registries, and Google Scholar from inception until April 17, 2024. Quality of studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal tools. Random-effects meta-analysis was used to estimate relative risks (RR) and 95 % confidence intervals (CI) for ALAN exposures.

We identified 9835 studies and included 28 for qualitative synthesis with 2,508,807 individuals (15 cohort, 13 case-control). Out of the included studies, 20 studies on breast cancer (731,493 individuals) and 2 studies on prostate cancer (53,254 individuals) were used for quantitative synthesis. Higher levels of outdoor ALAN were associated with breast cancer risk (meta-estimate = 1.12, 95 % CI 1.03–1.23 (I2 = 69 %)). We observed a non-significant positive association between indoor ALAN levels and breast cancer risk (meta-estimate = 1.07, 0.95–1.21, I2 = 60 %), and no differences by menopausal status. The meta-analysis for prostate cancer suggested a non-statistically significant increased risk for higher levels of outdoor ALAN (meta-estimate = 1.43, 0.75–2.72, I2 = 90 %). In the qualitative synthesis, we observed positive associations with non-Hodgkin lymphoma and colorectal, pancreatic and thyroid cancer. We found an association between outdoor ALAN and breast cancer risk. However, most studies relied on satellite-images with a very low resolution (1 to 5 km, from the Defense Meteorological Program [DMSP]) and without information on color of light. Future studies with better exposure assessment should focus on investigating other cancer sites.

https://www.sciencedirect.com/science/article/pii/S0048969724072164

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**Effect of exposure to RF on cancer risk: A systematic review of human observational studies – Part I: Most researched outcomes (WHO SR 1A)**

**My note:** See Biased WHO-commissioned review claims no cancer link

Karipidis K, Baaken D, Loney T, Blettner M, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part I: Most researched outcomes. Environment International (2024), doi: 10.1016/j.envint.2024.108983. Open access paper: https://doi.org/10.1016/j.envint.2024.108983

Abstract

Background The objective of this review was to assess the quality and strength of the evidence provided by human observational studies for a causal association between exposure to radiofrequency electromagnetic fields (RF-EMF) and risk of the most investigated neoplastic diseases.

Methods Eligibility criteria: We included cohort and case-control studies of neoplasia risks in relation to three types of exposure to RF-EMF: near-field, head-localized, exposure from wireless phone use (SR-A); far-field, whole body, environmental exposure from fixed-site transmitters (SR-B); near/far-field occupational exposures from use of hand-held transceivers or RF-emitting equipment in the workplace (SR-C). While no restrictions on tumour type were applied, in the current paper we focus on incidence-based studies of selected “critical” neoplasms of the central nervous system (brain, meninges, pituitary gland, acoustic nerve) and salivary gland tumours (SR-A); brain tumours and leukaemias (SR-B, SR-C). We focussed on investigations of specific neoplasms in relation to specific exposure sources (i.e. E-O pairs), noting that a single article may address multiple E-O pairs.

Information sources: Eligible studies were identified by literature searches through Medline, Embase, and EMF-Portal.

Risk-of-bias (RoB) assessment: We used a tailored version of the Office of Health Assessment and Translation (OHAT) RoB tool to evaluate each study's internal validity. At the summary RoB step, studies were classified into three tiers according to their overall potential for bias (low, moderate and high).

Data synthesis: We synthesized the study results using random effects restricted maximum likelihood (REML) models (overall and subgroup meta-analyses of dichotomous and categorical exposure variables), and weighted mixed effects models (dose–response meta-analyses of lifetime exposure intensity).

Evidence assessment: Confidence in evidence was assessed using the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach.

Results  We included 63 aetiological articles, published between 1994 and 2022, with participants from 22 countries, reporting on 119 different E-O pairs. RF-EMF exposure from mobile phones (ever or regular use vs no or non-regular use) was not associated with an increased risk of glioma [meta-estimate of the relative risk (mRR) = 1.01, 95 % CI = 0.89–1.13), meningioma (mRR = 0.92, 95 % CI = 0.82–1.02), acoustic neuroma (mRR = 1.03, 95 % CI = 0.85–1.24), pituitary tumours (mRR = 0.81, 95 % CI = 0.61–1.06), salivary gland tumours (mRR = 0.91, 95 % CI = 0.78–1.06), or paediatric (children, adolescents and young adults) brain tumours (mRR = 1.06, 95 % CI = 0.74–1.51), with variable degree of across-study heterogeneity (I2 = 0 %-62 %). There was no observable increase in mRRs for the most investigated neoplasms (glioma, meningioma, and acoustic neuroma) with increasing time since start (TSS) use of mobile phones, cumulative call time (CCT), or cumulative number of calls (CNC). Cordless phone use was not significantly associated with risks of glioma [mRR = 1.04, 95 % CI = 0.74–1.46; I2 = 74 %) meningioma, (mRR = 0.91, 95 % CI = 0.70–1.18; I2 = 59 %), or acoustic neuroma (mRR = 1.16; 95 % CI = 0.83–1.61; I2 = 63 %). Exposure from fixed-site transmitters (broadcasting antennas or base stations) was not associated with childhood leukaemia or paediatric brain tumour risks, independently of the level of the modelled RF exposure. Glioma risk was not significantly increased following occupational RF exposure (ever vs never), and no differences were detected between increasing categories of modelled cumulative exposure levels.

Discussion  In the sensitivity analyses of glioma, meningioma, and acoustic neuroma risks in relation to mobile phone use (ever use, TSS, CCT, and CNC) the presented results were robust and not affected by changes in study aggregation.

In a leave-one-out meta-analyses of glioma risk in relation to mobile phone use we identified one influential study. In subsequent meta-analyses performed after excluding this study, we observed a substantial reduction in the mRR and the heterogeneity between studies, for both the contrast Ever vs Never (regular) use (mRR = 0.96, 95 % CI = 0.87–1.07, I2 = 47 %), and in the analysis by increasing categories of TSS ("<5 years": mRR = 0.97, 95 % CI = 0.83–1.14, I2 = 41 %; "5-9 years ": mRR = 0.96, 95 % CI = 0.83–1.11, I2 = 34 %; "10+ years": mRR = 0.97, 95 % CI = 0.87–1.08, I2 = 10 %).

There was limited variation across studies in RoB for the priority domains (selection/attrition, exposure and outcome information), with the number of studies evenly classified as at low and moderate risk of

bias (49 % tier-1 and 51 % tier-2), and no studies classified as at high risk of bias (tier-3). The impact of the biases on the study results (amount and direction) proved difficult to predict, and the RoB tool was inherently unable to account for the effect of competing biases. However, the sensitivity meta-analyses stratified on bias-tier, showed that the heterogeneity observed in our main meta-analyses across studies of glioma and acoustic neuroma in the upper TSS stratum (I2 = 77 % and 76 %), was explained by the summary RoB-tier. In the tier-1 study subgroup, the mRRs (95 % CI; I2) in long-term (10+ years) users were 0.95 (0.85–1.05; 5.5 %) for glioma, and 1.00 (0.78–1.29; 35 %) for acoustic neuroma.

The time-trend simulation studies, evaluated as complementary evidence in line with a triangulation approach for external validity, were consistent in showing that the increased risks observed in some case-control studies were incompatible with the actual incidence rates of glioma/brain cancer observed in several countries and over long periods. Three of these simulation studies consistently reported that RR estimates > 1.5 with a 10+ years induction period were definitely implausible, and could be used to set a “credibility benchmark”. In the sensitivity meta-analyses of glioma risk in the upper category of TSS excluding five studies reporting implausible effect sizes, we observed strong reductions in both the mRR [mRR of 0.95 (95 % CI = 0.86–1.05)], and the degree of heterogeneity across studies (I2 = 3.6 %).

Conclusions  Consistently with the published protocol, our final conclusions were formulated separately for each exposure-outcome combination, and primarily based on the line of evidence with the highest confidence, taking into account the ranking of RF sources by exposure level as inferred from dosimetric studies, and the external coherence with findings from time-trend simulation studies (limited to glioma in relation to mobile phone use).

For near field RF-EMF exposure to the head from mobile phone use, there was moderate certainty evidence that it likely does not increase the risk of glioma, meningioma, acoustic neuroma, pituitary tumours, and salivary gland tumours in adults, or of paediatric brain tumours.

For near field RF-EMF exposure to the head from cordless phone use, there was low certainty evidence that it may not increase the risk of glioma, meningioma or acoustic neuroma.

For whole-body far-field RF-EMF exposure from fixed-site transmitters (broadcasting antennas or base stations), there was moderate certainty evidence that it likely does not increase childhood leukaemia risk and low certainty evidence that it may not increase the risk of paediatric brain tumours. There were no studies eligible for inclusion investigating RF-EMF exposure from fixed-site transmitters and critical tumours in adults.

For occupational RF-EMF exposure, there was low certainty evidence that it may not increase the risk of brain cancer/glioma, but there were no included studies of leukemias (the second critical outcome in SR-C).

The evidence rating regarding paediatric brain tumours in relation to environmental RF exposure from fixed-site transmitters should be interpreted with caution, due to the small number of studies. Similar interpretative cautions apply to the evidence rating of the relation between glioma/brain cancer and occupational RF exposure, due to differences in exposure sources and metrics across the few included

studies.

Other  This project was commissioned and partially funded by the World Health Organization (WHO). Co-financing was provided by the New Zealand Ministry of Health; the Istituto Superiore di Sanità in its capacity as a WHO Collaborating Centre for Radiation and Health; and ARPANSA as a WHO Collaborating Centre for Radiation Protection. Registration: PROSPERO CRD42021236798. Published protocol: [(Lagorio et al., 2021) DOI https://doi.org/10.1016/j.envint.2021.106828].

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024005695?via%3Dihub

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**The effects of radiofrequency exposure on adverse female reproductive outcomes: A systematic review of human observational studies with dose–response meta-analysis (WHO SR 3 female)**

My note: See WHO Radiofrequency EMF Health Risk Assessment Monograph (EHC series)

Johnson EE, Kenny RPW, Adesanya AM, Richmond C, Beyer F, Calderon C, Rankin J, Pearce MS, Toledano M, Craig D, Pearson F. The effects of radiofrequency exposure on adverse female reproductive outcomes: A systematic review of human observational studies with dose-response meta-analysis. Environ Int. 2024 Jun 12;190:108816. doi: 10.1016/j.envint.2024.108816.

Abstract

Background  To inform radiofrequency electromagnetic field (RF-EMF) exposure guidelines the World Health Organization (WHO) is bringing together evidence on RF-EMF in relation to health outcomes prioritised for evaluation by experts in this field. Given this, a network of topic experts and methodologists have conducted a series of systematic reviews collecting, assessing, and synthesising data of relevance to these guidelines. Here we present a systematic review of the effect of RF-EMF exposure on adverse pregnancy outcomes in human observational studies which follows the WHO handbook for guideline development and the COSTER conduct guidelines.

Methods  We conducted a broad, sensitive search for potentially relevant records within the following bibliographic databases: MEDLINE; Embase; and the EMF Portal. Grey literature searches were also conducted through relevant databases (including OpenGrey), organisational websites and via consultation of RF-EMF experts. We included quantitative human observational studies on the effect of RF-EMF exposure in adults' preconception or pregnant women on pre-term birth, small for gestational age (SGA; associated with intrauterine growth restriction), miscarriage, stillbirth, low birth weight (LBW) and congenital anomalies. In blinded duplicate, titles and abstracts then full texts were screened against eligibility criteria. A third reviewer gave input when consensus was not reached. Citation chaining of included studies was completed. Two reviewers' data extracted and assessed included studies for risk of bias using the Office of Health Assessment and Translation (OHAT) tool. Random effects meta-analyses of the highest versus the lowest exposures and dose–response meta-analysis were conducted as appropriate and plausible. Two reviewers assessed the certainty in each body of evidence using the OHAT GRADE tool.

Results  We identified 18 studies in this review; eight were general public studies (with the general public as the population of interest) and 10 were occupational studies (with the population of interest specific workers/workforces). General public studies. From pairwise meta-analyses of general public studies, the evidence is very uncertain about the effects of RF-EMF from mobile phone exposure on preterm birth risk (relative risk (RR) 1.14, 95% confidence interval (CI): 0.97–1.34, 95% prediction interval (PI): 0.83–1.57; 4 studies), LBW (RR 1.14, 95% CI: 0.96–1.36, 95% PI: 0.84–1.57; 4 studies) or SGA (RR 1.13, 95% CI: 1.02–1.24, 95% PI: 0.99–1.28; 2 studies) due to very low-certainty evidence. It was not feasible to meta-analyse studies reporting on the effect of RF-EMF from mobile phone exposure on congenital anomalies or miscarriage risk. The reported effects from the studies assessing these outcomes varied and the studies were at some risk of bias. No studies of the general public assessed the impact of RF-EMF exposure on stillbirth. Occupational studies. In occupational studies, based on dose–response meta-analyses, the evidence is very uncertain about the effects of RF-EMF amongst female physiotherapists using shortwave diathermy on miscarriage due to very low-certainty evidence (OR 1.02 95% CI 0.94–1.1; 2 studies). Amongst offspring of female physiotherapists using shortwave diathermy, the evidence is very uncertain about the effects of RF-EMF on the risk of congenital malformations due to very low-certainty evidence (OR 1.4, 95% CI 0.85 to 2.32; 2 studies). From pairwise meta-analyses, the evidence is very uncertain about the effects of RF-EMF on the risk of miscarriage (RR 1.06, 95% CI 0.96 to 1.18; very low-certainty evidence), pre-term births (RR 1.19, 95% CI 0.32 to 4.37; 3 studies; very low-certainty evidence), and low birth weight (RR 2.90, 95% CI: 0.69 to 12.23; 3 studies; very low-certainty evidence). Results for stillbirth and SGA could not be pooled in meta-analyses. The results from the studies reporting these outcomes were inconsistent and the studies were at some risk of bias.

Discussion  Most of the evidence identified in this review was from general public studies assessing localised RF-EMF exposure from mobile phone use on female reproductive outcomes. In occupational settings, each study was of heterogenous whole-body RF-EMF exposure from radar, short or microwave diathermy, surveillance and welding equipment and its effect on female reproductive outcomes. Overall, the body of evidence is very uncertain about the effect of RF-EMF exposure on female reproductive outcomes. Further prospective studies conducted with greater rigour (particularly improved accuracy of exposure measurement and using appropriate statistical methods) are required to identify any potential effects of RF-EMF exposure on female reproductive outcomes of interest.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024004021

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**The effects of radiofrequency exposure on male fertility: A systematic review of human observational studies with dose-response meta-analysis  (SR 3 male)**

My note: See WHO Radiofrequency EMF Health Risk Assessment Monograph (EHC series)

Kenny RPW, Evelynne Johnson E, Adesanya AM, Richmond C, Beyer F, Calderon C, Rankin J, Pearce MS, Toledano M, Craig D, Pearson F. The effects of radiofrequency exposure on male fertility: A systematic review of human observational studies with dose-response meta-analysis. Environ Int. 2024 Jun 11;190:108817. doi: 10.1016/j.envint.2024.108817.

Abstract

Background: The World Health Organization (WHO) is bringing together evidence on radiofrequency electromagnetic field (RF-EMF) exposure in relation to health outcomes, previously identified as priorities for research and evaluation by experts in the field, to inform exposure guidelines. A suite of systematic reviews have been undertaken by a network of topic experts and methodologists to collect, assess and synthesise data relevant to these guidelines. Following the WHO handbook for guideline development and the COSTER conduct guidelines, we systematically reviewed the evidence on the potential effects of RF-EMF exposure on male fertility in human observational studies.

Methods: We conducted a broad and sensitive search for potentially relevant records within the following bibliographic databases: MEDLINE; Embase; Web of Science and EMF Portal. We also conducted searches of grey literature through relevant databases including OpenGrey, and organisational websites and consulted RF-EMF experts. We hand searched reference lists of included study records and for citations of these studies. We included quantitative human observational studies on the effect of RF-EMF exposure in adult male participants on infertility: sperm concentration; sperm morphology; sperm total motility; sperm progressive motility; total sperm count; and time to pregnancy. Titles and abstracts followed by full texts were screened in blinded duplicate against pre-set eligibility criteria with consensus input from a third reviewer as required. Data extraction from included studies was completed by two reviewers, as was risk of bias assessment using the Office of Health Assessment and Translation (OHAT) tool. We conducted a dose-response meta-analysis as possible and appropriate. Certainty of the evidence was assessed by two reviewers using the OHAT GRADE tool with input from a third reviewer as required.

Results: We identified nine studies in this review; seven were general public studies (with the general public as the population of interest) and two were occupational studies (with specific workers/workforces as the population of interest). General public studies. Duration of phone use: The evidence is very uncertain surrounding the effects of RF-EMF on sperm concentration (10/6 mL) (MD (mean difference) per hour of daily phone use 1.6 $10^6$/mL, 95 % CI -1.7 to 4.9; 3 studies), sperm morphology (MD 0.15 percentage points of deviation of normal forms per hour, 95 % CI -0.21 to 0.51; 3 studies), sperm progressive motility (MD -0.46 percentage points per hour, 95 % CI -1.04 to 0.13; 2 studies) and total sperm count (MD per hour -0.44 $10^6$/ejaculate, 95 % CI -2.59 to 1.7; 2 studies) due to very low-certainty evidence. Four additional studies reported on the effect of mobile phone use on sperm motility but were unsuitable for pooling; only one of these studies identified a statistically significant effect. All four studies were at risk of exposure characterisation and selection bias; two of confounding, selective reporting and attrition bias; three of outcome assessment bias and one used an inappropriate statistical method. Position of phone: There may be no or little effect of carrying a mobile phone in the front pocket on sperm concentration, total count, morphology, progressive motility or on time to pregnancy. Of three studies reporting on the effect of mobile phone location on sperm total motility and, or, total motile count, one showed a statistically significant effect. All three studies were at risk of exposure characterisation and selection bias; two of confounding, selective reporting and attrition bias; three of outcome assessment bias and one used inappropriate statistical method. RF-EMF Source: One study indicates there may be little or no effect of computer or other electric device use on sperm concentration, total motility or total count. This study is at probably high risk of exposure characterisation bias and outcome assessment bias. Occupational studies. With only two studies of occupational exposure to RF-EMF and heterogeneity in the population and exposure source (technicians exposed to microwaves or seamen exposed to radar equipment), it was not plausible to statistically pool findings. One study was at probably or definitely high risk of bias across all domains, the other across domains for exposure characterisation bias, outcome assessment bias and confounding.

Discussion: The majority of evidence identified was assessing localised RF-EMF exposure from mobile phone use on male fertility with few studies assessing the impact of phone position. Overall, the evidence identified is very uncertain about the effect of RF-EMF exposure from mobile phones on sperm outcomes. One study assessed the impact of other RF-EMF sources on male fertility amongst the general public and two studies assessed the impact of RF-EMF exposure in occupational cohorts from different sources (radar or microwave) on male fertility. Further prospective studies conducted with greater rigour (in particular, improved accuracy of exposure measurement and appropriate statistical method use) would build the existing evidence base and are required to have greater certainty in any potential effects of RF-EMF on male reproductive outcomes. Prospero Registration: CRD42021265401 (SR3A).

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024004033

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**Response to letter from Bevington M., Electrosensitivity UK (WHO SR 8)**

Bosch-Capblanch X, Esu E, Oringanje CM, Dongus S, Jalilian H, Eyers J, Auer C, Meremikwu M, Röösli M. Response to letter from Bevington M., Electrosensitivity UK. Environment International. 191, 2024. doi: 10.1016/j.envint.2024.108982.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024005683

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**Bevington Letter to Editor re: WHO systematic review of RF-EMF effects in human experimental studies of self-reported symptoms (WHO SR 8)**

Bevington M. Letter to the Editor, Environment International 'Available evidence shows adverse symptoms from acute non-thermal RF-EMF exposure'. Comment on: Bosch-Capblanch X et al., The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies, Envir Int. vol. 187, May 2024, 108612, Environment International, 2024, 108888, doi: 10.1016/j.envint.2024.108888.

No abstract

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024004744

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**The effects of radiofrequency electromagnetic field exposure on biomarkers of oxidative stress in vivo and in vitro: A systematic review of experimental studies (WHO SR 9)**

**My note**: SR 9 is the eighth of the WHO SRs (systematic reviews) on RF-EMF effects to be published in *Environment International*.

Like its predecessors, the authors of this SR systematically excluded most of the relevant research. Most of the meta-analyses in this paper suffered from high levels of heterogeneity with little effort to understand the source of the varied results. Some meta-analyses were unreliable as they violated a key

assumption of the random effects model, namely, independence of observations. I think a critique of this SR could build a strong case for retraction of this paper.

Meyer F, Bitsch A, Forman HJ, Fragoulis A, Ghezzi P, Henschenmacher B, Kellner R, Kuhne J, Ludwig T, Sachno D, Schmid G, Tsaioun K, Verbeek J, Wright R. The effects of radiofrequency electromagnetic field exposure on biomarkers of oxidative stress in vivo and in vitro: A systematic review of experimental studies. Environment International, 2024. doi: 10.1016/j.envint.2024.108940.

Highlights

The evidence for or against a relation between RF-EMF and biomarkers of oxidative stress is overall of very low certainty.

Inconsistent overall study results.

Need for drastic improvements of studies on RF-EMF and biomarkers of oxidative stress.

**Abstract**

Background

Oxidative stress is thought to be related to many diseases. Furthermore, it is hypothesized that radiofrequency electromagnetic fields (RF-EMF) may induce excessive oxidative stress in various cell types and thereby have the potential to compromise human and animal health. The objective of this systematic review (SR) is to summarize and evaluate the literature on the relation between the exposure to RF-EMF in the frequency range from 100 kHz to 300 GHz and biomarkers of oxidative stress.

Methods

The SR framework was developed following the guidelines established in the WHO Handbook for Guideline Development and NTP/OHAT's Handbook for Conducting a Literature-Based Health Assessment. We used the latter handbook's methodology for implementing the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach for environmental health assessments. We searched the following databases up until June 30, 2023: PubMed, Embase, Web of Science Core Collection, Scopus, and the EMF-Portal. The reference lists of included studies and retrieved review articles were also manually searched. We rated Risk of Bias (RoB) using the OHAT RoB Rating Tool and assessed publication bias using funnel plots of included studies. We assessed the certainty of the evidence (high, moderate, low, or inadequate) for an association between RF-EMF and oxidative stress using an adapted version of the GRADE framework. Data were extracted according to a predefined set of forms developed in DistillerSR. Data were analysed after grouping them first as in vitro or in vivo and then according to outcome category, species category, and exposed tissue. We synthesized study results using a random effects meta-analysis when study characteristics were judged sufficiently similar to be combined and heterogeneity (I2) was lower than 75 %, otherwise we describe the findings narratively.

Results

Fifty-six (56) studies, 45 in vivo and 11 in vitro, exposed to frequencies in the range 800–2450 MHz, were included in the SR after eliminating 11,543 publications because they did not meet the criteria defined in the published protocol (Henschenmacher et al., 2022). Of 56 studies 51 studies with 168 individual results were included in the meta-analysis. Together, these studies examined six human in vitro samples and fifty animal samples, including rodents (mice, rats, hamsters, and guinea pigs, [n = 46]) and rabbits [n = 4]. RF-EMF were predominantly applied as continuous wave exposures in these studies. The outcome biomarkers for modified proteins and amino acids were measured in 30 studies, for oxidized DNA bases in 26 studies, for oxidized lipids in 2 studies and hydrogen peroxide production in 2 studies. Outcomes were mostly measured in the brain (n = 22), liver (n = 9), cells (n = 9), blood (n = 6), and testis (n = 2). RoB in studies was high, mainly due to biases in exposure and outcome assessment.

In vivo studies

Brain: The effect on biomarkers for oxidized DNA bases in the rodent brain (five studies, n = 98) had an inconsistent effect, varying from a large decrease with a standardized mean difference (SMD) of −3.40 (95 % CI [−5.15, −1.64]) to a large increase with an SMD of 2.2 (95 % CI [0.78, 3.62]). In the brain of rabbits (two studies, n = 44), the effect sizes also varied, from an SMD of −1.06 (95 % CI [−2.13, 0.00]) to an SMD of 5.94 (95 % CI [3.14, 8.73]). The effect on biomarkers for modified proteins and amino acids in the rodent brain (15 studies, n = 328) also varied from a large decrease with an SMD of −6.11 (95 % CI [−8.16, −4.06]) to a large increase with an SMD of 5.33 (95 % CI [2.49, 8.17]).

The effect on biomarkers for oxidized lipids in the brain of rodents (one study, n = 56) also varied from a large decrease with SMD = −4.10 (95 % CI [−5.48, −2.73]) to SMD = 1.27 (95 % CI [0.45, 2.10]).

Liver: The effect on biomarkers for oxidized DNA bases in the rodent liver (two studies, n = 26) was inconsistent with effect sizes in both directions: SMD = −0.71 (95 % CI [−1.80, 0.38]) and SMD = 1.56 (95 % CI [0.19, 2.92]). The effect on biomarkers for oxidized DNA bases in the rabbits' liver (two studies, n = 60) was medium with a pooled SMD of 0.39 (95 % CI [−0.79, 1.56]).

Biomarkers for modified proteins and amino acids in the liver of rodents (six studies, n = 159) increased with a pooled SMD of 0.55 (95 % CI [0.06, 1.05]).

Blood: The effect of RF-EMF on biomarkers for oxidized DNA bases in rodent blood (four studies, n = 104) was inconsistent, with SMDs ranging from −1.14 (95 % CI [−2.23, −0.06]) to 1.71 (95 % CI [−0.10, 3.53]).

RF-EMF had no effect on biomarkers for modified proteins and amino acids in rodent blood (three studies, n = 40), with a pooled SMD of −0.08 (95 % CI [−1.32, 1.16]).

There was a large increase in biomarkers for oxidized DNA bases in rodent plasma (two studies, n = 38) with a pooled SMD of 2.25 (95 % CI [1.27, 3.24]).

Gonads: There was an increase in biomarkers for oxidized DNA bases in the rodent testis (two studies, n = 24) with a pooled SMD of 1.60 (95 % CI [0.62, 2.59]).

The effect of RF-EMF on biomarkers for modified proteins and amino acids in the ovary of rodents (two studies, n = 52) was inconsistent with a small effect, SMD = 0.24 (95 % CI [−0.74, 1.23])) and a large effect (SMD = 2.08 (95 % CI [1.22, 2.94])).

Thymus: RF-EMF increased biomarkers for modified proteins and amino acids in the thymus of rodents (one study, n = 42) considerably with a pooled SMD of 6.16 (95 % CI [3.55, 8.76]).

Cells: RF-EMF increased oxidized DNA bases in rodent cells with SMD of 2.49 (95 % CI [1.30, 3.67]) (one study, n = 27). There was a small effect in oxidized lipids (one study, n = 18) but not statistically significant with an SMD of 0.34 (95 % CI [−0.62, 1.29]).

In vitro studies

In in vitro studies in human cells (three studies, n = 112), there were inconsistent increases in biomarkers for oxidized DNA bases, where the SMDs varied between 0.01 (95 % CI [−0.59, 0.62]) and 7.74 (95 % CI [2.24, 13.24]) in 4 results (2 of them statistically significant). In rodent cells (three studies, n = 24), there was a not statistically significant large effect in biomarkers for oxidized DNA bases with SMD = 2.07 (95 % CI [−1.38, 5.52]).

The RF-EMF biomarkers for modified proteins and amino acids in human cells (one study, n = 18) showed a large effect with SMD = 1.07 (95 % CI [−0.05, 2.19]). In rodent cells (two studies, n = 24) a medium effect of SMD = 0.56 (95 % CI [−0.29, 1.41]) was observed.

Discussion

The evidence on the relation between the exposure to RF-EMF and biomarkers of oxidative stress was of very low certainty, because a majority of the included studies were rated with a high RoB level and provided high heterogeneity. This is due to inaccurate measurements of exposure and/or of measurement of oxidative stress biomarkers and missing information on the blinding of the research personnel. There may be no or an inconsistent effect of RF-EMF on biomarkers of oxidative stress in the brain, liver, blood, plasma and serum, and in the female reproductive system in animal experiments but the evidence is of very low certainty. There may be an increase in biomarkers of oxidative stress in testes, serum and thymus of rodents but the evidence is of very low certainty. Future studies should improve experimental designs and characterization of exposure systems as well as the use of validated biomarker measurements with positive controls.

Other: This review was partially funded by the World Health Organization. The protocol for this review is registered in PROSPERO (https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021235573) and published in Environment International (https://doi.org/10.1016/j.envint.2021.106932) (Henschenmacher et al., 2022).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024005269

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**Occupational exposure to radiofrequency electromagnetic fields and brain tumor risk: application of the INTEROCC job-exposure matrix**

Maxime Turuban, Hans Kromhout, Javier Vila, Miquel Vallbona-Vistos, Frank de Vocht , Baldi, L Richardson, G Benke, D Krewski, E Parent, S Sadetzki, B Schlehofer, J Schuz, J Siemiatycki, M van Tongeren, A Woodward, E Cardis, M Turner. Occupational exposure to radiofrequency electromagnetic fields and brain tumor risk: application of the INTEROCC job-exposure matrix. International J Cancer. First published: 20 September 2024. doi: 10.1002/ijc.35182.

Abstract

Radiofrequency electromagnetic fields (RF-EMF, 100 kHz to 300 GHz) are classified by IARC as possibly carcinogenic to humans (Group 2B). This study evaluates the potential association between occupational RF-EMF exposure and brain tumor risk, utilizing for the first time, a RF-EMF job-exposure matrix (RF-JEM) developed in the multi-country INTEROCC case-control study. Cumulative and time-weighted average occupational RF-EMF exposures were estimated for study participants based on lifetime job histories linked to the RF-JEM using three different methods: 1) by considering RF-EMF intensity among all exposed jobs, 2) by considering RF-EMF intensity among jobs with an exposure prevalence ≥ the median exposure prevalence of all exposed jobs, and 3) by considering RF-EMF intensity of jobs of participants who reported RF-EMF source use. Stratified conditional logistic regression models were used, considering various lag periods and exposure time windows defined a priori. Generally, no clear associations were found for glioma or meningioma risk. However, some statistically significant positive associations were observed including in the highest exposure categories for glioma for cumulative and time-weighted average exposure in the 1-4 year time window for electric fields (E) in the first JEM application method (ORs = 1.36, 95% CI 1.08, 1.72 64 and 1.27, 95% CI 1.01, 1.59 respectively), as well as for meningioma for cumulative exposure in the 5-9 year time window for electric fields (E) in the third JEM application method (OR = 2.30, 95% CI 1.11, 4.78). We did not identify convincing associations between occupational RF-EMF exposure and risk of glioma or meningioma.

What's New?

Radiofrequency electromagnetic fields have been classified as possibly carcinogenic to humans. Here, the authors applied a novel job-exposure matrix to investigate the link between occupational radiofrequency electromagnetic field exposure and brain tumors within the multi-country INTEROCC case–control study. The findings revealed no clear associations, despite some positive findings for gliomas and meningiomas in the 1- to 4- and 5- to 9-year exposure windows. The study underlines the applicability of the job-exposure matrix in occupational research and the need to further investigate the association between brain tumors and occupational radiofrequency electromagnetic field exposure

Conclusions

The previous SEM-based and the current JEM-based analyses (with three ways of linking the JEM to participant job histories) produced similar results that fail to show clear trends of associations between various RF-EMF exposure measures and either glioma or meningioma risk. Nevertheless, interpretation of current findings remains challenging. The method of linking JEM estimates to a job only when RF source use was self-reported led to significantly lower exposure prevalences and similarly did not suggest clear evidence of increased risk from occupational IF-RF/RF-EMF exposures. Findings suggest

that the RF-JEM could potentially be used in studies without self-reported information available on working with or near RF sources.

While we generally found no associations or inverse associations overall, a few positive associations between exposure to IF-RF/RF in cumulative and TWA exposure analyses were found with glioma in Method 1 in the highest exposure category in the 1- to 4-year time window of exposure, and with meningioma in Method 3 in the 5- to 9-year window prior to diagnosis/reference date. However, these statistically significant results, not consistent across analysis methods, could be due to chance, and will require verification in other independent studies. Integrating additional criteria when using JEM, such as exposure prevalence similar to Method 2 in this paper, when attributing exposure levels could be considered in further work. Future improvements of the RF-JEM, including by collecting and integrating personally measured exposure data could be considered.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/ijc.35182

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**Link between Wi-Fi, cordless devices, mobile phone usage patterns, and behavioral problems among Japanese children: A prospective cohort study**

Ajmal A, Yamazaki K, Tamura N, Ait Bamai Y, Yoshikawa T, Hikage T, Ikeda A, Kishi R. Link between Wi-Fi, cordless devices, mobile phone usage patterns, and behavioral problems among Japanese children: A prospective cohort study. Environ Res. 2024 Aug 1:119715. doi: 10.1016/j.envres.2024.119715.

Highlights

- Persistence and change in behavioral problem over one year were assessed and grouped into normal, persistent, improved, and concurrent groups.
- Above 75th percentile mobile phone calls duration via Internet was associated with concurrent total difficulties.
- Cordless phone use at home was associated with improved total difficulties.
- Longer cordless phone call durations were less likely to lead to persistent problematic prosocial behavior.
- The observed findings may not be related to RF-EMF and could be affected by residual confounding and chance findings.

Abstract

Background: With the recent advent of technology, it is important to confirm the health and safety of the youth. This study aimed to prospectively evaluate the relationship between Wi-Fi, cordless phones, and mobile phone usage patterns and behavioral problems.

Methods: This study involved 2,465 children aged 8-17 years from the Hokkaido Study on Environment and Children's Health from October 2020 to January 2021, with a follow-up from September 2021 to March 2022. The mother-child dyad provided information on the presence of residential Wi-Fi and cordless phones, cordless phone call duration, and mobile phone usage pattern (duration of calls using mobile network and internet, online audio streaming, online video streaming, and playing online games)

via a baseline questionnaire. Based on the scores on Strength and Difficulties Questionnaire at baseline and follow-up,the children were categorized into four groups: normal, persistent, improved, and concurrent.

Results: No significant association was found between Wi-Fi, mobile phone calls via mobile networks, and behavioral problems. Cordless phone at home had higher odds for improvement in total difficulty scores, and cordless phone for calling more than 4 minutes per week had lower odds of persistent problematic prosocial behavior. Longer duration of mobile phone calling via the internet (>40 min/week) had higher odds of concurrent total difficulties. Mobile phone calling via mobile network for <5 minutes per week had higher odds for improved total difficulty scores. Audio streaming via mobile phones for 60-120 minutes had lower odds of persistent total difficulties.

Conclusion: Our results showed sporadic findings between residential RF-EMF indoor sources and mobile phone usage pattern. These observed findings could be affected by residual confounding and chance findings. Ongoing follow-up studies are necessary to further explore this association through detailed exposure assessment and addressing the potential limitations of our study.

https://pubmed.ncbi.nlm.nih.gov/39096992/

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**Evaluating the Effect on Heart Rate Variability of Adults Exposed to Radio-Frequency Electromagnetic Fields in Modern Office Environment**

Dale S, Reiz R, Popa S, Ardelean-Dale A, Keller J, Geier JU. Evaluating the Effect on Heart Rate Variability of Adults Exposed to Radio-Frequency Electromagnetic Fields in Modern Office Environment. International Journal of Advanced Computer Science and Applications (IJACSA), 15(6), 2024. doi: 10.14569/IJACSA.2024.0150609.

Abstract

The objective of the study was to investigate whether heart rate variability (HRV) is an appropriate method to describe potential effects of RF-EMF on humans considering a modern office environment radiation level with the frequencies 1.8 GHz (DECT) and 2.45 GHz (Wi-Fi) and an exposure time of 10 min. The emitters were 1 m distant from the test subjects. The HRV parameters SDNN, RMSSD, LF and HF were recorded from 60 adults in three runs, totaling up to 154 recordings. Effects were evident for the parameter SDNN. In two runs, HRV changed from control to exposure phase, in one run from exposure phase to control. The cofactors smoking, coffee consumption, and the use of strong medications did not modulate EMF effects. HRV seems to be suitable to detect effects of radio-frequency electromagnetic fields on humans under certain conditions. In the future, prolonged exposure and new frequencies (5G) should be included in order to provide a better description of RF-EMF effects in modern office environments.

http://dx.doi.org/10.14569/IJACSA.2024.0150609.

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**Hypersensitivity to man-made electromagnetic fields (EHS) correlates with immune responsivity to oxidative stress: a case report**

Thoradit T, Chabi M, Aguida B, Baouz S, Stierle V, Pooam M, Tousaints S, Akpovi CD, Ahmad M. Hypersensitivity to man-made electromagnetic fields (EHS) correlates with immune responsivity to oxidative stress: a case report. Commun Integr Biol. 2024 Aug 4;17(1):2384874. doi: 10.1080/19420889.2024.2384874.

Abstract

There is increasing evidence that exposure to weak electromagnetic fields (EMFs) generated by modern telecommunications or household appliances has physiological consequences, including reports of electromagnetic field hypersensitivity (EHS) leading to adverse health effects. Although symptoms can be serious, no underlying mechanism for EHS is known and there is no general cure or effective therapy. Here, we present the case study of a self-reported EHS patient whose symptoms include severe headaches, generalized fatigue, cardiac arrhythmia, attention and memory deficit, and generalized systemic pain within minutes of exposure to telecommunications (Wifi, cellular phones), high tension lines and electronic devices. Tests for cerebral, cardiovascular, and other physiological anomalies proved negative, as did serological tests for inflammation, allergies, infections, auto-immune conditions, and hormonal imbalance. However, further investigation revealed deficits in cellular anti-oxidants and increased radical scavenging enzymes, indicative of systemic oxidative stress. Significantly, there was a large increase in circulating antibodies for oxidized Low-Density Lipoprotein (LDLox), byproducts of oxidative stress accumulating in membranes of vascular cells. Because a known primary effect of EMF exposure is to increase the concentration of cellular oxidants, we propose that pathology in this patient may be causally related to a resulting increase in LDLox synthesis. This in turn could trigger an exaggerated auto-immune response consistent with EHS symptoms. This case report thereby provides a testable mechanistic framework for EHS pathology with therapeutic implications for this debilitating and poorly understood condition.

Open access paper: https://www.tandfonline.com/doi/full/10.1080/19420889.2024.2384874

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**Effects of 5G radiofrequency electromagnetic radiation on indicators of vitality and DNA integrity of in vitro exposed boar semen**

Butković I, Vince S, Lojkić M, Folnožić I, Tur SM, Vilić M, Malarić K, Berta V, Samardžija M, Kreszinger M, Žaja IŽ. Effects of 5G radiofrequency electromagnetic radiation on indicators of vitality and DNA integrity of in vitro exposed boar semen. Theriogenology. 2024 Sep 25;230:243-249. doi: 10.1016/j.theriogenology.2024.09.025.

Abstract

The effects of radiofrequency electromagnetic radiation (RF-EMR) on semen quality have been in the spotlight in recent years, though research results to date have been contradictory. The effects of RF-EMR amongst others depend upon frequency, and there is currently no literature concerning the influence of 5G frequencies on both DNA integrity and spermatozoa vitality in males. The aim of this study was to investigate the effect of 5G RF-EMR on sperm membrane integrity, mitochondrial potential, and DNA integrity of in vitro exposed semen of breeding boars. The study included semen

samples of eight breeding boars of the Pietren breed and four breeding boars of the German Landrace breed, from 1.5 to 3.5 years in age. Freshly diluted semen of each boar was divided into a control (n = 12) and experimental group (n = 12). The samples of the experimental group were exposed for 2 hours to continuous RF-EMR at a single frequency (700 MHz, 2500 MHz and 3500 MHz) and an electromagnetic field strength of 10 V/m using a transverse gigahertz electromagnetic cell. Sperm DNA fragmentation was assessed using a Halomax® kit and sperm membrane integrity and mitochondrial potential was assessed using a PI⁄SYBR-14 LIVE⁄DEAD viability kit with JC-1. A significantly higher proportion of spermatozoa with DNA fragmentation was found in exposed semen samples for all frequencies compared to the control group. The highest DNA damage was recorded in semen samples exposed to 5G RF-EMR at 2500 MHz ($p < 0.01$) and 3500 MHz ($p < 0.05$) vs. control semen samples. A significantly higher proportion of spermatozoa with damaged cell membrane and good mitochondrial potential was recorded in semen samples exposed with 3500 MHz. In vitro exposure of breading boar semen to 5G RF-EMR significantly increases the proportion of DNA fragmentation. The harmful effect of 5G RF-EMR on the proportion of spermatozoa with damaged DNA was frequency dependent. The 3500 MHz frequency displayed the most harmful effects due to significant impacts on DNA integrity and spermatozoa vitality indicators.

https://pubmed.ncbi.nlm.nih.gov/39342826/

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**Study of genotoxic and cytotoxic effects induced in human fibroblasts by exposure to pulsed and continuous 1.6 GHz radiofrequency**

Massaro L, De Sanctis S , Franchini V, Regalbuto E, Alfano G, Focaccetti C, Benvenuto M, Cifaldi L, Sgura A, Berardinelli F, Marinaccio J, Barbato F, Rossi E, Nardozi D, Masuelli L, Bei R, Lista F. Study of genotoxic and cytotoxic effects induced in human fibroblasts by exposure to pulsed and continuous 1.6 GHz radiofrequency. Frontiers in Public Health, Vol 12. 2024. doi: 10.3389/fpubh.2024.1419525.

Abstract

Background  The widespread use of radiofrequency (RF) sources, ranging from household appliances to telecommunications devices and military equipment, raises concerns among people and regulatory agencies about the potential health risks of RF exposure. Consequently, several *in vitro* and *in vivo* studies have been done to investigate the biological effects, in particular non-thermal, of this non-ionizing radiation. To date, this issue is still being debated due to the controversial results that have been reported. Furthermore, the impact of different RF signal modulations on biological systems remains poorly investigated. The present *in vitro* study aims to evaluate the cytotoxicity and genotoxicity of continuous or pulsed 1.6 GHz RF in human dermal fibroblasts (HDF).

Methods  HDF cultures were exposed to continuous and pulsed 1.6 GHz RF, for 2 h, with Specific Absorption Rate (SAR) of 0.4 W/kg. The potential biological effects of 1.6 GHz RF on HDF were assessed with a multi-methodological approach, analyzing the effects on cell cycle, ultrastructure, protein expression, mitotic spindle, CREST stained micronuclei, chromosome segregation and γ-H2AX/53BP1 foci.

Results  1.6 GHz RF exposure modified proteins expression and morphology of HDF. Specifically, the expression of different heat-shock proteins (HSP) (i.e., HSP-90, HSP-60, and HSP-25) and phospho-AKT

were affected. In addition, both continuous and pulsed RF modified the cytoskeletal organization in HDF and increased the number of lysosomes, while the formation of autophagosomes was observed only after pulsed RF exposure. Mitotic spindle anomalies were also found after exposure. However, no significant effect was observed on cell cycle, chromosome segregation, CREST-stained micronuclei and γ-H2AX/53BP1 foci.

Conclusion  The results of the present study show the absence of genotoxic damage in 1.6 GHz RF exposed HDF and, although mitotic spindle alterations were observed, they did not have an aneugenic effect. On the other hand, changes in some proteins expression and cell ultrastructure in exposed HDF suggest that RF can potentially induce cell alterations at the morphological and molecular levels.

Excerpt

In this controversial scientific scenario, our results are in agreement with most *in vitro* findings on different cell models about the lack of genotoxic damage induced by RF, either clastogenic or aneugenic. Despite this, we find alterations of the mitotic spindle, with a significant increase in multipolar spindles following PW exposure and we also observed a tendency of RF to induce non-disjunction events with both signals. However, our study reveals an increase in these spindle abnormalities without a concomitant increase in MN-positive CREST, suggesting no aneuploidy effect probably due to spindle abnormalities reversion, as proposed by other authors (78). Nonetheless, this apparent discordant result requires further investigations.

The reported observations indeed highlight the complexity of cellular response to RF and emphasize the need for further investigations to clarify the overall biological effects of 1.6 GHz PW and CW RF, given the widespread and constant public RF-EMF exposure, mostly due to mobile communication devices.

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1419525

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**Pulsed High-Power Radio Frequency Energy Can Cause Non-Thermal Harmful Effects on the BRAIN**

Yaghmazadeh O. Pulsed High-Power Radio Frequency Energy Can Cause Non-Thermal Harmful Effects on the BRAIN. IEEE Open Journal of Engineering in Medicine and Biology, 5:50-53, 2024. doi: 10.1109/OJEMB.2024.3355301.

Abstract

High-power microwave applications are growing for both military and civil purposes, yet they can induce brain-related risks and raise important public health concerns. High-power sub-millisecond radio frequency energy pulses have been demonstrated to be able to induce neurological and neuropathological changes in the brain while being compliant with current regulatory guidelines' limits, highlighting the necessity of revising them.

Impact Statement

This commentary piece looks into the different mechanisms of interaction of pulsed versus continuous-wave RF energy radiation and the brain. It also highlights potential harmful effects of pulsed high-power RF energy on the brain.

Open access paper: https://ieeexplore.ieee.org/document/10402080

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**External RF-EMF alters cell number and ROS balance possibly via the regulation of NADPH metabolism and apoptosis**

Chow S-C, Zhang Y, Ng RWM , Hui S-YR , Solov'yov IA , Lui W-Y. External RF-EMF alters cell number and ROS balance possibly via the regulation of NADPH metabolism and apoptosis. Frontiers in Public Health. 12 (2024). doi: 10.3389/fpubh.2024.1425023.

Abstract

The influence of weak radio-frequency electromagnetic field (RF-EMF) on living organisms raises new concern because of the Industrial, Scientific, and Medical (ISM) frequency band at 6.78 MHz being promoted by the AirFuel Alliance for mid-range wireless power transfer (WPT) applications and product development. Human exposure to the RF-EMF radiation is unavoidable. In this study, we employed *in vitro* cell culture and molecular biology approach coupled with integrated transcriptomic and proteomic analyses to uncover the effects of RF-EMF on cells at molecular and cellular levels. Our study has demonstrated that weak RF-EMF is sufficient to exert non-thermal effects on human umbilical vein endothelial cells (HUVEC). Exposure of weak RF-EMF promotes cell proliferation, inhibits apoptosis and deregulates ROS balance. Alteration of several signaling pathways and key enzymes involved in NADPH metabolism, cell proliferation and ferroptosis were identified. Our current study provide solid evidence for the first time that the present safety standards that solely considered the thermal effect of RF-EMF on cell tissue are inadequate, prompt response and modification of existing Guidelines, Standards and Regulation are warranted.

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1425023/full

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**No observable non-thermal effect of microwave radiation on the growth of microtubules**

Hammarin G, Norder P, Harimoorthy R, Chen G, Berntsen P, Widlund PO, Stoij C, Rodilla H, Swenson J, Brändén G, Neutze R. No observable non-thermal effect of microwave radiation on the growth of microtubules. Sci Rep. 2024 Aug 7;14(1):18286. doi: 10.1038/s41598-024-68852-3.

Abstract

Despite widespread public interest in the health impact of exposure to microwave radiation, studies of the influence of microwave radiation on biological samples are often inconclusive or contradictory. Here we examine the influence of microwave radiation of frequencies 3.5 GHz, 20 GHz and 29 GHz on the growth of microtubules, which are biological nanotubes that perform diverse functions in eukaryotic cells. Since microtubules are highly polar and can extend several micrometres in length, they are predicted to be sensitive to non-ionizing radiation. Moreover, it has been speculated that tubulin dimers

within microtubules might rapidly toggle between different conformations, potentially participating in computational or other cooperative processes. Our data show that exposure to microwave radiation yields a microtubule growth curve that is distorted relative to control studies utilizing a homogeneous temperature jump. However, this apparent effect of non-ionizing radiation is reproduced by control experiments using an infrared laser or hot air to heat the sample and thereby mimic the thermal history of samples exposed to microwaves. As such, no non-thermal effects of microwave radiation on microtubule growth can be assigned. Our results highlight the need for appropriate control experiments in biophysical studies that may impact on the sphere of public interest.

Open access paper: https://www.nature.com/articles/s41598-024-68852-3

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**Exploring edible bird nest's potential in mitigating Wi-Fi's impact on male reproductive health**

Maluin SM, Jaffar FHF, Osman K, Zulkefli AF, Mat Ros MF, Ibrahim SF. Exploring edible bird nest's potential in mitigating Wi-Fi's impact on male reproductive health. Reprod Med Biol. 2024 Sep 11;23(1):e12606. doi: 10.1002/rmb2.12606.

Abstract

Purpose: This study aimed to evaluate the protective effects of edible bird nest (EBN) against the detrimental impact of Wi-Fi on male reproductive health. Specifically, it examines whether EBN can mitigate Wi-Fi-induced changes in male reproductive hormones, estrogen receptors (ER), spermatogenesis, and sperm parameters.

Methods: Thirty-six adult male rats were divided into six groups (n = 6): Control, Control EBN, Control E2, Wi-Fi, Wi-Fi+EBN, and Wi-Fi+E2. Control EBN and Wi-Fi+EBN groups received 250 mg/kg/day EBN, while Control E2 and Wi-Fi+E2 groups received 12 μg/kg/day E2 for 10 days. Wi-Fi exposure and EBN supplementation lasted eight weeks. Assessments included organ weight, hormone levels (FSH, LH, testosterone, and E2), ERα/ERβ mRNA and protein expression, spermatogenic markers (c-KIT and SCF), and sperm quality.

Results: Wi-Fi exposure led to decreased FSH, testosterone, ERα mRNA, and sperm quality (concentration, motility, and viability). EBN supplementation restored serum FSH and testosterone levels, increased serum LH levels, and the testosterone/E2 ratio, and normalized mRNA ERα expression. Additionally, EBN increased sperm concentration in Wi-Fi-exposed rats without affecting motility or viability.

Conclusions: EBN plays a crucial role in regulating male reproductive hormones and spermatogenesis, leading to improved sperm concentration. This could notably benefit men experiencing oligospermia due to excessive Wi-Fi exposure.

Excerpts

Wi-Fi exposure setting: For Wi-Fi exposure, this study utilized the TP-LINK AC750 Wireless Dual Band Wi-

Fi Router Archer C20 (Shenzhen, China). This router features three external antennas, emitting signals at a frequency of 2.45 GHz using the IEEE 802.11n standard. The router was positioned 20 cm away from the rat cages and constantly exchanged data with a Raspberry Pi device through a ping protocol.3 The router was selected for its minimal vibration and noise output, which is typical for standard Wi-Fi routers used in laboratory settings. Additionally, the rats were housed in a controlled environment designed to minimize external disturbances, ensuring the reliability of our findings related to Wi-Fi exposure effects on male reproductive health.

Conclusion: This study highlights the negative impact of eight weeks of Wi-Fi exposure on sperm quality, including decreased concentration, motility, and viability, which can be ascribed to changes in male reproductive hormones. EBN supplementation appears to be a preventive intervention, significantly increasing gonadotrophin and testosterone levels, as well as sperm concentration in Wi-Fi-exposed rats, but not influencing sperm motility or viability. Furthermore, it increases the T/E2 ratio and restores estrogenic activity in the testes, resulting in enhanced sperm concentration. The study also reveals a discrepancy between the impacts of EBN supplementation and E2 treatment on sperm concentration in a Wi-Fi-exposed setting, emphasizing EBN's unique protective properties without adverse effects on male reproduction. In conclusion, EBN supplementation effectively restores spermatogenesis capabilities that are affected by Wi-Fi-induced damage. This is achieved through the modulation of male reproductive hormones, with a primary influence on sperm concentration. Nevertheless, further research is necessary to fully understand the mechanisms and establish safe usage limits for maximizing the benefits of EBN while minimizing potential risks.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/rmb2.12606

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**Spots with Extremely High Radiofrequency Radiation After Deployment of 5G Base Stations in Stockholm, Sweden**

Hardell L, Koppel T. Spots with Extremely High Radiofrequency Radiation After Deployment of 5G Base Stations in Stockholm, Sweden. Ann Clin Med Case Rep. 2024; V14(4): 1-8.

Abstract

During recent years there is an on-going deployment of 5G base stations for radiofrequency [RF] communication in Sweden as well in many other countries. This is made without investigations on risks to human health and the environment. Since 2016 we have made several measurements of environmental exposure to RF radiation in Stockholm, Sweden, including previous generations and now also 5G. In the current study, performed in October 2023, the broadband meter Narda-550 with the probe EF-1891 was used. It gives results in the root mean square [RMS] mode, thus not peak levels. Both the International Commission on Non-Ionizing Radiation Protection [ICNIRP] and the US Federal Communications Commission [FCC] base their guidelines on RMS levels of RF radiation. Measurements were made in similar city areas as in our previous studies. Results show that the RF radiation has increased substantially. High maximum levels were found at e.g. the Central Railway Station [3 637 191 µW/m2], and popular walking streets such as Mäster Samuelsgatan [11 613 976 µW/m2], and Drottninggatan [5 271 555 µW/m2]. The peak values would be much higher. These levels are in the

same magnitude or even higher than those measured in homes of persons that rapidly developed symptoms of the microwave syndrome after installation of 5G, usually in combination with 4G+, in the neighborhood. They are also substantially higher than levels that have previously been linked to cancer and the microwave syndrome in studies of people living near base stations and masts from previous generations of telecommunications.

Open access paper: https://acmcasereport.org/wp-content/uploads/2024/09/ACMCR-v14-2262-3-1.pdf

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**Mobile Phone Emissions in 5G FR1: Using Statistic Inferences and Deep Learning for Empiric Features Extraction**

Miclaus S, Deaconescu DB, Vatamanu D, Buda AM. Mobile Phone Emissions in 5G FR1: Using Statistic Inferences and Deep Learning for Empiric Features Extraction*. 2024 IEEE International Symposium on Measurements & Networking (M&N)*, Rome, Italy, 2024, pp. 01-06, doi: 10.1109/MN60932.2024.10615263.

Abstract

As the primary source of human exposure to electromagnetic fields, the emission of a 5G mobile phone is quantified for several mobile applications use. Following the time variability of the exposure, its peak levels and their statistic distributions, together with the time-frequency change in the spectrograms, we emphasize the peculiarities of the exposure in connection to modulation scheme used and to the application. The results show notable differences in amplitude probability densities, in complementary cumulative density functions and in repeatability of time-frequency features of the emissions.

Excerpts

It has been recently proved that the main exposure source of a person is the mobile phone itself [5], [6]. The study results of [7] confirmed that the human exposure in a 5G network is dominated by the uplink, and can be ten times larger than the downlink exposure....

Conducting measurements in real-life situations contributes to true assessment of the field exposure impact. It is essential to interpret all the findings on the background of dosimetric determinations and based on present regulatory guidelines [16], [17]. However, studies like [18] - [20] clearly pointed out that “cell phones emit a succession of pulse trains of different durations, the instantaneous fields of such signals allow activation of molecular, electronic, and protonic components within cells that have different thresholds and relaxation times, enriching the non-thermal effects of radiofrequency fields”.

In the current work we aimed to analyze the exposure situation generated by a 5G mobile phone in a static position, while emitting signals in a 100 MHz bandwidth centered on 3.58 GHz. While using four different mobile applications running on the phone ...

An Iphone 14pro (model A 2890, Apple, Zhengzhou, China) was the source of the emissions. It was maintained in a stationary position and connected to the 5G mobile network - Orange Romania operator. The central frequency was f=3.58 GHz, the bandwidth was 100 MHz and Time Division Multiple Access (TDMA) scheme was used....

... the phone was situated at the cell edge and it received a good downlink signal.

The receiving system was composed of a signal analyzer model FSW from Rhode & Schwarz, with a real time bandwidth of 160 MHz connected to a receiving antenna model Aaronia Omnilog 30800 (Fig. 1)....

... video streaming conducted to the highest mean emitted powers, while upload provokes the highest peak powers. Crest factors are the largest when a file is uploaded, and they can exceed 20 dB....

Variations of 19 dB around mean power is equivalent to a factor of approximately 8 x 10**3. Such a large variability during so short time (ms), may pose challenging biological response. The trends in the excessive exceedance of the mean power depend at least on mobile application type and on the modulation scheme. From this perspective, the tail features of time-variability of the exposure level may trigger unexpected consequences....

CONCLUSIONS

A mobile phone connected to a 5G-NR network in FR1 band was investigated for its emitted EMF level and the associated time-variability characterization (during 250 ms), in four situations of usage: during file-upload, file-download, video call and Internet streaming. The measurement set-up consisted in a receiving antenna mostly planar and parallel to the phone’s display connected to a vector signal analyzer with a capability of analysing bandwidth larger than the communication bandwidth (100 MHz). The antenna collected the field of the phone at 30 cm distance from it, and had an omnidirectional pattern in azimuth....

All the results showed that the uplink EMF level is far below the safe limit based on thermal effects of human exposure. However, other important features evolved and they may be further linked to the non-thermal/specific effects of microwaves....

When it comes to the prevalence of peaks in the exposure, it resulted that crest factors varied mostly in function of the mobile application used but also, in a lower measure, in function on the modulation scheme. The largest crest factors were more than one order of magnitude higher than the smallest ones, overall. Mean and peak powers of emissions could deviate from each other with approximately two orders of magnitude, for the same mobile application. Such short and pronounced extremes should be carefully investigated from the biological endpoint of view.

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**Estimates and measurements of radiofrequency exposures in smart-connected home**s

Joyner K, Milligan M, Knipe P. Estimates and measurements of radiofrequency exposures in smart-connected homes. Bioelectromagnetics. 2024 Jul 18. doi: 10.1002/bem.22518.

Abstract

The aim of this research was to quantify the levels of radiofrequency electromagnetic energy (RF-EME) in a residential home/apartment equipped with a range of wireless devices, often referred to as internet of things (IoT) devices or smart devices and subsequently develop a tool that could be useful for estimating the levels of RF-EME in a domestic environment. Over the course of 3 years measurements were performed in peoples' homes on a total of 43 devices across 16 device categories. Another 12 devices were measured in detail in a laboratory setup. In all a total of 55 individual devices across 23 device categories were measured. Based on this measurement data we developed predictive software

that showed that even with a single device in 23 device categories operating near maximum they would, in total, produce exposures at a distance of 1 m of 0.17% of the ICNIRP (2020) public exposure limits. Measurements were also made in two separate smart apartments—one contained over 50 IoT devices and a second with over 100 IoT devices with the devices driven as hard as could reasonably be achieved. The respective 6-min average exposure level recorded were 0.0077% and 0.44% of the ICNIRP (2020) 30-min average public exposure limit.

Excerpts

.... Based on all of these measurements, we have developed predictive software that can be used to estimate exposure levels on a conservative basis by incorporating a 3 dB enhancement to produce a realistic upper bound for the exposure estimation. The RF estimator tool, which is available from the Mobile & Wireless Forum (MWF) website (www.mwfai.org), has a drop-down menu that allows the selection of multiple IoT devices and separation distances and returns an estimate of the exposure level that could be expected in the home environment. Devices in neighboring rooms can be included in the software by selecting the appropriate device and distance. However, because of the inverse square dependence with distance and the attenuation through walls, the majority contribution in a particular room is determined by the proximity of devices in that room. Future work will include the expansion of the device categories and the inclusion of wall/window attenuation to account for neighboring homes and apartments.

CONFLICT OF INTEREST STATEMENT This work was fully funded by the Mobile and Wireless Forum (www.mwfai.org) and that KJ and MM are contractored by the MWF.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22518

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**Review Antenna Design for Modern Mobile Phones: A Review**

Wang Y, Sun L, Du Z, Zhang Z. Review Antenna Design for Modern Mobile Phones: A Review. Electromagnetic Science, 2(2):1-36. June 2024, doi: 10.23919/emsci.2023.0052.

Abstract

Due to limited antenna space, high communication requirements, and strict regulatory constraints, the design of antennas for modern mobile phones has become an exceedingly challenging task. In recent years, numerous studies have been conducted in this area, leading to significant advancements. This review paper comprehensively summarizes recent progress made in antenna design for modern mobile phones. Firstly, the challenges faced in antenna design for modern mobile phones are described, including bandwidth enhancement, integration and decoupling techniques, mm-wave array antennas, satellite communication antennas, as well as interactions between mobile antennas and the human body. Secondly, the basic antenna types (such as inverted-F, slot, loop, and planar inverted-F antennas) commonly used in modern metal-bezel mobile phones along with their key characteristics are briefly summarized. Thirdly, the commonly employed methods used in practical applications for designing wideband antennas within compact sizes and achieving decoupling among multiple antennas with wide bandwidths are collected. Fourthly, recent advances in the design of compact, wideband, and wide-angle scanning mm-wave arrays for modern mobile phones are summarized. Fifthly, recent progress

made in satellite communication antenna designs for modern mobile phones, including broadside and end-fire radiation patterns, is presented. Sixthly, recent studies on the interaction between mobile antennas and the human body are briefly concluded. Finally, the future challenge of antenna design for mobile phones is briefly discussed. It is our hope that this comprehensive review will provide readers with a systematic understanding of antenna design principles applicable to modern mobile phones.

Excerpts

"Currently, with the improvement of communication requirements and the evolution of communication specifications, the number of antennas in smartphones has reached 20–30 (as depicted in Figure 3), including the following antennas:

- Four antennas for LB (low band): 698–960 MHz;
- Four antennas for MHB (mid- and high-band) MIMO operation: 1710–2690 MHz;
- Four antennas for 5G New Radio (NR) band MIMO operation: 3300–4200 MHz & 4400–5000 MHz;
- Two or more dual-band millimeter-wave AiP antennas: 24.25-29.50 GHz and 37.00-43.50 GHz;
- One or more satellite communication antennas: the operating band is the L- or S-band;
- Two GNSS (global navigation satellite system) antennas: GPS L5 at 1176 MHz and GPS L1 at 1575 MHz;
- Two to four tri-band WiFi (wireless fidelity) and BT (Bluetooth) antennas: 2400–2484 MHz, 5150–5350 MHz, and 5725–5825 MHz;
- One NFC (near field communication) antenna: 13.56 MHz;
- Three UWB (ultra-wideband) antennas: 6240–6740 MHz and 7750–8250 MHz."

"In [199], the interaction principle of antenna radiation fields with nearby human bodies are analyzed by using electromagnetic boundary conditions. Under these boundary conditions, the horizontal E-field penetrates human tissue more easily than the vertical E-field does [199], as shown in Figure 49. Thus, mobile antennas with a vertical E-field have a higher on-body efficiency and lower SAR. As shown in Figure 50, a smartwatch antenna with a vertical E-field has a weak E-field in the human body, thus, the performance of an antenna with a vertical E-field is approximately 4 dB greater than that of an antenna with a horizontal E-field [200], [201]. Additionally, the vertical E-field method can also be applied to ear-bar TWS earphones, which can improve the antenna performance from 19.1% to 30.9% with a vertical E-field [202]."

Open access paper: https://ieeexplore.ieee.org/document/10636175

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**High Frequency Electromagnetic Field Exposure in Paediatric and Female Patients with Implanted Cardiac Pacemaker**

Bacova F, Benova M, Psenakova Z, Smetana M, Pacek M, Ochodnicky J. High Frequency Electromagnetic Field Exposure in Paediatric and Female Patients with Implanted Cardiac Pacemaker. *Applied Sciences*. 2024; 14(16):7198. doi: 10.3390/app14167198.

Abstract

This article investigates the effects of electromagnetic field (EMF) from mobile phones on human tissues and implanted medical devices. The intensity of the electric field (E) is evaluated based on simulations and measurements of various exposure scenarios. An area of interest is the case of a person with an implanted device (heart pacemaker) who may be affected by this exposure. Due to the rapid development of communication technologies and the growing awareness of the potential health risks of radio frequency (RF) EMF, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has established exposure limits within the European Union. Our study models and analyses EMF values in human tissues in an ideal environment, in a situation where a person uses a mobile phone in the DCS (Digital Cellular System) band, including the case of a person with an implanted pacemaker. Pilot simulations were verified by experimental measurements. Based on them, specific human models with the best matching results were selected for modelling other possible interactions of exogenous EMF and cardiac pacemaker in the same situations and locations

Excerpt

Based on our simulations and experimental measurements, we found that maintaining a minimum distance of 15 cm between the mobile phone and the pacemaker is not sufficient to ensure patient safety. Our results show that even at a distance of 30 cm, the E values for the models were: MM—54.96 V/m, for Child—65.34 V/m, for Laura—62.81 V/m, and measurements—52.72 In M. In the case of the Child and Laura complex models, the E values still exceeded the exposure limit of 58 V/m for a frequency of 1800 MHz. Our recommendation is to push this limit up to more than 30 cm.

Another recommendation is protective equipment that reduces the exposure of parts of the human body to EMF. However, these aids must have a certificate of satisfactory EM compatibility.

Open access paper: https://www.mdpi.com/2076-3417/14/16/7198

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**Importance of magnetic information for neuronal plasticity in desert ants**

Grob R, Müller VL, Grübel K, Fleischmann PN. Importance of magnetic information for neuronal plasticity in desert ants. PNAS. 2024. 121 (8) e2320764121. doi: pnas.2320764121.

Significance

The Earth's magnetic field is an essential navigational cue for many animal species. However, where in the brain magnetic information is processed is still little understood. In this paper, we analyzed structural neuronal plasticity in the brain of Cataglyphis desert ants following sky-compass calibration under permanently manipulated magnetic field conditions. Our results demonstrate that information from the Earth's magnetic field is integrated into the ants' internal compass (central complex) and into the learning and memory centers (mushroom bodies). Together with our behavioral analyses, the results show that the ants use magnetic information both as a navigational compass and as a reference system for visual compass calibration.

Abstract

Many animal species rely on the Earth's magnetic field during navigation, but where in the brain magnetic information is processed is still unknown. To unravel this, we manipulated the natural magnetic field at the nest entrance of Cataglyphis desert ants and investigated how this affects relevant brain regions during early compass calibration. We found that manipulating the Earth's magnetic field has profound effects on neuronal plasticity in two sensory integration centers. Magnetic field manipulations interfere with a typical look-back behavior during learning walks of naive ants. Most importantly, structural analyses in the ants' neuronal compass (central complex) and memory centers (mushroom bodies) demonstrate that magnetic information affects neuronal plasticity during early visual learning. This suggests that magnetic information does not only serve as a compass cue for navigation but also as a global reference system crucial for spatial memory formation. We propose a neural circuit for integration of magnetic information into visual guidance networks in the ant brain. Taken together, our results provide an insight into the neural substrate for magnetic navigation in insects.

https://www.pnas.org/doi/10.1073/pnas.2320764121

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**A critical appraisal of the WHO 2024 systematic review of the effects of RF-EMF exposure on tinnitus, migraine/headache, and non-specific symptoms (WHO SR 7)**

Frank J, Melnick R, Moskowitz J, on behalf of the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF). A critical appraisal of the WHO 2024 systematic review of the effects of RF-EMF exposure on tinnitus, migraine/headache, and non-specific symptoms. Reviews on Environmental Health. 2024. doi: 10.1515/reveh-2024-0069.

Abstract

The World Health Organization (WHO) in 2012 initiated an expert consultation about research on the health effects of radio-frequency electromagnetic fields (RF-EMF) for a WHO monograph that was last updated in 1993. The project was abandoned over concerns about the quality of the commissioned review papers. The WHO restarted the project in 2019 by commissioning ten systematic reviews (SRs) of the research on RF-EMF exposure and adverse biological and health outcomes in laboratory animals, cell cultures, and human populations. The second of these SRs, published in 2024, addresses human observational studies of RF-EMF exposure and non-specific symptoms, including tinnitus, migraine/headache, and sleep disturbance. The present commentary is a critical appraisal of the scientific quality of this SR (SR7) employing criteria developed by the Oxford Centre for Evidence-Based Medicine. Based upon our review, we call for a retraction of SR7 and an impartial investigation by unconflicted experts of the currently available evidence and future research priorities.

Conclusion

To summarize, the way in which any epidemiologically unsophisticated reader is likely to be misled by this SR is clear. It appears to conclude unequivocally that the body of scientific evidence reviewed supports the safety of current (e.g. ICNIRP-based) population exposure limits for RF-EMF [10]. We reiterate that, on the contrary, this body of evidence is not adequate to either support or refute the safety of current exposure limits – largely due to the very small number and low methodological quality

of the relevant primary studies to date, and the fundamental inappropriateness of meta-analysis for the handful of very heterogeneous primary studies identified by Röösli et al. [3] for each of the exposure/outcome combinations analysed.

We therefore call for a retraction of the SR by Röösli et al., and an impartial international investigation, by unconflicted experts, of both the currently available evidence base on these issues, as well as related research priorities for the future. That investigation should particularly address, above and beyond the topic of priority health outcomes to be researched (which was already assessed in the international expert consultation by WHO in 2018) [2], and the need for improved methods of accurately measuring RF-EMF exposures, suitable for large human observational studies in the general population – the Achilles heel of the current literature.

Open access paper: https://www.degruyter.com/document/doi/10.1515/reveh-2024-0069/html

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**WHO to build neglect of RF-EMF exposure hazards on flawed EHC reviews? Case study demonstrates how "no hazards" conclusion is drawn from data showing hazards (WHO SR 3)**

Nordhagen E, Flydal E. WHO to build neglect of RF-EMF exposure hazards on flawed EHC reviews? Case study demonstrates how "no hazards" conclusion is drawn from data showing hazards. *Reviews on Environmental Health*. 2024. doi: 10.1515/reveh-2024-0089.

Abstract

We examined one of the first published of the several systematic reviews being part of WHO's renewed initiative to assess the evidence of associations between man-made radiofrequency electromagnetic radiation (RF-EMF) and adverse health effects in humans. The examined review addresses experimental studies of pregnancy and birth outcomes in non-human mammals. The review claims that the analyzed data did not provide conclusions certain enough to inform decisions at a regulatory level. Our objective was to assess the quality of this systematic review and evaluate the relevance of its conclusions to pregnant women and their offspring. The quality and relevance were checked on the review's own premises: e.g., we did not question the selection of papers, nor the chosen statistical methods. While the WHO systematic review presents itself as thorough, scientific, and relevant to human health, we identified numerous issues rendering the WHO review irrelevant and severely flawed. All flaws found skew the results in support of the review's conclusion that there is no conclusive evidence for nonthermal effects. We show that the underlying data, when relevant studies are cited correctly, support the opposite conclusion: There are clear indications of detrimental nonthermal effects from RF-EMF exposure. The many identified flaws uncover a pattern of systematic skewedness aiming for uncertainty hidden behind complex scientific rigor. The skewed methodology and low quality of this review is highly concerning, as it threatens to undermine the trustworthiness and professionalism of the WHO in the area of human health hazards from man-made RF-EMF.

Conclusions

The rigorous protocol and extensive analyses presented in EHC2023 and its protocol, convey an impression of serious science, credibility, and reliability. However, we have shown that this is not the case.

We found EHC2023 to be a massive work with a rigorous and complex protocol and extensive and complex statistical analyses. A consequence of the complexity is that it can be assumed that no average reader – not even professionals – will check the results of the review, if not for other reasons, because of the major effort needed. Thereby, scientific exchange, debate and control is impeded and reduced to a matter of trust.

We had the opportunity to spend time on an in-depth analysis of representative parts of EHC2023 to assess its quality based to the extent possible on the review's own premises – that is, independent of our opinion about the professional premises chosen.

We cannot prove that the flaws and omissions are deliberately added to reach wanted conclusions, as we have next to no information about the authors, neither of the process behind the authoring EHC2023 or its protocol. Anyhow, and whatever the cause, the EHC2023 review is clearly of such a low quality, also when evaluated within the thermal only tradition, that its conclusions are without scientific value.

Our findings show that the conclusion of EHC2023 is not well-founded, and therefore the final conclusions of EHC2023 that no conclusion can be drawn that are (EHC2023, p. 31) "certain enough to inform decisions at a regulatory level" cannot be trusted. The errors, flaws and omissions are grave enough to render EHC2023 unscientific and unethical, and it should therefore be retracted.

As it now stands, the conclusion of ECH2023 stands out as what appears to be a manufactured argument for current regulations being adequate to protect the health of human mothers and their offspring. Manipulating and skewing research results in order to manufacture a wanted conclusion is a well-known strategy to avoid stricter regulations [11], [12], [13], [14], [15]. Further investigations and better sources would be needed to prove such an assault on humanity to be the case as to EHC2023.

EHC2023 is just one of several studies commissioned by the same organization (WHO EHC no. 137) and states clearly that consistency has been assured in the protocols for these studies. Our analysis of EHC2023 may in this view be seen as a case study of the results of the entire WHO EHC undertaking: Since many of our concerns are related to core elements of the protocol, there are good reasons also to question the quality of all present and forthcoming results being part of the WHO EHC undertaking unless a thorough revision of its course is made.

Open access paper: https://www.degruyter.com/document/doi/10.1515/reveh-2024-0089/html

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**A comprehensive review of 5G NR RF-EMF exposure assessment technologies: fundamentals, advancements, challenges, niches, and implications**

Korkmaz E, Aerts S, Coesoij R, Bhatt CR, Velghe M, Colussi L, Land D, Petroulakis N, Spirito M, Bolte J. A comprehensive review of 5G NR RF-EMF exposure assessment technologies: fundamentals, advancements, challenges, niches, and implications. Environ Res. 2024 Jul 6;260:119524. doi: 10.1016/j.envres.2024.119524.

Highlights

- Monitoring exposure to radiofrequency electromagnetic fields (RF-EMF) is crucial for environmental health and risk assessment
- A comprehensive review of the diverse landscape of RF-EMF assessment tools was missing.
- There is a definite need for cost-effective and long-lasting EMF sensors.
- Custom-developed RF-EMF measurement tools lack a standardized framework for comparison and validation.

Abstract

This review offers a detailed examination of the current landscape of radio frequency (RF) electromagnetic field (EMF) assessment tools, ranging from spectrum analyzers and broadband field meters to area monitors and custom-built devices. The discussion encompasses both standardized and non-standardized measurement protocols, shedding light on the various methods employed in this domain. Furthermore, the review highlights the prevalent use of mobile apps for characterizing 5G NR radio network data. A growing need for low-cost measurement devices is observed, commonly referred to as “sensors” or “sensor nodes”, that are capable of enduring diverse environmental conditions. These sensors play a crucial role in both microenvironmental surveys and individual exposures, enabling stationary, mobile, and personal exposure assessments based on body-worn sensors, across wider geographical areas. This review revealed a notable need for cost-effective and long-lasting sensors, whether for individual exposure assessments, mobile (vehicle-integrated) measurements, or incorporation into distributed sensor networks. However, there is a lack of comprehensive information on existing custom-developed RF-EMF measurement tools, especially in terms of measuring uncertainty. Additionally, there is a need for real-time, fast-sampling solutions to understand the highly irregular temporal variations EMF distribution in next-generation networks. Given the diversity of tools and methods, a comprehensive comparison is crucial to determine the necessary statistical tools for aggregating the available measurement data.

Conclusions

The objective of this review was to establish a groundwork for progress in the field of RF-EMF exposure assessment, ultimately contributing to a more thorough and efficient assessment. This review provides a comprehensive overview of the current state-of-the-art concerning RF-EMF measuring instruments. It covers a wide array of tools, such as spectrum analyzers, broadband field meters, area monitors, personal exposimeters, and custom-built instruments, as well as the existing measurement protocols, encompassing both standardized and non-standardized methods. In addition, we also have presented some of the most commonly used mobile apps for collecting 5G NR radio network data, which have also been used in RF-EMF exposure assessments. However, it is not yet clear on how accurate the measurement results of these apps are and how they compare among themselves and to more sophisticated tools.

Most importantly, this review revealed the need for cost-effective and long-lasting measurement devices or sensors that are capable of collecting data at a high time resolution in various frequency bands, as well as withstanding various environmental conditions. These sensors are essential for conducting stationary, mobile, and personal exposure assessments across larger geographical areas, time intervals, and populations than current capabilities allow. Additionally, it is important to recognize that the specific requirements for these sensors differ based on their intended usage, e.g., on-body

measurement devices need to take into account the influence of the body, vehicle-integrated sensors the influence of the speed and the relative position of the sensor on the vehicle, and sensors on infrastructure the influence of the height and the building materials. Furthermore, there exists a demand for real-time, fast-sampling solutions to comprehend the highly irregular temporal variations in EMF distribution within next-generation networks.

Moreover, there is a notable absence of extensive information regarding currently employed custom-developed RF-EMF measurement tools, particularly with respect to measuring uncertainty. Considering the diversity of tools and methodologies in use, conducting a thorough comparison becomes crucial to identify the necessary statistical tools for aggregating the available measurement data.

A more in-depth discussion relating the current 5G NR assessment methods to measurement equipment is intended for a follow-up study, which will describe more in detail the requirements, opportunities, and priorities for new, low-cost, custom-built measurement equipment.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0013935124014294

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**The effect of exposure to radiofrequency electromagnetic fields on cognitive performance in human experimental studies: Systematic review and meta-analyses (SR 6)**

Pophof B, Kuhne J, Schmid G, Weiser E, Dorn H, Henschenmacher B, Burns J, Danker-Hopfe H, Sauter C, Pophof B. The effect of exposure to radiofrequency electromagnetic fields on cognitive performance in human experimental studies: Systematic review and meta-analyses. Environment International (2024). doi: 10.1016/j.envint.2024.108899.

Abstract

Background  The objective of this review is to evaluate the associations between short-term exposure to radiofrequency electromagnetic fields (RF-EMF) and cognitive performance in human experimental studies.

Methods  Online databases (PubMed, Embase, Scopus, Web of Science and EMF-Portal) were searched for studies that evaluated effects of exposure to RF-EMF on seven domains of cognitive performance in human experimental studies. The assessment of study quality was based on the Risk of Bias (RoB) tool developed by the Office of Health Assessment and Translation (OHAT). Random effects meta-analyses of Hedges's g were conducted separately for accuracy- and speed-related performance measures of various cognitive domains, for which data from at least two studies were available. Finally, the certainty of evidence for each identified outcome was assessed according to Grading of Recommendations Assessment, Development, and Evaluation (GRADE).

Results  57,543 records were identified and 76 studies (80 reports) met the inclusion criteria. The included 76 studies with 3846 participants, consisting of humans of different age, sex and health status from 19 countries, were conducted between 1989 and 2021. Quantitative data from 50 studies (52 reports) with 2433 participants were included into the meta-analyses. These studies were performed in

15 countries between 2001 and 2021. The majority of the included studies used head exposure with GSM 900 uplink.

None of the meta-analyses observed a statistically significant effect of RF-EMF exposure compared to sham on cognitive performance as measured by the confidence interval surrounding the Hedges's g or the significance of the z-statistic.

For the domain Orientation and Attention, subclass Attention – Attentional Capacity RF-EMF exposure results in little to no difference in accuracy (Hedges's g 0.024, 95 % CI [-0.10; 0.15], I2 = 28 %, 473 participants).

For the domain Orientation and Attention, subclass Attention – Concentration / Focused Attention RF-EMF exposure results in little to no difference in speed (Hedges's g 0.005, 95 % CI [-0.17; 0.18], I2 = 7 %, 132 participants) and probably results in little to no difference in accuracy; it does not reduce accuracy (Hedges's g 0.097, 95 % CI [-0.05; 0.24], I2 = 0 %, 217 participants).

For the domain Orientation and Attention, subclass Attention – Vigilance RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g 0.118, 95 % CI [-0.04; 0.28], I2 = 41 %, 247 participants) and results in little to no difference in accuracy (Hedges's g 0.042, 95 % CI, [-0.09; 0.18], I2 = 0 %, 199 participants).

For the domain Orientation and Attention, subclass Attention – Selective Attention RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g 0.080, 95 % CI [-0.09; 0.25], I2 = 63 %, 452 participants); it may result in little to no difference in accuracy, but it probably does not reduce accuracy (Hedges's g 0.178, 95 % CI [-0.02; 0.38], I2 = 68 %, 480 participants).

For the domain Orientation and Attention, subclass Attention – Divided Attention RF-EMF exposure results in little to no difference in speed (Hedges's g −0.010, 95 % CI [-0.14; 0.12], I2 = 5 %, 307 participants) and may result in little to no difference in accuracy (Hedges's g −0.089, 95 % CI [-0.35; 0.18], I2 = 53 %, 167 participants).

For the domain Orientation and Attention, subclass Processing Speed − Simple Reaction Time Task RF-EMF exposure results in little to no difference in speed (Hedges's g 0.069, 95 % CI [-0.02; +0.16], I2 = 29 %, 820 participants).

For the domain Orientation and Attention, subclass Processing Speed – 2-Choice Reaction Time Task RF-EMF exposure results in little to no difference in speed (Hedges's g −0.023, 95 % CI [-0.13; 0.08], I2 = 0 %, 401 participants), and may result in little to no difference in accuracy (Hedges's g −0.063, 95 % CI [-0.38; 0.25], I2 = 63 %, 117 participants).

For the domain Orientation and Attention, subclass Processing Speed – >2-Choice Reaction Time Task RF-EMF exposure results in little to no difference in speed (Hedges's g −0.054, 95 % CI [-0.14; 0.03], I2 = 0 %, 544 participants) and probably results in little to no difference in accuracy (Hedges's g −0.129, 95 % CI [-0.30; 0.04], I2 = 0 %, 131 participants).

For the domain Orientation and Attention, subclass Processing Speed – Other Tasks RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g 0.067, 95 % CI

[-0.12; 0.26], I2 = 38 %, 249 participants); it results in little to no difference in accuracy (Hedges's g 0.036, 95 % CI [-0.08; 0.15], I2 = 0 %, 354 participants).

For the domain Orientation and Attention, subclass Working Memory – n-back Task (0–3-back) we found Hedges's g ranging from −0.090, 95 % CI [-0.18; 0.01] to 0.060, 95 % CI [-0.06; 0.18], all I2 = 0 %, 237 to 474 participants, and conclude that RF-EMF exposure results in little to no difference in both speed and accuracy.

For the domain Orientation and Attention, subclass Working Memory – Mental Tracking RF-EMF exposure results in little to no difference in accuracy (Hedges's g −0.047, 95 % [CI −0.15; 0.05], I2 = 0 %, 438 participants). For the domain Perception, subclass Visual and Auditory Perception RF-EMF exposure may result in little to no difference in speed (Hedges's g −0.015, 95 % CI [-0.23; 0.195], I2 = 0 %, 84 participants) and probably results in little to no difference in accuracy (Hedges's g 0.035, 95 % CI [-0.13; 0.199], I2 = 0 %, 137 participants).

For the domain Memory, subclass Verbal and Visual Memory RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g −0.042, 95 % CI [-0.15; 0.21], I2 = 0 %, 102 participants); it may result in little to no difference in accuracy (Hedges's g −0.087, 95 % CI [-0.38; 0.20], I2 = 85 %, 625 participants).

For the domain Verbal Functions and Language Skills, subclass Verbal Expression, a meta-analysis was not possible because one of the two included studies did not provide numerical values. Results of both studies did not indicate statistically significant effects of RF-EMF exposure on both speed and accuracy.

For the domain Construction and Motor Performance, subclass Motor Skills RF-EMF exposure may reduce speed, but the evidence is very uncertain (Hedges's g −0.919, 95 % CI [-3.09; 1.26], I2 = 96 %, 42 participants); it probably results in little to no difference in accuracy and does not reduce accuracy (Hedges's g 0.228, 95 % CI [-0.01; 0.46], I2 = 0 %, 109 participants).

For the domain Concept Formation and Reasoning, subclass Reasoning RF-EMF exposure results in little to no difference in speed (Hedges's g 0.010, 95 % CI [-0.11; 0.13], I2 = 0 %, 263 participants) and probably results in little to no difference in accuracy and does not reduce accuracy (Hedges's g 0.051, 95 % CI [-0.14; 0.25], I2 = 0 %, 100 participants).

For the domain Concept Formation and Reasoning, subclass Mathematical Procedures RF-EMF exposure results in little to no difference in speed (Hedges's g 0.033, 95 % CI [-0.12; 0.18], I2 = 0 %, 168 participants) and may result in little to no difference in accuracy but probably does not reduce accuracy (Hedges's g 0.232, 95 % CI [-0.12; +0.59], I2 = 86 %, 253 participants).

For the domain Executive Functions there were no studies.

Discussion  Overall, the results from all domains and subclasses across their speed- and accuracy-related outcome measures according to GRADE provide high to low certainty of evidence that short-term RF-EMF exposure does not reduce cognitive performance in human experimental studies. For 16 out of 35 subdomains some uncertainty remains, because of limitations in the study quality, inconsistency in the results or imprecision of the combined effect size estimate. Future research should focus on construction and motor performance, elderly, and consideration of both sexes.

Other  This review was partially funded by the WHO radioprotection programme. The protocol for this review was registered in Prospero reg. no. CRD42021236168 and published in Environment International (Pophof et al. 2021).

4.9. Implications of practice and policy

The present systematic review provides mostly moderate to high certainty of evidence that short-term RF-EMF exposure at SAR levels within the recommended limits (ICNIRP 2010) does not negatively affect the investigated domains of cognitive function.

4.10. Implications for research

Although the number of studies and participants is low for several domains / subclasses, the certainty of evidence for lack of an effect is very low only for the speed category of D5 *Construction and Motor Performance*. Only two small studies with a total number of 42 participants contribute to the result with substantial heterogeneity and the body of evidence suggests a large negative effect with very low certainty. Further studies are needed to confirm or refute this effect. In particular, all outcome measures used in both studies should be considered and reported numerically.

The number of studies that provide age-specific information on RF-EMF effects on cognitive performance is small. In particular, only five of the included studies were performed in children and only one in the elderly. Since children are generally considered to be a sensitive group, and the cognitive performance tends to decline with age, studies in children /adolescents and in elderly subjects are recommended to investigate whether these both age groups are more affected by RF-EMF exposure than young adults. Since the subgroup analyses (Supplementary Data 11) provide weak indications for a possible effect of sex, analyses stratified for sex of the participants are recommended.

In general, any new study should be designed in a way that any potential RoB is minimized. The criteria for definitely low RoB are summarized in Supplementary Data 7 of the protocol (Pophof et al. 2021). Furthermore, power calculations should be conducted prior to the final study design and study power should be sufficient for detecting even small effects. A comprehensive list of further issues that should be considered when conducting studies on possible effects of RF-EMF on cognitive performance, are published in Regel and Achermann (2011).

Authors of future studies are encouraged to make the original individual data publicly available in appropriate data repositories to avoid missing data due to incomplete reporting.

5.2. Deviations from the protocol

In the protocol, we did not describe how the ratings of the individual RoB questions for a given study would be used to define an overall quality rating for that study. This admission could be considered as a potential risk of bias for this systematic review if, for example, certain studies were selectively included/excluded from subgroup analyses based on the quality rating. However, given that the heterogeneity of effects across studies was low for most outcome measures, such selective analysis would in principle have little to no impact. The GRADE assessment, however, strongly depends on the overall study quality assessment. Thus, in order to be as transparent as possible, we have explained and justified the chosen method for allocating studies to quality tiers in detail in Methods − Risk of Bias assessment.

We did not conduct separate analyses for individuals with and without IEI-EMF, because there were only seven studies including subjects with IEI. Only six of the seven studies provided numerical data (for only some domains / subclasses) to be used to calculate effect sizes. The data of these six studies do not allow a detailed analysis following the approach pursued in this paper.

Because there was only one study investigating females, heterogeneity could not be assessed for this subgroup. Therefore, we performed subgroup analyses stratified by studies investigating only males, and studies investigating males and females together. However, the explanatory power of this approach should not be overestimated.

We did not evaluate a potential dose–response relationship or perform subgroup analyses regarding exposure levels, because independently from the exposure level there was predominantly no effect of RF-EMF, and the exposure assessment in most studies did not provide spatially resolved exposure levels in the brain. For similar reasons we did not analyse the exposure category D separately from A, B and C (see Protocol, Pophof et al. 2021), but combined all exposure categories in analyses.

Due to the huge amount of data available for the domains D1 and to a lesser extent for D6, and due to the fact that some studies reported results for a large number of different subclasses of domains, a problem with the unit of analysis would have resulted in a huge amount of original data that could not be used for a *meta*-analysis if we had kept the outcome categories defined in the protocol. Therefore, we defined more detailed outcome categories according to the domain subclasses (Table 2) as defined by Lezak et al. (2012, Part II The Compendium of Tests and Assessment Techniques, p. 391 ff.). This enables a better differentiation of different cognitive abilities, and increases the number of possible *meta*-analyses and a higher proportion of original data included in the *meta*-analyses.

In order to explore possible sources of heterogeneity, we additionally included a stratification according to sample sizes (<30; ≥ 30). Studies with small sample sizes are likely to have a higher variability than studies with larger sample sizes.

Deviating from the protocol, we did not conduct subgroup analyses for the exposure-related categories of signals with different modulation, time course of exposure, different frequencies, for the nine outcome measures of subclasses with results with at least moderate heterogeneity (Table 3). This is because a large number of studies falls in the category “continuous GSM-modulated near-field exposure with frequency lower than 1 GHz” (in six out of these nine outcome measures at least half of results include this exposure category) and most of the outlier studies that strongly contribute to heterogeneity of the results also fall into this category (five studies).

5.3. Support

This review was partly funded by the World Health Organization (contracts 2020/1028371–0, 2022/1276784–0). WHO provided the basis for the protocol and methodological support throughout the review process.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper. BP is member of the ICNIRP Scientific Expert Group (SEG) on environment, BfS observer in the working group SSK-A630 of the German Commission on Radiological Protection and was German delegate of European Cost Actions BM0704 and BM1309 “EMF-MED”. GS is member of the Committee “Non-Ionizing Radiation” (SSK-A6) and member of the working group SSK-A630 of the German Commission on Radiological Protection. GS is chair of the Austrian Standardization Sub-Committee TSK-EMV-EMF “Electromagnetic Fields”. HDHs research is entirely funded by public or not-for-profit foundations. She has served as advisor to a number of national and international public advisory groups concerning the potential health effects of exposure to non-ionizing radiation, including the World Health Organization, the German Commission on Radiological Protection (member of the committee “Non-Ionizing Radiation” (SSK-A6) and member of the working group 5G (SSK-A630)) and the Independent Expert Group of the Swedish Radiation Safety Authority. JK is member of the ICNIRP Scientific Expert Group (SEG) on ultrasound and BfS observer in the working group SSK-A630 of the German Commission on Radiological Protection].

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024004859?via%3Dihub

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**Literature review: potential non-thermal molecular effects of external radiofrequency electromagnetic fields on cancer**

Dieper A, Scheidegger S, Füchslin RM, Veltsista PD, Stein U, Weyland M, Gerster D, Beck M, Bengtsson O, Zips D, Ghadjar P. Literature review: potential non-thermal molecular effects of external radiofrequency electromagnetic fields on cancer. Int J Hyperthermia. 2024;41(1):2379992. doi: 10.1080/02656736.2024.2379992.

Abstract

Introduction: There is an ongoing scientific discussion, that anti-cancer effects induced by radiofrequency (RF)-hyperthermia might not be solely attributable to subsequent temperature elevations at the tumor site but also to non-temperature-induced effects. The exact molecular mechanisms behind said potential non-thermal RF effects remain largely elusive, however, limiting their therapeutical targetability.

Objective: Therefore, we aim to provide an overview of the current literature on potential non-temperature-induced molecular effects within cancer cells in response to RF-electromagnetic fields (RF-EMF).

Material and methods: This literature review was conducted following the PRISMA guidelines. For this purpose, a MeSH-term-defined literature search on MEDLINE (PubMed) and Scopus (Elsevier) was conducted on March 23rd, 2024. Essential criteria herein included the continuous wave RF-EMF nature (3 kHz - 300 GHz) of the source, the securing of temperature-controlled circumstances within the trials, and the preclinical nature of the trials.

Results: Analysis of the data processed in this review suggests that RF-EMF radiation of various

frequencies seems to be able to induce significant non-temperature-induced anti-cancer effects. These effects span from mitotic arrest and growth inhibition to cancer cell death in the form of autophagy and apoptosis and appear to be mostly exclusive to cancer cells. Several cellular mechanisms were identified through which RF-EMF radiation potentially imposes its anti-cancer effects. Among those, by reviewing the included publications, we identified RF-EMF-induced ion channel activation, altered gene expression, altered membrane potentials, membrane oscillations, and blebbing, as well as changes in cytoskeletal structure and cell morphology.

Conclusion: The existent literature points toward a yet untapped therapeutic potential of RF-EMF treatment, which might aid in damaging cancer cells through bio-electrical and electro-mechanical molecular mechanisms while minimizing adverse effects on healthy tissue cells. Further research is imperative to definitively confirm non-thermal EMF effects as well as to determine optimal cancer-type-specific RF-EMF frequencies, field intensities, and exposure intervals.

Open access paper: https://www.tandfonline.com/doi/full/10.1080/02656736.2024.2379992

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**Exposure to Electromagnetic Fields from Mobile Phones and Fructose Consumption Coalesce to Perturb Metabolic Regulators AMPK/SIRT1-UCP2/FOXO1 in Growing Rats**

Tripathi R, Banerjee SK, Nirala JP, Mathur R. Exposure to Electromagnetic Fields from Mobile Phones and Fructose Consumption Coalesce to Perturb Metabolic Regulators AMPK/SIRT1-UCP2/FOXO1 in Growing Rats[J]. Biomedical and Environmental Sciences, 2023, 36(11): 1045-1058. doi: 10.3967/bes2023.134

Abstract

Objective  In this study, the combined effect of two stressors, namely, electromagnetic fields (EMFs) from mobile phones and fructose consumption, on hypothalamic and hepatic master metabolic regulators of the AMPK/SIRT1-UCP2/FOXO1 pathway were elucidated to delineate the underlying molecular mechanisms of insulin resistance.

Methods  Weaned Wistar rats (28 days old) were divided into 4 groups: Normal, Exposure Only (ExpO), Fructose Only (FruO), and Exposure and Fructose (EF). Each group was provided standard laboratory chow ad libitum for 8 weeks. Additionally, the control groups, namely, the Normal and FruO groups, had unrestricted access to drinking water and fructose solution (15%), respectively. Furthermore, the respective treatment groups, namely, the ExpO and EF groups, received EMF exposure (1,760 MHz, 2 h/day x 8 weeks). In early adulthood, mitochondrial function, insulin receptor signaling, and oxidative stress signals in hypothalamic and hepatic tissues were assessed using western blotting and biochemical analysis.

Result  In the hypothalamic tissue of EF, SIRT1, FOXO 1, p-PI3K, p-AKT, Complex III, UCP2, MnSOD, and catalase expressions and OXPHOS and GSH activities were significantly decreased (P < 0.05) compared to the Normal, ExpO, and FruO groups. In hepatic tissue of EF, the p-AMPKα, SIRT1, FOXO1, IRS1, p-PI3K, Complex I, II, III, IV, V, UCP2, and MnSOD expressions and the activity of OXPHOS, SOD, catalase, and GSH were significantly reduced compared to the Normal group (P < 0.05).

Conclusion The findings suggest that the combination of EMF exposure and fructose consumption during childhood and adolescence in Wistar rats disrupts the closely interlinked and multi-regulated crosstalk of insulin receptor signals, mitochondrial OXPHOS, and the antioxidant defense system in the hypothalamus and liver.

Open access paper: https://www.besjournal.com/en/article/doi/10.3967/bes2023.134

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**Upper bound for broadband radiofrequency field disruption of magnetic compass orientation in night-migratory songbirds**

Leberecht B, Wong SY, Satish B, Döge S, Hindman J, Venkatraman L, Apte S, Haase K, Musielak I, Dautaj G, Solov'yov IA, Winklhofer M, Mouritsen H, Hore PJ. Upper bound for broadband radiofrequency field disruption of magnetic compass orientation in night-migratory songbirds. Proc Natl Acad Sci U S A. 2023 Jul 11;120(28):e2301153120. doi: 10.1073/pnas.2301153120. Epub 2023 Jul 3. PMID: 37399422; PMCID: PMC10334787.

Abstract

Night-migratory songbirds have a light-dependent magnetic compass sense, the mechanism of which is thought to depend on the photochemical formation of radical pairs in cryptochrome (Cry) proteins located in the retina. The finding that weak radiofrequency (RF) electromagnetic fields can prevent birds from orienting in the Earth's magnetic field has been regarded as a diagnostic test for this mechanism and as a potential source of information on the identities of the radicals. The maximum frequency that could cause such disorientation has been predicted to lie between 120 and 220 MHz for a flavin-tryptophan radical pair in Cry. Here we show that the magnetic orientation capabilities of Eurasian blackcaps (*Sylvia atricapilla*) are not affected by RF noise in the frequency bands 140 to 150 MHz and 235 to 245 MHz. From a consideration of its internal magnetic interactions, we argue that RF field effects on a flavin-containing radical-pair sensor should be approximately independent of frequency up to 116 MHz and that birds' sensitivity to RF disorientation should fall by about two orders of magnitude when the frequency exceeds 116 MHz. Taken together with our earlier finding that 75 to 85 MHz RF fields disrupt the magnetic orientation of blackcaps, these results provide compelling evidence that the magnetic compass of migratory birds operates by a radical pair mechanism.

Open access paper: https://www.pnas.org/doi/abs/10.1073/pnas.2301153120

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**Impact of high (1950 MHz) and extremely low (50 Hz) frequency electromagnetic fields on DNA damage caused by occupationally relevant exposures in human derived cell lines**

Worel N, Mišík M, Kundi M, Ferk F, Hutter HP, Nersesyan A, Wultsch G, Krupitza G, Knasmueller S. Impact of high (1950 MHz) and extremely low (50 Hz) frequency electromagnetic fields on DNA damage caused by occupationally relevant exposures in human derived cell lines. Toxicol In Vitro. 2024 Jul 16:105902. doi: 10.1016/j.tiv.2024.105902.

Highlights

- Mobile phone-specific (HF) and low-frequency (LF) electromagnetic fields (EMF) may cause cancer.
- We investigated the impact of these fields on DNA damage in human-derived cells.
- The cells were exposed to the EMF in combination with occupationally related carcinogens.
- We found no evidence for synergistic effects.
- In neural cells, we observed a significant reduction of DNA damage after exposure to the HF field.

Abstract

Epidemiological studies indicate that electromagnetic fields are associated with cancer in humans. Exposure to mobile phone specific high frequency fields (HF-EMF) may lead to increased glioma risks, while low frequency radiation (LF-EMF) is associated with childhood leukemia. We studied the impact of HF-EMF (1950 MHz, UMTS signal) on DNA stability in an astrocytoma cell line (1321N1), and the effect of LF-EMF (50 Hz) in human derived lymphoma (Jurkat) cells. To find out if these fields affect chemically induced DNA damage, co-exposure experiments were performed. The cells were exposed to HF-EMF or LF-EMF and treated simultaneously and sequentially with mutagens. The compounds cause DNA damage via different molecular mechanisms, i.e. pyrimidine dimers which are characteristic for UV light (4-nitroquinoline 1-oxide, 4NQO), bulky base adducts (benzo[a]pyrene diolepoxide, BPDE), DNA-DNA and DNA-protein cross links and oxidative damage ($NiCl_2$, $CrO_3$). DNA damage was measured in single cell gel electrophoresis (comet) assays. We found a moderate reduction of basal and 4NQO-induced DNA damage in the astrocytoma line, but no significant alterations of chemically induced DNA migration by the HF and LF fields under all other experimental series. The biological consequences of the moderate reduction remain unclear, but our findings indicate that acute mobile phone and power line specific EMF exposures do not enhance genotoxic effects caused by occupationally relevant chemical exposures.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0887233324001322

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**Estimates and measurements of radiofrequency exposures in smart-connected homes**

Joyner K, Milligan M, Knipe P. Estimates and measurements of radiofrequency exposures in smart-connected homes. Bioelectromagnetics. 2024 Jul 18. doi: 10.1002/bem.22518.

Abstract

The aim of this research was to quantify the levels of radiofrequency electromagnetic energy (RF-EME) in a residential home/apartment equipped with a range of wireless devices, often referred to as internet of things (IoT) devices or smart devices and subsequently develop a tool that could be useful for estimating the levels of RF-EME in a domestic environment. Over the course of 3 years measurements were performed in peoples' homes on a total of 43 devices across 16 device categories. Another 12 devices were measured in detail in a laboratory setup. In all a total of 55 individual devices across 23 device categories were measured. Based on this measurement data we developed predictive software

that showed that even with a single device in 23 device categories operating near maximum they would, in total, produce exposures at a distance of 1 m of 0.17% of the ICNIRP (2020) public exposure limits. Measurements were also made in two separate smart apartments-one contained over 50 IoT devices and a second with over 100 IoT devices with the devices driven as hard as could reasonably be achieved. The respective 6-min average exposure level recorded were 0.0077% and 0.44% of the ICNIRP (2020) 30-min average public exposure limit.

Conclusions

We have presented measurements of Wi-Fi signals from 55 individual IoT devices across 23 device categories, which showed that the respective 6-min average exposure levels recorded ranged from 0.0077% to 0.44% of the ICNIRP (2020) 30-min average public exposure limit. These results were corroborated by measurements made in two separate smart apartments—one contained over 50 IoT devices and a second with over 100 IoT devices with the devices driven as hard as could reasonably be achieved. Based on all of these measurements, we have developed predictive software that can be used to estimate exposure levels on a conservative basis by incorporating a 3 dB enhancement to produce a realistic upper bound for the exposure estimation. The RF estimator tool, which is available from the Mobile & Wireless Forum (MWF) website (www.mwfai.org), has a drop-down menu that allows the selection of multiple IoT devices and separation distances and returns an estimate of the exposure level that could be expected in the home environment. Devices in neighboring rooms can be included in the software by selecting the appropriate device and distance. However, because of the inverse square dependence with distance and the attenuation through walls, the majority contribution in a particular room is determined by the proximity of devices in that room. Future work will include the expansion of the device categories and the inclusion of wall/window attenuation to account for neighboring homes and apartments.

CONFLICT OF INTEREST STATEMENT

This work was fully funded by the Mobile and Wireless Forum (www.mwfai.org) and that KJ and MM are contractored by the MWF.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22518

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**Maternal linalool treatment protects against radiofrequency wave-induced deteriorations in adolescent rats: A behavioral and electrophysiological study**

Azimzadeh M, Noorbakhshnia M. Maternal linalool treatment protects against radiofrequency wave-induced deteriorations in adolescent rats: A behavioral and electrophysiological study. Sci Rep. 2024 Jul 27;14(1):17257. doi: 10.1038/s41598-024-68103-5.

Abstract

Recent years, the rapid advancement of technology has raised concerns. We studied the effects of prenatal exposure to 900 MHz radiofrequency (RF) from mobile phones and the protective effects of linalool on learning and memory, and anxiety in adolescent male and female offspring rats. Pregnant

rats were divided into four groups: control, wave, wave + linalool, and linalool. Rats received linalool (25mg/kg) by gavage for 21 days. Irradiation was conducted from day 0 to day 21 of pregnancy. Offsprings underwent behavioral and electrophysiological tests on days 50 and 60 after birth. Exposure to RF during pregnancy caused anxiety-like behavior in the EPM test and impairment of learning and memory in the Morris water maze and shuttle box tests. Electrophysiological properties and synaptic plasticity of the dorsal hippocampal CA3-CA1 synapse showed a decrease in fEPSP amplitude and slope. The trace element levels in both male and female offspring were consistent across all groups compared to their respective controls. In the hippocampus tissue, the levels of Fe, Cu, and Mn, as well as the Cu/Zn ratio, were significantly higher in the exposed groups (wave groups) compared to their controls. Moreover, Zn levels were significantly lower in the hippocampus tissue of the exposed groups. Linalool administration mitigated the excessive increase in Fe, Cu, Mn, and Cu/Zn ratio and normalized the disrupted levels of trace elements, except for Zn levels in both male and female offspring. Sex differences were observed in the EPM and shuttle box tests, females were more sensitive than males. In summary, our study demonstrates that prenatal exposure to mobile phone radiation induces stress-like behaviors, disrupts learning and memory, alters hippocampal electrophysiological properties and trace element balance in offspring. Treatment with linalool mitigates these deleterious effects, highlighting its potential as a therapeutic intervention. These findings contribute to our understanding of the impact of prenatal environmental exposures on neurodevelopment and offer insights into potential strategies for neuroprotection.

https://www.nature.com/articles/s41598-024-68103-5

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**Sulforaphane Effects on Neuronal-like Cells and Peripheral Blood Mononuclear Cells Exposed to 2.45 GHz Electromagnetic Radiation**

Bertuccio MP, Saija C, Acri G, Ientile R, Caccamo D, Currò M. Sulforaphane Effects on Neuronal-like Cells and Peripheral Blood Mononuclear Cells Exposed to 2.45 GHz Electromagnetic Radiation. Int J Mol Sci. 2024 Jul 18;25(14):7872. doi: 10.3390/ijms25147872.

Abstract

Exposure to 2.45 GHz electromagnetic radiation (EMR) emitted from commonly used devices has been reported to induce oxidative stress in several experimental models. Our study aims to evaluate the efficacy of sulforaphane, a well-known natural product, in preventing radiation-induced toxic effects caused by a 24 h exposure of SH-SY5Y neuronal-like cells and peripheral blood mononuclear cells (PBMCs) to 2.45 GHz EMR. Cells were exposed to radiation for 24 h in the presence or absence of sulforaphane at different concentrations (5-10-25 µg/mL). Cell viability, mitochondrial activity alterations, the transcription and protein levels of redox markers, and apoptosis-related genes were investigated. Our data showed a reduction in cell viability of both neuronal-like cells and PBMCs caused by EMR exposure and a protective effect of 5 µg/mL sulforaphane. The lowest sulforaphane concentration decreased ROS production and increased the Mitochondrial Transmembrane Potential ($\Delta\psi m$) and the NAD+/NADH ratio, which were altered by radiation exposure. Sulforaphane at higher concentrations displayed harmful effects. The hormetic behavior of sulforaphane was also evident after evaluating the expression of genes coding for Nrf2, SOD2, and changes in apoptosis markers. Our study underlined the vulnerability of neuronal-like cells to mitochondrial dysfunction and oxidative stress and

the possibility of mitigating these effects by supplementation with sulforaphane. To our knowledge, there are no previous studies about the effects of SFN on these cells when exposed to 2.45 GHz electromagnetic radiation.

Open access paper: https://www.mdpi.com/1422-0067/25/14/7872

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**Ubiquitous extremely low frequency electromagnetic fields induces anxiety-like behavior: mechanistic perspectives**

Hosseini E. Ubiquitous extremely low frequency electromagnetic fields induces anxiety-like behavior: mechanistic perspectives. Electromagn Biol Med. 2024 Jul 29:1-16. doi: 10.1080/15368378.2024.2380305.

Abstract

Anxiety is an adaptive condition characterized by heightened uneasiness, which in the long term can cause complications such as reducing the quality of life and problems related to the mental and physical health. Concerns have been raised regarding the potential dangers of extremely low frequency electromagnetic fields (ELF-EMF) ranging from 3 to 3000 Hz, which are omnipresent in our daily lives and there have been studies about the anxiogenic effects of these fields. Studies conducted in this specific area has revealed that ELF-EMF can have an impact on various brain regions, such as the hippocampus. In conclusion, studies have shown that ELF-EMF can interfere with hippocampus-prefrontal cortex pathway, inducing anxiety behavior. Also, ELF-EMF may initiate anxiety behavior by generating oxidative stress in hypothalamus and hippocampus. Moreover, ELF-EMF may induce anxiety behavior by reducing hippocampus neuroplasticity and increasing the $NMDA2_A$ receptor expression in the hippocampus. Furthermore, supplementation with antioxidants could serve as an effective protective measure against the adverse effects of ELF-EMF in relation to anxiety behavior.

Conclusion

In the present study, it was found out that:

1. ELF-EMF by creating oxidative stress in different regions of brain involved in anxiety behavior, results in an increase of stress hormones and also excitability subsequently.
2. ELF-EMF by decreasing in neuroplasticity and modulation of some receptors in the hippocampus may have a key role in initiating anxiety behavior.

https://pubmed.ncbi.nlm.nih.gov/39074042/

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**Characterizing parameters and incorporating action potentials via the Hodgkin-Huxley model in a novel electric model for living cells**

Bougandoura O, Achour Y, Zaoui A, Starzyński J. Characterizing parameters and incorporating action potentials via the Hodgkin-Huxley model in a novel electric model for living cells. Electromagn Biol Med. 2024 Jul 2;43(3):187-203. doi: 10.1080/15368378.2024.2372107.

Abstract

To enhance our understanding of electroporation and optimize the pulses used within the frequency range of 1 kHz to 100 MHz, with the aim of minimizing side effects such as muscle contraction, we introduce a novel electrical model, structured as a 2D representation employing exclusively lumped elements. This model adeptly encapsulates the intricate dynamics of living cells' impedance variation. A distinguishing attribute of the proposed model lies in its capacity to decipher the distribution of transmembrane potential across various orientations within living cells. This aspect bears critical importance, particularly in contexts such as electroporation and cellular stimulation, where precise knowledge of potential gradients is pivotal. Furthermore, the augmentation of the proposed electrical model with the Hodgkin-Huxley (HH) model introduces an additional dimension. This integration augments the model's capabilities, specifically enabling the exploration of muscle cell stimulation and the generation of action potentials. This broader scope enhances the model's utility, facilitating comprehensive investigations into intricate cellular behaviors under the influence of external electric fields.

https://pubmed.ncbi.nlm.nih.gov/38990565/

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**Risk Assessment for Workers with Wearable Medical Devices Exposed to Electromagnetic Fields**

Vivarelli C, Censi F, Calcagnini G, Falsaperla R, Mattei E. Risk Assessment for Workers with Wearable Medical Devices Exposed to Electromagnetic Fields. Health Physics 127(2):p 269-275, August 2024. doi: 10.1097/HP.0000000000001798.

Abstract

The exponential diffusion of wearable medical devices (WMD) in recent years has involved people of all ages, including workers. Workers who use WMDs should be considered at a particular risk from electromagnetic fields, and in accordance with EU Directive 2013/35/EU, they require an individual risk assessment. Currently, there is no international standard that provides specific guidance on how to perform such a risk assessment. This paper focuses on the effects of electromagnetic fields on WMDs and does not consider the direct effects on human body tissues. It aims to offer practical recommendations to employers and/or health physicists for the risk assessment of workers with WMDs. Focusing on EU countries, we first describe the requirements outlined by the technical standard for the electromagnetic compatibility (EMC) of medical electrical equipment EN 60601-1-2. Then, some general guidelines on how to perform the risk assessment are provided. The assessment can be conducted by comparing the field values measured in the workplace with the immunity test levels specified in the technical standards of medical electrical equipment. If the measured values are lower than the immunity test levels indicated in the standard and the distance from the electromagnetic source is greater than the distance used by the manufacturer during the EMC (electromagnetic compatibility) tests (typically 30 cm), the risk for the worker may be considered acceptable. However, if the measured

values exceed the immunity test levels or the distance criteria, a specific evaluation based on a case-by-case analysis is required.

https://journals.lww.com/health-physics/abstract/2024/08000/risk_assessment_for_workers_with_wearable_medical.1.aspx

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**Health risks for medical personnel due to magnetic fields in magnetic resonance imaging**

König AM, Pöschke A, Mahnken AH. Health risks for medical personnel due to magnetic fields in magnetic resonance imaging. Rofo. 2024 Jul 19. English, German. doi: 10.1055/a-2296-3860.

Abstract

The current state of medical and scientific knowledge on the effects of exposure to electromagnetic fields on workers in the field of clinical magnetic resonance imaging (MRI) is summarized here.A systematic literature search was conducted to analyze the health risks to medical personnel from magnetic fields in MRI. A total of 7273 sources were identified, with 7139 being excluded after screening of the title and abstract. After full-text screening, 34 sources remained and were included in this paper. There are a number of scientific publications on the occurrence of short-term sensory effects such as vertigo, metallic taste, phosphenes as well as on the occurrence of neurocognitive and neurobehavioral effects. For example, short-term exposure to clinical magnetic fields has been reported to result in a 4% reduction in speed and precision and a 16% reduction in visual contrast sensitivity at close range. Both eye-hand precision and coordination speed are affected. The long-term studies concern, among other things, the influence of magnetic fields on sleep quality, which could be linked to an increased risk of accidents. The data on the exposure of healthcare workers to magnetic fields during pregnancy is consistently outdated. However, it has been concluded that there are no particular deviations with regard to the duration of pregnancy, premature births, miscarriages, and birth weight. Epidemiological studies are lacking. With a focus on healthcare personnel, there is a considerable need for high-quality data, particularly on the consequences of long-term exposure to electromagnetic fields from clinical MRI and the effects on pregnancy.

Key points

- Short-term sensory effects such as vertigo, metallic taste, phosphenes as well as neurocognitive and neurological behavioral effects may occur upon exposure to magnetic fields.
- Long-term effects mainly concern quality of sleep, which can be associated with an increased risk of accidents.
- When pregnant women were exposed to magnetic fields, no particular deviations were found with regard to the duration of pregnancy, premature births, miscarriages, and birth weight.

Open access paper: https://www.thieme-connect.com/products/ejournals/html/10.1055/a-2296-3860?articleLanguage=en

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**A Reexamination of Peto's Paradox: Insights Gained from Human Adaptation to Varied Levels of Ionizing and Non-ionizing Radiation**

Mortazavi SMJ, Zare O, Ghasemi L, Taghizadeh P, Faghani P, Arshadi M, Mortazavi SAR, Sihver L. A Reexamination of Peto's Paradox: Insights Gained from Human Adaptation to Varied Levels of Ionizing and Non-ionizing Radiation. J Biomed Phys Eng. 2024 Jun 1;14(3):309-314. doi: 10.31661/jbpe.v0i0.2402-1729.

Abstract

Humans have generally evolved some adaptations to protect against UV and different levels of background ionizing radiation. Similarly, elephants and whales have evolved adaptations to protect against cancer, such as multiple copies of the tumor suppressor gene p53, due to their large size and long lifespan. The difference in cancer protection strategies between humans and elephants/whales depends on genetics, lifestyle, environmental exposures, and evolutionary pressures. In this paper, we discuss how the differences in evolutionary adaptations between humans and elephants could explain why elephants have evolved a protective mechanism against cancer, whereas humans have not. Humans living in regions with high levels of background radiation, e.g. in Ramsar, Iran where exposure rates exceed those on the surface of Mars, seem to have developed some kind of protection against the ionizing radiation. However, humans in general have not developed cancer-fighting adaptations, so they instead rely on medical technologies and interventions. The difference in cancer protection strategies between humans and elephants/whales depends on genetics, lifestyle, environmental exposures, and evolutionary pressures. In this paper, we discuss how the differences in evolutionary adaptations between humans and elephants could explain why elephants have evolved a protective mechanism against cancer, whereas humans have not. Studying elephant adaptations may provide insights into new cancer prevention and treatment strategies for humans, but further research is required to fully understand the evolutionary disparities.

Open access paper: https://jbpe.sums.ac.ir/article_50037.html

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**A review on point mutations via proton transfer in DNA base pairs in the absence and presence of electric fields**

Pushkaran AC, Arabi AA. A review on point mutations via proton transfer in DNA base pairs in the absence and presence of electric fields. Int J Biol Macromol. 2024 Jul 26:134051. doi: 10.1016/j.ijbiomac.2024.134051.

Abstract

This is a comprehensive review that focuses on spontaneous mutations that may occur during DNA replication, the fundamental process responsible for transferring genetic information. In 1963, Löwdin postulated that these mutations are primarily a result of proton transfer reactions within the hydrogen-bonded DNA base pairs. The single and double proton transfer reactions within the base pairs result in zwitterions and rare tautomers, respectively. For persistent mutations, these products must be generated at high rates and should be thermodynamically stable. This review covers the proton transfer

reactions studied experimentally and computationally. The review also examines the influence of externally applied electric fields on the thermodynamics and kinetics of proton transfer reactions within DNA base pairs, and their biological implications.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0141813024048566

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**Corrigendum to "The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies"**

Bosch-Capblanch X, Esu E, Moses Oringanje C, Dongus S, Jalilian H, Eyers J, Auer C, Meremikwu M, Röösli M. Corrigendum to "The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies" [Environ. Int. 187 (2024) 108612]. Environ Int. 2024 Jul 20:108892. doi: 10.1016/j.envint.2024.108892. Epub ahead of print. Erratum for: Environ Int. 2024 May;187:108612. doi: 10.1016/j.envint.2024.108612. PMID: 39034214.

No abstract

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024004781?via%3Dihub

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**Investigating the impact of anthropogenic radiofrequency electromagnetic fields on animals and plants in the environment: analysis from a systematic map**

Brzozek C, Mate R, Bhatt CR, Loughran S, Wood AW, Karipidis K. (2024). Investigating the impact of anthropogenic radiofrequency electromagnetic fields on animals and plants in the environment: analysis from a systematic map. *International Journal of Environmental Studies*, 1–16. doi: 10.1080/00207233.2024.2375861.

Abstract

Radiofrequency electromagnetic fields (RF EMF) from anthropogenic sources have become ubiquitous in the environment. International guidelines have been set by expert scientific bodies to protect human health from excessive exposure. There are no specifically established exposure guidelines to protect plants and animals. A previous systematic map identified 334 studies investigating the effects of RF EMF exposure from anthropogenic sources on animals and plants. This study aimed to analyse the effect of RF EMF and its relationship to different exposure parameters and the quality of those studies. Statistically significant inverse relationships were found between effect size and exposure-level parameters for studies investigating effects in animals. The results indicated that quality score is more indicative of the magnitude of the effect size than exposure-level parameters or exposure duration. This highlights the need for further, high-quality research on the effects of RF EMF exposure on plants and animals.

Quality score

A risk of bias assessment for each study was not conducted as this is more appropriate for a systematic

review rather than a systematic map [Citation22]. Instead an assessment of the quality of the studies included in the systematic map was conducted with separate methods used for assessing experimental and observational studies. This was considered important to describe the distribution of quality of evidence across the research in this field. For experimental studies, the method of Vijayalaxmi and Prihoda was used which assessed five quality criteria including adequate dosimetry, use of controls, use of positive controls, use of blinding, use of temperature monitoring [Citation24]. For observational studies, the five quality criteria used in the assessment were as follows: appropriate exposure assessment, appropriate subject selection/comparison groups, consideration of confounders, follow-up assessment, and appropriate outcome assessment. A quality score (QS) was given for each study by two assessors independently, with the final quality score being the average of the two scores. Pearson correlation coefficients were used to assess the reliability and consistency between assessors. The QS was derived by scoring each of the five quality criteria; a score of 1 was awarded when the criterion was adequately addressed, 0.5 awarded when it was partially addressed and a score of 0 when the criterion was not addressed. This resulted in the QS for each study ranging between 0 and 5 with a higher value indicating higher quality for that study. The quality score results were further categorised as studies with QS ≤ 2 being 'poor quality', studies with QS > 2 - < 3.5 as 'average quality' and studies with QS ≥ 3.5 as 'good quality'.

Effect size

Studies investigating the impact of RF EMF on animals and plants have reported a range in the magnitude of effects including no effect and from small effects to large effects. It is therefore important to map the distribution of the effect size (ES) across the different studies, noting that ES = 0 denotes no statistically significant effect and ES > 0 denotes an effect size with a larger number corresponding to a larger effect. We extracted the ES for every study in the systematic map where this could be gleaned from the information provided. The ES was estimated using a number of different methods available in Thalheimer and Cook and according to the type of data provided by each study [Citation23]. Thalheimer and Cook include calculating the effect size from t-test (with and without the standard deviation or standard error) and from F-tests (with and without the mean squared error). Studies that used other statistics did not receive an effect size score. In many of the included studies more than one frequency and exposure intensity was investigated, and in some studies, several endpoints were investigated (and occasionally, more than one animal/plant). In these cases, the largest statistically significant effect was selected to represent that study. For effects that were not statistically significant the ES was set to zero.

Conclusion

The analysis of the systematic map dataset has identified that quality score is more indicative of the magnitude of the effect size than exposure-level parameters or exposure duration in fauna. Similar trends are seen in flora studies; but, these results were not found to be statistically significant. This highlights the need for further, high-quality research.

An investigation of the effect size in relation to different exposure characteristics, as well as the quality of the studies, raises doubts on whether animals and plants are truly affected at levels below human exposure limits. There are distinct evidence clusters on insect and bird reproduction, development and behaviour for animals, and grain and legume germination and growth for plants that would benefit from specific systematic reviews, with appropriate risk of bias assessments and pooling of the data in meta-

analyses. Our review also highlights the need for studies of additional animal and plant species and additional effects that are yet to be investigated. Further, there is a particular need for more observational studies and for an improvement in the quality of all studies.

Disclosure statement

KK, CBr, CBh, RM and SL as part of their employment at ARPANSA provide advice to the Australian Government, Australian States and Territories and the general public on the effects and risks of exposure to ionising and non-ionising radiation. KK and SL are also members of the main commission and scientific expert group, respectively, of the International Commission on Non-Ionising Radiation Protection where they contribute in the development and dissemination of science-based advice on limiting exposure to non-ionising radiation. KK, AW and CBr are members of systematic review teams into the WHO assessment of health effects of exposure to radiofrequency electromagnetic fields. SL is a member of the WHO Task Group on Radiofrequency Fields and Health Risks. No member of the mapping team screened or extracted data from any study in which he or she is an author.

https://www.tandfonline.com/doi/full/10.1080/00207233.2024.2375861

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**Electrostatic pollination by butterflies and moths**

England SJ, Robert D. Electrostatic pollination by butterflies and moths. J R Soc Interface. 2024 Jul;21(216):20240156. doi: 10.1098/rsif.2024.0156.

Abstract

Animals, most notably insects, generally seem to accumulate electrostatic charge in nature. These electrostatic charges will exert forces on other charges in these animals' environments and therefore have the potential to attract or repel other objects, for example, pollen from flowers. Here, we show that butterflies and moths (Lepidoptera) accumulate electrostatic charge while in flight. Then, using finite element analysis, we demonstrate that when within millimetres of a flower, the electrostatic charge of a lepidopteran generates an electric field in excess of 5 kV $m^{-1}$, and that an electric field of this magnitude is sufficient to elicit contactless pollen transfer from flowers across air gaps onto the body of a butterfly or moth. Furthermore, we see that phylogenetic variations exist in the magnitude and polarity of net charge between different species and families and Lepidoptera. These phylogenetic variations in electrostatic charging correlate with morphological, biogeographical and ecological differences between different clades. Such correlations with biogeographical and ecological differences may reflect evolutionary adaptations towards maximizing or minimizing charge accumulation, in relation to pollination, predation and parasitism, and thus we introduce the idea that electrostatic charging may be a trait upon which evolution can act.

Open access paper: https://royalsocietypublishing.org/doi/10.1098/rsif.2024.0156

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**COSMOS. A methodologically-flawed cohort study of the health effects from exposure to radiofrequency radiation from mobile phone use**

Moskowitz JM, Frank JW, Melnick RL, Hardell L, Belyaev I, Héroux P, Kelley E, Lai H, Maisch D, Mallery-Blythe E, Philips A; International Commission on the Biological Effects of Electromagnetic Fields. COSMOS: A methodologically-flawed cohort study of the health effects from exposure to radiofrequency radiation from mobile phone use. Environ Int. 2024 Jun 21;190:108807. doi: 10.1016/j.envint.2024.108807.

No abstract

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024003933

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**Response to the letter to the editor regarding "Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study"**

Feychting M, Schüz J, Toledano MB, Vermeulen R, Auvinen A, Poulsen AH, Deltour I, Smith RB, Heller J, Kromhout H, Huss A, Johansen C, Tettamanti G, Elliott P. Response to the Letter to the Editor regarding "Mobile phone use and brain tumour risk - COSMOS, a prospective cohort study". Environ Int. 2024 May;187:108664. doi: 10.1016/j.envint.2024.108664.

No abstract

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024003945

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**Summary of seven Swedish case reports on the microwave syndrome associated with 5G radiofrequency radiation**

Hardell L, Nilsson M. Summary of seven Swedish case reports on the microwave syndrome associated with 5G radiofrequency radiation. Rev Environ Health. 2024 Jun 19. doi: 10.1515/reveh-2024-0017.

**Abstract**

The fifth generation, 5G, for wireless communication is currently deployed in Sweden since 2019/2020, as well as in many other countries. We have previously published seven case reports that include a total of 16 persons aged between 4 and 83 years that developed the microwave syndrome within a short time after being exposed to 5G base stations close to their dwellings. In all cases high radiofrequency (RF) radiation from 4G/5G was measured with a broadband meter. RF radiation reached >2,500,000 to >3,180,000 $\mu W/m^2$ in peak maximum value in three of the studies. In total 41 different health issues were assessed for each person graded 0 (no complaint) to 10 (worst symptoms). Most prevalent and severe were sleeping difficulty (insomnia, waking night time, early wake-up), headache, fatigue, irritability, concentration problems, loss of immediate memory, emotional distress, depression tendency, anxiety/panic, dysesthesia (unusual touched based sensations), burning and lancinating skin, cardiovascular symptoms (transitory high or irregular pulse), dyspnea, and pain in muscles and joints. Balance disorder and tinnitus were less prevalent. All these symptoms are included in the microwave syndrome. In most cases the symptoms declined and disappeared within a short time period after the studied persons had moved to a place with no 5G. These case histories are classical examples of provocation studies. They reinforce the urgency to inhibit the deployment of 5G until more safety studies have been performed.

Open access paper: https://www.degruyter.com/document/doi/10.1515/reveh-2024-0017/html

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**Follow-Up Research on NTP's Clear Evidence on RF Causing Malignant Tumors in Rats**

Lin JC. Follow-Up Research on NTP's Clear Evidence on RF Causing Malignant Tumors in Rats [Health Matters]. *IEEE Microwave Magazine*. 25(6):16-18. June 2024. doi: 10.1109/MMM.2024.3378608.

Abstract

The recent disclosure of the U.S. National Toxicology Program (NTP) closing down its RF radiation research program on how RF radiation causes cancer was a surprise [1], [2], [3]. NTP is a part of the National Institutes of Health and reports to the U.S. Department of Health and Human Services. NTP's mandates are to provide the scientific basis for programs, activities, and policies that promote health or lead to the prevention of disease.

Excerpts

In 2018, NTP published the final report on its US$30 million laboratory research showing "clear evidence" that lifelong exposure to low-level RF radiation caused cancers in rats [6], [7], [8]. The statistically significant findings showed that both GSM- and CDMA-modulated 900-MHz RF radiation had led to the development of malignant schwannoma, a rare form of tumor in the hearts of male rats. Furthermore, an independent analysis of the NTP data for overall cancer incidence detected in any organ or tissue inside the animal showed that rats exposed to GSM and CDMA cellphone RF radiation had significantly higher overall or total primary tumor incidence than the concurrent controls....

The NTP findings of clear evidence that RF radiation can cause cancer was already reaffirmed by the Ramazzini Institute study from Italy [10]....

In 2019, NTP announced a new genotoxicology project designed to examine how RF radiation causes cancer....

Apparently, now, close to five years later, the new project has never progressed beyond the feasibility studies with the compact exposure chambers. Moreover, the NTP located in Research Triangle Park, NC, USA, no longer plans to study biological effects from cellphone RF radiation. NTP has decided that "the research was technically challenging and more resource-intensive than expected." This effectively marks the end of the nonmilitary governmental project in the United States to study the biological effects of cellphone or RF radiation. Any future NTP publications on the topic would come from the feasibility studies only [3].

Unfortunately, whether the U.S. civilian government halts doing the important research on mechanistic causes for cancer from low-level chronic exposure to RF radiation or not, nearly 100% of all Americans are being cast as subjects in a massive health experiment without a formal protocol. Furthermore, billions of people worldwide, including the young and older adults, are being exposed to unnecessary levels of human-made wireless RF radiation.

The obvious question is, what happened? Should we all forget about NTP's findings of clear scientific evidence that lifelong exposure to low-level RF radiation causes cancer from a federal government

health agency that prides itself in telling the nation that its product is “science you can depend on for decisions that matter”?

Postscript: It is interesting to recall that the recently announced termination of NTP’s RF research program on how RF radiation causes cancer practically halts most, if not all, biological research of RF radiation supported by the civilian U.S. government. In contrast, the military arm of the U.S. government through its Defense Advanced Research Projects Agency (DARPA) has initiated a new research program on the roles RF radiation may have in biological systems [11]. DARPA’s historical and contemporary contributions to scientific and technological advancements are widely known. Thus, it poses the question, what does DARPA know about RF radiation on biological systems?

https://ieeexplore.ieee.org/document/10523054

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**Epidemiological exploration of the impact of bluetooth headset usage on thyroid nodules using Shapley additive explanations method**

Zhou N, Qin W, Zhang JJ, Wang Y, Wen JS, Lim YM. Epidemiological exploration of the impact of bluetooth headset usage on thyroid nodules using Shapley additive explanations method. Sci Rep. 2024 Jun 21;14(1):14354. doi: 10.1038/s41598-024-63653-0.

Abstract

With an increasing prevalence of thyroid nodules globally, this study investigates the potential correlation between the use of Bluetooth headsets and the incidence of thyroid nodules, considering the cumulative effects of non-ionizing radiation (NIR) emitted by these devices. In this study, we analyzed 600 valid questionnaires from the WenJuanXing platform using Propensity Score Matching (PSM) and the XGBOOST model, supplemented by SHAP analysis, to assess the risk of thyroid nodules. PSM was utilized to balance baseline characteristic differences, thereby reducing bias. The XGBOOST model was then employed to predict risk factors, with model efficacy measured by the area under the Receiver Operating Characteristic (ROC) curve (AUC). SHAP analysis helped quantify and explain the impact of each feature on the prediction outcomes, identifying key risk factors. Initially, 600 valid questionnaires from the WenJuanXing platform underwent PSM processing, resulting in a matched dataset of 96 cases for modeling analysis. The AUC value of the XGBOOST model reached 0.95, demonstrating high accuracy in differentiating thyroid nodule risks. SHAP analysis revealed age and daily Bluetooth headset usage duration as the two most significant factors affecting thyroid nodule risk. Specifically, longer daily usage durations of Bluetooth headsets were strongly linked to an increased risk of developing thyroid nodules, as indicated by the SHAP analysis outcomes. Our study highlighted a significant impact relationship between prolonged Bluetooth headset use and increased thyroid nodule risk, emphasizing the importance of considering health impacts in the use of modern technology, especially for devices like Bluetooth headsets that are frequently used daily. Through precise model predictions and variable importance analysis, our research provides a scientific basis for the formulation of public health policies and personal health habit choices, suggesting that attention should be paid to the duration of Bluetooth headset use in daily life to reduce the potential risk of thyroid nodules. Future research should further investigate the biological mechanisms of this relationship and consider additional potential influencing factors to offer more comprehensive health guidance and preventive measures.

Open access paper: https://www.nature.com/articles/s41598-024-63653-0

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**The effects of radiofrequency exposure on male fertility: A systematic review of human observational studies with dose–response meta-analysis (SR 3--male)**

Kenny RPW, Johnson EE, Adesanya AM, Richmond C, Beyer F, Calderon C, Rankin J, Pearce MS, Toledano M, Craig D, Pearson F. The effects of radiofrequency exposure on male fertility: A systematic review of human observational studies with dose–response meta-analysis. Environment International, 2024. doi: 10.1016/j.envint.2024.108817.

Abstract

Background The World Health Organization (WHO) is bringing together evidence on radiofrequency electromagnetic field (RF-EMF) exposure in relation to health outcomes, previously identified as priorities for research and evaluation by experts in the field, to inform exposure guidelines. A suite of systematic reviews have been undertaken by a network of topic experts and methodologists to collect, assess and synthesise data relevant to these guidelines. Following the WHO handbook for guideline development and the COSTER conduct guidelines, we systematically reviewed the evidence on the potential effects of RF-EMF exposure on male fertility in human observational studies.

Methods We conducted a broad and sensitive search for potentially relevant records within the following bibliographic databases: MEDLINE; Embase; Web of Science and EMF Portal. We also conducted searches of grey literature through relevant databases including OpenGrey, and organisational websites and consulted RF-EMF experts. We hand searched reference lists of included study records and for citations of these studies. We included quantitative human observational studies on the effect of RF-EMF exposure in adult male participants on infertility: sperm concentration; sperm morphology; sperm total motility; sperm progressive motility; total sperm count; and time to pregnancy. Titles and abstracts followed by full texts were screened in blinded duplicate against pre-set eligibility criteria with consensus input from a third reviewer as required. Data extraction from included studies was completed by two reviewers, as was risk of bias assessment using the Office of Health Assessment and Translation (OHAT) tool. We conducted a dose–response meta-analysis as possible and appropriate. Certainty of the evidence was assessed by two reviewers using the OHAT GRADE tool with input from a third reviewer as required.

Results We identified nine studies in this review; seven were general public studies (with the general public as the population of interest) and two were occupational studies (with specific workers/workforces as the population of interest). General public studies. Duration of phone use: The evidence is very uncertain surrounding the effects of RF-EMF on sperm concentration (10/6 mL) (MD (mean difference) per hour of daily phone use 1.6 106/mL, 95 % CI −1.7 to 4.9; 3 studies), sperm morphology (MD 0.15 percentage points of deviation of normal forms per hour, 95 % CI −0.21 to 0.51; 3 studies), sperm progressive motility (MD −0.46 percentage points per hour, 95 % CI −1.04 to 0.13; 2 studies) and total sperm count (MD per hour −0.44 106/ejaculate, 95 % CI −2.59 to 1.7; 2 studies) due to very low-certainty evidence. Four additional studies reported on the effect of mobile phone use on sperm motility but were unsuitable for pooling; only one of these studies identified a statistically significant effect. All four studies were at risk of exposure characterisation and selection bias; two of

confounding, selective reporting and attrition bias; three of outcome assessment bias and one used an inappropriate statistical method. Position of phone: There may be no or little effect of carrying a mobile phone in the front pocket on sperm concentration, total count, morphology, progressive motility or on time to pregnancy. Of three studies reporting on the effect of mobile phone location on sperm total motility and, or, total motile count, one showed a statistically significant effect. All three studies were at risk of exposure characterisation and selection bias; two of confounding, selective reporting and attrition bias; three of outcome assessment bias and one used inappropriate statistical method. RF-EMF Source: One study indicates there may be little or no effect of computer or other electric device use on sperm concentration, total motility or total count. This study is at probably high risk of exposure characterisation bias and outcome assessment bias. Occupational studies. With only two studies of occupational exposure to RF-EMF and heterogeneity in the population and exposure source (technicians exposed to microwaves or seamen exposed to radar equipment), it was not plausible to statistically pool findings. One study was at probably or definitely high risk of bias across all domains, the other across domains for exposure characterisation bias, outcome assessment bias and confounding.

Discussion

The majority of evidence identified was assessing localised RF-EMF exposure from mobile phone use on male fertility with few studies assessing the impact of phone position. Overall, the evidence identified is very uncertain about the effect of RF-EMF exposure from mobile phones on sperm outcomes. One study assessed the impact of other RF-EMF sources on male fertility amongst the general public and two studies assessed the impact of RF-EMF exposure in occupational cohorts from different sources (radar or microwave) on male fertility. Further prospective studies conducted with greater rigour (in particular, improved accuracy of exposure measurement and appropriate statistical method use) would build the existing evidence base and are required to have greater certainty in any potential effects of RF-EMF on male reproductive outcomes.

Prospero Registration: CRD42021265401 (SR3A)

Excerpts

Conclusions  Overall, the evidence is very uncertain about the effect of RF-EMF on male fertility outcomes. Where dose–response *meta*-analysis was possible, the evidence was rated as very low-certainty on OHAT GRADE, while the majority of included studies were at risk of bias and only a small number of studies reported on each outcome of interest. Given this, we cannot be confident in what the current body of research concludes about the effect of RF-EMF on male fertility.

Further prospective studies conducted with greater rigour (in particular, improved accuracy of exposure measurement and appropriate statistical method use) are required to build on the existing evidence base and provide greater certainty in any potential effects of RF-EMF on male reproductive outcomes.

Competing interests  Carolina Calderon was involved in both MOBI-Kids (risk of brain cancer from exposure to radiofrequency fields in childhood and adolescence) and GERoNIMO, Tsarna et al. 2019 was one of the outcomes of this project. Although Carolina was not involved in the publication, with her involvement being in the intermediate frequency exposure assessment.

Mireille Toledano has been involved in funded research assessing mobile phone and other wireless technologies usage on health outcomes. The SCAMP (study cognition adolescents and mobile phones) prospective cohort study which is currently ongoing (2015–2021). The COSMOS (cohort study of mobile phone use and health) a longitudinal cohort study which is completed (2019).

Declaration of competing interest  The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024004033

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**The effects of radiofrequency exposure on adverse female reproductive outcomes: A systematic review of human observational studies with dose–response meta-analysis (SR 3--female)**

Johnson EE, Kenny RPW, Adesanya AM, Richmond C, Beyer F, Calderon C, Rankin J, Pearce MS, Toledano M, Craig D, Pearson F. The effects of radiofrequency exposure on adverse female reproductive outcomes: A systematic review of human observational studies with dose–response meta-analysis. Environment International, 2024. doi: 10.1016/j.envint.2024.108816.

Abstract

Background  To inform radiofrequency electromagnetic field (RF-EMF) exposure guidelines the World Health Organization (WHO) is bringing together evidence on RF-EMF in relation to health outcomes prioritised for evaluation by experts in this field. Given this, a network of topic experts and methodologists have conducted a series of systematic reviews collecting, assessing, and synthesising data of relevance to these guidelines. Here we present a systematic review of the effect of RF-EMF exposure on adverse pregnancy outcomes in human observational studies which follows the WHO handbook for guideline development and the COSTER conduct guidelines.

Methods  We conducted a broad, sensitive search for potentially relevant records within the following bibliographic databases: MEDLINE; Embase; and the EMF Portal. Grey literature searches were also conducted through relevant databases (including OpenGrey), organisational websites and via consultation of RF-EMF experts. We included quantitative human observational studies on the effect of RF-EMF exposure in adults' preconception or pregnant women on pre-term birth, small for gestational age (SGA; associated with intrauterine growth restriction), miscarriage, stillbirth, low birth weight (LBW) and congenital anomalies. In blinded duplicate, titles and abstracts then full texts were screened against eligibility criteria. A third reviewer gave input when consensus was not reached. Citation chaining of included studies was completed. Two reviewers' data extracted and assessed included studies for risk of bias using the Office of Health Assessment and Translation (OHAT) tool. Random effects meta-analyses of the highest versus the lowest exposures and dose–response meta-analysis were conducted as

appropriate and plausible. Two reviewers assessed the certainty in each body of evidence using the OHAT GRADE tool.

Results We identified 18 studies in this review; eight were general public studies (with the general public as the population of interest) and 10 were occupational studies (with the population of interest specific workers/workforces). General public studies. From pairwise meta-analyses of general public studies, the evidence is very uncertain about the effects of RF-EMF from mobile phone exposure on preterm birth risk (relative risk (RR) 1.14, 95% confidence interval (CI): 0.97–1.34, 95% prediction interval (PI): 0.83–1.57; 4 studies), LBW (RR 1.14, 95% CI: 0.96–1.36, 95% PI: 0.84–1.57; 4 studies) or SGA (RR 1.13, 95% CI: 1.02–1.24, 95% PI: 0.99–1.28; 2 studies) due to very low-certainty evidence. It was not feasible to meta-analyse studies reporting on the effect of RF-EMF from mobile phone exposure on congenital anomalies or miscarriage risk. The reported effects from the studies assessing these outcomes varied and the studies were at some risk of bias. No studies of the general public assessed the impact of RF-EMF exposure on stillbirth. Occupational studies. In occupational studies, based on dose–response meta-analyses, the evidence is very uncertain about the effects of RF-EMF amongst female physiotherapists using shortwave diathermy on miscarriage due to very low-certainty evidence (OR 1.02 95% CI 0.94–1.1; 2 studies). Amongst offspring of female physiotherapists using shortwave diathermy, the evidence is very uncertain about the effects of RF-EMF on the risk of congenital malformations due to very low-certainty evidence (OR 1.4, 95% CI 0.85 to 2.32; 2 studies). From pairwise meta-analyses, the evidence is very uncertain about the effects of RF-EMF on the risk of miscarriage (RR 1.06, 95% CI 0.96 to 1.18; very low-certainty evidence), pre-term births (RR 1.19, 95% CI 0.32 to 4.37; 3 studies; very low-certainty evidence), and low birth weight (RR 2.90, 95% CI: 0.69 to 12.23; 3 studies; very low-certainty evidence). Results for stillbirth and SGA could not be pooled in meta-analyses. The results from the studies reporting these outcomes were inconsistent and the studies were at some risk of bias.

Discussion Most of the evidence identified in this review was from general public studies assessing localised RF-EMF exposure from mobile phone use on female reproductive outcomes. In occupational settings, each study was of heterogenous whole-body RF-EMF exposure from radar, short or microwave diathermy, surveillance and welding equipment and its effect on female reproductive outcomes. Overall, the body of evidence is very uncertain about the effect of RF-EMF exposure on female reproductive outcomes. Further prospective studies conducted with greater rigour (particularly improved accuracy of exposure measurement and using appropriate statistical methods) are required to identify any potential effects of RF-EMF exposure on female reproductive outcomes of interest.

Excerpts

Summary of the evidence and interpretation of the results In total, 18 studies were identified for this review: in eight the general public was the population of interest and in 10 the populations of interest were occupational. Within the general population, the evidence is very uncertain about the effects of RF-EMF on pre-term birth, SGA and low birth weight. It was not possible to conduct meta-analyses for miscarriage and congenital anomalies due to significant heterogeneity between studies. Within the occupational studies, the evidence is very uncertain about the effects of RF-EMF on miscarriage and the effects of maternal RF-EMF exposure on pre-term birth, congenital anomalies and low birth weight.

Limitations of the evidence The are multiple limitations with the evidence base of human observational studies assessing the effect of localised and whole-body RF-EMF exposure on pre-term birth; SGA;

miscarriage; still birth and, or, congenital anomalies compared to no or low level exposure in preconception or pregnant adults.

Risk of bias was often apparent in both general public and occupational studies; all but one of the included studies were rated as probably or definitely high risk for at least two domains on the OHAT risk of bias tool. Nine studies were at probably or definitely high risk of exposure characterisation bias (Allam, 2016, Baste et al., 2012, Cromie et al., 2002, Källén et al., 1982, Karuserci et al., 2019, Lu et al., 2017, Taskinen et al., 1990, Tsarna et al., 2019, Zhao et al., 2021), while another nine were at risk of outcome assessment bias (Baste et al., 2012, Cromie et al., 2002, Källén et al., 1982, Karuserci et al., 2019, Lu et al., 2017, Mahmoudabadi et al., 2015, Tsarna et al., 2019, Xu et al., 2016, Zhao et al., 2021). In 10 studies, issues surrounding the identification and handling of confounders was present (Allam, 2016, Baste et al., 2012, Baste et al., 2015, Brizzi and Marinelli, 2018, Cromie et al., 2002, Källén et al., 1982, Karuserci et al., 2019, Kolmodin-Hedman et al., 1988, Mahmoudabadi et al., 2015, Xu et al., 2016), while three were also at risk of selective reporting (Cromie et al., 2002, Källén et al., 1982, Kolmodin-Hedman et al., 1988).

More generally, reporting of exposures across studies was often inconsistent and lacking in detail (see Table 1, Table 2). Most studies in the general population used a proxy exposure, such as time spent on mobile phone or mobile phone usage, with heterogeneity between how these were measured.

One of the main issues of the evidence base is a lack of confounding assessment in studies (Baste et al., 2015, Allam, 2016, Brizzi and Marinelli, 2018, Karuserci et al., 2019, Kolmodin-Hedman et al., 1988, Baste et al., 2012, Källén et al., 1982, Cromie et al., 2002, Mahmoudabadi et al., 2015, Xu et al., 2016) and inconsistency regarding the method of exposure measurement. All analyses were downgraded to either low-certainty or very low-certainty evidence on OHAT GRADE, with risk of bias, indirectness and imprecision causing concerns. Indirectness was an issue for occupational studies measuring congenital anomalies. Many of the studies only stated that they were assessing the risk of any congenital anomalies rather than identifying and assessing the risk of specific congenital anomalies (e.g. the effect of RF-EMF could potentially affect different congenital anomalies in different ways). This limits our ability to assess the risk of different kinds of congenital anomalies following RF-EMF exposure.

Conclusions  Overall, the majority of evidence suggest that there is little to no effect of RF-EF on female reproductive outcomes. The evidence was rated as low to very low certainty, was at risk of bias and only a small number of studies reported on each outcome of interest. Given this we cannot be confident in what the body of research is indicating about the effect of RF-EMF on female reproductive outcomes. The *meta*-analyses that were possible suggest no increased relative risk for female reproductive outcomes due to RF-EMF exposure in the general public or occupational settings. This is further supported by the dose–response *meta*-analysis in female physiotherapists using SWD. For studies that were not *meta*-analysed, there was variation in effect. Most included studies were at risk of bias.

Overall, while we observe a lack of effect, further prospective studies conducted with greater rigour would build the existing evidence base and are required to have greater certainty in any potential effects of RF-EMF on female reproductive outcomes.

Registration and protocol  The protocol was published in Environment International (Kenny et al., 2022) and an abridged version is also available on PROSPERO (CRD42021265401; referred to as SR3B).

Declaration of competing interest  The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Mireille Toledano has been involved in funded research assessing mobile phone and other wireless technologies usage on health outcomes: the SCAMP (study cognition adolescents and mobile phones) prospective cohort study which is currently ongoing (2015–2021), and the COSMOS (cohort study of mobile phone use and health) a longitudinal cohort study which is completed (2019). Carolina Calderon has been involved in MOBI-Kids (risk of brain cancer from exposure to radiofrequency fields in childhood adolescence) and GERoNIMO, of which the Tsarna 2019 study was one of the outcomes. However, they were not directly involved in the Tsarna 2019 paper and was not involved in the selection, data extraction or risk of bias assessment for this study.].

Acknowledgements  We would like to thank Jos Verbeek, Emilie Van Deventer and Maria Feychting for their expertise and support throughout the systematic review.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024004021

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**Detrimental impact of cell phone radiation on sperm DNA integrity**

Koohestanidehaghi Y, Khalili MA, Dehghanpour F, Seify M. Detrimental impact of cell phone radiation on sperm DNA integrity. Clinical and Experimental Reproductive Medicine 2024;51(1):13-19.

Abstract

Radiofrequency electromagnetic radiation (RF-EMR) from various sources may impact health due to the generation of frequency bands. Broad pulses emitted within frequency bands can be absorbed by cells, influencing their function. Numerous laboratory studies have demonstrated that mobile phones—generally the most widely used devices—can have harmful effects on sex cells, such as sperm and oocytes, by producing RF-EMR. Moreover, some research has indicated that RF-EMR generated by mobile phones can influence sperm parameters, including motility, morphology, viability, and (most critically) DNA structure. Consequently, RF-EMR can disrupt both sperm function and fertilization. However, other studies have reported that exposure of spermatozoa to RF-EMR does not affect the functional parameters or genetic structure of sperm. These conflicting results likely stem from differences among studies in the duration and exposure distance, as well as the species of animal used. This report was undertaken to review the existing research discussing the effects of RF-EMR on the DNA integrity of mammalian spermatozoa.

Conclusion

EMW can induce oxidative stress, which subsequently leads to disorders such as reduced mobility, morphological changes, acrosome disturbances, and ultimately, damage to the nucleus and genetic material. This oxidative damage to DNA can result in the breakdown of both single-stranded and double-stranded DNA structures, culminating in fragmentation. If the DNA is not repaired and the damage accumulates, the sperm may undergo apoptosis. Damage to the sperm genome can ultimately impact

fertility, potentially leading to infertility. Therefore, it is advisable to limit daily exposure to these sources to prevent irreversible damage caused by EMWs. Many men carry their cell phones in their trouser pockets or clipped to their belts, and the use of Bluetooth can increase their susceptibility to RF-EMR exposure. This exposure can induce changes in sperm quality through oxidative stress, potentially leading to infertility. Agarwal et al. [11] suggested that carrying a cell phone in a pocket could lead to a decline in sperm quality. However, it is important to note that the phone and male reproductive organs are separated by multiple tissue layers. Therefore, extrapolating these in vitro effects to real-life conditions requires further studies [11].

In July 2021, the European Parliament commissioned a research report titled “Health impact of 5G.” The report concluded that the commonly used RF-EMFs are likely carcinogenic to humans and have a definitive impact on male fertility. It also suggested potential adverse effects on the development of embryos, fetuses, and newborns. To mitigate these adverse effects, the organization proposed several strategies. These include favoring non-wireless connections, increasing distance from the source of RF-EMFs, switching off devices when not in use, and practicing safe phone usage [55].

Open access paper: https://ecerm.org/journal/view.php?doi=10.5653/cerm.2023.06121

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**A comprehensive review of 5G NR RF-EMF exposure assessment technologies: fundamentals, advancements, challenges, niches, and implications**

Korkmaz E, Aerts S, Coesoij R, Bhatt CR, Velghe M, Colussi L, Land D, Petroulakis N, Spirito M, Bolte J. A comprehensive review of 5G NR RF-EMF exposure assessment technologies: fundamentals, advancements, challenges, niches, and implications. Environ Res. 2024 Jul 5:119524. doi: 10.1016/j.envres.2024.119524.

Abstract

This review offers a detailed examination of the current landscape of radio frequency (RF) electromagnetic field (EMF) assessment tools, ranging from spectrum analyzers and broadband field meters to area monitors and custom-built devices. The discussion encompasses both standardized and non-standardized measurement protocols, shedding light on the various methods employed in this domain. Furthermore, the review highlights the prevalent use of mobile apps for characterizing 5G-NR radio network data. A growing need for low-cost measurement devices is observed, commonly referred to as ”sensors” or ”sensor nodes,” that are capable of enduring diverse environmental conditions. These sensors play a crucial role in both microenvironmental surveys and individual exposures, enabling stationary, mobile, and personal exposure assessments based on body-worn sensors, across wider geographical areas. This review revealed a notable need for cost-effective and long-lasting sensors, whether for individual exposure assessments, mobile (vehicle-integrated) measurements, or incorporation into distributed sensor networks. However, there is a lack of comprehensive information on existing custom-developed RF-EMF measurement tools, especially in terms of measuring uncertainty. Additionally, there is a need for real-time, fast-sampling solutions to understand the highly irregular temporal variations EMF distribution in next-generation networks.

Given the diversity of tools and methods, a comprehensive comparison is crucial to determine the necessary statistical tools for aggregating the available measurement data.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0013935124014294

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**Under the Hood of Electromagnetic Field Estimation and Evaluation in 5G Networks**

Estrada-Jimenez JC, Pardo E, Roth U, L. Selmane L, Faye S. Under the Hood of Electromagnetic Field Estimation and Evaluation in 5G Networks. *IEEE Access*, doi: 10.1109/ACCESS.2024.3418301.

Abstract

The estimation of Electromagnetic Field (EMF) exposure is critical for evaluating the potential health risks associated with wireless network implementation. With the advent of new communication technologies, such as 5G and 6G, new methodologies are required. Indeed, higher frequency ranges are being studied, necessitating an increased number of base stations for service provision. In this paper, we introduce a novel methodology for EMF estimation in 5G mobile networks. We also evaluate common scenarios that mobile network operators frequently encounter, resulting in additional exposure, such as interference, overpropagation, and the presence of other users. Our approach is validated through a combination of simulated values and real data collected from sensors deployed in the field. Finally, a digital twin approach is proposed to combine the simulated values with the real data obtained from radio frequency sensors. The scenario is deployed in Belval, Luxembourg.

Open access paper: https://ieeexplore.ieee.org/document/10568919

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**Demonstration of Safe Electromagnetic Radiation Emitted by 5G Active Antenna Systems**

Kumar S, Sheemar CK, Astro A, Querol J, Chatzinotas S. Demonstration of Safe Electromagnetic Radiation Emitted by 5G Active Antenna Systems. arXiv:2406.07910v1 [cs.ET] 12 Jun 2024.

Abstract

The careful planning and safe deployment of 5G technologies will bring enormous benefits to society and economy. Higher frequency, beamforming and small-cells are key technologies that will provide unmatched throughput and seamless connectivity to the 5G users. Superficial knowledge of these technologies has raised concerns among the general public about the harmful effects of radiation. Several standardization bodies are active to put limits on the emissions which are based on a defined set of radiation measurement methodologies. However, due to the peculiarity of 5G such as dynamicity of the beams, network densification, Time Division Duplexing mode of operation, etc, using existing EMF measurement methods may provide inaccurate results. In this context, we discuss our experimental studies aimed towards the measurement of radiation caused by beam-based transmissions from 5G base-station equipped with an Active Antenna System (AAS). We elaborate on the shortcomings of current measurement methodologies and address several open questions. Next, we demonstrate that using user-specific downlink beamforming, not only better performance is achieved compared to non-beamformed downlink, but also the radiation in the vicinity of the intended user is significantly

decreased. Further, we show that under weak reception conditions, an uplink transmission can cause significantly high radiation in the vicinity of the user-equipment. We believe that our work will help in clearing several misleading concepts about the 5G EMF radiation effects. We conclude the work by providing guidelines to improve the methodology of EMF measurement by considering the spatio-temporal dynamicity of the 5G transmission.

Open access paper: https://arxiv.org/html/2406.07910v1

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**Smartphone-Based Methodology Applied to Electromagnetic Field Exposure Assessment**

López-Espí PL, Sánchez-Montero R, Guillén-Pina J, Castro-Sanz R, Chocano-Del-Cerro R, Martínez-Rojas JA. Smartphone-Based Methodology Applied to Electromagnetic Field Exposure Assessment. Sensors (Basel). 2024 May 31;24(11):3561. doi: 10.3390/s24113561.

Abstract

This study presents the measurements of exposure to electromagnetic fields, carried out comparatively following standard methods from fixed sites using a broadband meter and using a smartphone on which an App designed for this purpose has been installed. The results of two measurement campaigns carried out on the campus of the University of Alcalá over an area of 1.9 $km^2$ are presented. To characterize the exposure, 20 fixed points were measured in the first case and 860 points along the route made with a bicycle in the last case. The results obtained indicate that there is proportionality between the two methods, making it possible to use the smartphone for comparative measurements. The presented methodology makes it possible to characterize the exposure in the area under study in four times less time than that required with the traditional methodology

Open access paper: https://www.mdpi.com/1424-8220/24/11/3561

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**A boundary element method of bidomain modeling for predicting cellular responses to electromagnetic fields**

Czerwonky DM, Aberra AS, Gomez LJ. A boundary element method of bidomain modeling for predicting cellular responses to electromagnetic fields. J Neural Eng. 2024 Jun 11. doi: 10.1088/1741-2552/ad5704.

Abstract

Objective: Commonly used cable equation approaches for simulating the effects of electromagnetic fields on excitable cells make several simplifying assumptions that could limit their predictive power. Bidomain or “whole” finite element methods have been developed to fully couple cells and electric fields for more realistic neuron modeling. Here, we introduce a novel bidomain integral equation designed for determining the full electromagnetic coupling between stimulation devices and the intracellular, membrane, and extracellular regions of neurons.

Methods: Our proposed boundary element formulation offers a solution to an integral equation that connects the device, tissue inhomogeneity, and cell membrane-induced E-fields. We solve this integral equation using first-order nodal elements and an unconditionally stable Crank-Nicholson time-stepping

scheme. To validate and demonstrate our approach, we simulated cylindrical Hodgkin-Huxley axons and spherical cells in multiple brain stimulation scenarios.

Main Results: Comparison studies show that a boundary element approach produces accurate results for both electric and magnetic stimulation. Unlike bidomain finite element methods, the bidomain boundary element method does not require volume meshes containing features at multiple scales. As a result, modeling cells, or tightly packed populations of cells, with microscale features embedded in a macroscale head model, is simplified, and the relative placement of devices and cells can be varied without the need to generate a new mesh.

Significance: Device-induced electromagnetic fields are commonly used to modulate brain activity for research and therapeutic applications. Bidomain solvers allow for the full incorporation of realistic cell geometries, device E-fields, and neuron populations. Thus, multi-cell studies of advanced neuronal mechanisms would greatly benefit from the development of fast-bidomain solvers to ensure scalability and the practical execution of neural network simulations with realistic neuron morphologies.

Conclusion

We introduced a novel bidomain integral equation for modeling the electric response of neuron cells to device-induced E-fields. Our study includes several canonical test cases with unmyelinated cells, including scenarios with multiple cells, transverse polarization, DBS electrodes at varying proximity to multiple axon geometries, and TMS with a spherical head model. The study results indicate that (1) the hybrid cable-equation approach is a sufficient choice for most simulations, (2) longitudinal stimulation serves as the primary activation mechanism for electromagnetic brain stimulation, and (3) multi-cell studies of advanced mechanisms would greatly benefit from further development of fast-bidomain or hybrid cable-bidomain solvers. Our future efforts will focus on developing fast bidomain solvers to fully incorporate realistic neuron morphologies.

Acknowledgements

Preliminary results for this work have been presented at the Applied Computational Electromagnetics Society (ACES) 2023 conference (March 2023, Monterey, California, USA)[67], the 2023 IEEE MTTS International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization (NEMO'2023, June 2023, Winnipeg, Canada), the IEEE International Symposium on Antennas and Propagation Society and USNC-URSI Radio Science Meeting (IEEE-AP-S 2023, July 2023, Portland, Oregon, USA), and the Brain and Human Body Modeling conference 2023 (BHBM 2023, August 2023, Boston, Massachusetts, USA). Additionally, a preprint of this manuscript has been uploaded to https://www.biorxiv.org.

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Open access paper: https://iopscience.iop.org/article/10.1088/1741-2552/ad5704

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**(In)accuracy and convergent validity of daily end-of-day and single-time self-reported estimations of smartphone use among adolescents**

Tkaczyk M, Tancoš M, Smahel D, Elavsky S, Plhák J. (In)accuracy and convergent validity of daily end-of-day and single-time self-reported estimations of smartphone use among adolescents. Computers in Human Behavior. Vol. 158, 2024, doi: 10.1016/j.chb.2024.108281.

Abstract

Understanding the measurement inaccuracy and bias introduced by self-reports of smartphone use is essential for making meaningful inferences about smartphone use and its effects. Evidence for the self-reports of smartphone use in intensive longitudinal studies is largely missing. Based on self-reported and digital trace data from 137 Czech adolescents (41% girls, Mage = 14.95 years), this study examined the accuracy, directional bias, and convergent validity of daily end-of-day and single-time reports of screen time and phone-checking behavior. Overall, the study found considerable discrepancies between self-reported smartphone use and digital trace and low between-person convergent validity for all self-reports considered for the study. Respondents usually reported shorter screen time and lower frequency of phone-checking behavior as compared to digital trace, both in daily and single-time self-reports. The within-person convergent validity between daily reports and digital tracking was low, indicating poor self-reports ability to capture the actual day-to-day fluctuations in smartphone use. This study adds to the existing evidence showing that self-reports based insights into how people use smartphones differ considerably from digital trace data and shows that both person and situational levels contribute to explaining the discrepancy between digital trace and self-report data among adolescents.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0747563224001493

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**Fuzzy-Based Bioengineering System for Predicting and Diagnosing Diseases of the Nervous System Triggered by the Interaction of Industrial Frequency Electromagnetic Fields**

Korenevskiy NA, Al-Kasasbeh RT, Krikunova EA, Rodionova SN, Shaqdan A, Al-Habahbeh OM, Filist S, Alshamasin MS, Khrisat MS, Ilyash M. Fuzzy-Based Bioengineering System for Predicting and Diagnosing Diseases of the Nervous System Triggered by the Interaction of Industrial Frequency Electromagnetic Fields. Crit Rev Biomed Eng. 2024;52(5):1-16. doi: 10.1615/CritRevBiomedEng.2024053240.

Abstract

The study aims to enhance the standard of medical care for individuals working in the electric power industry who are exposed to industrial frequency electromagnetic fields and other relevant risk factors. This enhancement is sought through the integration of fuzzy mathematical models with contemporary information and intellectual technologies. The study addresses the challenges of forecasting and diagnosing illnesses within a specific demographic characterized by a combination of poorly formalized issues with interconnected conditions. To tackle this complexity, a methodological framework was developed for synthesizing hybrid fuzzy decision rules. This approach combines clinical expertise with artificial intelligence methodologies to promote innovative problem-solving strategies. Additionally, the researchers devised an original method to evaluate the body's protective capacity, which was integrated into these decision rules to enhance the precision and efficacy of medical decision-making processes. The research findings indicate that industrial frequency electromagnetic fields contribute to illnesses of societal significance. Additionally, it highlights that these effects are worsened by other risk factors such as adverse microclimates, noise, vibration, chemical exposure, and psychological stress. Diseases of the neurological, immunological, cardiovascular, genitourinary, respiratory, and digestive systems are caused by these variables in conjunction with unique physical traits. The development of mathematical models in this study makes it possible to detect and diagnose disorders in workers exposed to electromagnetic fields early on, especially those pertaining to the autonomic nervous system and heart rhythm regulation. The results can be used in clinical practice to treat personnel in the electric power industry since expert evaluation and modeling showed high confidence levels in decision-making accuracy.

https://pubmed.ncbi.nlm.nih.gov/38884210/

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**Exposure assessment and cytogenetic biomonitoring study of workers occupationally exposed to extremely low-frequency magnetic fields**

Nguyen H, Vandewalle G, Mertens B, Collard JF, Hinsenkamp M, Verschaeve L, Feipel V, Magne I, Souques M, Beauvois V, Ledent M. Exposure assessment and cytogenetic biomonitoring study of workers occupationally exposed to extremely low-frequency magnetic fields. Bioelectromagnetics. 2024 Jun 11. doi: 10.1002/bem.22506.

Abstract

Human cytogenetic biomonitoring (HCB) has long been used to evaluate the potential effects of work environments on the DNA integrity of workers. However, HCB studies on the genotoxic effects of occupational exposure to extremely low-frequency electromagnetic fields (ELF-MFs) were limited by the quality of the exposure assessment. More specifically, concerns were raised regarding the method of exposure assessment, the selection of exposure metrics, and the definition of exposure group. In this study, genotoxic effects of occupational exposure to ELF-MFs were assessed on peripheral blood lymphocytes of 88 workers from the electrical sector using the comet and cytokinesis-block micronucleus assay, considering workers' actual exposure over three consecutive days. Different methods were applied to define exposure groups. Overall, the summarized ELF-MF data indicated a low exposure level in the whole study population. It also showed that relying solely on job titles might misclassify 12 workers into exposure groups. We proposed combining hierarchical agglomerative clustering on personal exposure data and job titles to define exposure groups. The final results showed

that occupational MF exposure did not significantly induce more genetic damage. Other factors such as age or past smoking rather than ELF-MF exposure could affect the cytogenetic test outcomes.

Highlights

- The study results indicated that exposure assessment had better rely on the workers' actual exposure data.
- Electrical workers in this study were exposed on average to quite low levels of 50 Hz magnetic fields at work. But there was wide variability between workers. This highlights the value of using cluster analysis on workers' actual exposure data to define exposure groups.
- Occupational exposure to 50 Hz magnetic fields did not significantly increase the level of DNA or chromosomal damage on workers' blood samples.

Open access paper: https://pubmed.ncbi.nlm.nih.gov/38862415/

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**Thoughts on the entanglement of electromagnetism and life: A theoretical study**

Zsarnovszky A. Thoughts on the entanglement of electromagnetism and life: A theoretical study. Acta Vet Hung. 2024 Jun 18. doi: 10.1556/004.2023.00976. Epub ahead of print. PMID: 38888962.

Abstract

Dissection of the matter into its constituents leads us to the smallest particles that we know. These particles form a material structure that is determined by the electromagnetic field generated and carried by those particles. Changes in any of the two major constituents leads to changes in that material system, be it a living organism or a lifeless object. The latter statement carries the mystery of life that is born from a continuous and programmed series of system changes fuelled by an energy source with a yet unknown functioning mechanism. The present work is a theoretical approach towards the understanding and potential discovery of the aforementioned, not-yet-known cellular energetic mechanism. Understanding the energetic basis of intracellular biochemistry is equally important in human and animal therapeutics. Additionally, as all such discoveries offer novel solutions in various fields of the global industry, the final outcome of this theoretical work also brings about the idea of a new discovery in electronics industry.

Open access paper: https://akjournals.com/view/journals/004/aop/article-10.1556-004.2023.00976/article-10.1556-004.2023.00976.xml

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**Investigation of genetic stress parameters in brain tissues of rats exposed to 1.8 GHz cell phone radiofrequency electromagnetic field**

Arslan B, Aras N, Yaman S, Comelekoglu U. Investigation of genetic stress parameters in brain tissues of rats exposed to 1.8 GHz cell phone radiofrequency electromagnetic field. Med Science. 2024;13(1):78-82.

Abstract

Heat Shock Proteins (HSPs) may induce various cellular processes, including replication, apoptosis, cell-cycle progression. Mitogen-activated protein kinase (MAPK) cascades are the primary mechanism that mediates the cellular stress response to extracellular stimuli and regulates transcriptional activity. It has been shown that mobile phone exposure can stimulate the Hsp27/p38MAPK stress pathway. In this study, twenty-seven mature female Wistar albino rats were exposed to 1.8 GHz radiofrequency electromagnetic field (RF-EMF) 2h/day for 8 weeks (SAR: 0.06 W/kg). Hsp27 and p38MAPK gene expressions were investigated in rat brains. Rats were divided into groups sham-exposed, cage control, and 1.8 GHz RF-EMF exposed. Hsp27 and p38MAPK gene expression levels were investigated from the brain. p38MAPK expression was found to be upregulated in RF-EMF exposed group (p=0.018) Hsp27 expressions were not altered (p=0.897). In conclusion, long-term exposure to 1.8 GHz cell phone radiation can activate the Hsp27/p38MAPK stress pathway. It may cause several cellular disorders and can affect brain function.

Open access paper: https://www.medicinescience.org/article/4261

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**Critical role of model organism selection in assessing weak urban electromagnetic field effects: Implications for human health**

Sincak M, Adamkova P, Demeckova V, Smelko M, Lipovsky P, Oravec M, Luptakova A, Sedlakova-Kadukova J. Critical role of model organism selection in assessing weak urban electromagnetic field effects: Implications for human health. Bioelectrochemistry. 2024 Jun 29;160:108756. doi: 10.1016/j.bioelechem.2024.108756.

Highlights

- Real urban electromagnetic field present a combination 50 and 150 Hz in ratio 4:1.
- Macrophages shifted from M2 to M1 phenotype in 2 h in urban magnetic field.
- Urban magnetic fields can induce pro-inflammatory macrophage phenotype.
- Yeast showed only one change: 17 h exponential growth phase extension.
- Is crucial to choose proper organism for study of urban magnetic field perception.

Abstract

The impact of electromagnetic fields on human health has been investigated in recent years using various model organisms, yet the findings remain unclear. In our work, we examined the effect of less-explored, weak electromagnetic fields commonly found in the urban environments we inhabit. We studied different impacts of electromagnetic fields with a frequency of 50 Hz and a combination of 50 Hz and 150 Hz, on both yeasts (Saccharomyces cerevisiae) and human macrophages. We determined growth, survival, and protein composition (SDS-PAGE) (Saccharomyces cerevisiae) and morphology of macrophages (human monocytic cell line). In yeast, the sole observed change after 24 h of exposure was the extension of the exponential growth phase by 17 h. Conversely, macrophages exhibited morphological transformations from the anti-inflammatory to the pro-inflammatory type within just 2 h of exposure to the electromagnetic field. Our results suggest that effects of electromagnetic field largely depend on the model organism. The selection of an appropriate model organism proves essential for the study of the specific impacts of electromagnetic fields. The potential risk associated with the presence of

pro-inflammatory M1 macrophages in everyday urban environments primarily arises from the continual promotion of inflammatory reactions within a healthy organism and deserves further investigation.

https://pubmed.ncbi.nlm.nih.gov/38959750/

Conclusion

Based on our observations, macrophages appear to be more responsive to the presence of an electromagnetic field, making them a more proper model organism for describing the influence of the urban electromagnetic environment on humans compared to yeasts. Our results demonstrate that while yeasts did not exhibit changes in growth, pH, and redox potential within 24 h under low-intensity fields (20 µT and 50 or 50/150 Hz), immune system cells detected a magnetic field alteration within just 2 h, manifested in a shift in their phenotype.

Though these changes were temporary, the transformation of macrophages into pro-inflammatory M1 macrophages raises concerns about the potential risks associated with prolonged exposure to the weak urban electromagnetic fields that surround us daily. Continuous exposure to electromagnetic fields in our daily lives may have adverse effects on our health, as demonstrated through the use of macrophages as model organisms.

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**On the origin of the biological effects of time varying magnetic fields: quantitative insights**

Ravikumar K, Roy Choudury AN, Dubey AK, Kumaran V, Basu B. On the origin of the biological effects of time varying magnetic fields: quantitative insights. J Mater Chem B. 2024 Jul 3. doi:10.1039/d4tb00362d.

Abstract

In a number of recently published experimental studies from our research group, the positive impact of magnetic stimuli (static/pulsed) on cell functionality modulation or bactericidal effects, *in vitro*, has been established. In order to develop a theoretical understanding of such magnetobiological effects, the present study aimed to present two quantitative models to determine magnetic Maxwell stresses as well as pressure acting on the cell membrane, under the influence of a time varying magnetic field. The model predicts that magnetic field-induced stress on the cell/bacteria is dependent on the conductivity properties of the extracellular region, which is determined to be too low to cause any significant effect. However, the force on the cell/bacteria due to the induced electric field is more influential than that of the magnetic field, which has been used to determine the membrane tension that can cause membrane poration. With a known critical membrane tension for cells, the field parameters necessary to cause membrane rupture have been estimated. Based on the experimental results and theoretically predicted values, the field parameters can be classified into three regimes, wherein the magnetic fields cause no effect or result in biophysical stimulation or induce cell death due to membrane damage. Taken together, this work provides some quantitative insights into the impact of magnetic fields on biological systems.

https://pubmed.ncbi.nlm.nih.gov/38958687/

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**Do non-ionizing radiation concerns affect people's choice between hybrid and traditional cars?**

Anat Tchetchik, Sigal Kaplan, Orit Rotem-Mindali O. Do non-ionizing radiation concerns affect people's choice between hybrid and traditional cars? Transportation Research Part D: Transport and Environment, Volume 131, 2024, doi: 10.1016/j.trd.2024.104226.

Abstract

The growing market for hybrid electric vehicles (HEV) has raised concerns about the long-term impacts of non-ionizing radiation (NIR) exposure. This study is the first to address the impact of NIR on consumer choice between HEV and internal combustion engine (ICE) vehicles. We explore the hypothesis that NIR is associated with a lower probability of HEV choice in the presence of NIR information and the relative effect of NIR-health concerns versus environmental attitudes and driving norms. The data are collected from a stated choice experiment and estimated via a hybrid choice model. The results show that i NIR is associated with a lower choice probability of HEV, ii NIR-dread is associated with a higher probability of choosing ICE vehicles, while skepticism about NIR is associated with a higher probability of choosing HEV, iii prompting positively or negatively framed information about NIR discourages HEV choice compared to providing no information.

Conclusions and policy recommendations

The results show the effect of NIR-associated barriers on the choice of HEV versus ICE and highlight the following policy recommendations.

First, the massive production of EVs combined with the lack of regulatory frameworks can lead to the introduction of low-cost car models with low NIR safety standards (Trentadue et al., 2020). The European Union recommends a clear regulatory framework and international standards to promote the transition toward EVs. This study showed that NIR levels negatively affect the choice of HEV, signaling to car manufacturers and policymakers that consumers are concerned about NIR levels. Accordingly, setting NIR safety standards and maintaining low NIR levels are important goals for the transition toward autonomous, connected, electric vehicles.

Second, this study showed that while NIR dread was a discouraging factor, NIR skepticism was a strong choice motivator. Thus, perceived occurrence probability is as important as NIR risk dread. As with other health issues, prevalence across the population is an important decision-making factor that, in the absence of information, may lead to self-exemption beliefs. Scientific evidence from large-scale studies regarding both short- and long-term NIR effects and their prevalence in the population and among risk groups will enable informed decision-making, help mitigate NIR dread, and establish meaningful guidelines for in-vehicle NIR levels. With climate goals requiring the transition toward EV by 2030 and with the rapid technological advancement of autonomous, connected, electric vehicles, establishing the prevalence of NIR short- and long-term health effects is important for the future of the industry.

Third, better information quality strengthens the relationship between the depiction of new vehicle technologies and perceived purchase value (Zhang et al., 2022). Our study showed that both positive and negative framing can lead to a lower choice probability when an NIR safety threshold is provided. In this study, the information that “Studies show that long-term exposure to NIR levels below 4 mG is safe”

was associated with lower choice probabilities, similar to the case of negative framing, “Studies show that long-term exposure to NIR levels below 4 mG increases the health risks to health concerns.” Policymakers and manufacturers must consider information quality in terms of accuracy, clarity, ambiguity, and potential sources of confusion and decision bias. In this study, consumers used the provided threshold of 4 mG as a decision anchor, which means that consumers in some cultural contexts seek clear, “fast and frugal” evaluation criteria without engaging in complex exposure evaluations.

Finally, the model shows that travel with children is negatively associated with HEV leasing. Nevertheless, while NIR dread is negatively associated with HEV leasing, an additional interaction effect between NIR levels and travel with children was not statistically significant. These results indicate that while NIR dread is important, there is no additional health concerns particularly asso- ciated with travel with children. Hence, the decrease in the HEV leasing propensity when traveling with children may be associated with other reasons, such as vehicle reliability or other concerns that were not investigated in the current study. Notably, previous studies found a particular concern for children’s health-related to NIR from mobile phones and cellular stations. Leach and Bromwich (2018) found that two-thirds of the participants believed that mobile technology use should be restricted due to possible health risks to children’s health. P¨olzl (2011) added that 30 % of the population had strong or considerable concerns regarding NIR health risks to children, and noted that adults can be motivated to adjust their behavior to protect their children. Further research is important in other regions and contexts, to understand more thoroughly the issue of HEV leasing or purchase when traveling with children.

https://www.sciencedirect.com/science/article/pii/S1361920924001834

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**50 Hz magnetic field influences caspase-3 activity and cell cycle distribution in ionizing radiation exposed SH-SY5Y neuroblastoma cells**

Nieminen V, Martikainen MV, Kalliomäki S, Virén T, Seppälä J, Juutilainen J, Naarala J, Luukkonen J. 50 Hz magnetic field influences caspase-3 activity and cell cycle distribution in ionizing radiation exposed SH-SY5Y neuroblastoma cells. Int J Radiat Biol. 2024 Jun 26:1-10. doi: 10.1080/09553002.2024.2369105.

Abstract

Purpose: Earlier evidence suggests that extremely low frequency magnetic fields (ELF MFs) can modify the effects of carcinogenic agents. However, the studies conducted so far with ionizing radiation as the co-exposure agent are sparse and have provided inconclusive results. We investigated whether 50 Hz MFs alone, or in combination with ionizing radiation alter cell biological variables relevant to cancer and the biological effects of ionizing radiation.

Materials and methods: Human SH-SY5Y neuroblastoma cells were sham exposed or exposed to 100 or 500 µT MF for 24 h either before or after ionizing radiation exposure (0, 0.4 or 2 Gy). After the exposures, cells were assayed for viability, clonogenicity, reactive oxygen species, caspase-3 activity, and cell cycle distribution. Cell cycle distribution was assayed with propidium iodide staining followed by flow cytometry analysis and ROS levels were assayed together with cell viability by double staining with DeepRed and Sytox Blue followed by flow cytometry analysis.

Results: Increased caspase-3 activity was observed in cells exposed to 500 µT MF before or after ionizing radiation. Furthermore, exposure to the 500 µT MF after the ionizing radiation decreased the percentage of cells in S-phase. No changes in the ROS levels, clonogenicity, or viability of the cells were observed in the MF exposed groups compared to the corresponding sham exposed groups, and no MF effects were observed in cells exposed at 100 µT.

Conclusions: Only the 500 µT magnetic flux density affected SH-SY5Y cells significantly. The effects were small but may nevertheless help to understand how MFs modify the effects of ionizing radiation. The increase in caspase-3 activity may not reflect effects on apoptosis, as no changes were observed in the subG1 phase of the cell cycle. In contrast to some earlier findings, 50 Hz MF exposure after ionizing radiation was not less effective than MF treatment given prior to ionizing radiation.

https://pubmed.ncbi.nlm.nih.gov/38924721/

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**Electromagnetic field-induced adaptive response in Schwann cells through DNA methylation, histone deacetylation, and oxidative stress**

Colciago A, Mohamed T, Colleoni D, Melfi V, Magnaghi V. Electromagnetic field-induced adaptive response in Schwann cells through DNA methylation, histone deacetylation, and oxidative stress. J Cell Physiol. 2024 Jun 30:e31365. doi: 10.1002/jcp.31365.

Abstract

Schwannomas are benign tumors of the peripheral nervous system arising from the transformation of Schwann cells (SCs). On the whole, these tumors are related to alterations of the neurofibromin type 2 gene, coding for the oncosuppressor merlin, a cytoskeleton-associated protein belonging to the ezrin-radixin-moesin family. However, the underlying mechanisms of schwannoma onset and progression are not fully elucidated, whereas one of the challenges might be the environment. In this light, the exposure to electromagnetic field (EMF), generated by the use of common electrical devices, has been defiantly suggested as the cause of SCs transformation even if the evidence was mostly epidemiologic. Indeed, insubstantial mechanisms have been so far identified to explain SCs oncotransformation. Recently, some in vitro evidence pointed out alterations in proliferation and migration abilities in SCs exposed to EMF (0.1 T, 50 Hz, 10 min). Here, we used the same experimental paradigma to discuss the involvement of putative epigenetic mechanisms in SCs adaptation to EMF and to explain the occurrence of hypoxic alterations after the exposure. Our findings indicate a set of environmental-induced changes in SCs, toward a less-physiological state, which may be pathologically relevant for the SCs differentiation and the schwannoma development.

https://pubmed.ncbi.nlm.nih.gov/38946084/

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**The Slowest Shared Resonance: A Review of Electromagnetic Field Oscillations Between Central and Peripheral Nervous Systems**

Young A, Hunt T, Ericson M. The Slowest Shared Resonance: A Review of Electromagnetic Field Oscillations Between Central and Peripheral Nervous Systems. Front Hum Neurosci. 2022 Feb 16;15:796455. doi: 10.3389/fnhum.2021.796455.

Abstract

Electromagnetic field oscillations produced by the brain are increasingly being viewed as causal drivers of consciousness. Recent research has highlighted the importance of the body's various endogenous rhythms in organizing these brain-generated fields through various types of entrainment. We expand this approach by examining evidence of extracerebral shared oscillations between the brain and other parts of the body, in both humans and animals. We then examine the degree to which these data support one of General Resonance Theory's (GRT) principles: the Slowest Shared Resonance (SSR) principle, which states that the combination of micro- to macro-consciousness in coupled field systems is a function of the slowest common denominator frequency or resonance. This principle may be utilized to develop a spatiotemporal hierarchy of brain-body shared resonance systems. It is predicted that a system's SSR decreases with distance between the brain and various resonating structures in the body. The various resonance relationships examined, including between the brain and gastric neurons, brain and sensory organs, and brain and spinal cord, generally match the predicted SSR relationships, empirically supporting this principle of GRT.

Open access paper:
https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2021.796455/full

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**Brain structure alterations following neonatal exposure to low-frequency electromagnetic fields: A histological analysis**

Sissons SM, Dotta BT. Brain structure alterations following neonatal exposure to low-frequency electromagnetic fields: A histological analysis. Int J Dev Neurosci. 2024 Jul 5. doi: 10.1002/jdn.10361.

Abstract

Nitric oxide (NO) and electromagnetic fields (EMF) have been extensively studied for their roles in neurobiology, particularly in regulating cerebral functions and synaptic plasticity. This study investigates the impact of EMFs on NO modulation and its subsequent effects on neurodevelopment, building upon prior research examining EMF exposure's consequences on Wistar albino rats. Rats were exposed perinatally to either tap water, 1 g/L of L-arginine (LA) or 0.5 g/L of N-methylarginine (NMA). Half of the rats in each group were also exposed to a 7-Hz square-wave EMF at three separate intensities (5, 50 and 500 nT) for 2-14 days following birth. Animals were allowed to develop, and their brains were harvested later in adulthood (mean age = 568.17 days, SD = 162.73). Histological analyses were used to elucidate structural changes in key brain regions. All brains were stained with Toluidine Blue O (TBO), enabling the visualization of neurons. Neuronal counts were then conducted in specific regions of interest (e.g. hippocampus, cortices, amygdala and hypothalamus). Histological analyses revealed significant alterations in neuronal density in specific brain regions, particularly in response to EMF exposure and pharmacological interventions. Notable findings include a main EMF exposure effect where increased neuronal counts were observed in the secondary somatosensory cortex under low EMF intensities ($p <$

0.001) and sex-specific responses in the hippocampus, where a significant increase in neuronal counts was observed in the left CA3 region in female rats exposed to EMF compared to unexposed females ($t(18) = 2.371$, $p = 0.029$). Additionally, a significant increase in neuronal counts in the right entorhinal cortex was seen in male rats exposed to EMF compared to unexposed males ($t(18) = 2.216$, $p = 0.040$). These findings emphasize the complex interaction among sex, EMF exposure and pharmacological agents on neuronal dynamics across brain regions, highlighting the need for further research to identify underlying mechanisms and potential implications for cognitive function and neurological health in clinical and environmental contexts.

https://pubmed.ncbi.nlm.nih.gov/38967459/

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**Electromagnetic Exposure Levels of Electric Vehicle Drive Motors to Passenger Wearing Cardiac Pacemakers**

Dong X, Qian Y, Lu M. Electromagnetic Exposure Levels of Electric Vehicle Drive Motors to Passenger Wearing Cardiac Pacemakers. *Sensors*. 2024; 24(13):4395. doi: 10.3390/s24134395

Abstract

The number of individuals wearing cardiac pacemakers is gradually increasing as the population ages and cardiovascular disease becomes highly prevalent. The safety of pacemaker wearers is of significant concern because they must ensure that the device properly functions in various life scenarios. Electric vehicles have become one of the most frequently used travel tools due to the gradual promotion of low-carbon travel policies in various countries. The electromagnetic environment inside the vehicle is highly complex during driving due to the integration of numerous high-power electrical devices inside the vehicle. In order to ensure the safety of this group, the paper takes passengers wearing cardiac pacemakers as the object and the electric vehicle drive motors as the exposure source. Calculation models, with the vehicle body, human body, heart, and cardiac pacemaker, are built. The induced electric field, specific absorption rate, and temperature changes in the passenger's body and heart are calculated by using the finite element method. Results show that the maximum value of the induced electric field of the passenger occurs at the ankle of the body, which is 60.3 mV/m. The value of the induced electric field of the heart is greater than that of the human trunk, and the maximum value (283 mV/m) is around the pacemaker electrode. The maximum specific absorption rate of the human body is $1.08 \times 10^{-6}$ W/kg, and that of heart positioned near the electrode is $2.76 \times 10^{-5}$ W/kg. In addition, the maximum temperature increases of the human torso, heart, and pacemaker are $0.16 \times 10^{-5}$ °C, $0.4 \times 10^{-6}$ °C, and $0.44 \times 10^{-6}$ °C within 30 min, respectively. Accordingly, the induced electric field, specific absorption rate, and temperature rise in the human body and heart are less than the safety limits specified in the ICNIRP. The electric field intensity at the pacemaker electrode and the temperature rise of the pacemaker meet the requirements of the medical device standards of ICNIRP and ISO 14708-2. Consequently, the electromagnetic radiation from the motor operation in the electric vehicle does not pose a safety risk to the health of passengers wearing cardiac pacemakers in this paper. This study also contributes to advancing research on the electromagnetic environment of electric vehicles and provides guidance for ensuring the safe travel of individuals wearing cardiac pacemakers.

Open access paper: https://www.mdpi.com/1424-8220/24/13/4395

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**Personal light exposure patterns and incidence of type 2 diabetes: analysis of 13 million hours of light sensor data and 670,000 person-years of prospective observation**

Daniel P. Windred, Angus C. Burns, Martin K. Rutter, Chris Ho Ching Yeung, Jacqueline M. Lane, Qian Xiao, Richa Saxena, Sean W. Cain, Andrew J. K. Phillips. Personal light exposure patterns and incidence of type 2 diabetes: analysis of 13 million hours of light sensor data and 670,000 person-years of prospective observation. Lancet. 2024. doi: 10.1016/j.lanepe.2024.100943.

Abstract

Background  Light at night disrupts circadian rhythms, and circadian disruption is a risk factor for type 2 diabetes. Whether personal light exposure predicts diabetes risk has not been demonstrated in a large prospective cohort. We therefore assessed whether personal light exposure patterns predicted risk of incident type 2 diabetes in UK Biobank participants, using ∼13 million hours of light sensor data.

Methods  Participants (N = 84,790, age (M ± SD) = 62.3 ± 7.9 years, 58% female) wore light sensors for one week, recording day and night light exposure. Circadian amplitude and phase were modeled from weekly light data. Incident type 2 diabetes was recorded (1997 cases; 7.9 ± 1.2 years follow-up; excluding diabetes cases prior to light-tracking). Risk of incident type 2 diabetes was assessed as a function of day and night light, circadian phase, and circadian amplitude, adjusting for age, sex, ethnicity, socioeconomic and lifestyle factors, and polygenic risk.

Findings  Compared to people with dark nights (0–50th percentiles), diabetes risk was incrementally higher across brighter night light exposure percentiles (50–70th: multivariable-adjusted HR = 1.29 [1.14–1.46]; 70–90th: 1.39 [1.24–1.57]; and 90–100th: 1.53 [1.32–1.77]). Diabetes risk was higher in people with lower modeled circadian amplitude (aHR = 1.07 [1.03–1.10] per SD), and with early or late circadian phase (aHR range: 1.06–1.26). Night light and polygenic risk independently predicted higher diabetes risk. The difference in diabetes risk between people with bright and dark nights was similar to the difference between people with low and moderate genetic risk.
Interpretation  Type 2 diabetes risk was higher in people exposed to brighter night light, and in people exposed to light patterns that may disrupt circadian rhythms. Avoidance of light at night could be a simple and cost-effective recommendation that mitigates risk of diabetes, even in those with high genetic risk.

Open access paper: https://www.thelancet.com/pdfs/journals/lanepe/PIIS2666-7762(24)00110-8.pdf

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**IEC/IEEE Draft International Standard - Assessment methods of the human exposure to electric and magnetic fields from wireless power transfer systems**

IEC/IEEE Draft International Standard - Assessment methods of the human exposure to electric and magnetic fields from wireless power transfer systems - models, instrumentation, measurement and numerical methods and procedures (Frequency range of 1 kHz to 30 MHz). *IEC/IEEE P63184/FDIS, June 2024* , vol., no., pp.1-153, 26 June 2024.

Abstract

The objective of this document is to specify the assessment methods to evaluate compliance of stationary and dynamic wireless power transfer (WPT) systems with electromagnetic human exposure guidelines (specific absorption rate (SAR), internal electric fields, or current density including contact currents). The frequency range covered by this document is from 1 kHz to 30 MHz. This version of the standard focuses on exposures from inductive WPT systems. Future versions will consider extended guidance for assessments of exposure from capacitive WPT systems.

https://ieeexplore.ieee.org/document/10576682

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**Evaluation of oxidative stress and genetic instability among residents near mobile phone base stations in German**y

Gulati S, Mosgoeller W, Moldan D, Kosik P, Durdik M, Jakl L, Skorvaga M, Markova E, Kochanova D, Vigasova K, Belyaev I. Evaluation of oxidative stress and genetic instability among residents near mobile phone base stations in Germany. Ecotoxicology and Environmental Safety, Volume 279, 2024, doi: 10.1016/j.ecoenv.2024.116486.

Highlights

- Residents exposed to RF-EMR from base stations were tested for genetic instability.
- The years long exposure had no measurable effect on specific cancer related genes.
- We found high level of lipid peroxidation and DNA-lesions but not significant.
- Chromosomal aberrations were significantly more pronounced in highly exposed group.

Abstract

Human exposure to radiofrequency electromagnetic fields (RF-EMF) is restricted to prevent thermal effects in the tissue. However, at very low intensity exposure "non-thermal" biological effects, like oxidative stress, DNA or chromosomal aberrations, etc. collectively termed genomic-instability can occur after few hours. Little is known about chronic (years long) exposure with non-thermal RF-EMF. We identified two neighboring housing estates in a rural region with residents exposed to either relatively low (control-group) or relatively high (exposed-group) RF-EMF emitted from nearby mobile phone base stations (MPBS). 24 healthy adults that lived in their homes at least for 5 years volunteered. The homes were surveyed for common types of EMF, blood samples were tested for oxidative status, transient DNA alterations, permanent chromosomal damage, and specific cancer related genetic markers, like MLL gene rearrangements. We documented possible confounders, like age, sex, nutrition, life-exposure to ionizing radiation (X-rays), occupational exposures, etc. The groups matched well, age, sex, lifestyle and occupational risk factors were similar. The years long exposure had no measurable effect on MLL gene rearrangements and c-Abl-gene transcription modification. Associated with higher exposure, we found higher levels of lipid oxidation and oxidative DNA-lesions, though not statistically significant. DNA double strand breaks, micronuclei, ring chromosomes, and acentric chromosomes were not significantly different between the groups. Chromosomal aberrations like dicentric chromosomes ($p=0.007$), chromatid gaps ($p=0.019$), chromosomal fragments ($p<0.001$) and the total of chromosomal aberrations ($p<0.001$) were significantly higher in the exposed group. No potential confounder interfered with these

findings. Increased rates of chromosomal aberrations as linked to excess exposure with ionizing radiation may also occur with non-ionizing radiation exposure. Biological endpoints can be informative for designing exposure limitation strategies. Further research is warranted to investigate the dose-effect-relationship between both, exposure intensity and exposure time, to account for endpoint accumulations after years of exposure. As established for ionizing radiation, chromosomal aberrations could contribute to the definition of protection thresholds, as their rate reflects exposure intensity and exposure time.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0147651324005621

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**Analysis of the metabolic profile of humans naturally exposed to RF-EM radiation**

Rangesh NM, Malaisamy AK, Kumar N, Kumar S. Analysis of the metabolic profile of humans naturally exposed to RF-EM radiation. Metabolomics. 2024 May 18;20(3):55. doi: 10.1007/s11306-024-02121-2.

Abstract

Introduction: The world is experiencing exponential growth in communication, especially wireless communication. Wireless connectivity has recently become a part of everyone's daily life. Recent developments in low-cost, low-power, and miniature devices contribute to a significant rise in radiofrequency-electromagnetic field (RF-EM) radiation exposure in our environment, raising concern over its effect on biological systems. The inconsistent and conflicting research results make it difficult to draw definite conclusions about how RF-EM radiation affects living things.

Objectives: This study identified two micro-environments based on their level of exposure to cellular RF-EM radiation, one with significantly less exposure and another with very high exposure to RF-EM radiation. Emphasis is given to studying the metabolites in the urine samples of humans naturally exposed to these two different microenvironments to understand short-term metabolic dysregulations.

Methods: Untargeted 1H NMR spectroscopy was employed for metabolomics analyses to identify dysregulated metabolites. A total of 60 subjects were recruited with 5 ml urine samples each. These subjects were divided into two groups: one highly exposed to RF-EM (n = 30) and the other consisting of low-exposure populations (n = 30).

Results: The study found that the twenty-nine metabolites were dysregulated. Among them, 19 were downregulated, and 10 were upregulated. In particular, Glyoxylate and dicarboxylate and the TCA cycle metabolism pathway have been perturbed. The dysregulated metabolites were validated using the ROC curve analysis.

Conclusion: Untargeted urine metabolomics was conducted to identify dysregulated metabolites linked to RF-EM radiation exposure. Preliminary findings suggest a connection between oxidative stress and gut microbiota imbalance. However, further research is needed to validate these biomarkers and understand the effects of RF-EM radiation on human health. Further research is needed with a diverse population.

Conclusion

The purpose of this study was to initiate an exploration using urine metabolomics and $^{1}$H NMR spectroscopy to identify specific dysregulated metabolites associated with RF-EM radiation exposure. The objective was to pinpoint potential biomarkers for future validation. Based on these preliminary findings, there appears to be a possible connection between RF-EM radiation exposure, oxidative stress, and disruptions in the gut microbiota balance. Nevertheless, it's imperative to stress that additional investigations with a larger and more diverse population are necessary to validate these identified biomarkers and gain a more comprehensive understanding of the effects of RF-EM radiation exposure on human health. Furthermore, individuals with lower levels of radiation exposure exhibited metabolite signatures of a healthier gut microbiota system, indicating a potential association between radiation exposure and microbiota health. However, it is crucial to emphasize that further research is essential for confirmation. Future studies involve conducting a comprehensive study involving individuals with substantial RF-EM radiation exposure alongside a control group of unexposed individuals.

https://pubmed.ncbi.nlm.nih.gov/38762651/

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**Investigation of the Adverse Health Effects of Cell Phone Radiation and Propose Solutions to Minimize Them: A Systematic Review**

Elyasi H, Ghanbari M, Nadri F. Investigation of the Adverse Health Effects of Cell Phone Radiation and Propose Solutions to Minimize Them: A Systematic Review. Indian J Occup Environ Med. 2024 Jan-Mar;28(1):18-22. doi: 10.4103/ijoem.ijoem_89_23.

Abstract

Today, mobile phones are one of the most common devices emitting electromagnetic radiation and are available to more than seven billion people in different age groups around the world. The effects of electromagnetic radiation on biological systems have been studied for several years. In this systematic review to find relevant articles, international databases such as Google Scholar, PubMed, Scopus, Science Direct, Web of Science, and Cochrane were used since 2007-2022 by selecting appropriate keywords. The result revealed that exposure to cell phone radiation can lead to disturb in the metabolic activity of the cerebellum by increasing the migration of granulosa cells, decrease the water around the fetus in pregnant women, decrease in the number of blood plates, increasing levels of ALT and AST that they are the key biomarkers of liver damage, decrease of phagocytosis and induced apoptosis of neutrophils, changes at the level of glucose and even at the microscopic level of pancreas this may be a predisposing factor for diabetes, increment in tissue temperature in all depth of the brain tissue, EMF increase the volume, weight, and atresia follicles of the ovaries of the children, also it can cause oxidative stress, DNA fragmentation, etc. Mobile phone radiation is harmful and depends on its intensity, frequency, wave type, and exposure duration. It can cause different biological effects in humans. Due to the uncertainty of the results and mechanism of the effect of these waves, research in this field is still ongoing.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11111148/

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**Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy**

Büyükeren M, Karanfil Yaman F. Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy. J Turk Ger Gynecol Assoc. 2024 Mar 6;25(1):7-12. doi: 10.4274/jtgga.galenos.2023.2022-10-1.

Abstract

Objective: The aim was to compare neonatal outcomes according to cell phone specific absorption rate (SAR) levels and daily time spent on cell phones by pregnant women.

Material and Methods: Women who gave birth at Konya City Hospital between September 2020 and February 2021 were included in this retrospective study. Gestational ages, birth weight, birth length, head circumference, sex, 5-minute APGAR scores, neonate postpartum resuscitation requirement, delivery type, the model of phone used by the pregnant women, and the average time spent on the phone during a day were recorded. To determine the relation between the SAR values of the phones used and delivering a small for gestational age (SGA) baby, receiver operating characteristic curve analysis was performed.

Results: In total 1495 pregnant women were included. The rate of delivering a SGA fetus was significantly higher in women who used phones with higher SAR values (p=0.001). The cut-off value for the SAR level was 1.23 W/kg with 69.3% sensitivity and 73.0% specificity (area under the curve: 0.685; 95% confidence interval: 0.643-0.726). No correlation was found between time spent on the phone and SGA birth rate. Although both phone SAR values and time spent on the phone were higher in the symmetrical SGA group compared to the asymmetrical SGA group, the difference was not significant (p>0.05). Although the women who had preterm delivery had higher phone SAR values and had spent more time on the phone compared to those who had term deliveries, the difference was again not significant (p>0.05).

Conclusion: As the SAR values of cell phones used during pregnancy increased, there was a trend towards delivering a SGA baby.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10921072/

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**1.7 GHz LTE radiofrequency EMF with stable power monitoring and efficient thermal control has no effect on the proliferation of various human cell types**

My note: The study employed a Western blot analysis which is less likely to detect DNA damage than a comet assay.

Goh J, Suh D, Park G, Jeon S, Lee Y, Kim N, Song K. 1.7 GHz long-term evolution radiofrequency electromagnetic field with stable power monitoring and efficient thermal control has no effect on the proliferation of various human cell types. PLoS One. 2024 May 7;19(5):e0302936. doi: 10.1371/journal.pone.0302936.

Abstract

Long-term evolution (LTE) radiofrequency electromagnetic field (RF-EMF) is widely used in communication technologies. Thus, the influence of RF-EMF on biological systems is a major public concern and its physiological effects remain controversial. In our previous study, we showed that continuous exposure of various human cell types to 1.7 GHz LTE RF-EMF at a specific absorption rate (SAR) of 2 W/Kg for 72 h can induce cellular senescence. To understand the precise cellular effects of LTE RF-EMF, we elaborated the 1.7 GHz RF-EMF cell exposure system used in the previous study by replacing the RF signal generator and developing a software-based feedback system to improve the exposure power stability. This refinement of the 1.7 GHz LTE RF-EMF generator facilitated the automatic regulation of RF-EMF exposure, maintaining target power levels within a 3% range and a constant temperature even during the 72-h-exposure period. With the improved experimental setup, we examined the effect of continuous exposure to 1.7 GHz LTE RF-EMF at up to SAR of 8 W/Kg in human adipose tissue-derived stem cells (ASCs), Huh7, HeLa, and rat B103 cells. Surprisingly, the proliferation of all cell types, which displayed different growth rates, did not change significantly compared with that of the unexposed controls. Also, neither DNA damage nor cell cycle perturbation was observed in the 1.7 GHz LTE RF-EMF-exposed cells. However, when the thermal control system was turned off and the subsequent temperature increase induced by the RF-EMF was not controlled during continuous exposure to SAR of 8 W/Kg LTE RF-EMF, cellular proliferation increased by 35.2% at the maximum. These observations strongly suggest that the cellular effects attributed to 1.7 GHz LTE RF-EMF exposure are primarily due to the induced thermal changes rather than the RF-EMF exposure itself.

Conclusion

To understand the precise cellular effect of 1.7 GHz LTE RF-EMF, we developed an RF-EMF cell exposure system with an improved RF signal generator and control software. With a refined RF-EMF exposure system, we could maintain a consistent target power during the 72-h-exposure period with minimal thermal effects. With this refined experimental setup, exposure to 1.7 GHz LTE RF-EMF at the SAR ranging from 0.4 W/Kg to 8 W/Kg neither affects the proliferation of various human cells with different growth rates nor induces DNA damage and cell cycle perturbation. Before upgrading the exposure system, we observed that the exposure of human cells to 1.7 GHz RF-EMF increased or decreased cell proliferation, depending on the SAR values. In addition, we verified that exposure to 1.7 GHz RF-EMF with this refined system affected cell proliferation when heat was not properly controlled. Altogether, these results suggest that exposure to 1.7 GHz LTE RF-EMF does not directly influence cell proliferation and that the physiological changes induced by RF-EMF might be associated with thermal effects.

Open access paper: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0302936

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**The effects of radiofrequency exposure on cognition: A systematic review and meta-analysis of human observational studies**

(My note: Systematic reviews require a multitude of macro- and micro-decisions. When conducted by biased investigative teams, systematic reviews generate erroneous conclusions and policy implications. By design, this review excluded most of the relevant research; hence, its conclusion is very limited in scope.)

Benke G, Abramson MJ, Brzozek C, McDonald S, Kelsall H, Sanagou M, Zeleke BM, Kaufman J, Brennan S, Verbeek J, Karipidis K. The effects of radiofrequency exposure on cognition: A systematic review and meta-analysis of human observational studies. Environment International. 2024. doi: 10.1016/j.envint.2024.108779.

Abstract

Background We aimed to assess evidence of long-term effects of exposure to radiofrequency (RF) electromagnetic fields (EMF) on indicators of cognition, including domains of learning and memory, executive function, complex attention, language, perceptual motor ability and social cognition, and of an exposure–response relationship between RF-EMF and cognition.

Methods We searched PubMed, Embase, PsycInfo and the EMF-Portal on September 30, 2022 without limiting by date or language of publication. We included cohort or case-control studies that evaluated the effects of RF exposure on cognitive function in one or more of the cognitive domains. Studies were rated for risk of bias using the OHAT tool and synthesised using fixed effects meta-analysis. We assessed the certainty of the evidence using the GRADE approach and considered modification by OHAT for assessing evidence of exposures.

Results We included 5 studies that reported analyses of data from 4 cohorts with 4639 participants consisting of 2808 adults and 1831 children across three countries (Australia, Singapore and Switzerland) conducted between 2006 and 2017. The main source of RF-EMF exposure was mobile (cell) phone use measured as calls per week or minutes per day. For mobile phone use in children, two studies (615 participants) that compared an increase in mobile phone use to a decrease or no change were included in meta-analyses. Learning and memory. There was little effect on accuracy (mean difference, MD −0.03; 95% CI −0.07 to 0.02) or response time (MD −0.01; 95% CI −0.04 to 0.02) on the one-back memory task; and accuracy (MD −0.02; 95%CI −0.04 to 0.00) or response time (MD −0.01; 95%CI −0.04 to 0.03) on the one card learning task (low certainty evidence for all outcomes). Executive function. There was little to no effect on the Stroop test for the time ratio ((B-A)/A) response (MD 0.02; 95% CI −0.01 to 0.04, very low certainty) or the time ratio ((D-C)/C) response (MD 0.00; 95% CI −0.06 to 0.05, very low certainty), with both tests measuring susceptibility to interference effects. Complex attention. There was little to no effect on detection task accuracy (MD 0.02; 95% CI −0.04 to 0.08), or response time (MD 0.02;95% CI 0.01 to 0.03), and little to no effect on identification task accuracy (MD 0.00; 95% CI −0.04 to 0.05) or response time (MD 0.00;95% CI −0.01 to 0.02) (low certainty evidence for all outcomes). No other cognitive domains were investigated in children. A single study among elderly people provided very low certainty evidence that more frequent mobile phone use may have little to no effect on the odds of a decline in global cognitive function (odds ratio, OR 0.81; 95% CI 0.42 to 1.58, 649 participants) or a decline in executive function (OR 1.07; 95% CI 0.37 to 3.05, 146 participants), and may lead to a small, probably unimportant, reduction in the odds of a decline in complex attention (OR 0.67;95%CI 0.27 to 1.68, 159 participants) and a decline in learning and memory (OR 0.75; 95% CI 0.29 to 1.99, 159 participants). An exposure–response relationship was not identified for any of the cognitive outcomes.

Discussion This systematic review and meta-analysis found only a few studies that provided very low to low certainty evidence of little to no association between RF-EMF exposure and learning and memory, executive function and complex attention. None of the studies among children reported on global cognitive function or other domains of cognition. Only one study reported a lack of an effect for all domains in elderly persons but this was of very low certainty evidence. Further studies are needed to

address all types of populations, exposures and cognitive outcomes, particularly studies investigating environmental and occupational exposure in adults. Future studies also need to address uncertainties in the assessment of exposure and standardise testing of specific domains of cognitive function to enable synthesis across studies and increase the certainty of the evidence.

Other  This review was partially funded by the WHO radioprotection programme and prospectively registered on PROSPERO CRD42021257548.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Dr Geza Benke reports financial support was provided by World Health Organization. MA declares that he holds a small parcel of Telstra shares. KK, CB and MS as part of their employment are involved in the provision of advice to the Australian Commonwealth Government, Australian States and Territories and the general public on the risks and health effects of exposure to ionising and non-ionising radiation. KK is also a member of the International Commission on Non-Ionizing Radiation Protection where he contributes in the development and dissemination of science-based advice on limiting exposure to non-ionizing radiation. No member of the review team was involved in screening or extracting data from a study in which he or she was an author].

Acknowledgements

We would like to thank Emilie Van Deventer, WHO, Geneva, Switzerland; Martin Röösli, Swiss TPH, Basel, Switzerland and Anke Huss, Utrecht University, Utrecht, The Netherlands; for their contributions to the protocol.

Supplementary files can be downloaded.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024003659

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**Effects of recall and selection biases on modeling cancer risk from mobile phone use: Results from a case-control simulation study**

(My note: The models tested in this simulation study were based on questionable assumptions.)

Bouaoun L, Byrnes G, Lagorio S, Feychting M, Abou-Bakre A, Beranger R, Schüz J. Effects of recall and selection biases on modeling cancer risk from mobile phone use: Results from a case-control simulation study. Epidemiology. 2024 May 20. doi: 10.1097/EDE.0000000000001749.

Abstract

Background: The largest case-control study (Interphone Study) investigating glioma risk related to mobile phone use showed a J-shaped relationship with reduced relative risks for moderate use and a 40% increased relative risk among the 10% heaviest regular mobile phone users, using a categorical risk model based on deciles of lifetime duration of use among ever regular users.

Methods: We conducted Monte-Carlo simulations examining whether the reported estimates are

compatible with an assumption of no effect of mobile phone use on glioma risk when the various forms of biases present in the Interphone study are accounted for. Four scenarios of sources of error in self-reported mobile phone use were considered, along with selection bias. Input parameters used for simulations were those obtained from Interphone validation studies on reporting accuracy and from using a non-response questionnaire.

Results: We found that the scenario simultaneously modeling systematic and random reporting errors produced a J-shaped relationship perfectly compatible with the observed relationship from the main Interphone study with a simulated spurious increased relative risk among heaviest users (OR = 1.91) compared to never regular users. The main determinant for producing this J shape was higher reporting error variance in cases compared to controls, as observed in the validation studies. Selection bias contributed to the reduced risks as well.

Conclusions: Some uncertainty remains, but the evidence from the present simulation study shifts the overall assessment to making it less likely that heavy mobile phone use is causally related to an increased glioma risk.

Open access paper: https://pubmed.ncbi.nlm.nih.gov/38771708/

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**Validation of mobile phone use recall in the multinational MOBI-kids study**

van Wel L, Huss A, Kromhout H, Momoli F, Krewski D, Langer CE, Castaño-Vinyals G, Kundi M, Maule M, Miligi L, Sadetzki S, Albert A, Alguacil J, Aragones N, Badia F, Bruchim R, Goedhart G, de Llobet P, Kiyohara K, Kojimahara N, Lacour B, Morales-Suarez-Varela M, Radon K, Remen T, Weinmann T, Vrijheid M, Cardis E, Vermeulen R; MOBI-Kids consortium. Validation of mobile phone use recall in the multinational MOBI-kids study. Bioelectromagnetics. 2024 May 22. doi: 10.1002/bem.22507.

Abstract

Potential differential and non-differential recall error in mobile phone use (MPU) in the multinational MOBI-Kids case-control study were evaluated. We compared self-reported MPU with network operator billing record data up to 3 months, 1 year, and 2 years before the interview date from 702 subjects aged between 10 and 24 years in eight countries. Spearman rank correlations, Kappa coefficients and geometric mean ratios (GMRs) were used. No material differences in MPU recall estimates between cases and controls were observed. The Spearman rank correlation coefficients between self-reported and recorded MPU in the most recent 3 months were 0.57 and 0.59 for call number and for call duration, respectively. The number of calls was on average underestimated by the participants (GMR = 0.69), while the duration of calls was overestimated (GMR = 1.59). Country, years since start of using a mobile phone, age at time of interview, and sex did not appear to influence recall accuracy for either call number or call duration. A trend in recall error was seen with level of self-reported MPU, with underestimation of use at lower levels and overestimation of use at higher levels for both number and duration of calls. Although both systematic and random errors in self-reported MPU among participants were observed, there was no evidence of differential recall error between cases and controls. Nonetheless, these sources of exposure measurement error warrant consideration in interpretation of

the MOBI-Kids case-control study results on the association between children's use of mobile phones and potential brain cancer risk.

Highlights

- Self-reported and operator-registered phone calls were compared among MobiKids participants.
- On average, number of calls was underestimated, and duration overestimated.
- No differential recall error was found between brain tumor cases and controls in MobiKids.

Excerpts

The comparison of self-reported and recorded MPU was conducted separately for the number and duration (in minutes) of calls in the 3 months preceding the date of interview. In addition, a subset of subjects who had data available for 1 year, and a subset for 2 years preceding the date of interview were assessed....

A total of 702 subjects from eight different countries (Canada, France, Germany, Greece, Israel, Italy, Korea, and Spain) had data on both self-reported and recorded MPU in the 3 months preceding the interview date (Table 1)....

The overall GMRs of self-reported versus recorded MPU in the most recent 3 months were 1.59 for call duration and 0.69 for call number, indicating systematic errors in the form of overreporting of call duration of calls and underreporting of the number of calls. Looking at recall over time for subjects with 2 years of data available, there appears to be a lower level of overreporting of duration of calls for both cases (initial GMR 1.62, 1.44 at 1 year) and controls (initial GMR 1.37, 1.08 at 1 year) between recent and 1 year recall. There is however little difference in recall in call duration over time between the 1 and 2 year time points for either cases or controls (1.44 vs. 1.41 and 1.08 vs. 1.07, respectively) (Table 5). Although this same initial decrease can be seen in controls for recall of number of calls, it is less clear for cases (Table 4)....

While not all subjects from the main MOBI-Kids study provided informed consent to obtain their network operator data and not all operators provided data, we managed to include a large proportion of subjects (24.8%) from the MOBI-Kids case–control study in this validation study. The proportion of subjects where longer-term data was available (at 1- and 2-year time periods) was smaller, with no subjects from some of the participating countries....

... it may not always be clear from billing records who the actual user of the phone was when making calls. Therefore, while billing records provide insight into validity and possible calibration of self-reports, they may not represent the gold standard for studies, especially due to the low number of retained study participants, and also because internet-based calling (VoiP) is not included in the records....

Both the COSMOS (Reedijk et al., 2024) as well as the INTERPHONE validation (Vrijheid et al., 2009) studies found significantly differing ratios between countries. In the present study we did see some differences in GMRs among the eight participating countries, but the differences did not achieve statistical significance. In contrast, the MOBI-Expo validation study by Goedhart et al. (2018) did find significant differences among countries with participants from Greece, Israel, and Korea underestimating the duration of calls while in other countries duration was overestimated....

CONCLUSIONS

We compared self-reported MPU with operator data at 3 months, 1 year, and 2 years preceding the interview date. No indication of differential recall error between cases and controls was found. Both non-differential systematic and random errors were observed, with number of calls being underreported and duration of calls being over-reported on average in both cases and controls. If there are true underlying risks, then the observed non-differential random errors may bias risk estimates towards their null values and decrease study power.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22507

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**Micro-environmental personal radio-frequency electromagnetic field exposures in Melbourne: A longitudinal trend analysis**

Bhatt CR, Henderson S, Sanagou M, Brzozek C, Thielens A, Benke G, Loughran S. Micro-environmental personal radio-frequency electromagnetic field exposures in Melbourne: A longitudinal trend analysis. Environ Res. 2024 Mar 13;251(Pt 2):118629. doi: 10.1016/j.envres.2024.118629

Highlights

- RF-EMF exposure may be affected by changes in telecommunication technologies.
- Personal RF-EMF exposure assessments were undertaken in 2015/16 and 2022.
- Quantile regression models were used to compare exposure levels and overall trend.
- Median total exposure level at follow-up did not change over time.
- Overall trend of total exposure at follow-up increased.

Abstract

Background  A knowledge gap exists regarding longitudinal assessment of personal radio-frequency electromagnetic field (RF-EMF) exposures globally. It is unclear how the change in telecommunication technology over the years translates to change in RF-EMF exposure. This study aims to evaluate longitudinal trends of micro-environmental personal RF-EMF exposures in Australia.

Methods  The study utilised baseline (2015-16) and follow-up (2022) data on personal RF-EMF exposure (88 MHz-6 GHz) measured across 18 micro-environments in Melbourne. Simultaneous quantile regression analysis was conducted to compare exposure data distribution percentiles, particularly median (P50), upper extreme value (P99) and overall exposure trends. RF-EMF exposures were compared across six exposure source types: mobile downlink, mobile uplink, broadcast, 5G-New Radio, Others and Total (of the aforementioned sources). Frequency-specific exposures measured at baseline and follow-up were compared. Total exposure across different groups of micro-environment types were also compared.

Results  For all micro-environmental data, total (median and P99) exposure levels did not significantly change at follow-up. Overall exposure trend of total exposure increased at follow-up. Mobile downlink contributed the highest exposure among all sources showing an increase in median exposure and overall

exposure trend. Of seven micro-environment types, five of them showed total exposure levels (median and P99) and overall exposure trend increased at follow-up.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0013935124005334

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**Evaluating radiofrequency electromagnetic field exposure in confined spaces: a systematic review of recent studies and future directions**

Ahsan Ashraf M, Celik T. Evaluating radiofrequency electromagnetic field exposure in confined spaces: a systematic review of recent studies and future directions. Radiat Prot Dosimetry. 2024 Apr 20;200(6):598-616. doi: 10.1093/rpd/ncae045.

Abstract

This study reviews recent research on Radiofrequency Electromagnetic Field (RF-EMF) exposure in confined environments, focusing on methodologies and parameters. Studies typically evaluate RF-EMF exposure using an electric field and specific absorption rate but fail to consider temperature rise in the tissues in confined environments. The study highlights the investigation of RF-EMF exposure in subterranean environments such as subways, tunnels and mines. Future research should evaluate the exposure of communication devices in such environments, considering the surrounding environment. Such studies will aid in understanding the risks and developing effective mitigation strategies to protect workers and the general public.

Conclusion

In this study, we conducted an SLR of 63 articles related to RF-EMF exposure in confined environments. The articles were selected based on a QA and divided into measurement and simulation studies. Our literature analysis demonstrates that RF-EMF exposure is higher in working spaces and transport than in dwellings, largely due to multiple exposure frequencies and excessive users. However, evaluating sub-terrain environments remains limited despite the growing use of wearable wireless devices in these settings. We also identified the different exposimeters and numerical dosimetry software tools commonly used for measuring and simulating RF-EMF exposure in confined environments. Furthermore, we found that the electric field is the most commonly investigated parameter for evaluating RF-EMF exposure using dosimetry simulation and measurement in confined environments. Given the increasing use of wearable wireless devices in sub-terrain and other occupational environments, there is a critical need to evaluate RF-EMF exposure in high-temperature environments, particularly with respect to temperature elevation in tissue. Future studies should evaluate the potential health impacts of long-term exposure to RF-EMF, especially in occupational settings where workers are exposed for extended periods.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11033578/

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**Optimal design of electromagnetic field exposure maps in large areas**

López-Espí PL, Sánchez-Montero R, Guillén-Pina J, Chocano-del-Cerro R, Rojas JAM. Optimal design of electromagnetic field exposure maps in large areas. Environmental Impact Assessment Review. Volume 106, 2024, doi: 10.1016/j.eiar.2024.107525.

Abstract

The mapping of electromagnetic field (EMF) exposure over large areas is a very useful tool for the analysis of epidemiological data and risk assessment. Its production requires a costly measurement process. To optimize the effort and ensure the representativeness of the exposure map, criteria for the selection of the sites to be measured must be established. This paper presents a methodology for conducting EMF exposure maps suitable for risk assessment evaluation in large areas. The proposal combines radio wave propagation criteria and GIS methods to optimize the sampling effort. The design criteria are based on the determination of a rectangular grid of 250 m side and the identification of the emitters within the area under study. Both urban and rural sites are analysed in the proposal and line of sight conditions (LOS) are considered to reduce the number of points required and thus optimize the measurement effort. Depending on the extent and regularity of the surface, the density of measurement points has been estimated to be between 8 and 10 points per square kilometre in the urban area. The proposed methodology has been applied to a case study of a 2.8 km2 urban area within a 35.11 km2 municipality, obtaining an average point density of 9.64 points/km2 in the urban area. The differences in exposure depending on the application of the criteria have been analysed by means of the statistical values of the sets and the subtraction of the maps generated using kriging techniques. According to our results, if LOS measurements are not properly incorporated, the mean value of the EMF is underestimated in the area under study.

Conclusions

In this proposal, the methodology for EMF exposure mapping in large areas has been analysed. To optimize the measurement effort over a large area, a division into 250 × 250 $m^2$ urban grids should be considered, in which the possible sources of radiation should be known. A measurement under LOS conditions must be performed in each of the grids in which any of the emitters is present. The absence of measurements under LOS conditions implies an underestimation of the mean values. To select the rest of the grids to be measured, the viewshed analysis allows to simplify the number of measurements by grouping those grids determined as N-LOS. To achieve optimal interpolation results over the entire surface, sufficient measurements must also be available on its perimeter. Interpolation by ordinary stable kriging obtains adequate results under LOS and N-LOS conditions. The generated maps contribute to a better perception of risk as they provide an objective and simple tool to show the level of EMF. They do not require complex propagation models but are based on interpolations made within a GIS. They can also be combined, using these techniques, for risk assessment and even, if epidemiological data are available, for possible correlations studies.

The proposal considers the differences between urban areas, with the possibility of multipath, and rural (non-urban) areas. For the analysis of urban areas, a grid of 250 × 250 $m^2$ has been proposed as a guideline for the spatial organisation of the territory in urban areas and 500 × 500 $m^2$ in rural areas.

Depending on the extent and regularity of the surface, the density of measurement points has been estimated to be between 8 and 10 points per square kilometre in the urban area. Lower point densities

result in IDW representations and higher densities increase the measurement effort excessively. In the case under study, for the urban area, a density of 9.64 points/km$^2$ has been reached.

The study has been performed following the six-minute averaging criterion and in a bandwidth from 100 kHz to 3 GHz. The latest ICNIRP recommendations modify these values to take into account, among others, the new 5G signals, not yet present in the area. The urban study was carried out in a mainly residential area, where there are no concentrations of the general public, which could lead to areas of greater exposure due to greater use of the network. For future studies, therefore, the measurement and comparison according to the latest ICNIRP recommendations is still pending in areas where the new 5G networks have been incorporated and in urban micro-environments where there is a higher population density or uses significantly different from residential. Another point of continuation of this research is the correlation of the measured values with tumor statistics and other diseases. The opportunity provided by exposure maps created for entire urban environments may allow, where appropriate, to find possible relationships.

https://www.sciencedirect.com/science/article/pii/S0195925524001124

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**Electromagnetic field exposure monitoring of commercial 28-GHz band 5G base stations in Tokyo, Japan**

Liu S, Tobita K, Onishi T, Taki M, Watanabe S. Electromagnetic field exposure monitoring of commercial 28-GHz band 5G base stations in Tokyo, Japan. Bioelectromagnetics. 2024 May 22. doi: 10.1002/bem.22505.

Abstract

Fifth generation (5G) wireless communication is being rolled out around the world. In this work, the latest radio frequency electromagnetic field (EMF) exposure measurement results on commercial 28-GHz band 5G base stations (BSs) deployed in the urban area of Tokyo, Japan, are presented. The measurements were conducted under realistic traffic conditions with a 5G smartphone and using both omnidirectional and horn antennas. First and foremost, in all cases, the electric-field (E-field) intensity is much lower (<-38 dB) than the exposure limits. The E-field intensities for traffic-off cases do not show any significant difference between the two antennas with the maximum being 3.6 dB. For traffic-on cases, the omnidirectional antenna can undesirably capture the radio wave from the smartphone in some cases, resulting in a 7-13 dB higher E-field intensity than that using the horn antenna. We also present comparative results between 4G long term evolution BSs and sub-6-GHz band and 28-GHz band 5G BSs and provide recommendations on acquiring meaningful EMF exposure data. This work is a further step toward the standardization of the measurement method regarding quasi-millimeter/millimeter wave 5G BSs.

https://pubmed.ncbi.nlm.nih.gov/38778514/

Conclusions

The latest EMF exposure measurement results on commercial 28-GHz band 5G FR2 BSs in Tokyo, Japan, were presented in this paper. The measurements were evaluated under realistic traffic conditions and in an isotropic state using both omnidirectional and horn antennas. In all cases (sites and spots, antennas,

and traffic conditions), the E-field intensity was within the limits established by ICNIRP and IEEE/ICES. The maximal time-averaged E-field intensity (118 dBμV/m) reached only 0.016% of the limit. It was found that the E-field intensity varied with measurement height with a variance in amplitude reaching 10–25 dB over different measurement spots. The E-field intensities for traffic-off cases did not show any significant difference between the two antennas with the maximum being 3.6 dB. However, for traffic-on cases, the omnidirectional antenna may undesirably capture the radio wave from the smartphone in some cases, thus leading to a time-averaged E-field intensity 7–13 dB higher than that in the cases of using the horn antenna. Despite this, an omnidirectional antenna is always preferred as it can detect all the reflections and scatterings of the environment. A horn antenna is preferred only in situations where the reflections and scatterings are negligible. On the other hand, the distance between the smartphone and the antenna (50 cm in this study) may be increased to avoid the capture of the irradiation from the smartphone. For the horn antenna, there is generally a 23–27 dB rise in the time-averaged E-field intensity of traffic-on cases compared with that of traffic-off cases. The rise for the omnidirectional antenna is 19–37 dB.

5G, especially 5G FR2, is being continuously deployed. The measurements in this work were mainly limited to the urban area of Tokyo, Japan. With the expansion of the 5G service coverage, measurements in suburban and rural areas will be conducted in the future. Comparative studies between 5G FR1 and FR2 will also be of considerable interest and will be a future target. In summary, investigations will be successively conducted following the deployment of 5G.

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**The exposure of nonhuman living organisms to mobile communication emissions: A survey to establish European stakeholders' policy option preferences**

Recuero Virto L, Thielens A, Czerwiński M, Froidevaux J. (2024). The exposure of nonhuman living organisms to mobile communication emissions: A survey to establish European stakeholders' policy option preferences. *Risk Analysis*, 1–15. doi: 10.1111/risa.14322.

Abstract

There is an unprecedented exposure of living organisms to mobile communications radiofrequency electromagnetic field (RF-EMF) emissions. Guidelines on exposure thresholds to limit thermal effects from these emissions are restricted to humans. However, tissue heating can occur in all living organisms that are exposed. In addition, exposure at millimetric frequencies used by 5G may impact surface tissues and organs of plants and small-size species. It is also expected that the addition of 5G to existing networks will intensify radiofrequency absorption by living organisms.

A European Parliament report proposed policy options on the effects of RF-EMF exposure of plants, animals, and other living organisms in the context of 5G: funding more research, implementing monitoring networks, accessing more information from operators on antennas and EMF emissions, and developing compliance studies when antennas are installed. However, there is no evidence on the preferences of relevant stakeholders regarding these policy options. This paper reports the findings of a survey of key European stakeholders' policy option preferences based on the European Parliament's report. It reveals a broad consensus on funding more research on the effects of exposure of plants, animals, and other living organisms to EMFs. It also highlights the need for deliberation concerning the

other policy options that could provide solutions for regulatory authorities, central administrations, the private sector, nongovernmental associations and advocates, and academics. Such deliberation would pave the way for effective solutions, focusing on long-term output from funding research, and enabling short-term socially and economically acceptable actions for all parties concerned.

Excerpts

From a regulatory perspective, current guidelines on exposure thresholds to limit thermal energy from mobile communications emissions developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and by the Institute of Electrical and Electronics Engineers (IEEE) only concern human health (ICNIRP, 1998, 2020; IEEE, 1991, 2019).3 It is worth noting that ICNIRP and IEEE thresholds, developed under the assumptions that biological effects are due to excessive tissue heating and that no effects occur below the threshold, remain controversial (ICBE-EMF, 2022). According to the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF), adverse effects have been observed below the threshold, such as nonthermal induction of reactive oxygen species, DNA damage, cardiomyopathy, carcinogenicity, sperm damage, and neurological effects (e.g., electromagnetic hypersensitivity)....

According to the International Commission on Radiological Protection (ICRP), steps taken to protect the environment from ionizing radiation should fall within the concept of optimization, the latter understood as the process of determining the level of protection and safety that makes exposures, and the probability and magnitude of potential exposures, as low as reasonably achievable, economic and societal factors being taken into account. Reference levels were derived by the ICRP to relate the effects of ionizing radiation to doses to nonhuman organisms, but the institution states that these values are not limited and are not intended to be used in that manner. Potential synergies between ICNIRP and ICRP approaches were already subject to discussion in the past for human health, in particular, whether ALARA approaches developed by the ICRP could be meaningfully applied to nonionizing radiation (ICNIRP/WHO/ICRP/IRPA/ILO, 2014).

To conclude, humans have so far chosen not to address the effects of RF-EMF on nonhuman organisms even if there is evidence of thermal effects on all living organisms. The controversial debates on RF-EMF effects on human health have probably hampered early attempts to address the effects on nonhuman organisms. Our results show that, for the consulted stakeholders, this topic calls for some action. It is not a matter of hindering progress, but understanding the optimal conditions for technological proliferation, given the current state of knowledge.

https://onlinelibrary.wiley.com/doi/10.1111/risa.14322

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**RF-EMF Exposure Assessment of Fetus During The First Trimester of Pregnancy**

Sandeep S, Vard A, Guxens M, Bloch I, Wiart J. RF-EMF Exposure Assessment of Fetus During The First Trimester of Pregnancy. *IEEE Access*, doi: 10.1109/ACCESS.2024.3404369.

Abstract

This article describes the computational analysis of Radio Frequency - Electromagnetic Field (RF-EMF) exposure of Uterus-Fetus Units (UFUs) embedded inside the body of a 26 year old human female. Realistic UFU models are obtained from ultrasound images acquired for different fetuses and at specific development stages (7 weeks, 9 weeks and 11 weeks old), for which a deep-learning based segmentation method is developed. Each UFU model is then inserted into a computational electromagnetic model of a 26 year old female. The Specific Absorption Rate (SAR) of the fetus at commonly used wireless communication frequencies is estimated using a commercially available numerical electromagnetic solver. The Inverted F antenna (IFA), which is a commonly used mobile phone antenna was used as the excitation source. Fetus SAR values are reported for different combinations of excitation frequencies, phone positions and UFU ages. It was found that the fetus SAR for all the cases is well below the maximum allowable exposure limit of 80 mW/kg, as prescribed by ICNIRP. Furthermore, we replaced the embryo with uterus tissues and calculated the SAR in the uterus tissues (i.e. uterus tissues with same volume and shape, and at the same location as that of UFU). The uterus SAR values were found to be only marginally different from that of fetus SAR.

Open access paper:
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10536873&isnumber=6514899

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**Regression calibration of self-reported mobile phone use to optimize quantitative risk estimation in the COSMOS study**

Reedijk M, Portengen L, Auvinen A, Kojo K, Heinävaara S, Feychting M, Tettamanti G, Hillert L, Elliott P, Toledano MB, Smith RB, Heller J, Schüz J, Deltour I, Poulsen AH, Johansen C, Verheij R, Peeters P, Rookus M, Traini E, Huss A, Kromhout H, Vermeulen R, Study Group TC. Regression calibration of self-reported mobile phone use to optimize quantitative risk estimation in the COSMOS study. Am J Epidemiol. 2024 May 13:kwae039. doi: 10.1093/aje/kwae039.

Abstract

The Cohort Study of Mobile Phone Use and Health (COSMOS) has repeatedly collected self-reported and operator-recorded data on mobile phone use. Assessing health effects using self-reported information is prone to measurement error, but operator data were available prospectively for only part of the study population and did not cover past mobile phone use. To optimize the available data and reduce bias, we evaluated different statistical approaches for constructing mobile phone exposure histories within COSMOS. We evaluated and compared the performance of four regression calibration (RC) methods (simple, direct, inverse, and generalized additive model for location, shape, and scale), complete-case (CC) analysis and multiple imputation (MI) in a simulation study with a binary health outcome. We used self-reported and operator-recorded mobile phone call data collected at baseline (2007-2012) from participants in Denmark, Finland, the Netherlands, Sweden, and the UK. Parameter estimates obtained using simple, direct, and inverse RC methods were associated with less bias and lower mean squared error than those obtained with CC analysis or MI. We showed that RC methods resulted in more accurate estimation of the relation between mobile phone use and health outcomes, by combining self-reported data with objective operator-recorded data available for a subset of participants.

Excerpts

Self-reported duration of mobile phone use (REPORT) at baseline [21] was based on answers to the question: “Over the last three months, on average, how much time per week did you spend talking on a mobile phone?”. The following response options were provided: “< 5 min/week”, “5-29 min/week”, “30-59 min/week”, “1-3 hours/week”, “4-6 hours/week”, and “>6 hours/week”. In the Netherlands and the UK two further categories of call duration were included, “7-9 hours/week” and “10 or more hours/week”, but these were combined into “>6 hours/week” for the present analyses....

Operator-recorded duration of mobile phone use (RECORD) was collected for all participants who provided consent and had a subscription under their own name. Operator-recorded data were used only when available for all mobile phones that were reported (up to two phones in Denmark, the Netherlands, Sweden, Finland, and up to three in the UK) and for at least three full months at the time the baseline questionnaire was administered. Participants with mobile phones that were also used by others were excluded. Operator-recorded data were available for 21% of participants in Denmark, 76% in Finland, 40% in the Netherlands, 63% in Sweden, and 76% in the UK....

A major issue is how well mobile phone use predicts the exposure of interest, namely radiofrequency electromagnetic fields. While past validation studies have been carried out for the 2nd mobile phone generation, showing fair agreement between amount of use and cumulated emission from the handset [4], fewer data are available on the predictive power of mobile phones of the 3rd, 4th and 5th generations that have and are being used by COSMOS participants....

Table 1 (excerpt)

Complete data by country: Denmark (11%: 2993/25912), Finland (70%: 9162/13062), Netherlands (3%: 3039/88466), Sweden (49%: 24881/50678), United Kingdom (58%: 56862/98685)

Recorded call duration in minutes/week by country (geometric mean): Denmark (60.6), Finland (81.5), Netherlands (23.4), Sweden (78.3), United Kingdom (46.5)

Conclusion

This study addressed an important concern in mobile phone research and more generally in environmental epidemiology: how to leverage self-reported exposure estimates that are often available but error-prone, with more objective measurements that may be obtained in only a subset of participants. Our simulation study indicated RC approaches may improve estimation of exposure-outcome relations between mobile phone use and health outcomes within COSMOS. The prospective design and improved exposure assessment within COSMOS compared to that in previous case-control studies are expected to lead to more robust conclusions about possible health effects from use of mobile phones.

Conflict of Interest: MF was vice chairman (2012-2020) of the International Commission on Non-Ionizing Radiation Protection, an independent body setting guidelines for non-ionizing radiation protection. She has served as advisor to a number of national and international public advisory and research steering groups concerning the potential health effects of exposure to non-ionizing radiation, currently for the World Health Organization (WHO). HK was the chair of the Committee on Electromagnetic Fields of the Health Council of The Netherlands till 2022. He currently is a member of the WHO Task Group for the Environmental Health Criteria Monograph on RF-EMF. AH is a member of the International Commission on Non-Ionizing Radiation Protection since 2020, and of the Committee on Electromagnetic Fields of the

Health Council of The Netherlands, and chairs the Swedish Radiation Safety Authority's (SSM) Scientific Council on Electromagnetic Fields since 2020. AA currently is a member of the WHO Task Group for the Environmental Health Criteria Monograph on RF-EMF. MBT is currently member of the WHO groups tasked with systematic review of evidence on non-ionizing radiation and health, that is feeding into the Environmental Health Criteria Monograph on RF-EMF. All other authors declare they have no competing financial interests.

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https://academic.oup.com/aje/advance-article/doi/10.1093/aje/kwae039/7671112?login=false

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**Monitoring of the exposure to electromagnetic fields with autonomous probes installed outdoors in France**

Jawad O, Conil E, Agnani J-B, Wang S, Wiart J. Monitoring of the exposure to electromagnetic fields with autonomous probes installed outdoors in France. Comptes Rendus. Physique, Online first (2024), pp. 1-21. doi : 10.5802/crphys.182.

Abstract

The study is based on a new temporal analysis of exposure based on the deployment of autonomous broadband E-field monitoring probes in many French cities. The combination of the probe's data with frequency-selective in situ measurements performed by ANFR and the knowledge of the nearby base station antennas, allows to draw statistical conclusions on the exposure of the population. Indeed, the data collected by the probes reveal that different periodicities exist (seasonality, day/night). This paper shows that the monitoring probes are able to detect the seasonality of the exposure and provide analysis of correlation between monitoring probes and radio environment.

Excerpt

The analysis indicates that the monitoring probes have varying exposure levels. Probes measuring significant levels show a difference in exposure between day and night, a phenomenon observed for the first time in France. An empirical time interval from 8 AM to 11 PM enables to calculate the ratio of averaged E-field levels between day and night. This ratio is between 1.28 and 1.42 for the three probes with the highest RMS level. Several papers, such as [8–10], have characterized the day and night fluctuation, but this has never been demonstrated using French data.

For the first time, the variability of daily working hours has been quantified for all the probes installed in France. The data shows that most of the probes exhibit a 30% variation percentage based on the data gathered from 8 AM to 5 PM. Based on our knowledge, this is the first time that the assessment of the daily variation contributor based on more than 150 probes installed in different environments is achieved. It confirms the level of daily variation contributor to the in situ measurement uncertainty budget, as communicated in the accredited in situ measurement reports [3, 16, 17]....

For the first time, the seasonality of the level of exposure has been analyzed at the French national level. The PCA on dataset No. 2 emphasizes the observation that the positioning of the probe is crucial to

observe a remarkable variation of the exposure level. The probe must not only be installed in an area with many base stations, but also in close proximity to them and in a line-of-sight position for the exposure. A large number of probes measuring low exposure levels can be explained by the fact that the probes are not in a line-of-sight situation. In some cities, probes were installed in low-density areas rather than in front of base stations due to public concern over electromagnetic waves. Upon analysis, we find that some probes measure a lower level of exposure in summer time. This interpretation was confirmed with the Principal Component Analysis, which showed that the second component of the PCA characterizes the difference between probes with higher exposure in summer or winter. This phenomenon can be explained by the fact that some of the cities are very touristic during the summer, leading to increased use of the telecommunication infrastructure. In general, the exposure levels measured by the autonomous probe are very low compared to the limits. The increase of the exposure level is relatively slow, as it has been shown in several ANFR studies [4, 18–20].

Open access paper:

https://comptes-rendus.academie-sciences.fr/physique/articles/10.5802/crphys.182/

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**Statistical Analysis of RF-EMF Exposure Induced by Cellular Wireless Networks in Public Transportation Facilities of the Paris Regionx**

Y. Zhang *et al*. Statistical Analysis of RF-EMF Exposure Induced by Cellular Wireless Networks in Public Transportation Facilities of the Paris Regionx. *IEEE Access*, vol. 12, pp. 79741-79753, 2024, doi: 10.1109/ACCESS.2024.3410090.

Abstract

Wireless communications are increasingly used today. Despite such use, there is a significant perception of risk which makes exposure monitoring a significant concern today. The work described in this article was carried out within the framework of the European SEAWave project and the French Beyond5G project. The exposure assessment was evaluated using a personal exposimeter (MVG EMF Spy) whose compactness and ease of use make it more suitable and portable than a system combining measuring probes and spectrum analyzers. Measurements were carried out on the cellular frequency bands used by 2G, 3G, 4G, and 5G, as well as that of Wi-Fi, in different modes of public transportation (RER, metro, tramway, bus, and train) circulating in the Paris region. The measurements have been analyzed by frequency band, type of public transportation, and type of environment encountered. For each set of measurements (e.g., metro lines, tramways), the mean, standard deviation, skewness, and kurtosis were evaluated and analyzed. For all exposure measurements taken in the 700, 800, 900, 1800, 2100, 2600, and 3500 MHz frequency bands, the overall average values are 0.39, 0.43, 0.30, 0.21, 0.18, 0.24 and 0.18 V/m, respectively. These measurements have, in all cases, a significant dispersion as shown by the ratios of standard deviations to mean values. The well-known K-means clustering technique was applied to these four parameters for different subsets of data. The number of clusters k = 3 has been chosen based on the analysis of the optimal value of k for the current dataset. Our analysis indicates that the first group's members display the highest mean values with moderate variance and the lowest values for the third and fourth moments. The second cluster is distinguished by points with large mean and variance,

accompanied by moderate skewness and kurtosis. Conversely, the third group comprises points with the smallest mean and variance values, yet the largest measurements for the third and fourth moments.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10549999&isnumber=10380310

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**Expression levels of tam receptors and ligands in the testes of rats exposed to short and middle-term 2100 MHz radiofrequency radiation**

Katirci E, Kirimlioglu E, Oflamaz AO, Hidisoglu E, Cernomorcenco A, Yargıcoğlu P, Ozen S, Demir N. Expression levels of tam receptors and ligands in the testes of rats exposed to short and middle-term 2100 MHz radiofrequency radiation. Bioelectromagnetics. 2024 May 9. doi: 10.1002/bem.22504.

Abstract

With advances in technology, the emission of radiofrequency radiation (RFR) into the environment, particularly from mobile devices, has become a growing concern. Tyro 3, Axl, and Mer (TAM) receptors and their ligands are essential for spermatogenesis and testosterone production. RFR has been shown to induce testicular cell apoptosis by causing inflammation and disrupting homeostasis. This study aimed to investigate the role of TAM receptors and ligands in the maintenance of homeostasis and elimination of apoptotic cells in the testes (weeks), short-term sham exposure (sham/1 week), and middle-term sham exposure (sham/10 weeks). Testicular morphology was assessed using hematoxylin-eosin staining, while immunohistochemical staining was performed to assess expression levels of TAM receptors and ligands in the testes of all groups. The results showed that testicular morphology was normal in the control, sham/1 week, and sham/10 weeks groups. However, abnormal processes of spermatogenesis and seminiferous tubule morphology were observed in RFR exposure groups. Cleaved Caspase 3 immunoreactivity showed statistically significant difference in 1 and 10 weeks exposure groups compared to control group. Moreover, there was no significant difference in the immunoreactivity of Tyro 3, Axl, Mer, Gas 6, and Pros 1 between groups. Moreover, Tyro 3 expression in Sertoli cells was statistically significantly increased in RFR exposure groups compared to the control. Taken together, the results suggest that RFR exposure negatively affects TAM signalling, preventing the clearance of apoptotic cells, and this process may lead to infection and inflammation. As a result, rat testicular morphology and function may be impaired.

https://pubmed.ncbi.nlm.nih.gov/38725116/

Highlights

Exposure to radiofrequency radiation (RFR) disrupts normal seminiferous tubule morphology.
RFR exposure in round spermatids may induce apoptosis independent of Tyro 3, Axl, and Mer (TAM) receptors.
TAM receptors and ligands are expressed in rat testis.

Conclusions

TAM receptors and ligands may play an important role in the spermatogenesis processes and may affect the functions of Leydig cells and Sertoli cells. In the present study, we have reported that RFR exposure

impair the morphology of rat testis. However, the impact on testicular function remains uncertain and requires further investigation. RFR exposure may negatively affect TAM signaling and enhances the accumulation of apoptotic cells.

Humans are exposed to RFR at a variable rate on a daily basis. Cell phones are the main source of RFR exposure, further complicating personal exposure times. In this study, cleaved caspase 3, TAM receptors and ligands were evaluated in rat testicular tissue exposed to 2100 MHz RFR. This study highlights the importance of radiofrequency exposure in male infertility. It provides a model for RFR reproductive toxicity studies. In order to better study the toxicity potential of RFR in the male reproductive system, it is necessary to study the intrauterine development and possibly live/healthy birth rates of the fetuses produced by mating RFR-exposed male mice with healthy female mice. In addition, long-term animal studies are urgently needed to investigate the potential health effects of frequencies used by upcoming 5G on the male reproductive system.

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**Effects of non-ionizing radio frequency electromagnetic radiation on the development and behavior of early embryos of *Danio rerio* (zebrafish)**

Khira R, Uggini GK. Effects of non-ionizing radio frequency electromagnetic radiation on the development and behavior of early embryos of *Danio rerio*. Electromagn Biol Med. 2024 May 12:1-8. doi: 10.1080/15368378.2024.2352429.

Abstract

Biological effects of radio frequency electromagnetic radiation (RF-EMR) in the range of 900-1800 MHz emerging from the mobile phone were investigated and were found to influence the locomotor pattern when exposure was initiated from 1 hour post fertilization (hpf) in zebrafish embryos (ZE), *Danio rerio*. Mobile phones and other wireless devices offer tremendous advantages. However, on the flipside they are leading to an increased electromagnetic energy in the environment, an excess of which could be termed as electromagnetic pollution. Herein, we tried to understand the effects of RF-EMR emerging from the mobile phone, on the development and behavior of ZE, exposed to RF-EMR (specific absorption rate of 1.13 W/kg and 1800 MHz frequency) 1 hr daily, for 5 days. To understand if there could be any developmental stage-specific vulnerability to RF-EMR, the exposure was initiated at three different time points: 1hpf, 6hpf and 24hpf of ZE development. Observations revealed no significant changes in the survival rate, morphology, oxidative stress or cortisol levels. However, statistically significant variations were observed in the batch where exposure started at 1 hpf, with respect to locomotion patterns (distance travelled: 659.1 ± 173.1 mm Vs 963.5 ± 200.4 mm), which could be correlated to anxiety-like behavior; along with a corresponding increase in yolk consumption (yolk sac area: 0.251 ± 0.019 $mm^2$ Vs 0.225 ± 0.018 $mm^2$). Therefore, we conclude that RF-EMR exposure influences the organism maximally during the earliest stage of development, and we also believe that an increase in the time of exposure (corresponding to the patterns of current usage of mobile phones) might reveal added afflictions.

Plain Language Summary

Mobile phones and other wireless devices are on a rampant usage worldwide. They work by radiating low energy radiofrequency electromagnetic radiations. An excessive usage of wireless devices is leading

to increased presence of these radiations in our surroundings. Since these radiations are not physically sensed by the organisms, its impact stays elusive. Nevertheless, the interaction of these radiations with biological systems may produce some unwarranted effects. When we exposed the ZE to the mobile phone radiation daily 1 hr for 5 days, our observations revealed that the youngest of the experimental group showed susceptibility. The effect was evident through haphazard movements and stressed behavior. So, it is important to be aware of the potential effects and take necessary precautions by following safety guidelines, especially when the organism is in its early life stage.

https://pubmed.ncbi.nlm.nih.gov/38734994

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**Multi-frequency electromagnetic radiation induces anxiety in mice via inflammation in the cerebral cortex**

Jing X, Menghua L, Lihui Z, Qian W, Xueli W, Xuelong Z, Zhihui L, Guofu D, Changzhen W. Multi-frequency electromagnetic radiation induces anxiety in mice via inflammation in the cerebral cortex. Environ Sci Pollut Res Int. 2024 May 9. doi: 10.1007/s11356-024-33447-y.

Abstract

Modern life is filled with radiofrequency electromagnetic radiation (RF-EMR) in various frequency bands, while the health risks are not clear. In this study, mice were whole-body exposed to 0.9/1.5/2.65 GHz radiofrequency radiation at 4 W/kg for 2 h per day for 4 weeks to investigate the emotional effects. It was found that the mice showed anxiety but no severe depression. The ELISA results showed a significant decrease in amino acid neurotransmitters (GABA, DA, 5-HT), although acetylcholine (ACH) levels were not significantly altered. Furthermore, Western blot results showed that BDNF, TrkB, and CREB levels were increased in the cerebral cortex, while NF-κB levels were decreased. In addition, pro-inflammatory factors (IL-6, IL-1β, TNF-α) were significantly elevated, and anti-inflammatory factors (IL-4, IL-10) tended to decrease. In conclusion, multi-frequency electromagnetic radiation induces an inflammatory response through the CREB-BDNF-TrkB and NF-κB pathways in the cerebral cortex and causes a decrease in excitatory neurotransmitters, which ultimately causes anxiety in mice.

Excerpt

In conclusion, these findings suggest that multi-frequency RF-EMR may induce anxiety by decreasing brain neurotransmitter levels and triggering inflammatory responses via the CREB-BDNF-TrkB pathway (Fig. 5). Currently, there are few studies on the relationship between multi-frequency electromagnetic radiation and mood changes, and this study provides some data support and a direction for future research. However, further in-depth investigations are needed to elucidate the specific mechanism of whether multi-frequency RF-EMR can induce negative emotions.

https://pubmed.ncbi.nlm.nih.gov/38724846/

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**The endocannabinoid system is involved in the anxiety-like behavior induced by dual-frequency 2.65/0.8 GHz electromagnetic radiation in mice**

Xue T, Ma RH, Xu C, Sun B, Yan DF, Liu XM, Gao D, Li ZH, Gao Y, Wang CZ. The endocannabinoid system is involved in the anxiety-like behavior induced by dual-frequency 2.65/0.8 GHz electromagnetic radiation in mice. Front Mol Neurosci. 2024 Apr 15;17:1366855. doi: 10.3389/fnmol.2024.1366855.

Abstract

As wireless communication devices gain popularity, concerns about the potential risks of environmental exposure to complex frequency electromagnetic radiation (EMR) on mental health have become a public health issue. Historically, EMR research has predominantly focused on single- frequency electromagnetic waves, neglecting the study of multi-frequency electromagnetic waves, which more accurately represent everyday life. To address these concerns, our study compared the emotional effects of single-frequency and dual-frequency EMR while exploring potential molecular mechanisms and intervention targets. Our results revealed that single-frequency EMR at 2.65 or 0.8 GHz did not induce anxiety-like behavior in mice. However, exposure to dual-frequency EMR at 2.65/0.8 GHz significantly led to anxiety-like behavior in mice. Further analysis of mouse sera revealed substantial increases in corticosterone and corticotrophin releasing hormone levels following exposure to 2.65/0.8 GHz EMR. Transcriptome sequencing indicated a significant decrease in the expression of *Cnr1*, encoding cannabinoid receptor 1 Type (CB1R), in the cerebral. This finding was consistently verified through western blot analysis, revealing a substantial reduction in CB1R content. Additionally, a significant decrease in the endocannabinoid 2-arachidonoylglycerol was observed in the cerebral cortex. Remarkably, administering the cannabinoid receptor agonist Win55-212-2 significantly alleviated the anxiety-like behavior, and the cannabinoid receptor antagonist AM251 effectively counteracted the anti-anxiety effects of Win55-212-2. In summary, our research confirmed that dual-frequency EMR is more likely to induce anxiety-like behavior in mice than single-frequency EMR, with implications for the hypothalamic–pituitary–adrenal axis and the endocannabinoid system. Furthermore, our findings suggest that Win55-212-2 may represent a novel avenue for researching and developing anti-EMR drugs.

Open access paper: https://www.frontiersin.org/articles/10.3389/fnmol.2024.1366855/full

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**Assessment of the potential threats to brain health posed by the radiation from 5G sub-6 GHz base stations in China using dosimetric methods**

Lin J, Ding G, Liu X, Li J. Assessment of the potential threats to brain health posed by the radiation from 5G sub-6 GHz base stations in China using dosimetric methods. Environ Sci Pollut Res Int. 2024 May;31(21):31015-31027. doi: 10.1007/s11356-024-33172-6.

Abstract

The 5G sub-6 GHz radio frequency (RF) electromagnetic fields (EMF) are the most widely used in China's communications. The public has expressed concerns about possible brain health effects of the higher frequency bands in 5G compared to 2G, 3G, and 4G bands. It is imperative to empirically investigate the potential health hazards of these novel frequency bands in 5G communication technology. This study evaluates the assessment of brain tissue dose coupling from sub-6 GHz band EMF emitted by base stations in China. Based on the 3D virtual human body model, the simulation environment was established. Dose including specific absorption rate (SAR) and internal electric field (IEF) between 2G, 3G, and 4G bands and 5G sub-6 GHz was investigated using normalized exposure values and exposure

limits. The results indicate that the sub-6 GHz high-frequency band of 5G has the lowest dose value. It can be concluded that high-frequency electromagnetic radiation in 5G sub-6 GHz reduces the dose and health threats to the brain. This provides strong support for the promotion of 5G commutation in China and other regions.

Conclusion

The research employed dosimetric methodology to comparatively evaluate the potential threat of communication EMF emitted by base stations to the human brain in China. Normalized evaluation showed that the dose value of brain tissue decreased with the increase of frequency. Moreover, the study explored the brain dose and health threats in accordance with both international mainstream ICNIRP guidelines and Chinese national standards. The findings indicate that the sub-6 GHz high-frequency band of 5G has the lowest dose value, thus ensuring a low risk of use. However, it should be noted that the choice of industry standards and physical evaluation quantities can slightly influence the evaluation results and trends. The research supplements the inadequacy of laboratory animal experiments and comparatively elaborates on the potential harm of EMF exposure from 5G sub-6 GHz to the brain's health. From a perspective of normalized assessment and the guideline comparison assessment, it can be concluded that high-frequency electromagnetic radiation in 5G sub-6 GHz reduces the harm of dose and risk values. This provides strong support for the promotion of 5G commutation in China and other regions. However, the limitation of this study is that the actual public exposure value does not take into account the measured value as the massive geographic information and statistical data. In the subsequent stage, the investigation of exposure measurement and dose evaluation can be merged with epidemiological research to probe deeper into the repercussions of novel frequency bands on the brain and its affiliated organ system.

Open access paper: https://link.springer.com/article/10.1007/s11356-024-33172-6

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**Whole-body SAR measurements of millimeter-wave base station in reverberation chambers**

Eilers Bischoff J, Joshi P, Colombi D, Xu B, Törnevik C. Whole-body SAR measurements of millimeter-wave base station in reverberation chambers. International Journal of Microwave and Wireless Technologies. Published online 2024:1-6. doi:10.1017/S1759078724000515

Abstract

This paper presents a method for measuring whole-body specific absorption rate (WBSAR) of millimeter-wave base stations (BSs) in a reverberation chamber (RC). The absorbed power in the phantom from the equipment under test (EUT) and hence WBSAR is determined as the difference between the total radiated power with and without the phantom. A chamber transfer function is determined and used to include only the absorption in the phantom due to direct illumination from the EUT, i.e., excluding absorption due to the RC multipath reflections. The measurement method was evaluated at 28 GHz using a horn antenna and a commercial massive multi-input–multi-output BS. The experimental results are in good agreement with simulations. The proposed method allows for measurements of WBSAR within 3 minutes, which is much shorter than traditional approaches. The method is suitable for compliance assessments of BS products with the International Commission on Non-Ionizing Radiation

Protection 2020 electromagnetic field exposure guidelines, which extend the applicability of WBSAR as basic restrictions up to 300 GHz.

https://doi.org/10.1017/S1759078724000515

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**Retraction notice to "Exercise ameliorates hippocampal damage induced by Wi-Fi radiation; A biochemical, histological, and immunohistochemical study"**

Mohamed AO, Abdel Hafez SMN, Ibrahim RA, Rifaai RA. Retraction notice to "Exercise ameliorates hippocampal damage induced by Wi-Fi radiation; A biochemical, histological, and immunohistochemical study" [J. Chem. Neuroanat. 129 (2023) 102252]. J Chem Neuroanat. 2024 Jun 8:102433. doi: 10.1016/j.jchemneu.2024.102433. Epub ahead of print. PMID: 38851999.

https://pubmed.ncbi.nlm.nih.gov/38851999/

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**Review on the impact of cell phone radiation effects on green plants**

Panda DK, Das DP, Behera SK, Dhal NK. Review on the impact of cell phone radiation effects on green plants. Environ Monit Assess. 2024 May 21;196(6):565. doi: 10.1007/s10661-024-12623-0.

Abstract

The aim of this review is to assess the impact of cell phone radiation effects on green plants. Rapid progress in networking and communication systems has introduced frequency- and amplitude-modulated technologies to the world with higher allowed bands and greater speed by using high-powered radio generators, which facilitate high definition connectivity, rapid transfer of larger data files, and quick multiple accesses. These cause frequent exposure of cellular radiation to the biological world from a number of sources. Key factors like a range of frequencies, time durations, power densities, and electric fields were found to have differential impacts on the growth and development of green plants. As far as the effects on green plants are concerned in this review, alterations in their morphological characteristics like overall growth, canopy density, and pigmentation to physiological variations like chlorophyll fluorescence and change in membrane potential etc. have been found to be affected by cellular radiation. On the other hand, elevated oxidative status of the cell, macromolecular damage, and lipid peroxidation have been found frequently. On the chromosomal level, micronuclei formation, spindle detachments, and increased mitotic indexes etc. have been noticed. Transcription factors were found to be overexpressed in many cases due to the cellular radiation impact, which shows effects at the molecular level.

https://pubmed.ncbi.nlm.nih.gov/38773047/

Conclusion

Cellular radiation affects plant seed germination, physiological, biochemical, cytogenetic, and molecular characters. In some cases, the effect has been shown to be positive. There is definitely some impact of these radiations; still there are controversies. Negative impacts can be described as heating stress or

charged effect of electric fields, but how the changes are positive nobody explains. Where the positive changes happen or on what frequency, and if power and SAR value is required have not been described. Not much research was found on wild plants, despite having more height and highly exposed in field conditions. Molecular changes in level of mRNA transcriptions have been seen with very less numbers of publications. Changes in the level of ion transports and electron transport chains have been done in very less numbers. Physical absorption and behavior of plant tissues have to be done more widely. The importance of these studies is most crucial because of the increased demand of technology with more number of users and requirement of high-end communication. Vast research in this field is required in order to avoid further hazards.

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**Effect of moisture content variation on dielectric properties of various plant leaves at microwave frequencies**

Chauhan PD, Gadani DH, Rana VA. Effect of moisture content variation on dielectric properties of various plant leaves at microwave frequencies. Sci Rep. 2024 Jun 8;14(1):13204. doi: 10.1038/s41598-024-64266-3.

Abstract

Complex permittivity of Corn, Jowar, Ashoka and Banana plant leaves was measured using a Vector Network Analyzer (Anritsu Shockline Model-MS46322A) over 500 MHz to 15 GHz frequency range, at different moisture contents. The dielectric constant ( ε ') and dielectric loss ( ε ") of the leaves decrease with decrease in moisture content over this frequency range. For the leaves having moisture content less than certain critical moisture level (CML), the values of ε ' and ε " remain almost constant with frequency variation. ε " does not increase appreciably with the increase in moisture content up to CML. CML is found to vary for different types of leaves. At higher moisture level, ε ' and ε " exhibit frequency dependence. Above certain moisture level in the leaves, ε " starts to increase slowly with the increase in frequency above 3 GHz approaching towards the dielectric relaxation of water. The values of ε ' and ε " were also measured for the extract of leaves and compared with the values calculated using Stogryn equations for the same salinity, and the results agree with the calculated values. The measured values of ε ' and ε " for the leaves were compared with the values calculated using Debye-Cole dual dispersion dielectric model and are found to match very well.

Open access paper: https://www.nature.com/articles/s41598-024-64266-3

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**How the Impact of Electromagnetic Fields on Plants Can Greatly Increase Severity of and Even Occurrence of "Wildfires": A Four-Part Structure**

Pall ML. How the Impact of Electromagnetic Fields on Plants Can Greatly Increase Severity of and Even Occurrence of "Wildfires": A Four-Part Structure.Ecology & Conservation Science: Open Access. 2024. doi: 10.19080/ECOA.2023.04.555631

Abstract

Low growing plants near buildings and electric powerlines often burn explosively at extreme temperatures, leaving a light gray powder whereas plants away from such sources of electromagnetic fields (EMFs) burn more normally, leaving slightly burned and/or charred materials. It is argued here that EMFs trigger a four-part mechanism producing this unusual pattern. Electronically generated EMFs impact plants via activation of voltage-controlled calcium channels, causing increases in plant terpenes and three other classes of volatiles (polyamines, lipid peroxidation volatiles and methyl jasmonate) and large increases in peroxynitrite and reactive free radicals. Four processes ensue: 1. The volatile terpenes make plants much more flammable. 2. Each of the four classes of volatiles accumulate in the air under very low wind conditions, and the heavy volatile-containing air spreads over the ground, selectively producing plasma membrane depolarization in low growing plants and parts of plants. Depolarization activates the same calcium channels activated by EMFs, selectively spreading and amplifying EMF-like effects to these low growing plants. 3. The terpenes react with free radicals and O2 to produce three classes of explosive terpene-derived chemicals, hydroperoxides, nitrate esters and nitro compounds. Accordingly, the explosive burning of these three classes of terpene derived chemicals in low growing plants produces very rapidly advancing low level firestorms which when they hit adjacent buildings also causes the buildings to burn at extremely high temperatures, leaving a light gray powder. 4. Terpene hydroperoxides because of their low thermostability may cause spontaneous combustion. Appropriate conditions for spontaneous combustion may be limited to plant materials in depressions in the ground. Sixteen fire observations are inconsistent with climate change being the sole cause of fire severity but are consistent with the proposed mechanism. Wind records from four large explosive US fires were examined and were found to be consistent with prediction. High voltage powerline roles in fires may be caused by powerline dirty electricity produced EMFs rather than poor maintenance as has previously been claimed.

Open access paper: https://juniperpublishers.com/ecoa/pdf/ECOA.MS.ID.555631.pdf

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**Oxidative Stress Response of Honey Bee Colonies during Long-Term Exposure at a Frequency of 900 MHz under Field Conditions**

Vilić M, Žura Žaja I, Tkalec M, Tucak P, Malarić K, Popara N, Žura N, Pašić S, Gajger IT. Oxidative Stress Response of Honey Bee Colonies (*Apis mellifera* L.) during Long-Term Exposure at a Frequency of 900 MHz under Field Conditions. Insects. 2024 May 20;15(5):372. doi: 10.3390/insects15050372.

Abstract

In this study, oxidative stress and lipid peroxidation in honey bee larvae, pupae and the midguts of adult bees were investigated during a one-year exposure to radiofrequency electromagnetic fields (RF-EMFs) at a frequency of 900 MHz under field conditions. The experiment was carried out on honey bee colonies at three locations with electric field levels of 30 mV $m^{-1}$, 70 mV $m^{-1}$ and 1000 mV $m^{-1}$. Antioxidant enzymes, glutathione-S-transferase (GST), catalase (CAT) and superoxide dismutase (SOD) and thiobarbituric acid reactive substances (TBARS) as indicators of lipid peroxidation were measured spectrophotometrically. The GST activity within the same developmental stage showed no significant differences regardless of electric field level or sampling time. The highest GST activity was found in the pupae, followed by activity in the larvae and midguts. Both CAT activity and TBARS concentration were the highest in the midguts, regardless of field level and sampling time. The larvae showed a significantly

higher TBARS concentration at the location with an electric field level of 1000 mV $m^{-1}$ compared to the locations with lower levels. Our results show that RF-EMFs at a frequency of 900 MHz can cause oxidative stress in honey bees, with the larval stage being more sensitive than the pupal stage, but there was no linear relationship between electric field level and effect in any of the developmental stages.

Open access paper: https://www.mdpi.com/2075-4450/15/5/372

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**The Cellular Response Is Determined by a Combination of Different ELF-EMF Exposure Parameters: A Scope Review**

López de Mingo I, Rivera González M-X, Maestú Unturbe C. The Cellular Response Is Determined by a Combination of Different ELF-EMF Exposure Parameters: A Scope Review. *International Journal of Molecular Sciences*. 2024; 25(10):5074. doi: 10.3390/ijms25105074.

Abstract

Since the establishment of regulations for exposure to extremely low-frequency (0–300) Hz electromagnetic fields, scientific opinion has prioritised the hypothesis that the most important parameter determining cellular behaviour has been intensity, ignoring the other exposure parameters (frequency, time, mode, waveform). This has been reflected in the methodologies of the in vitro articles published and the reviews in which they are included. A scope review was carried out, grouping a total of 79 articles that met the proposed inclusion criteria and studying the effects of the different experiments on viability, proliferation, apoptosis, oxidative stress and the cell cycle. These results have been divided and classified by frequency, intensity, exposure time and exposure mode (continuous/intermittent). The results obtained for each of the processes according to the exposure parameter used are shown graphically to highlight the importance of a good methodology in experimental development and the search for mechanisms of action that explain the experimental results, considering not only the criterion of intensity. The consequence of this is a more than necessary revision of current exposure protection regulations for the general population based on the reductionist criterion of intensity.

Conclusions

This review arises from the need to consider each of the parameters of exposure to magnetic fields as an entity capable of producing a determined response in the cell. The importance that has been given to the intensity parameter since the establishment of regulations for the exposure of the general public to low-frequency electromagnetic fields has led to it also being the main parameter in in vitro experiments, considering intensity as the determining parameter for the occurrence of the main cellular effects and placing the “dose effect” as one of the main theories explaining the effects found. We must begin to think of combinations of exposure parameters that act at the cellular level as specific codes that give rise to specific responses. Biology, and more specifically cell biology, entails a set of rules that must be protected as a fundamental right. There must be a commitment on the part of scientific researchers in bioelectromagnetism to develop quality experiments based on rigorous working methodologies and the search for experimental conclusions that contribute to existing knowledge in this field in order to establish models of interaction between magnetic fields and biological systems that allow us to think of

magnetic fields not only as a tool for modulating cell behaviour but also as a possible therapeutic application for various fields of medicine such as oncology, neurodegeneration or the healing of wounds and lesions.

Open access paper: https://www.mdpi.com/1422-0067/25/10/5074

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**Modulation of Zebrafish Heart Rate by Alternating Magnetic Fields with Frequencies Close to Heart Rhythm**

Krylov VV, Sizov DA, Machikhin AS, Guryleva AV, Tchougounov V, Burlakov AB. Modulation of Zebrafish Heart Rate by Alternating Magnetic Fields With Frequencies Close to Heart Rhythm. *IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology*. 2024. doi: 10.1109/JERM.2024.3397557.

Abstract

Extremely low-frequency magnetic fields (ELF-MF) up to 100 μT exhibit impacts on physiological processes, including heart function. The mechanisms underlying the influence of these fields on fish heart rates remain insufficiently explored. We assumed that the direct impact of ELF-MF with a frequency close to the heart rate could entrain oscillatory processes responsible for autonomously maintaining heart rhythm in zebrafish embryos. Embryos' heart rates ranged from 1.44 to 3 Hz depending on age, and ELF-MF with frequencies precisely matched, 10% higher, or lower than the heart rate were applied. Additionally, embryos experienced ELF-MF with amplitudes varying by an order of magnitude. Almost all tested ELF-MF induced an increased heart rate effect. This effect was the most pronounced when the exposure occurred earlier during ontogenesis. Fields with frequencies close to the heart rate did not entrain cardiac contractions in zebrafish embryos. A significant negative correlation between heart rate increase and ELF-MF frequency was observed for ELF-MF with amplitudes of 1.98–3.2 μT and 46.8 μT but not 30 μT. Probable molecular mechanisms underlying these effects are discussed in terms of magnetic influence on radical pairs within biochemical oscillating processes.

https://ieeexplore.ieee.org/document/10529610

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**Prey can detect predators via electroreception in air**

England SJ, Robert D. Prey can detect predators via electroreception in air. Proc Natl Acad Sci U S A. 024 Jun 4;121(23):e2322674121. doi: 10.1073/pnas.2322674121.

Abstract

Predators and prey benefit from detecting sensory cues of each other's presence. As they move through their environment, terrestrial animals accumulate electrostatic charge. Because electric charges exert forces at a distance, a prey animal could conceivably sense electrical forces to detect an approaching predator. Here, we report such a case of a terrestrial animal detecting its predators by electroreception. We show that predatory wasps are charged, thus emit electric fields, and that caterpillars respond to such fields with defensive behaviors. Furthermore, the mechanosensory setae of caterpillars are deflected by these electrostatic forces and are tuned to the wingbeat frequency of their insect

predators. This ability unveils a dimension of the sensory interactions between prey and predators and is likely widespread among terrestrial animals.

Open access paper: https://www.pnas.org/doi/10.1073/pnas.2322674121

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**Associations between solar and geomagnetic activity and cognitive function in the Normative Aging study**

Liddie JM, Vieira CLZ, Coull BA, Sparrow D, Koutrakis P, Weisskopf MG. Associations between solar and geomagnetic activity and cognitive function in the Normative Aging study. Environ Int. 2024 Apr 16;187:108666. doi: 10.1016/j.envint.2024.108666.

Abstract

Background: Studies show that changes in solar and geomagnetic activity (SGA) influence melatonin secretion and the autonomic nervous system. We evaluated associations between solar and geomagnetic activity and cognitive function in the Normative Aging Study from 1992 to 2013.

Methods: We used logistic and linear generalized estimating equations and regressions to evaluate the associations between moving averages of sunspot number (SSN) and Kp index (a measure of geomagnetic activity) and a binary measure for Mini-Mental State Examination (MMSE) scores (≤25 or > 25) and six other cognitive tests as continuous measures, combined into one global composite score and considered separately.

Results: A one-IQR increase in same-day SSN and Kp index were associated with 17% (95% CI: 3%, 34%) and 19% (95% CI: 4%, 36%) increases in the odds of low MMSE score. We observed small increases in the global cognitive score with increasing SSN, although we observed decreases specifically in relation to the backwards digit span test.

Conclusions: Periods of high SGA were associated with cognitive function. SGA may not equally impact all aspects of cognitive function, as evidenced by differences in associations observed for the MMSE, global cognitive score, and individual cognitive tests. Given that much of the pathology of cognitive decline in the elderly remains unexplained, studies specifically targeting decline and with longer follow-up periods are warranted.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024002526?via%3Dihub

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**ICNIRP Statement on Short Wavelength Light Exposure from Indoor Artificial Sources and Human Health**

Miller S, Cajochen C, Green A, Hanifin J, Huss A, Karipidis K, Loughran S, Oftedal G, O'Hagan J, Sliney DH, Croft R, van Rongen E, Cridland N, d'Inzeo G, Hirata A, Marino C, Röösli M, Watanabe S; International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP Statement on Short Wavelength Light Exposure from Indoor Artificial Sources and Human Health. Health Phys. 2024 Apr 1;126(4):241-248. doi: 10.1097/HP.0000000000001790.

Abstract

Concerns have been raised about the possibility of effects from exposure to short wavelength light (SWL), defined here as 380-550 nm, on human health. The spectral sensitivity of the human circadian timing system peaks at around 480 nm, much shorter than the peak sensitivity of daytime vision (i.e., 555 nm). Some experimental studies have demonstrated effects on the circadian timing system and on sleep from SWL exposure, especially when SWL exposure occurs in the evening or at night. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has identified a lack of consensus among public health officials regarding whether SWL from artificial sources disrupts circadian rhythm, and if so, whether SWL-disrupted circadian rhythm is associated with adverse health outcomes. Systematic reviews of studies designed to examine the effects of SWL on sleep and human health have shown conflicting results. There are many variables that can affect the outcome of these experimental studies. One of the main problems in earlier studies was the use of photometric quantities as a surrogate for SWL exposure. Additionally, the measurement of ambient light may not be an accurate measure of the amount of light impinging on the intrinsically photosensitive retinal ganglion cells, which are now known to play a major role in the human circadian timing system. Furthermore, epidemiological studies of long-term effects of chronic SWL exposure per se on human health are lacking. ICNIRP recommends that an analysis of data gaps be performed to delineate the types of studies needed, the parameters that should be addressed, and the methodology that should be applied in future studies so that a decision about the need for exposure guidelines can be made. In the meantime, ICNIRP supports some recommendations for how the quality of future studies might be improved.

Open access paper: https://journals.lww.com/health-physics/fulltext/2024/04000/icnirp_statement_on_short_wavelength_light.7.aspx

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**Mobile telephony radiation exerts genotoxic action and significantly enhances the effects of gamma radiation in human cells**

Panagopoulos DJ. Mobile telephony radiation exerts genotoxic action and significantly enhances the effects of gamma radiation in human cells. Gen Physiol Biophys. 2024 Mar;43(2):103-120. doi: 10.4149/gpb_2023036.

Abstract

I previously reported chromosomal damage in human peripheral blood lymphocytes (HPBLs) induced by: a) Mobile telephony (MT) electromagnetic fields (EMFs)/electromagnetic radiation (EMR), b) a high caffeine dose, and c) the combination of the two stressors. HPBLs from the same subjects exposed to gamma radiation at doses 0.1, 0.3, or 0.5 Gy, displayed more aberrations than those exposed to MT EMFs or the high caffeine dose in a dose- dependent manner. When the cells exposed to these gamma radiation doses were pre-exposed to a single 15-min MT EMF exposure, the number of aberrations

increased significantly more than the sum number of aberrations induced by the individual stressors in all subjects. Thus, MT EMF exposure at a power density ~ 136 times below the latest International Commission on Non-Ionizing Radiation Protection-ICNIRP exposure limit, apart from the fact that it is genotoxic by itself, significantly enhanced the genotoxic action of gamma radiation. Since gamma radiation at similar doses is applied for diagnostic and therapeutic purposes, people should be aware of the increased risk during treatment periods. Comparison of the genotoxic action between MT EMF and gamma radiation shows that the ICNIRP limits are, at least, $\sim 4.5\times10^4$ times less stringent than the limits for gamma radiation.

Excerpts

The studies that found real-life UMTS (3G/4G) exposure to be even more genotoxic than real-life GSM (2G) (D'Silva et al. 2017, 2021) are in line with the fact that newer types of MT/WC EMFs (3G, 4G, 5G) transmit increasingly higher amount/density of variable information (speech, text, images, video, Internet) making the signal increasingly complicated, unpredictably varying each moment, and thus, increasingly more bioactive due to the inability of the living organisms to adapt to a highly variable stressor. Thus, **the effects under deployment 5G MT EMF are expected to be even more intense than those of 2G, 3G, 4G**. This should have been seriously considered by the responsible public health authorities....

The disruption of cell electrochemical balance by manmade (polarized and coherent) EMFs through irregular gating of voltage-gated ion channels (VGICs) in cell membranes is described by the **"ion forced-oscillation and VGIC dysfunction" mechanism (IFO-VGIC mechanism)** (Panagopoulos et al. 2000, 2002, 2015b, 2021; Panagopoulos 2022b). According to this mechanism, the mobile ions in the cells are forced to oscillate in parallel and in phase with the applied man-made oscillating EMFs and this coordinated oscillation of electric charge exerts constructive Coulomb forces on the channel sensors of the VGICs similar to those exerted by membrane voltage changes that physiologically gate the VGICs. This causes irregular gating, and thus, dysfunction of the VGICs, which leads to intracellular release of ROS that finally cause genetic/cellular damage (Panagopoulos et al. 2021, 2022b)....

What has been referred to by Pall (2018) as voltage-gated calcium channel activation mechanism ("VGCC activation mechanism") is no other than the IFO-VGIC mechanism specifically on the calcium voltage-gated ion channels, and should not be reported as a different mechanism. Pall claimed he suggested a different mechanism simply because he hypothesized that the VGICs are gated by "direct" forces on their voltage-sensors by "penetrating" RF EMFs instead of ELF forces exerted by the oscillating ions in close proximity to the sensors. The impossibility of Pall's claims is analyzed in commentary papers (Foster and Balzano 2021; Panagopoulos 2021; Arribas et al. 2022).

Conclusions:

(1) MT EMF exposure, apart from the fact that it is genotoxic by itself, significantly enhanced the genotoxic action of gamma radiation in combined exposure;

(2) People/patients who are subjected to diagnostic or therapeutic treatment with ionizing radiation should be prudently advised to avoid using Wireless Communication (WC) devices (mobile/smart phones, wi-fi, cordless domestic phones, etc.) for a few days before, during, and after such treatments;

(3) Medical/radiology practitioners should be specifically educated on the risks of anthropogenic EMF-exposures in addition to those of ionizing radiations;

(4) Comparison with caffeine and gamma radiation suggests that the ICNIRP (2020) limits for WC EMF exposure should be lowered by 40,000 and 45,000 times respectively;

**(5) The limit for short-term (acute) exposure should then become 0.1 µW/cm2 and accordingly for long- term exposure 0.001 µW/cm2;**

(6) The combined effects of real-life man-made EMFs with a variety of other environmental stressors should be examined as a priority by next studies.

Open access paper:
http://www.elis.sk/download_file.php?product_id=8263&session_id=ef2ijbhbn0hevd1s33q2nvkrp6

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**Effect of exposure to RF-EMF from lab simulator of 5G NR base station on physiological parameters & cognitive abilities of male rats of different ages**

(My note: Methodological limitations of this study reduce generalizability to real-world 5G exposures.)

Krivova NA, Kudabaeva MS, Zaeva OB *et al.* The effect of exposure to RF-EMF from the laboratory simulator of 5G NR base station on physiological parameters and cognitive abilities of male wistar rats of different ages. *Sci Rep* **14**, 10283 (2024). doi: 10.1038/s41598-024-60862-5.

Abstract

In this article, the impact of radiofrequency electromagnetic field (RF-EMF) exposure from a simulated base station for the 5G New Radio (5G NR) telecommunication on rats was studied. The base station affects all age groups of the population, thus, for the first time, the experiment was conducted on male Wistar rats of three different ages (juvenile, adult, and presenile). The base station exposure parameters were chosen according to ICNIRP recommendations for limiting the exposure to radiofrequency electromagnetic field: frequency 2.4 GHz with an average specific absorption rate of 0.0076 W/kg and 0.0059 W/kg over the whole body of experimental animals. Throughout the experiment, body weight was examined weekly, and the dynamics of body weight gain was monitored. Rectal and skin surface temperature on the right hind limb was monitored weekly. Testing in the Morris water maze was performed during the last, Week 5, of RF-EMF exposure. After euthanasia, organ weights were determined in experimental and control animals. None of the investigated parameters did show any statistically significant differences between exposed and control animals of the same age. The data obtained can be used to assess the possible consequences of chronic exposure to RF-EMF from 5G NR base stations.

Open access paper: https://www.nature.com/articles/s41598-024-60862-5

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**Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods**

Expósito I, Hakizimali C, Sánchez MG, Cuiñas I, Verhaevert J. Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods. Measurement, Volume 229, 2024. doi: 10.1016/j.measurement.2024.114434.

## Highlights

This paper analyzes the feasibility of assessing the 5G base stations compliance using broadband field probes and compares their performance with alternative methodologies and equipment.

Performance of three different methodologies and equipment (broadband probes, spectrum analyzers, and drive test scanners), in the context of human exposure to electromagnetic fields (EMF) from 5G base stations, is compared.

Quantification of the uncertainty that the fluctuation in 5G signal levels induces in the assessment of electromagnetic fields exposure is provided.

The use of broadband field probes for 5G exposure assessment is still possible under certain considerations and correcting the results considering the base station load and beamforming effects.

## Abstract

5G networks deployment poses new challenges when evaluating human exposure to electromagnetic fields. Fast variation of the user load and beamforming techniques may cause large fluctuations of 5G base stations field level. They may be underestimated, resulting in compliance of base stations not fitting the requirements. Apparently, broadband field meters would not be adequate for measuring such environments. However, we analyze the feasibility of confidently using broadband field meters and compare their performance with alternative equipment. Measurements based on the synchronization signals power level, using spectrum analyzers or drive test scanners, may be valid, if gain differences between the signaling and data radiation patterns are characterized. These methods lead to good results but require more time and knowledge. Nevertheless, using broadband field meters is still possible if the measurement results are corrected considering the base station load. Under specific conditions, explained here, fast assessment of 5G compliance could be provided.

## Conclusions

Assessing human exposure to an electromagnetic field in presence of a 5G base station is not an easy task. The implementation of M−MIMO techniques in 5G base stations results in adaptive beamforming. This makes difficult to guarantee that the field levels are at their maximum at the measurement location during the complete measurement period, which would limit the applicability of broadband instruments as having been done for previous generations. In this research, we have compared different methods for 5G exposure assessment, using a broadband field meter with an isotropic probe, a spectrum analyzer and a drive test scanner.

Along the paper, we first give an overview of the 5G signal structure, describing the frequency domain and time domain specifications. Afterwards, possible assessment methods are described. The SSB level is measured using the Keysight FieldFox N9913A SA and the Rohde & Schwarz TSM6 DTS. The values are extrapolated to the worst-case exposure and compared to the measurements done with the

Wavecontrol WPF8 broadband field probe. Measurements are repeated increasing the base station load by performing a heavy download from a 5G user terminal located near the testers.

The proposed methods were field tested at the University of Vigo, Spain, with a commercial 5G base station located on its campus. The measurements were performed at 7 locations in LOS conditions around the base station, gathering data with the three different equipment at the same locations and at the same time. This data collection allows the comparison of the three methodologies under the same radiating conditions.

All results have been analyzed considering the specific measurement uncertainties, which allows a deeper and more precise comparison among them.

From the measurement results, we can extract that the exposure levels are low at this stage of the 5G deployment. When loading the base station, the results showed that using the broadband field meter can overestimate the field level. Thus, it is still a useful method to check if the field levels comply with the regulation in human exposure; very simple and cost-effective compared with others. In-situ measurements of human exposure to EMF have to be practical and easy to carry, involving only the resources and equipment strictly necessary, but without compromising the validity of the results. When the reference levels are surpassed, more accurate methods based in the assessment and extrapolation of the SSB level could be a solution. The drawback is the required post processing, specially correcting the gain difference between SSB and data signals. If not provided by the network operator, this difference can be determined through measurements, as explained along this document. Measuring with an SA in max-hold mode in the bandwidth of the SSB does not work in 5G as it does in LTE, as we cannot be sure if the measured level corresponds to the SSB or to the user data, no matter if we are forcing the load of the station or not.

The analysis of the results demonstrate that broadband instruments can be used for assessing human exposure to EMF in the vicinity of 5G base stations, which radiating elements provide fields with extreme fluctuations in their intensity as a function of the system load and beamforming configuration. This is accurate when measurements are done by forcing an extra load of the station and the pointing of an antenna beam towards the probe. The validation of this fast method as a first attempt to assess the compliance of 5G stations permits the testing of these base stations in an efficient way. Only when broadband instrument results (including their uncertainties) would overpass the reference levels, a more detailed analysis would be necessary, which procedure and tips are also depicted along this paper.

https://www.sciencedirect.com/science/article/pii/S0263224124003191

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**Absorption of 5G sub-6 GHz electromagnetic radiation from base station to male reproduction system**

Lin J, Li J, Ding G. Absorption of 5G sub-6 GHz electromagnetic radiation from base station to male reproduction system. Int J Radiat Biol. 2024 May 6:1-8. doi: 10.1080/09553002.2024.2347354.

Abstract

Background: The impact of electromagnetic radiation from communication on the male reproductive system has emerged as a significant concern in public health. A notable distinction of the 5G sub-6 GHz

band, compared to traditional 2G, 3G, and 4G frequency bands, is the inclusion of higher frequency bands. This has raised public concerns regarding the potential effects of these higher frequencies on organisms, particularly their reproductive systems. While it is imperative to investigate the biological effects and potential risks associated with these new frequency bands in laboratory settings, comparing and evaluating differences between various frequency bands remain challenging due to the absence of standardized parameters such as exposure conditions and duration. In contrast, dose assessment offers a simpler and more reliable approach.

Materials and methods: The dose assessment method was employed in this study to investigate the risks associated with sub-6 GHz electromagnetic radiation from 5G base stations on the male reproductive system. A classical human body model (Duke) was utilized, and an electromagnetic simulation environment was established based on the actual polarization direction of the exposed base stations and various body postures. This research explored the effects of field direction, posture, public population, and frequency on the specific absorption rate of the reproductive system.

Results and conclusions: While maintaining the same level of exposure, a higher frequency results in a reduced dosage on reproductive system. Further analysis reveals that, considering the public exposure threshold, the employment of higher frequency bands in 5G sub-6 GHz does not present a greater dosage on reproductive system compared to lower frequency bands. Consequently, with regard to dosage, there is no need for excessive concern among the general public regarding the impact of electromagnetic radiation emitted by 5G base stations operating below 6 GHz on male reproductive health.
https://pubmed.ncbi.nlm.nih.gov/38709715/

Excerpts

The normalized evaluation revealed a strong negative correlation between the RSSAR results and frequency (figures 6 and 8), indicating the reproductive system's response to varying frequencies of electromagnetic waves. It also indicates that high-frequency skin effects are particularly prominent in the reproductive system. In the exposure limit assessment, there was an evident inflection point at 2.2 GHz where the trend of RSSAR values with frequency changes reached its maximum peak (figure 10). Therefore, when considering the exposure threshold, the higher frequency bands in 5G did not show higher dose values on RSSAR, but on the contrary, higher dose values were obtained in the 4G bands (such as 2.2 GHz in this study). These findings suggest that the potential risk of higher frequency electromagnetic waves in 5G sub-6 GHz is lower, as indicated by both normalized and exposure limit assessments.

Restriction and future focus

This research also has certain limitations. The exposure environment has not been considered in the context of the actual 5G exposure environment. With the introduction of 5G base stations, the grid of base stations may become denser and the energy of a single beam of electromagnetic radiation may be higher (Sofri et al. Citation2022). Although reference (Celaya-Echarri et al. Citation2020) simulated and compared the exposure values caused by base stations in the 2G–5G frequency band, the electric field conditions in real communities should also be measured and compared in detail. In future work,

exposure measurements and dose assessing could be combined with epidemiological investigations to further explore the effects of new frequency bands on reproductive and other systems.

Conclusions

The absorbed dose level of electromagnetic radiation emitted by communication base stations on the male reproductive system was analyzed, with a specific focus on the primary frequency points within the sub-6 GHz frequency band. The study revealed that higher frequencies resulted in reduced dose values while maintaining equivalent exposure levels. Further analysis demonstrated that, considering the exposure threshold, the utilization of higher frequencies in 5G sub-6 GHz did not present a greater risk compared to lower frequencies. Therefore, from a dosage assessment perspective, concerns regarding the impact of sub-6 GHz electromagnetic radiation emitted by 5G base stations on male reproductive health are unwarranted.

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**Central Causation of Autism/ASDs via Excessive [$Ca^{2+}$]i Impacting Six Mechanisms Controlling Synaptogenesis during the Perinatal Period: The Role of Electromagnetic Fields and Chemicals and the NO/ONOO(-) Cycle, as Well as Specific Mutations**

Pall ML. Central Causation of Autism/ASDs via Excessive [Ca2+]i Impacting Six Mechanisms Controlling Synaptogenesis during the Perinatal Period: The Role of Electromagnetic Fields and Chemicals and the NO/ONOO(-) Cycle, as Well as Specific Mutations. Brain Sciences. 2024; 14(5):454. doi: 10.3390/brainsci14050454. (Published: 30 April 2024)

Abstract

The roles of perinatal development, intracellular calcium [Ca2+]i, and synaptogenesis disruption are not novel in the autism/ASD literature. The focus on six mechanisms controlling synaptogenesis, each regulated by [Ca2+]i, and each aberrant in ASDs is novel. The model presented here predicts that autism epidemic causation involves central roles of both electromagnetic fields (EMFs) and chemicals. EMFs act via voltage-gated calcium channel (VGCC) activation and [Ca2+]i elevation. A total of 15 autism-implicated chemical classes each act to produce [Ca2+]i elevation, 12 acting via NMDA receptor activation, and three acting via other mechanisms. The chronic nature of ASDs is explained via NO/ONOO(-) vicious cycle elevation and MeCP2 epigenetic dysfunction. Genetic causation often also involves [Ca2+]i elevation or other impacts on synaptogenesis. The literature examining each of these steps is systematically examined and found to be consistent with predictions. Approaches that may be used for ASD prevention or treatment are discussed in connection with this special issue: The current situation and prospects for children with ASDs. Such approaches include EMF, chemical avoidance, and using nutrients and other agents to raise the levels of Nrf2. An enriched environment, vitamin D, magnesium, and omega-3s in fish oil may also be helpful.

Excerpts

Figure 1 is an outline of the mechanisms proposed here and, in some cases, elsewhere, to act during the perinatal period of brain development [5], to disrupt synaptogenesis and therefore cause autism spectrum disorders (ASDs). Accordingly, key factors in autism/ASD causation are proposed to be the six

mechanisms in the lower left part of Figure 1 (in red), each of which have been shown to have important roles in synaptogenesis in the developing brain. These six mechanisms are neuronal migration, dendritic outgrowth, synapse formation, synapse maturation, synaptic pruning, and lowered MeCP2 function. It is shown below that these six mechanisms are regulated by intracellular calcium ([Ca2+]i).

VGCC activity acts via [Ca2+]i to produce diverse biological effects via the pathways shown in Figure 2

.... Let us shift now to ASD treatment and prevention. These are presented here not to give medical advice, but rather to enlighten the reader in the central issues of this special issue: The current situation and prospects for children with ASDs. Both treatment and prevention require avoidance of electronically-generated EMFs and diverse chemicals, however difficult that may be. Let us start with EMFs. There are many sources of EMFs in our living spaces, workplaces, educational and recreational environments, and even outdoors. Many of these are discussed in Section 2.1.

There are “safety guidelines” initially proposed by ICNIRP, an organization set up by the industry and these ICNIRP safety guidelines have been adopted, sometimes with minor modifications, over much of the world. The ICNIRP and similar “safety guidelines” are all based on thermal effects produced over either a 6 min or 30 min period. However, as discussed above, biological effects are caused by electric forces or time-varying magnetic forces produced by electronically-generated EMFs, and are unrelated to thermal effect “safety guidelines”. It follows that all assurances of safety based on these “safety guidelines” have no scientific merit.

Pregnant women should not use cell phones, cordless phones, should avoid Wi-Fi fields, and should use wired connections to the internet, avoid Bluetooth, should not spend time near smart meters, cell phone towers, avoid high voltage powerlines, etc. Pregnant women should avoid being in buildings with high dirty electricity in their electric powerlines. Such avoidance is very challenging. A second choice is to use shielding to protect the fetus and the young baby after birth.

You can get large shielded T-shirts to protect the fetus, wearing a regular cloth T-shirt underneath to minimize body contact. Such shielding materials have large numbers of metal (often silver) fibers. I believe that shielding mostly acts by disrupting the coherence of the EMFs, therefore greatly lowering any electric or magnetic forces. Shielding has been extensively studied in the scientific literature [271,272,273,274,275,276,277]. For example, ref. [271] states that “By using wireless technologies, we increase the influence of the electromagnetic field on the human body. The basic measures for the protection against electromagnetic radiation are: (1) shielding of the radiation source, (2) shielding of the workplace, (3) personal protective equipment, (4) reduction of radiation in the immediate vicinity of the radiation source”. [271] goes on to discuss the shielding effects of both fabrics containing tiny metal fibers and also brick walls.

You can buy shielding paint of two different types to protect yourself in your house and, if you live in an apartment, this may be the only way to protect yourself from your neighbors’ EMFs. Shielding paint can be either graphite (black) paint which can be painted over with other colors. Other more pleasant colored shielding paint can be purchased containing tiny metallic particles. You can also buy open shielding cloth to put over windows, making them into lace like curtains to lower EMF exposures coming through the windows. Similar approaches can be used after birth to protect the young baby. It is highly desirable to purchase a good EMF meter to provide information and prevent the worst exposures throughout the perinatal period.

Open access paper: https://www.mdpi.com/2076-3425/14/5/454

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**The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies (WHO SR8)**

(Note: Methodological problems with many studies included in this systematic review undermine the validity of this review paper.)

Bosch-Capblanch X, Esu E, Oringanje CM, Dongus S, Jalilian H, Eyers J, Auer C, Meremikwu M, Röösli M. The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies. Environment International. doi: 10.1016/j.envint.2024.108612. Available online 2 April 2024.

**Abstract**

Background The technological applications of radiofrequency electromagnetic fields (RF-EMF) have been steadily increasing since the 1950s exposing large proportions of the population. The World Health Organization (WHO) is assessing the potential health effects of exposure to RF-EMF.

Objectives To systematically assess the effects of exposure to RF-EMF on self-reported non-specific symptoms in human subjects and to assess the accuracy of perception of presence or absence of RF-EMF exposure.

Methods Eligibility criteria: experimental studies carried out in the general population and in individuals with idiopathic environmental intolerance attributed to EMF (IEI-EMF), in any language.

Information sources: Medline, Web of Science, PsycInfo, Cochrane Library, Epistemonikos and Embase and consulted the EMF portal, searched till April 2022.

Risk of bias: we used the Risk of Bias (RoB) tool developed by OHAT adapted to the topic of this review.

Synthesis of results: we synthesized studies using random effects meta-analysis and sensitivity analyses where appropriate.

Results Included studies: 41 studies were included, mostly cross over trials and from Europe, with a total of 2,874 participants.

Synthesis of results: considering the primary outcomes, we carried out meta-analyses of 10 exposure-outcomes pairs. All evidence suggested no or small non-significant effects of exposure on symptoms with high (three comparisons), moderate (four comparisons), low (one comparison) or very low (two comparisons) certainty of evidence. The effects (standard mean difference, where positive values indicate presence of symptom being exposed) in the general population for head exposure were (95% confidence intervals) 0.08 (−0.07 to 0.22) for headache, −0.01 (−0.22 to 0.20) for sleeping disturbances and 0.13 (−0.51 to 0.76) for composite symptoms; and for whole-body exposure: 0.09 (−0.35 to 0.54), 0.00 (−0.15 to 0.15) for sleeping disturbances and −0.05 (−0.17 to 0.07) for composite symptoms. For IEI-EMF individuals SMD ranged from −0.19 to 0.11, all of them with confidence intervals crossing the value

of zero. Further, the available evidence suggested that study volunteers could not perceive the EMF exposure status better than what is expected by chance and that IEI-EMF individuals could not determine EMF conditions better than the general population.

Discussion  Limitations of evidence: experimental conditions are substantially different from real-life situations in the duration, frequency, distance and position of the exposure. Most studies were conducted in young, healthy volunteers, who might be more resilient to RF-EMF than the general population. The outcomes of interest in this systematic review were symptoms, which are self-reported. The available information did not allow to assess the potential effects of exposures beyond acute exposure and in elderly or chronic ill people. It cannot be ruled out that a real EMF effect in IEI-EMF groups is masked by a mix with insensitive subjects. However, studies on symptom reporting and/or field perception did not find any evidence that there are particularly vulnerable individuals in the IEI-EMF group, although in open provocation studies, when volunteers were informed about presence or absence of EMF exposure, such differences have been consistently observed.

Interpretation: available evidence suggests that acute RF-EMF below regulatory limits does not cause symptoms and corresponding claims in everyday life are related to perceived and not real EMF exposure status.

Excerpts

4.4. Implications for practice

We could not find any evidence that would support an association between exposure to RF-EMF below regulatory recommendations and a large variety of short term reported symptoms; neither evidence that could suggest the capacity of individuals to detect the exposure to RF-EMF. This is the case for the general population, for IEI-EMF individuals, in the main meta-analyses as well as in the exposure–response and sensitivity analyses.

While these findings cannot rule out other long term potential harms of RF-EMF, they suggest that the presence or absence of common symptoms may not become good clinical predictors of the occurrence or evolution of IEI-EMF. It may also indicate that notion of acute effects from RF-EMF below regulatory limits in the everyday environment are better explained with the nocebo or the attribution hypothesis (Dieudonné, 2020).

4.5. Implications for research

The body of evidence in this review seems to consistently suggest the lack of association between EMF exposure and symptoms, in a variety of conditions and populations. The most critical aspect challenging the certainty of the evidence was the limited detail in the methodology of included studies, particularly in the issues related to the exposure randomisation and allocation concealment. While we hardly downgrades the evidence on the grounds of ‘indirectness’, most of the studies were focusing on adults, young adults and even adolescents, which may have limited the external validity of findings.

In order to confirm the findings of this systematic review, future research should, thus, consider adhering to best reporting practices and considering a wider scope of participants, including, for example, the elderly.

Future research should also be carried out standardising the design of experiments in terms of exposure ranges, timing and sequence of events, so as to make studies more comparable. It may be worth to increase exposure levels above regulatory limits for the general population to explore potential critical threshold for non-specific symptoms. Self-evident such studies need to follow a prudent approach to ensure that any symptoms are transient and do not result in a long term health impairment.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024001983

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**Is the sustainability of exposure to non-ionizing electromagnetic radiation possible?**

Calvente I, Núñez MI. Is the sustainability of exposure to non-ionizing electromagnetic radiation possible? Medicina Clínica (English Edition), 162(8):387-393. 2024. doi: 10.1016/j.medcle.2023.11.016.

Abstract

Technological advances imply an increase in artificially generating sources of electromagnetic fields (EMF), therefore, resulting in a permanent exposure of people and the environment (electromagnetic pollution). Inconsistent results have been published considering the evaluated health effects. The purpose of this study was to review scientific literature on EMF to provide a global and retrospective perspective, on the association between human exposure to non-ionizing radiation (NIR, mainly radiofrequency-EMF) and health and environmental effects. Studies on the health effects of 5G radiation exposure have not yet been performed with sufficient statistical power, as the exposure time is still relatively short and also the latency and intensity of exposure to 5G. The safety standards only consider thermal effects, do not contemplate non-thermal effects. We consider relevant to communicate this knowledge to the general public to improve education in this field, and to healthcare professionals to prevent diseases that may result from RF-EMF exposures.

Excerpts

ICNIRP reviews safety guidelines but does not provide solutions, uses SAR, only considers thermal effects, does not consider non-thermal effects. Scientific evidence shows the importance of considering both thermal and non-thermal effects, short and long-term biological effects, and other factors. On the other hand, more frequent periodic reviews of the regulations are needed. According to ICNIRP the last one was in 2020. Even considering the leap in technology use in 2020, should we wait as many years as now (approx. 10) for a new update?

There are countries with stricter regulations than those established by IARC (sic) that are more concerned about the effects of this type of exposure (Italy, Belgium, Austria (Salzburg), Switzerland, Russia, China)....

In the face of such divergent assessments of wireless RF radiation, the practice of ALARA – as low as reasonably achievable – for RF health and safety should be followed.

On the basis of the evidence presented here, is it possible to speak of sustainability in relation to electromagnetic fields?

https://www.sciencedirect.com/science/article/pii/S2387020624001268

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**Environmental Factors as the Main Hormonal Disruptors of Male Fertility**

Wdowiak N, Wójtowicz K, Wdowiak-Filip A, Pucek W, Wróbel A, Wróbel J, Wdowiak A. Environmental Factors as the Main Hormonal Disruptors of Male Fertility. J Clin Med. 2024 Mar 29;13(7):1986. doi: 10.3390/jcm13071986.

Abstract

Introduction and objective: Many scientific reports confirm a systematic decline in male semen parameters over the last decades. This phenomenon has been observed in all parts of the world, and its occurrence is associated, among others, with the hazardous effects of some environmental factors. The environmental factors for which the adverse effect on male fertility has been proven include water, air, and soil pollution, as well as electromagnetic fields and ionizing radiation. The aim of this article was the evaluation of the effect of selected environmental factors on male reproductive capacity based on an analysis of the current scientific reports.

Review methods: A systematic literature review was carried out using three databases: PubMed, EMBASE, and Scopus. The search was limited to the period from 2015 until the end of December 2023. Brief description of the state of knowledge: Environmental factors, such as heavy metals, tobacco smoke, pesticides, dioxins, furans, phthalates, and bisphenols, are well-tested substances that exert an adverse effect on male fertility. A harmful effect of electromagnetic fields and water and air pollution on reproductive functions may be expected; however, this has not been fully proven.

Summary: Results obtained by many researchers published to date should evoke great concern regarding the quality of the environment in which we live, as well as fears about the effect of environmental factors not only on male fertility, but also on all aspects of human health. The majority of environmental pollutants affect the male body by causing oxidative stress and through their effect on the endocrine system.

Excerpt

12. Electromagnetic Fields

Electromagnetic radiation (EMR) originating from both the natural environment and human activity constantly affects living organisms. The effect of EMR on the reproductive system may occur as a result of the thermal effect, generation of oxidative stress, changes in the structure of proteins, and causing changes in ion transport through cell membranes; however, these pathomechanisms have not yet been

fully explained. Based on studies conducted to date it is known that electromagnetic fields generate oxidative stress, disrupting the function of sperm mitochondria and causing the activation of cell membrane NADH oxidase [43].

Balance in the free radical system, which is affected by the electromagnetic fields, as well as the activity of ion channels, are together responsible for the process of sperm hyperactivation. Human spermatozoa, in order to become ready to fertilize an oocyte, undergo many metabolic changes affecting the cell membrane, which leads to capacitation occurring in the woman's reproductive tract. As a result of these transformations, sperm can interact with the structures of the corona radiata, and subsequently with the zona pellucida of the oocyte. This process is necessary for fertilization. Possible premature capacitation taking place in the seminal plasma causes energy depletion of the sperm and reduces the chance for fertilization. Balance in the free radical system is the factor responsible for the proper moment of capacitation. Ion channels are responsible for the proper course of this process, including CatSper, a pH-regulated, calcium-selective ion channel, KSper (Slo3), and the voltage-gated channel Hv1. To date, it has been considered that many other channels regulate these processes; however, this was not supported by research, and only the implementation of the patch–clamp technique shed new light on the possibilities of opportunities to learn about this process. It is known that mutations and deletions of the genes responsible for the function of these channels are responsible for the existence of certain types of male infertility. The voltage-gated channel Hv1, which is an electrical voltage sensor responsible for processes related to fertilization, seems to be the most sensitive to the effect of EMF. The results of studies concerning the effect of EMF on the immune system cells confirmed that the frequency close to 15 Hz has the greatest impact on the transport of $Ca^{2+}$ ions into the cell. Therefore, it may be expected that similar relationships will also concern sperm [43,44].

It has long been known that welding arcs are a very harmful source of EMF for males. Their radiation consists of intensive thermal radiation of high-temperature welding gases, welded or cut elements, electrode, and flux material, on which the lines and bands of radiation characteristic of these materials overlap. The gas burner flame temperature usually does not exceed 2000 K. Thus, this radiation consists mainly of infrared and light, and only hydrogen and acetylene burners are characterized by a higher combustion temperature and emit near-ultraviolet light. Scientific reports concerning the effect of welding on male fertility confirm that in males performing this profession, deterioration of the main sperm parameters occurs, and their partners are at an increased risk of miscarriage. The type of harmful effect on the male reproductive system depends on the type of materials to be welded and applies primarily to mild steel [43,44].

Exposure to strong EMF also concerns employees operating radar stations. Currently, various types of radars operate on frequencies from 3 MHz (HF band) to 110 GHz (W band). In the lower part of this range operate radars which measure the height of the ionosphere, and those using the phenomenon of reflection of electromagnetic waves from the ionosphere for detecting objects hidden beyond the horizon, often over a distance of thousands of kilometers. Most radars operate at frequencies ranging from several hundred megahertz to 100 GHz, including speed cameras known to drivers, which are used to take photos of cars and are based on the 34.3 ± 0.1 GHz band. The reports concerning their effect on male fertility are contradictory. Some researchers describe an increase in the percentage of abnormal sperm and reduction in sperm motility, with a simultaneous absence of effect on its density in

employees of radar stations. In turn, other researchers describe a decreased sperm density in people exposed to radar waves. There are also reports that do not indicate any differences in the quality of sperm between males exposed to a radar, and those not exposed to its effect.

Due to the development of telecommunication technologies, at present, almost every person is exposed to EMF related to GSM. Our own study conducted at the beginning of the 'era of mobile phones' demonstrated an increase in the percentage of abnormal sperm and a decrease in the percentage of sperm in progressive movement, together with an increase in exposure to GSM. Studies concerning the effect of mobile phone technology on sperm have been continued by many researchers. They demonstrated that the waves emitted by mobile phones cause an increased production of the reactive oxygen species (ROS), leading to oxidative stress in sperm, and intensification of sperm DNA fragmentation. Similar relationships were confirmed on animal models. In a study in which mice were exposed to radiation of 900 mW/kg for 12 h daily for 7 days an adverse effect of EMR was observed on mitochondrial genome integrity. It was also proven that long-lasting telephone calls lead to an increase in temperature in the brain, which may affect the activity of the hypothalamic–pituitary–gonadal axis [43,44].

A significant exposure to electromagnetic fields also concerns males working on high-voltage electrical installations. It was found that among employees exposed for many years to contact with voltage of 400 kV, fewer children were born compared to the control group. Among children exposed to high voltage, the male gender prevailed. It was also observed that among offspring of males exposed to high voltage, congenital defects occurred more frequently.

There are also other scientific reports that confirm a beneficial effect of electromagnetic fields with lower frequency ranges on both sperm parameters and the function of tissues responsible for human reproduction. Some scientific studies confirmed that exposure of sperm to magnetic fields within the range from 10–50 Hz contributes to the improvement of the motility of human sperm, whereas others presented opposite results.

In animal models, while investigating the exposure of fish reproductive cells to magnetic fields, an improvement was observed in sperm motility parameters, and an increase in the percentage of fertilizations. Electromagnetic fields have found application in the treatment of prostate disorders in animals. A group of researchers confirmed that in dogs, the exposure of the prostate to frequencies of 4–12 Hz has a healing effect on prostate enlargement, not causing changes in sperm parameters of the animals. The results of studies confirming a beneficial effect of electromagnetic fields provide hope for their use in the treatment of human infertility; however, a long-term impact of this type of energy will require meticulous research, especially regarding possible epigenetic effects diagnosed only in future generations. Own studies of sperm exposed in vitro to weak EMF, close to that used at security checkpoints, showed an effect on DNA methylation [43,44].
At present, we are unable to specify what amount of energy related to EMF is harmful, neutral, or beneficial for human reproductive capacity. It may be expected that there are amounts of energy with neutral or beneficial effect, and only exceeding them may cause harmful effects.

Open access paper: https://www.mdpi.com/2077-0383/13/7/1986

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**Influence of power control in the mobile network on the radiation level**

Mitić D, Lebl A, Markov Ž. Influence of power control in the mobile network on the radiation level. Journal of Electrical Engineering, 75(2):161-165. 2024. doi: 10.2478/jee-2024-0019.

Abstract

The paper evaluates how the control of transmitted power affects the intensity of radiation in a mobile network cell. Cell models without power control, with standard power control and a model with power control and channel reallocation are considered. The relative reduction of radiation is evaluated and several examples of calculations are presented. Remarks are given on the dependence of radiation reduction on the number of traffic channels, traffic intensity and signal attenuation coefficient. The assessment procedure and results are based on previously verified traffic process simulation models.

Conclusion

The paper shows that control of emitted power, in addition to saving energy and reducing interference, also contributes to the radiation reduction.

Control of the emission power by matching the power with the user's distance affects the reduction of radiation in proportion to the increase in the number of frequency carriers. The radiation level depends on the distribution of the users' surface density in the cell and on the environmental signal attenuation coefficient.

Additional control of the emission power by channel reallocation can further reduce the radiation level. This reduction is greater when there is a smaller number of frequency carriers (but greater than 1), with less offered traffic and with a higher attenuation coefficient.

Open access paper: https://doi.org/10.2478/jee-2024-0019

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**Frequency selective human-centric sub 6 GHz electromagnetic measurements in shopping mall**

Berisha D, Rexhëbeqaj-Hamiti V, Dobruna J, Maloku H, Limani Fazliu Z, Ibrani M. (2024). Frequency selective human-centric sub 6 GHz electromagnetic measurements in shopping mall. *Cogent Engineering*, *11*(1). doi: 10.1080/23311916.2024.2340311.

Abstract

Limiting human exposure to radio frequency electromagnetic fields in crowded indoor public spaces such as shopping malls, is identified as one of the key metrics in the process of green and digital environment transformation. To assess the exposure levels in shopping malls, we conducted a human centric extensive measurement campaign using three-axial frequency selective measurement equipment. Our study involved various indoor locations within the mall, capturing electrical field levels at different times and days of the week. A total of 529,340 samples were collected during working days, and 430,020 samples were collected during weekends. We measured E-field strength, power density,

and calculated total exposures for frequency bands ranging from 88 MHz to 5850 MHz. The presented comparative analysis revealed that mobile communications technologies operating at 900 MHz and 1800 MHz were the main contributors to personal exposure levels in different mall environments.

Conclusions

This paper presents the exposure levels in shopping malls during different days of the week, obtained through a rigorous 3-month measurement campaign utilizing frequency selective measurement equipment. The collected data underwent careful processing, including screening of each measured E-field exposure level to ensure accurate sampling and minimize errors.

The average total E-field exposure value during the weekday was 0.39 V/m, while during the weekend 0.33 V/m. The highest contributors to the total exposure levels in various shopping mall environments are mobile communication technologies operating at 900 MHz and 1800 MHz (2G–3G–4G). The Downlink 2G–3G operating at 900 MHz, has an average electric field exposure value of 0.2 V/m during the weekdays and during the weekend, while the Downlink 2G–4G operating at 1800 MHz has an average E-field value of 0.1 V/m during the weekdays and 0.17 V/m during the weekend.

On weekdays, the main factor contributing to total exposure levels was 2G–3G mobile communications operating at 900 MHz (Downlink), accounting for 52.4% of the exposure, followed by mobile communications at 1800 MHz (Uplink and Downlink. Furthermore, the highest E-field values during weekdays were observed in the Downlink 2G–3G band and Wi-Fi 2 G technology, exceeding the upper limit of 6 V/m.

During the weekend, the primary contributor to total exposure levels remained the 2G–3G communications at 900 MHz (Downlink), accounting for 37% of the exposure. However, there was an increase in e-field values for 2G–4G communications at 1800 MHz (Downlink), with its contribution rising to 34% compared to 15% during weekdays. The highest observed value was for Wi-Fi 5G technology, reaching 4.98 V/m, although its contribution to the total exposure levels was only 0.6%.

Based on the cumulative distribution analysis, it can be inferred that during the weekdays, 90% of the measured data have an E-field exposure value of less than 1 V/m. On the other hand, during the weekend, 90% of the measured data have a value smaller than 0.64 V/m. These values are in line with the E-field values recorded in similar studies as referenced in.

In conclusion, based on our extensive measurement campaign, personal exposure levels are higher in shopping malls during the weekdays compared to the weekend. The highest contributors to the total personal exposure at shopping malls are the Mobile communication technologies (Uplink/Downlink) and WI-FI technologies.

Contrary to our initial expectations regarding the indoor environment of the shopping mall, our measurement data reveals that Wi-Fi technologies are not the primary contributors to the total exposure. Instead, mobile communication technologies operating at 900 MHz and 1800 MHz have emerged as the dominant sources due to their high data rates and extensive coverage.

https://www.tandfonline.com/doi/full/10.1080/23311916.2024.2340311

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**Progress in microwave absorbing materials: A critical review**

Sharma S, Parne SR, Panda SSS, Gandi S. Progress in microwave absorbing materials: A critical review. Adv Colloid Interface Sci. 2024 Apr 4;327:103143. doi: 10.1016/j.cis.2024.103143.

Abstract

Microwave-absorbing materials play a significant role in various applications that involve the attenuation of electromagnetic radiation. This critical review article provides an overview of the progress made in the development and understanding of microwave-absorbing materials. The interaction between electromagnetic radiation and absorbing materials is explained, with a focus on phenomena such as multiple reflections, scattering, and polarizations. Additionally, types of losses that affect the performance of microwave absorbers are also discussed, including dielectric loss, conduction loss, relaxation loss, magnetic loss, and morphological loss. Each of these losses has different implications for the effectiveness of microwave absorbers. Further, a detailed review is presented on various types of microwave absorbing materials, including carbonaceous materials, conducting polymers, magnetic materials, metals and their composites, 2D materials (such as MXenes and 2D-transition metal dichalcogenides), biomass-derived materials, carbides, sulphides, phosphides, high entropy (HE) materials and metamaterials. The characteristics, advantages, and limitations of each material are examined. Overall, this review article highlights the progress achieved in the field of microwave-absorbing materials. It underlines the importance of optimizing different types of losses to enhance the performance of microwave absorbers. The review also recognizes the potential of emerging materials, such as 2D materials and high entropy materials, in further advancing microwave-absorbing properties.

https://pubmed.ncbi.nlm.nih.gov/38598925/

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**Rosmarinic Acid Protects the Testes of Rats against Cell Phone and Ultra-high Frequency Waves Induced Toxicity**

Fatahi Asl J, Goudarzi M, Mansouri E, Shoghi H. Rosmarinic Acid Protects the Testes of Rats against Cell Phone and Ultra-high Frequency Waves Induced Toxicity. Iran J Med Sci. 2024 Apr 1;49(4):237–46. doi: 10.30476/ijms.2023.97695.2952.

Abstract

Background: Cell phone and Ultra-High Frequency (UHF) waves produce oxidative stress and cause testicular toxicity. This investigation was directed to evaluate the effectiveness of Rosmarinic Acid (RA) against oxidative stress caused by UHF radiation in rats.

Methods: Forty-two male Wistar rats were divided into six groups. The control received 5 mL normal saline (0.9% NaCl) by gavage, the cell phone group received 915 MHz, the UHF waves group just received 2450 MHz, the RA/cell phone group received RA plus 915 MHz, RA/UHF waves group received RA plus 2450 MHz, and RA just received RA (20 mg/kg). After 30 days of consecutive radiation, the biochemical and histopathological parameters of their testes were measured. Statistical comparison was made using one-way ANOVA followed by Tukey's post hoc test.

Results: Cell phone and UHF wave radiation significantly diminished the activity of antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase, and glutathione content (P<0.001). On the opposite, UHF significantly increased oxidative stress indices including malondialdehyde level, nitric oxide level, and protein carbonyl content (P<0.001). UHF also significantly reduced the number of Sertoli cells, spermatogonia, primary spermatocyte, epithelial height, and seminiferous tubular and luminal diameters (P<0.001). RA, as an effective antioxidant, reverses the above-mentioned harms and moderates the adverse effects of UHF on the testes of rats by significantly diminishing the oxidative stress indices and antioxidant enzyme rise and improving the histological parameters (P<0.001).

Conclusion: RA can protect the testes of rats from UHF-induced toxicity by reducing oxidative stress. RA as a food supplement might be useful for protecting humans exposed to UHF environmental contamination.

Open access paper: https://ijms.sums.ac.ir/article_49676.html

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**Panax ginseng Ameliorates Pituitary-Ovarian Dysfunction Induced by RF EMR from Cell Phones via Upregulation of the CREM Signaling Pathway**

Oyewopo OA, Badejogbin OC, Ajadi IO, Enye LA, Ajadi MB, Ebuwa IV, Owolabi OV, Areloegbe SE, Olaniyi KS. Panax ginseng Ameliorates Pituitary-Ovarian Dysfunction Induced by Radiofrequency Electromagnetic Radiation from Cell Phones via Upregulation of the CREM Signaling Pathway. Curr Drug Discov Technol. 2024 Apr 30. doi: 10.2174/0115701638279386240425050818.

Abstract

Background: Panax ginseng (PG) is a plant that contains ginsenosides, which are considered adaptogens that confer cellular protection. However, the impact of PG on pituitary-ovarian dysfunction and subsequent infertility is unknown. This study investigated the hypothesis that PG would attenuate pituitary-ovarian dysfunction associated with mobile phone's Radiofrequency Electromagnetic Radiation (RF-EMR) in experimental rat models and the possible involvement of a cAMP Response Element Modulator (CREM)-dependent pathway.

Methods: Twenty adult female Wistar rats were divided randomly into four groups, each consisting of five rats. The control group was administered a vehicle (distilled water) orally, while the P. ginseng group received 200 mg/kg of P. ginseng extract orally. The RF-EMR group was exposed to 900MHz radiation, and the RF-EMR + PG group was exposed to the same radiation while also being treated with 200 mg/kg of P. ginseng orally. These treatments were administered daily for a period of 56 days.

Results: The RF-EMR group exhibited significant reductions in serum levels of LH, FSH, estradiol, and progesterone compared to the control group. Moreover, levels of superoxide dismutase (SOD) and glutathione peroxidase (GPx) were significantly lower in the RF-EMR group compared to the control. Additionally, there was a notable decrease in the expression of the CREM gene, accompanied by disrupted pituitary/ovarian morphology in the RF-EMR group compared to the control. However, the administration of PG mitigated these changes.

Conclusion: The findings of this study indicate that P. ginseng extract shields against pituitary-ovarian impairment linked to RF-EMR exposure from cell phones by boosting antioxidant capacity and promoting the CREM-dependent pathway.

https://pubmed.ncbi.nlm.nih.gov/38693729/

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**Electric and magnetic field pollution in near substations and investigation of anxiety and depressive effects on adult individuals living in this area**

Sert C, Başak N, Koruk İ. Electric and magnetic field pollution in near substations and investigation of anxiety and depressive effects on adult individuals living in this area. Electromagn Biol Med. 2024 May 3:1-11. doi: 10.1080/15368378.2024.2348574.

Abstract

Exposure to electromagnetic fields causes a variety of health problems in living systems. We investigated EMF pollution in Şanlıurfa city center and also investigated anxiety-depression symptoms in individuals (18-40 years old) exposed to this pollution. For this purpose, electric field and magnetic field measurements were taken at Electricity Distribution Center and 44 substations (for each transformer), at 0 points, 1 meter away, 2 meters away and the house/office closest to the transformer. The experimental group was individuals living in electricity distribution center residences and individuals living near transformers ($n$ = 55). The control group was selected from individuals who lived outside the city center of Şanlıurfa, did not have transformers or high transmission lines near their homes, and did not have any chronic diseases that could cause stress ($n$ = 50). Anxiety and depression symptoms of the groups were measured using the Beck Anxiety Inventory Scale (BAI) and Beck Depression Inventory Scale (BDI). The relationship between EMF pollution and anxiety-depression was evaluated statistically. Maximum MF and EF values were recorded as 0.22 mT and 65.9 kV/m, respectively. All measured MF values were below standards, but EF values were above standards at some points. In conclusion, there is no statistically convincing evidence of a relationship between EMF exposure and anxiety-depression ($p$ > 0.05). This result shows that there may be more meaningful results in places with higher EMF levels. We interpreted the fact that exposure to electromagnetic fields does not cause anxiety and depression in individuals, as the measured values are below the limit values.

Plain language summary

Electromagnetic field pollution causes various health problems in living systems. Research on this subject continues. We investigated electromagnetic field pollution in Şanlıurfa city center and investigated the psychological effects on individuals exposed to this pollution. For this purpose, electric and magnetic field measurements were made at 0 points, 1 meter, 2 meters away and at the closest places to the transformer in 44 substations. The experimental group was individuals living near a transformer, the control group was individuals living outside the city center and without a transformer/high transmission line near their home. Anxiety and depression symptoms of the groups were measured using the Beck Anxiety and Depression test. The relationship between EMF pollution and anxiety-depression was evaluated statistically. As a result, no statistical change was observed regarding a relationship between electromagnetic pollution and anxiety-depression.

https://pubmed.ncbi.nlm.nih.gov/38699873/

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**The effect of a rotating magnetic field on the antioxidant system in healthy volunteers - preliminary study**

Cecerska-Heryć E, Gliźniewicz M, Grygorcewicz B, Serwin N, Stodolak P, Słodzińska W, Birger R, Goszka M, Polikowska A, Budkowska M, Rakoczy R, Dołęgowska B. The effect of a rotating magnetic field on the antioxidant system in healthy volunteers - preliminary study. Sci Rep. 2024 Apr 15;14(1):8677. doi: 10.1038/s41598-024-59391-y.

Abstract

Oxidative stress is characterized by an excessive concentration of reactive oxygen species (ROS) resulting from a disturbance in the balance between ROS production and their removal by antioxidant systems (SOD, CAT, GPx). Prolonged and intense oxidative stress can cause various forms of damage to cells, which markers are total antioxidant capacity (TAC), reactive oxygen species modulator (ROMO1), and malondialdehyde (MDA). It has been demonstrated that magnetic fields can positively affect human health, for example, by reducing oxidative stress. Determination of the effect of a rotating magnetic field (RMF) on the activity/concentration of selected oxidative stress markers. A group of 30 healthy volunteers (15 women and 15 men) (mean age 24.8 ± 5.1) in the study classified into the following groups: internal control group (CG);1 h 25 Hz (samples placed in the field for one hour at 25 Hz); 3 h 25 Hz (samples placed in the field for 3 h at 25 Hz), the 1 h 50 Hz group ( placed in RMF for an hour at 50 Hz), and a group of 3 h 50 Hz (samples placed in the field for 3 h at 50 Hz). Serum samples were collected in $K_2$EDTA tubes.. The magnetic induction value obtained for RMF is 37.06 mT and 42.64 mT. Activity/concentration of selected oxidative stress markers was analyzed by ELISA. The influence of an RMF on the activity/concentration of SOD, MDA, TAC, and ROMO1 was demonstrated ($p < 0.001$; $p = 0.0013$; $p < 0.001$; $p = 0.003$). The RFM can reduce oxidative stress, as evidenced by higher SOD and CAT activities in the CG than in samples placed in the RFM. Prolonged exposure to the RFM at 50 Hz increased the TAC level, indicating an intensification of oxidative stress in these samples. The optimal conditions for staying in the RFM (reducing oxidative stress) are 1 h 50 Hz for SOD and MDA; 3 h 25 Hz for CAT and TAC. In the case of ROMO1, it is stated that 1 h 25 Hz are the optimal conditions for no increased production of ROS.

Open access paper: https://www.nature.com/articles/s41598-024-59391-y

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**Pulsating Extremely Low-Frequency Electromagnetic Fields Influence Differentiation of Mouse Neural Stem Cells towards Astrocyte-like Phenotypes: In Vitro Pilot Study**

Isaković J, Slatković F, Jagečić D, Petrović DJ, Mitrečić D. Pulsating Extremely Low-Frequency Electromagnetic Fields Influence Differentiation of Mouse Neural Stem Cells towards Astrocyte-like Phenotypes: In Vitro Pilot Study. Int J Mol Sci. 2024 Apr 4;25(7):4038. doi: 10.3390/ijms25074038.

Abstract

Even though electromagnetic fields have been reported to assist endogenous neurogenesis, little is known about the exact mechanisms of their action. In this pilot study, we investigated the effects of pulsating extremely low-frequency electromagnetic fields on neural stem cell differentiation towards specific phenotypes, such as neurons and astrocytes. Neural stem cells isolated from the telencephalic wall of B6(Cg)-Tyrc-2J/J mouse embryos (E14.5) were randomly divided into three experimental groups and three controls. Electromagnetic field application setup included a solenoid placed within an incubator. Each of the experimental groups was exposed to 50Hz ELF-EMFs of varied strengths for 1 h. The expression of each marker (NES, GFAP, β-3 tubulin) was then assessed by immunocytochemistry. The application of high-strength ELF-EMF significantly increased and low-strength ELF-EMF decreased the expression of GFAP. A similar pattern was observed for β-3 tubulin, with high-strength ELF-EMFs significantly increasing the immunoreactivity of β-3 tubulin and medium- and low-strength ELF-EMFs decreasing it. Changes in NES expression were observed for medium-strength ELF-EMFs, with a demonstrated significant upregulation. This suggests that, even though ELF-EMFs appear to inhibit or promote the differentiation of neural stem cells into neurons or astrocytes, this effect highly depends on the strength and frequency of the fields as well as the duration of their application. While numerous studies have demonstrated the capacity of EMFs to guide the differentiation of NSCs into neuron-like cells or β-3 tubulin+ neurons, this is the first study to suggest that ELF-EMFs may also steer NSC differentiation towards astrocyte-like phenotypes.

Open access paper: https://www.mdpi.com/1422-0067/25/7/4038

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**Invited Perspective: Why Systematic Reviews, Scoping Reviews, and Evidence-to-Decision Frameworks Are Critical for Transparent, Consistent, Equitable, and Science-Based Decision-Making in Environmental Health**

My note: Systematic reviews require a multitude of macro- and micro-decisions. When conducted by biased investigative teams, systematic reviews generate erroneous conclusions and policy implications. This applies to EMF as well as chemical exposures.

Chartres N, Joglekar R. Invited Perspective: Why Systematic Reviews, Scoping Reviews, and Evidence-to-Decision Frameworks Are Critical for Transparent, Consistent, Equitable, and Science-Based Decision-Making in Environmental Health. Environ Health Perspect. 2024 Mar;132(3):31304. doi: 10.1289/EHP14346.

No abstract

Excerpt

"... systematic review is simultaneously being corrupted as agencies, including the Texas Commission on Environmental Quality (TCEQ) and the US Environmental Protection Agency (EPA), as part of implementing the amended the Toxic Substances Control Act, are appropriating the term in regulatory decision-making without meeting many of the standards of an empirically based systematic review. 4,9–12 This could result in rulemakings that underestimate the true risk of harm posed by toxic chemical exposures, which could have devastating implications for vulnerable populations, including low-wealth communities of color. 11"

Open access paper: https://ehp.niehs.nih.gov/doi/10.1289/EHP14346

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**Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study**

(My note: Numerous methodological problems undermine the validity of the results and conclusions of this study.)

Feychting M, Schüz J, Toledano MB, Vermeulen R, Auvinen A, Poulsen AH, Deltour I, Smith RB, Heller J, Kromhout H, Huss A, Johansen C, Tettamanti G, Elliott P. Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study. Environment International. 2024, doi: 10.1016/j.envint.2024.108552.

Abstract

Background: Each new generation of mobile phone technology has triggered discussions about potential carcinogenicity from exposure to radiofrequency electromagnetic fields (RF-EMF). Available evidence has been insufficient to conclude about long-term and heavy mobile phone use, limited by differential recall and selection bias, or crude exposure assessment. The Cohort Study on Mobile Phones and Health (COSMOS) was specifically designed to overcome these shortcomings.

Methods: We recruited participants in Denmark, Finland, the Netherlands, Sweden, and the UK 2007-2012. The baseline questionnaire assessed lifetime history of mobile phone use. Participants were followed through population-based cancer registers to identify glioma, meningioma, and acoustic neuroma cases during follow-up. Non-differential exposure misclassification was reduced by adjusting estimates of mobile phone call-time through regression calibration methods based on self-reported data and objective operator-recorded information at baseline. Hazard ratios (HR) and 95% confidence intervals (CI) for glioma, meningioma, and acoustic neuroma in relation to lifetime history of mobile phone use were estimated with Cox regression models with attained age as the underlying time-scale, adjusted for country, sex, educational level, and marital status.

Results: 264,574 participants accrued 1,836,479 person-years. During a median follow-up of 7.12 years, 149 glioma, 89 meningioma, and 29 incident cases of acoustic neuroma were diagnosed. The adjusted HR per 100 regression-calibrated cumulative hours of mobile phone call-time was 1.00 (95 % CI 0.98-1.02) for glioma, 1.01 (95 % CI 0.96-1.06) for meningioma, and 1.02 (95 % CI 0.99-1.06) for acoustic neuroma. For glioma, the HR for ≥ 1908 regression-calibrated cumulative hours (90th percentile cut-point) was 1.07 (95 % CI 0.62-1.86). Over 15 years of mobile phone use was not associated with an increased tumour risk; for glioma the HR was 0.97 (95 % CI 0.62-1.52).

Conclusions: Our findings suggest that the cumulative amount of mobile phone use is not associated with the risk of developing glioma, meningioma, or acoustic neuroma.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024001387
Supplementary material:
https://www.sciencedirect.com/science/article/pii/S0160412024001387#s0065

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**Dominance of Smartphone Exposure in 5G Mobile Networks**

Chiaraviglio L, Lodovisi C, Bartoletti S, Elzanaty A, M. Slim-Alouini M. Dominance of Smartphone Exposure in 5G Mobile Networks. IEEE Transactions on Mobile Computing, 23(3):2284-2302, 2024. doi: 10.1109/TMC.2023.3252662.

Abstract

The deployment of 5G networks is sometimes questioned due to the impact of ElectroMagnetic Field (EMF) generated by Radio Base Station (RBS) on users. The goal of this work is to analyze such issue from a novel perspective, by comparing RBS EMF against exposure generated by 5G smartphones in commercial deployments. The measurement of exposure from 5G is hampered by several implementation aspects, such as dual connectivity between 4G and 5G, spectrum fragmentation, and carrier aggregation. To face such issues, we deploy a novel framework, called 5G-EA, tailored to the assessment of smartphone and RBS exposure through an innovative measurement algorithm, able to remotely control a programmable spectrum analyzer. Results, obtained in both outdoor and indoor locations, reveal that smartphone exposure (upon generation of uplink traffic) dominates over the RBS one. Moreover, Line-of-Sight locations experience a reduction of around one order of magnitude on the overall exposure compared to Non-Line-of-Sight ones. In addition, 5G exposure always represents a small share (up to 38%) compared to the total one radiated by the smartphone.

Excerpt

Our results demonstrate that the smartphone exposure dominates over the RBS one upon generation of UL traffic, especially when the UE is in Non-Line-of-Sight (NLOS) with respect to the RBS. On the contrary, both smartphone exposure and total EMF are reduced up to one order of magnitude when the smartphone UL traffic traverses a radio link in Line-of-Sight (LOS) with respect to the serving RBS. Interestingly, the exploitation of dual connectivity feature between 4G and 5G reveals that only a small smartphone exposure share (at most equal to 38%) is due to 5G, while the largest exposure levels are derived from the carrier aggregation over 4G bands. Moreover, both total and smartphone exposure-per-bit metrics are inversely proportional to the maximum amount of UL traffic generated by the smartphone in the measurement location, thus suggesting that innovative exposure estimators, based on the reporting of maximum UL traffic from the smartphone, can be designed.

Open access paper: https://doi.ieeecomputersociety.org/10.1109/TMC.2023.3252662

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**Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods**

Expósito I, Hakizimali C, García Sánchez M, Cuiñas I, Verhaevert J. Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods. Measurement. 2024. doi: 10.1016/j.measurement.2024.114434.

Highlights

- This paper analyzes the feasibility of assessing the 5G base stations compliance using broadband field probes and compares their performance with alternative methodologies and equipment.
- Performance of three different methodologies and equipment (broadband probes, spectrum analyzers, and drive test scanners), in the context of human exposure to electromagnetic fields (EMF) from 5G base stations, is compared.
- Quantification of the uncertainty that the fluctuation in 5G signal levels induces in the assessment of electromagnetic fields exposure is provided.
- The use of broadband field probes for 5G exposure assessment is still possible under certain considerations and correcting the results considering the base station load and beamforming effects.

Abstract

5G networks deployment poses new challenges when evaluating human exposure to electromagnetic fields. Fast variation of the user load and beamforming techniques may cause large fluctuations of 5G base stations field level. They may be underestimated, resulting in compliance of base stations not fitting the requirements. Apparently, broadband field meters would not be adequate for measuring such environments. However, we analyze the feasibility of confidently using broadband field meters and compare their performance with alternative equipment. Measurements based on the synchronization signals power level, using spectrum analyzers or drive test scanners, may be valid, if gain differences between the signaling and data radiation patterns are characterized. These methods lead to good results but require more time and knowledge. Nevertheless, using broadband field meters is still possible if the measurement results are corrected considering the base station load. Under specific conditions, explained here, fast assessment of 5G compliance could be provided.

Conclusions

Assessing human exposure to an electromagnetic field in presence of a 5G base station is not an easy task. The implementation of M−MIMO techniques in 5G base stations results in adaptive beamforming. This makes difficult to guarantee that the field levels are at their maximum at the measurement location during the complete measurement period, which would limit the applicability of broadband instruments as having been done for previous generations. In this research, we have compared different methods for 5G exposure assessment, using a broadband field meter with an isotropic probe, a spectrum analyzer and a drive test scanner.

Along the paper, we first give an overview of the 5G signal structure, describing the frequency domain and time domain specifications. Afterwards, possible assessment methods are described. The SSB level is measured using the Keysight FieldFox N9913A SA and the Rohde & Schwarz TSM6 DTS. The values are extrapolated to the worst-case exposure and compared to the measurements done with the Wavecontrol WPF8 broadband field probe. Measurements are repeated increasing the base station load by performing a heavy download from a 5G user terminal located near the testers.

The proposed methods were field tested at the University of Vigo, Spain, with a commercial 5G base station located on its campus. The measurements were performed at 7 locations in LOS conditions around the base station, gathering data with the three different equipment at the same locations and at

the same time. This data collection allows the comparison of the three methodologies under the same radiating conditions.

All results have been analyzed considering the specific measurement uncertainties, which allows a deeper and more precise comparison among them.

From the measurement results, we can extract that the exposure levels are low at this stage of the 5G deployment. When loading the base station, the results showed that using the broadband field meter can overestimate the field level. Thus, it is still a useful method to check if the field levels comply with the regulation in human exposure; very simple and cost-effective compared with others. In-situ measurements of human exposure to EMF have to be practical and easy to carry, involving only the resources and equipment strictly necessary, but without compromising the validity of the results. When the reference levels are surpassed, more accurate methods based in the assessment and extrapolation of the SSB level could be a solution. The drawback is the required post processing, specially correcting the gain difference between SSB and data signals. If not provided by the network operator, this difference can be determined through measurements, as explained along this document. Measuring with an SA in max-hold mode in the bandwidth of the SSB does not work in 5G as it does in LTE, as we cannot be sure if the measured level corresponds to the SSB or to the user data, no matter if we are forcing the load of the station or not.

The analysis of the results demonstrate that broadband instruments can be used for assessing human exposure to EMF in the vicinity of 5G base stations, which radiating elements provide fields with extreme fluctuations in their intensity as a function of the system load and beamforming configuration. This is accurate when measurements are done by forcing an extra load of the station and the pointing of an antenna beam towards the probe. The validation of this fast method as a first attempt to assess the compliance of 5G stations permits the testing of these base stations in an efficient way. Only when broadband instrument results (including their uncertainties) would overpass the reference levels, a more detailed analysis would be necessary, which procedure and tips are also depicted along this paper.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0263224124003191

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**5G NR launching in Greece: Preliminary in situ and monitoring network measurements of electromagnetic fields exposure levels at rooftops**

Christopoulou MI, Kyritsi T, Yalofas A, Koutounidis D, Karabetsos E. 5G NR launching in Greece: Preliminary in situ and monitoring network measurements of electromagnetic fields exposure levels at rooftops. Bioelectromagnetics. 2024 Mar 5. doi: 10.1002/bem.22502.

Highlights

- In situ measurements of electromagnetic field (EMF) exposure levels at rooftops, close to 117 base stations operating at 5G FR1 in Greece in order to evaluate the contribution of 5G to the total exposure.
- Statistical analysis of the follow-up for inspections of the same base stations, before and after the 5G FR1 launching in Greece.
- Case study of a 5G FR1 base station during its pilot and regular operation based on in situ and broadband & frequency selective 24/7 monitoring sensors measurements data.

Abstract

In Greece, 5G New Radio (NR) has started launching in the end of 2020, at the 3400-3800 MHz (FR1) frequency band. Focusing on 117 Base Stations (BSs) which were already equipped with 5G NR antennas, in situ broadband and frequency selective measurements have been conducted at minimum three points of interest, at adjacent rooftops (when accessible). The points have been selected according to the sweeping method and the electric field strength (E) value has been stored on the selected worst-case scenario point. Spectrum analysis was conducted in the FR1, for the allocated spectrum that corresponds to each mobile communication provider, in order to get preliminary results concerning the contribution of the 5G NR emissions in the general public exposure levels. The vast majority of the in situ measurements has been conducted in urban environments from the beginning of 2021 until the mid of 2022, since in Greece 5G NR services launching started from the big cities. Additionally, a 5G NR BS, installed in a suburban environment (in the city of Kalamata) is thoroughly investigated during its pilot and regular operation, based on broadband and frequency selective measurements data derived by the National Observatory of Electromagnetic Fields (NOEF) monitoring sensor network. In situ measurement data within the 5G NR frequency range are verified via the NOEF's output. The 5G NR contribution to the total E-field levels is assessed in time, from pilot to regular operation of the BS. In all cases, compliance with the reference levels for general public exposure is affirmed.

https://pubmed.ncbi.nlm.nih.gov/38444067/

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**The determinants of legislation for radiofrequency electromagnetic fields (RF-EMFs) with the onset of 5G: An empirical analysis**

Recuero Virto L, Czerwiński M, Froidevaux J. The determinants of legislation for radiofrequency electromagnetic fields (RF-EMFs) with the onset of 5G: An empirical analysis with a worldwide cross-sectional dataset. Risk Anal. 2024 Mar 31. doi: 10.1111/risa.14298.

Abstract

The unprecedented exposure of radiofrequency electromagnetic field (RF-EMF) to humans from mobile communications raises serious public concern about the possibility of unexpected adverse health effects and has stimulated authorities to adopt precautionary exposure limits. These limits are distinctly different across countries, and the causes of these differences are unclear from the literature. This article is the first empirical analysis on the determinants of RF-EMF exposure legislation, using a novel cross-sectional database of 164 countries worldwide. The analysis shows that decentralization and mobile competition in countries with low mobile network deployment tend to promote more stringent RF-EMF exposure limits across the dataset with 164 countries. In more decentralized countries, the regions had a greater influence on national legislation and could accommodate local demands with the advent of mobile technology in the 2000s. In contrast, decentralization and mobile competition in countries with high levels of mobile network deployment tend to relax RF-EMF exposure limits in the sample of 61 countries with fifth-generation (5G) technology. Indeed, restrictive RF-EMF exposure limits are constraining 5G deployment in a context of the widespread adoption of mobile-broadband technologies. These results should be useful for policymakers and mobile operators alike to anticipate the outcome of legislation in countries that have yet to introduce 5G technology. The results should also

be useful when reviewing policies and strategies for the implementation of the upcoming 6G technology in frequency bands that will be increasingly higher (above 6 GHz up to THz for very local usage), and hence where the health effects on humans are less well studied.

https://pubmed.ncbi.nlm.nih.gov/38556257/

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**Editorial: Neurological Illness and National Security: Lessons to Be Learned**

Relman DA. Neurological Illness and National Security: Lessons to Be Learned. JAMA. Published online March 18, 2024. doi:10.1001/jama.2023.26818

No abstract

Excerpt

In 2016, a set of troubling neurological symptoms was reported through confidential channels by US government personnel based at the US Embassy in Havana, Cuba. As the number of cases in Havana escalated and then similar cases occurred over the next 5 years in other locations around the globe, efforts to understand this syndrome, now known as anomalous health incidents (AHIs), were hampered by their unusual features, incomplete information, nonstandardized clinical testing, delayed reporting, and the sensitive nature of the circumstances, individuals, and their work. A subset of individuals described the abrupt onset, sometimes in the middle of the night, of a loud, grinding, clicking, buzzing, or high-pitched piercing sound inside the head, occasionally likened to a slide whistle, and a sensation of pressure, sometimes in one ear, on one side of the head, or in the face or chest. Most strikingly, these phenomena often displayed strong location dependence, in that they quickly dissipated when the individuals vacated their initial location, and then returned when the location was revisited. In some cases, this location dependence was reported to occur repeatedly by the same individual or by multiple individuals as they moved away from and then returned within minutes to a specific location, such as part of a room. These abrupt-onset sensory phenomena were followed by a mix of vertigo, dizziness, imbalance, blurry vision, tinnitus, headache, nausea, and cognitive dysfunction, sometimes leading to chronic disability.

In this issue of JAMA, Chan et al1 and Pierpaoli et al2 at the National Institutes of Health (NIH) report on an extensive clinical assessment of 86 participants with AHIs and 30 control participants, and on magnetic resonance imaging (MRI) findings of 81 of these participants with AHIs and 48 control participants, respectively. Overall, the authors found few significant differences between participants with AHIs and control participants, and no consistent evidence of brain injury. These findings differ from previous clinical and imaging studies of smaller numbers of cases from Havana and China that found evidence of vestibular, oculomotor, and pupillary abnormalities3,4 and a variety of MRI findings.5

With few differences between cases and controls in the 2 current studies, one might suspect that nothing or nothing serious happened with these cases. This would be ill-advised. Two detailed investigations of AHIs (in which I played a role) found the cases with abrupt-onset, location-dependent sensory phenomena to be unlike any disorder reported in the neurological or general medical literature, and potentially caused by an external mechanism.6-9 The first of these investigations was undertaken

by the US National Academy of Sciences in 2019-2020 and the second by a panel of experts on behalf of the US Intelligence Community in 2021-2022. The latter is described in more detail below. Both of these investigations involved experienced clinicians, detailed interviews with many affected individuals, careful reviews of the literature, and informal reviews of some medical records, but not physical examinations or directed testing. After considering a wide variety of possible mechanisms, both studies concluded that some of the cases with abrupt-onset, location-dependent sensory phenomena could be plausibly explained by exposure to directed, pulsed radiofrequency energy, despite important uncertainties. Others have also pointed to pulsed radiofrequency energy as a plausible mechanism.10,11 The US Intelligence Community has discounted this possibility and concluded that reported symptoms were probably the result of "preexisting conditions, conventional illnesses, and environmental factors," influenced by their assessment that no foreign adversary played a role in these cases.12 While many cases may be explained in this fashion, the evidence that might favor known conditions, illnesses, and factors in some of the cases with abrupt-onset, location-dependent auditory-vestibular phenomena is weak at best....

Open access paper: https://jamanetwork.com/journals/jama/fullarticle/2816534

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**Clinical, biomarker, and research tests among US government personnel and their family members involved in anomalous health incidents**

Chan L, Hallett M, Zalewski CK, et al; NIH AHI Intramural Research Program Team. Clinical, biomarker, and research tests among US government personnel and their family members involved in anomalous health incidents. JAMA. Published March 18, 2024. doi:10.1001/jama.2024.2413

Key Points

Questions Do US government officials and their family members involved in anomalous health incidents (AHIs) differ from control participants with respect to clinical, biomarker, and research assessments?

Findings In this exploratory study that included 86 participants reporting AHIs and 30 vocationally matched control participants, there were no significant differences in most tests of auditory, vestibular, cognitive, visual function, or blood biomarkers between the groups. Participants with AHIs performed significantly worse on self-reported and objective measures of balance, and had significantly increased symptoms of fatigue, posttraumatic stress disorder, and depression compared with the control participants; 24 participants (28%) with AHIs presented with functional neurological disorders.

Meaning In this exploratory study, there were no significant differences between individuals reporting AHIs and matched control participants with respect to most clinical, research, and biomarker measures, except for self-reported and objective measures of imbalance; symptoms of fatigue, posttraumatic stress, and depression; and the development of functional neurological disorders in some.

Abstract

Importance  Since 2015, US government and related personnel have reported dizziness, pain, visual problems, and cognitive dysfunction after experiencing intrusive sounds and head pressure. The US government has labeled these anomalous health incidents (AHIs).

Objective  To assess whether participants with AHIs differ significantly from US government control participants with respect to clinical, research, and biomarker assessments.

Design, Setting, and Participants  Exploratory study conducted between June 2018 and July 2022 at the National Institutes of Health Clinical Center, involving 86 US government staff and family members with AHIs from Cuba, Austria, China, and other locations as well as 30 US government control participants.

Exposures  AHIs.

Main Outcomes and Measures  Participants were assessed with extensive clinical, auditory, vestibular, balance, visual, neuropsychological, and blood biomarkers (glial fibrillary acidic protein and neurofilament light) testing. The patients were analyzed based on the risk characteristics of the AHI identifying concerning cases as well as geographic location.

Results  Eighty-six participants with AHIs (42 women and 44 men; mean [SD] age, 42.1 [9.1] years) and 30 vocationally matched government control participants (11 women and 19 men; mean [SD] age, 43.8 [10.1] years) were included in the analyses. Participants with AHIs were evaluated a median of 76 days (IQR, 30-537) from the most recent incident. In general, there were no significant differences between participants with AHIs and control participants in most tests of auditory, vestibular, cognitive, or visual function as well as levels of the blood biomarkers. Participants with AHIs had significantly increased fatigue, depression, posttraumatic stress, imbalance, and neurobehavioral symptoms compared with the control participants. There were no differences in these findings based on the risk characteristics of the incident or geographic location of the AHIs. Twenty-four patients (28%) with AHI presented with functional neurological disorders.

Conclusions and Relevance  In this exploratory study, there were no significant differences between individuals reporting AHIs and matched control participants with respect to most clinical, research, and biomarker measures, except for objective and self-reported measures of imbalance and symptoms of fatigue, posttraumatic stress, and depression. This study did not replicate the findings of previous studies, although differences in the populations included and the timing of assessments limit direct comparisons.

Open access paper: https://jamanetwork.com/journals/jama/fullarticle/2816533

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**Neuroimaging findings in US government personnel and their family members involved in anomalous health incidents**

Pierpaoli  C, Nayak  A, Hafiz  R,  et al; NIH AHI Intramural Research Program Team.  Neuroimaging findings in US government personnel and their family members involved in anomalous health incidents.  JAMA. Published March 18, 2024. doi:10.1001/jama.2024.2424

Key Points

Question  Can a systematic evaluation using quantitative magnetic resonance imaging (MRI) metrics identify potential brain lesions in patients who have experienced anomalous health incidents (AHIs) compared with a well-matched control group?

Findings  In this exploratory study that involved brain imaging of 81 participants who experienced AHIs and 48 matched control participants, there were no significant between-group differences in MRI measures of volume, diffusion MRI–derived metrics, or functional connectivity using functional MRI after adjustments for multiple comparisons. The MRI results were highly reproducible and stable at longitudinal follow-ups. No clear relationships between imaging and clinical variables emerged.

Meaning  In this exploratory neuroimaging study, there was no significant MRI-detectable evidence of brain injury among the group of participants who experienced AHIs compared with a group of matched control participants. This finding has implications for future research efforts as well as for interventions aimed at improving clinical care for the participants who experienced AHIs.

Abstract

Importance  US government personnel stationed internationally have reported anomalous health incidents (AHIs), with some individuals experiencing persistent debilitating symptoms.

Objective  To assess the potential presence of magnetic resonance imaging (MRI)–detectable brain lesions in participants with AHIs, with respect to a well-matched control group.

Design, Setting, and Participants  This exploratory study was conducted at the National Institutes of Health (NIH) Clinical Center and the NIH MRI Research Facility between June 2018 and November 2022. Eighty-one participants with AHIs and 48 age- and sex-matched control participants, 29 of whom had similar employment as the AHI group, were assessed with clinical, volumetric, and functional MRI. A high-quality diffusion MRI scan and a second volumetric scan were also acquired during a different session. The structural MRI acquisition protocol was optimized to achieve high reproducibility. Forty-nine participants with AHIs had at least 1 additional imaging session approximately 6 to 12 months from the first visit.

Exposure  AHIs.

Main Outcomes and Measures  Group-level quantitative metrics obtained from multiple modalities: (1) volumetric measurement, voxel-wise and region of interest (ROI)–wise; (2) diffusion MRI–derived metrics, voxel-wise and ROI-wise; and (3) ROI-wise within-network resting-state functional connectivity using functional MRI. Exploratory data analyses used both standard, nonparametric tests and bayesian multilevel modeling.

Results  Among the 81 participants with AHIs, the mean (SD) age was 42 (9) years and 49% were female;

among the 48 control participants, the mean (SD) age was 43 (11) years and 42% were female. Imaging scans were performed as early as 14 days after experiencing AHIs with a median delay period of 80 (IQR, 36-544) days. After adjustment for multiple comparisons, no significant differences between participants with AHIs and control participants were found for any MRI modality. At an unadjusted threshold ($P < .05$), compared with control participants, participants with AHIs had lower intranetwork connectivity in the salience networks, a larger corpus callosum, and diffusion MRI differences in the corpus callosum, superior longitudinal fasciculus, cingulum, inferior cerebellar peduncle, and amygdala. The structural MRI measurements were highly reproducible (median coefficient of variation <1% across all global volumetric ROIs and <1.5% for all white matter ROIs for diffusion metrics). Even individuals with large differences from control participants exhibited stable longitudinal results (typically, <±1% across visits), suggesting the absence of evolving lesions. The relationships between the imaging and clinical variables were weak (median Spearman $\rho = 0.10$). The study did not replicate the results of a previously published investigation of AHIs.

Conclusions and Relevance  In this exploratory neuroimaging study, there were no significant differences in imaging measures of brain structure or function between individuals reporting AHIs and matched control participants after adjustment for multiple comparisons.

Open access paper: https://jamanetwork.com/journals/jama/fullarticle/2816532

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**Do blue light filter applications improve sleep outcomes? A study of smartphone users' sleep quality in an observational setting**

Rabiei M, Masoumi SJ, Haghani M, Nematolahi S, Rabiei R, Mortazavi SMJ (2024). Do blue light filter applications improve sleep outcomes? A study of smartphone users' sleep quality in an observational setting. Electromagnetic Biology and Medicine, DOI: 10.1080/15368378.2024.2327432.

Abstract

Exposure to blue light at bedtime, suppresses melatonin secretion, postponing the sleep onset and interrupting the sleep process. Some smartphone manufacturers have introduced night-mode functions, which have been claimed to aid in improving sleep quality. In this study, we evaluate the impact of blue light filter application on decreasing blue light emissions and improving sleep quality. Participants in this study recorded the pattern of using their mobile phones through a questionnaire. In order to evaluate sleep quality, we used a PSQI questionnaire. Blue light filters were used by 9.7% of respondents, 9.7% occasionally, and 80% never. The mean score of PSQI was more than 5 in 54.10% of the participants and less than 5 in 45.90%. ANOVA test was performed to assess the relationship between using blue light filter applications and sleep quality (p-value = 0.925). The findings of this study indicate a connection between the use of blue light filter apps and habitual sleep efficiency in the 31–40 age group. However, our results align only to some extent with prior research, as we did not observe sustained positive effects on all parameters of sleep quality from the long-term use of blue light filtering apps. Several studies have found that blue light exposure can suppress melatonin secretion, exacerbating sleep problems. Some studies have reported that physical blue light filters, such as lenses, can affect melatonin secretion and improve sleep quality. However, the impact of blue light filtering applications remains unclear and debatable.

Plain Language Summary

Using smartphones before bedtime and being exposed to its blue light can make it harder to fall asleep and disrupt your sleep. Some smartphone makers have introduced a night mode feature claiming it can help improve your sleep. In this study, we wanted to find out if using these blue light filters on smartphones really makes a difference. We asked people how often they used blue light filters on their phones and also had them fill out a questionnaire about their sleep quality. Only about 10% of people said they used blue light filters regularly, another 10% used them occasionally, and the majority, around 80%, never used them. When we looked at the results, more than half of the participants had sleep scores higher than 5, indicating they might have sleep problems. Less than half had sleep scores lower than 5, suggesting better sleep quality. We used some statistical tests to see if using blue light filters had any link to sleep quality, and the results showed that there was only a connection between the use of blue light filter apps and habitual sleep efficiency in the 31–40 age group. Our findings matched what other studies have found before, that using blue light filters on smartphones may not significantly help improve sleep. So, while it might be a good idea to limit smartphone use before bed, using a blue light filter app may not be the magic solution for better sleep.

https://www.tandfonline.com/doi/full/10.1080/15368378.2024.2327432

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**Mobile phone radiation disturbs cytokinesis and causes cell death in buccal cells: Results of controlled human intervention study**

Kundi M, Nersesyan A, Schmid G, Hutter HP, Eibensteiner F, Mišík M, Knasmüller S. Mobile phone specific radiation disturbs cytokinesis and causes cell death but not acute chromosomal damage in buccal cells: Results of a controlled human intervention study. Environ Res. 2024 Mar 5:118634. doi: 10.1016/j.envres.2024.118634.

Abstract

Several human studies indicate that mobile phone specific electromagnetic fields may cause cancer in humans but the underlying molecular mechanisms are currently not known. Studies concerning chromosomal damage (which is causally related to cancer induction) are controversial and are based on the use of questionnaires to assess the exposure. We realized the first human intervention trial in which chromosomal damage and acute toxic effects were studied under controlled conditions. The participants were exposed via headsets at one randomly assigned side of the head to low and high doses of a UMTS signal (n = 20, to 0.1 W/kg and n = 21 to 1.6 W/kg Specific Absorption Rate) for 2h on 5 consecutive days. Before and three weeks after the exposure buccal cells were collected from both cheeks and micronuclei (MN, which are formed as a consequence of structural and numerical chromosomal aberrations) and other nuclear anomalies reflecting mitotic disturbance and acute cytotoxic effects were scored. We found no evidence for induction of MN and of nuclear buds which are caused by gene amplifications, but a significant increase of binucleated cells which are formed as a consequence of disturbed cell divisions, and of karyolitic cells, which are indicative for cell death. No such effects were seen in cells from the less exposed side. Our findings indicate that mobile phone specific high frequency electromagnetic fields do not cause acute chromosomal damage in oral mucosa cells under the present experimental conditions. However, we found clear evidence for disturbance of the cell cycle and cytotoxicity. These effects may play a causal role in the induction of adverse long term health effects in humans.

Final paragraph of paper:

As mentioned in the introduction, evidence is accumulating that exposure to HF-EMF is associated with specific brain tumors (Brabant et al., 2023; Carlberg et al., 2017; Coureau et al., 2014; Hardell and Carlberg, 2015; Hardell et al., 2013; IARC, 2013; INTERPHONE Study Group, 2010). The results of the present investigation indicate that molecular mechanisms other than chromosomal damage may cause neoplastic transformation of the cells as a consequence of exposure to mobile phone specific HF-EMF. As described in the result section, we found in the present study clear evidence for induction of acute toxicity and disturbance of the cell cycle (cytokinesis) as a consequence of exposure to a high radiation dose (1.6 W/kg). It is possible that these effects cause inflammatory responses and/or release of ROS, which were seen in a number of laboratory studies (e.g. Alipour et al., 2022; Benavides et al., 2023; IARC, 2013; Yakymenko et al., 2016). These processes may possibly lead to formation of neoplastic cells.

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**Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy**

Büyükeren M, Karanfil Yaman F. Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy. J Turk Ger Gynecol Assoc. 2024 Mar 6;25(1):7-12. doi: 10.4274/jtgga.galenos.2023.2022-10-1.

Abstract

Objective: The aim was to compare neonatal outcomes according to cell phone specific absorption rate (SAR) levels and daily time spent on cell phones by pregnant women.

Material and methods: Women who gave birth at Konya City Hospital between September 2020 and February 2021 were included in this retrospective study. Gestational ages, birth weight, birth length, head circumference, sex, 5-minute APGAR scores, neonate postpartum resuscitation requirement, delivery type, the model of phone used by the pregnant women, and the average time spent on the phone during a day were recorded. To determine the relation between the SAR values of the phones used and delivering a small for gestational age (SGA) baby, receiver operating characteristic curve analysis was performed.

Results: In total 1495 pregnant women were included. The rate of delivering a SGA fetus was significantly higher in women who used phones with higher SAR values (p=0.001). The cut-off value for the SAR level was 1.23 W/kg with 69.3% sensitivity and 73.0% specificity (area under the curve: 0.685; 95% confidence interval: 0.643-0.726). No correlation was found between time spent on the phone and SGA birth rate. Although both phone SAR values and time spent on the phone were higher in the symmetrical SGA group compared to the asymmetrical SGA group, the difference was not significant (p>0.05). Although the women who had preterm delivery had higher phone SAR values and had spent more time on the phone compared to those who had term deliveries, the difference was again not significant (p>0.05).

Conclusion: As the SAR values of cell phones used during pregnancy increased, there was a trend towards delivering a SGA baby.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10921072/

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**Do somatic symptom distress and attribution predict symptoms associated with environmental factors?**

Köteles F, Nordin S. Do somatic symptom distress and attribution predict symptoms associated with environmental factors? J Psychosom Res. 2024 Mar 1;179:111637. doi: 10.1016/j.jpsychores.2024.111637.

Abstract

Objective: Not much is known on the development of symptoms associated with environmental factors (SAEF), also known as (idiopathic) environmental intolerances. Findings from qualitative studies suggest that appearance of symptoms might be the first step, followed by the acquisition of a specific attribution. The current study investigated cross-sectional and longitudinal (three years) associations between attribution and symptoms with respect to symptoms associated with chemical substances, certain indoor environments (buildings), sounds, and electromagnetic fields (EMFs).

Methods: We used data from the first two waves of the population-based Västerbotten Environmental Health Study (n = 2336). Participants completed the Patient Health Questionnaire Somatic Symptom Scale (PHQ-15), the Environmental Symptom-Attribution Scale, and answered single questions on the four aforementioned SAEFs.

Results: Using binary logistic regression analyses, all four SAEFs showed significant cross-sectional associations with somatic symptom distress and the respective attribution. In the longitudinal analysis, development of SAEF-Sound and SAEF-Chemicals were predicted by both somatic symptom distress and attribution. SAEF-EMFs was predicted only by attribution, whereas neither somatic symptom distress nor attribution forecasted SAEF-Buildings.

Conclusion: Overall, these findings suggest that attribution (i.e., a specific expectation) plays a substantial role in the development and maintenance of many SAEFs.

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https://www.sciencedirect.com/science/article/pii/S0022399924000497?via%3Dihub

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**Micro-environmental personal radio-frequency electromagnetic field exposures in Melbourne: A longitudinal trend analysis**

Bhatt CR, Henderson S, Sanagou M, Brzozek C, Thielens A, Benke G, Loughran S. Micro-environmental personal radio-frequency electromagnetic field exposures in Melbourne: A longitudinal trend analysis. Environ Res. 2024 Mar 13:118629. doi: 10.1016/j.envres.2024.118629.

Abstract

Background: A knowledge gap exists regarding longitudinal assessment of personal radio-frequency electromagnetic field (RF-EMF) exposures globally. It is unclear how the change in telecommunication technology over the years translates to change in RF-EMF exposure. This study aims to evaluate longitudinal trends of micro-environmental personal RF-EMF exposures in Australia.

Methods: The study utilised baseline (2015-16) and follow-up (2022) data on personal RF-EMF exposure (88 MHz-6 GHz) measured across 18 micro-environments in Melbourne. Simultaneous quantile regression analysis was conducted to compare exposure data distribution percentiles, particularly median (P50), upper extreme value (P99) and overall exposure trends. RF-EMF exposures were compared across six exposure source types: mobile downlink, mobile uplink, broadcast, 5G-New Radio, Others and Total (of the aforementioned sources). Frequency-specific exposures measured at baseline and follow-up were also compared. Total exposure across different groups of micro-environment types were also compared.

Results: For all micro-environmental data, total (median and P99) exposure levels did not significantly change at follow-up. Overall exposure trend of total exposure increased at follow-up. Mobile downlink contributed the highest exposure among all sources showing an increase in median exposure and overall exposure trend. Of seven micro-environment types, five of them showed total exposure levels (median and P99) and overall exposure trend increased at follow-up.

Excerpt

The assessment of change in total personal RF-EMF exposure distribution at follow-up across all micro-environments and those for different micro-environment types showed inconsistent changes in the exposure levels and overall exposure trend. The median and upper extreme total RF-EMF exposure levels across the micro-environments showed no significant change; whilst overall trend of total exposure at follow-up increased during the study period. Mobile downlink, the largest exposure source, median exposure and overall exposure trend increased (26.7%, up to 34.3%, respectively) at follow-up. The observed increase in median and upper extreme exposure levels as well as overall total exposure trend at follow-up remained consistent for the majority of micro-environment types.

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https://www.sciencedirect.com/science/article/pii/S0013935124005334?via%3Dihub

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**New-generation electronic appliances and cardiac implantable electronic devices: a systematic literature review of mechanisms and in vivo studies**

Kewcharoen J, Shah K, Bhardwaj R, Contractor T, Turagam MK, Mandapati R, Lakkireddy D, Garg J. New-generation electronic appliances and cardiac implantable electronic devices: a systematic literature

review of mechanisms and in vivo studies. J Interv Card Electrophysiol. 2024 Mar 5. doi: 10.1007/s10840-024-01777-z.

Abstract

Introduction: Cardiac implantable electronic device (CIED) functions are susceptible to electromagnetic interference (EMI) from electromagnetic fields (EMF). Data on EMI risks from new-generation electronic appliances (EA) are limited.

Objective: We performed a systematic literature review on the mechanisms of EMI, current evidence, and recently published trials evaluating the effect of EMF on CIEDs from electric vehicles (EV), smartphone, and smartwatch technology and summarize its safety data.

Methods: Electronic databases, including PubMed and EMBASE, were searched for in vivo studies evaluating EMF strength and incidence between CIEDs and commercial EVs, new-generation smartphones, and new-generation smartwatches.

Results: A total of ten studies (three on EVs, five on smartphones, one on smartphones, one on smartphones and smartwatches) were included in our systematic review. There was no report of EMI incidence associated with EVs or smartwatches. Magnet-containing smartphones (iPhone 12) can cause EMI when placed directly over CIEDs - thereby triggering the magnet mode; otherwise, no report of EMI was observed with other positions or smartphone models.

Conclusion: Current evidence suggests CIED recipients are safe from general interaction with EVs/HEVs, smartphones, and smartwatches. Strictly, results may only be applied to commercial brands or models tested in the published studies. There is limited data on EMI risk from EVs wireless charging and smartphones with MagSafe technology.

https://pubmed.ncbi.nlm.nih.gov/38443707/

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**Electric vehicles and health: A scoping review**

Pennington AF, Cornwell CR, Sircar KD, Mirabelli MC. Electric vehicles and health: A scoping review. Environ Res. 2024 Mar 16:118697. doi: 10.1016/j.envres.2024.118697.

Abstract

Background: The health impacts of the rapid transition to the use of electric vehicles are largely unexplored. We completed a scoping review to assess the state of the evidence on use of battery electric and hybrid electric vehicles and health.

Methods: We conducted a literature search of MEDLINE, Embase, Global Health, CINAHL, Scopus, and Environmental Science Collection databases for articles published January 1990 to January 2024. We included articles if they presented observed or modeled data on the association between battery electric or hybrid electric cars, trucks, or buses and health-related outcomes. We abstracted data and

summarized results.

Results: Out of 897 reviewed articles, 52 met our inclusion criteria. The majority of included articles examined transitions to the use of electric vehicles (n = 49, 94%), with fewer studies examining hybrid electric vehicles (n = 11, 21%) or plug-in hybrid electric vehicles (n = 8, 15%). The most common outcomes examined were premature death (n = 41, 79%) and monetized health outcomes such as medical expenditures (n = 33, 63%). We identified only one observational study on the impact of electric vehicles on health; all other studies reported modeled data. Almost every study (n = 51, 98%) reported some evidence of a positive health impact of transitioning to electric or hybrid electric vehicles, although magnitudes of association varied. There was a paucity of information on the environmental justice implications of vehicle transitions.

Conclusions: The results of the current literature on electric vehicles and health suggest an overall positive health impact of transitioning to electric vehicles. Additional observational studies would help expand our understanding of the real-world health effects of electric vehicles. Future research focused on the environmental justice implications of vehicle fleet transitions could provide additional information about the extent to which the health benefits occur equitably across populations.

https://pubmed.ncbi.nlm.nih.gov/38499224/

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**Electromagnetic exposure analysis of the subway passenger under the civil communication system radiation**

Zhou WY, Zhang XY, Lu M. Electromagnetic exposure analysis of the subway passenger under the civil communication system radiation. PLoS One. 2024 Mar 11;19(3):e0300049. doi: 10.1371/journal.pone.0300049.

Abstract

In order to assess the electromagnetic exposure safety of passengers under the civil communication system of the subway, the radio-frequency (RF) electromagnetic environment of subway carriage is established by using COMSOL Multiphysics software, it includes a 1-1/4 " leaky coaxial cable (LCX1) and a 1-5/8" leaky coaxial cable (LCX2), which are designed to be the exposure sources, and twelve passengers at different position. The electromagnetic environment model has been verified through field measurement. The exposure dose distribution of twelve passengers is compared and analyzed, when LCX1 and LCX2 works respectively. The simulated results show that, to compare with LCX2, the electromagnetic dose absorbed by the passengers is reduced by 9.19% and 22.50% at 2100 MHz and 2600 MHz respectively. The specific absorption rate (SAR) of passengers obtains the maximum value of $1.91\times10^{-4}$ W/Kg and the temperature rise to 0.214 K when the LCX1 works at 3400 MHz. By comparing with the public exposure limitation of the International Commission of Non-Ionizing Radiation Protection (ICNIRP), it demonstrates the electromagnetic exposure safety of the passengers under the civil communication system. More importantly, the proposed LCX1 not only could add the 5G signal cover but also lower the SAR absorbed by the passengers, which indicates that the public electromagnetic exposure dose could be reduced by adjusting the radiation performances of exposure source, which provide a new way for electromagnetic protecting.

Open access paper: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0300049

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**Impact of specific electromagnetic radiation on wakefulness in mice**

Deng H, Liu L, Tang X, Lu Y, Wang X, Zhao Y, Shi Y. Impact of specific electromagnetic radiation on wakefulness in mice. Proc Natl Acad Sci U S A. 2024 Apr 9;121(15):e2313903121. doi: 10.1073/pnas.2313903121.

Abstract

Electromagnetic radiation (EMR) in the environment, particularly in the microwave range, may constitute a public health concern. Exposure to 2.4 GHz EMR modulated by 100 Hz square pulses was recently reported to markedly increase wakefulness in mice. Here, we demonstrate that a similar wakefulness increase can be induced by the modulation frequency of 1,000 Hz, but not 10 Hz. In contrast to the carrier frequency of 2.4 GHz, 935 MHz EMR of the same power density has little impact on wakefulness irrespective of modulation frequency. Notably, the replacement of the 100 Hz square-pulsed modulation by sinusoidal-pulsed modulation of 2.4 GHz EMR still allows a marked increase of wakefulness. In contrast, continuous sinusoidal amplitude modulation of 100 Hz with the same time-averaged power output fails to trigger any detectable change of wakefulness. Therefore, alteration of sleep behavior by EMR depends upon not just carrier frequency but also frequency and mode of the modulation. These results implicate biological sensing mechanisms for specific EMR in animals.

Significance

Increased wakefulness in mice was previously found to be a direct result of prolonged exposure to 2.4 GHz electromagnetic radiation (EMR) with 100 Hz square-pulsed modulation at 1/8 duty cycle. Several key issues remain unaddressed. Does the frequency of the square-pulsed modulation matter? Are the sharp edges of the square pulses a major contributor to sleep/wakefulness alteration? Can carrier frequencies other than 2.4 GHz induce sleep/wakefulness alteration? Does the duty cycle matter? In this study, we answer these questions by demonstrating the dependency of sleep/wakefulness alteration on EMR modulation frequency, carrier frequency, and modulation mode.

Excerpts

Modeling and experimental assessment of human exposure to 935 MHz or 2.14 GHz EMR at a dose level of 3.6 W/kg local SAR revealed a maximal skin temperature increase of 0.31 °C and a brain temperature elevation of <0.1 °C (21). In our case, the maximum local SAR value measured with the cSAR3D testing system is 3.6 W/kg and the averaged SAR is 2.81 ± 0.15 W/kg. Hence, the observed EMR impact on sleep in our study is most likely nonthermal....

In conclusion, our study reveals distinct specificity of EMR. Prolonged exposure to the carrier frequency 2.4 GHz EMR with square pulse modulation of different frequencies induces varying changes of wakefulness in mice. In contrast to 2.4 GHz, the carrier frequency 935 MHz has little impact on wakefulness or NREM sleep. Then, 2.4 GHz EMR with sinusoidal pulse modulation, but not continuous sinusoidal modulation of 100 Hz, results in an increase in wakefulness. These findings link specific biological responses to specific parameters of EMR, namely carrier frequency, modulation frequency, and modulation mode. The underlying mechanisms for these observations remain to be unveiled.

https://pubmed.ncbi.nlm.nih.gov/38557178/

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**Effect of 2.45 GHz Microwave Radiation on the Inner Ear: A Histopathological Study on 2.45 GHz Microwave Radiation and Cochlea**

Tahir E, Akar Karadayı A, Gülşen Gürgen S, Korunur Engiz B, Turgut A. Effect of 2.45 GHz Microwave Radiation on the Inner Ear: A Histopathological Study on 2.45 GHz Microwave Radiation and Cochlea. J Int Adv Otol. 2024 Jan;20(1):35-43. doi: 10.5152/iao.2024.231142.

Abstract

Background: The present study aims to determine the possible low dose-dependent adverse effects of 2.45 GHz microwave exposure and Wi-Fi frequency on the cochlea.

Methods: Twelve pregnant female rats (n=12) and their male newborns were exposed to Wi-Fi frequencies with varying electric field values of 0.6, 1.9, 5, 10 V/m, and 15 V/m during the 21-day gestation period and 45 days after birth, except for the control group. Auditory brainstem response testing was performed before exposure and sacrification. After removal of the cochlea, histopathological examination was conducted by immunohistochemistry methods using caspase (cysteine-aspartic proteases, cysteine aspartates, or cysteine-dependent aspartate-directed proteases)-3, -9, and terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL). Kruskal-Wallis and Wilcoxon tests and multivariate analysis of variance were used.

Results: Auditory brainstem response thresholds in postexposure tests increased statistically significantly at 5 V/m and above doses. When the number of apoptotic cells was compared in immunohistochemistry examination, significant differences were found at 10 V/m and 15 V/m doses ($F(5,15)=23.203$, $P=.001$; Pillai's trace=1.912, $\eta 2=0.637$). As the magnitude of the electric field increased, all histopathological indicators of apoptosis increased. The most significant effect was noted on caspase-9 staining ($\eta 2$ c9=0.996), followed by caspase-3 ($\eta 2$ c3=0.991), and TUNEL staining ($\eta 2$ t=0.801). Caspase-3, caspase-9, and TUNEL-stained cell densities increased directly by increasing the electric field and power values.

Conclusion: Apoptosis and immune activity in the cochlea depend on the electric field and power value. Even at low doses, the electromagnetic field in Wi-Fi frequency damages the inner ear and causes apoptosis.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10895889/

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**Ashwagandha Diminishes Hippocampal Apoptosis Induced by Wi-Fi Radiation in Male Quails**

Gupta V, Srivastava R. Ashwagandha Diminishes Hippocampal Apoptosis Induced by Microwave Radiation by Acetylcholinesterase Dependent Neuro-Inflammatory Pathway in Male Coturnix coturnix Japonica. Neurochem Res. 2024 Mar 20. doi: 10.1007/s11064-024-04127-7.

Abstract

Microwave radiation (MWR) has been linked to neurodegeneration by inducing oxidative stress in the hippocampus of brain responsible for learning and memory. Ashwagandha (ASW), a medicinal plant is known to prevent neurodegeneration and promote neuronal health. This study investigated the effects of MWR and ASW on oxidative stress and cholinergic imbalance in the hippocampus of adult male Japanese quail. One control group received no treatment, the second group quails were exposed to MWR at 2 h/day for 30 days, third was administered with ASW root extract orally 100 mg/day/kg body weight and the fourth was exposed to MWR and also treated with ASW. The results showed that MWR increased serum corticosterone levels, disrupted cholinergic balance and induced neuro-inflammation. This neuro-inflammation further led to oxidative stress, as evidenced by decreased activity of antioxidant enzymes SOD, CAT and GSH. MWR also caused a significant decline in the nissil substances in the hippocampus region of brain indicating neurodegeneration through oxidative stress mediated hippocampal apoptosis. ASW, on the other hand, was able to effectively enhance the cholinergic balance and subsequently lower inflammation in hippocampus neurons. This suggests that ASW can protect against the neurodegenerative effects of MWR. ASW also reduced excessive ROS production by increasing the activity of ROS-scavenging enzymes. Additionally, ASW prevented neurodegeneration through decreased expression of caspase-3 and caspase-7 in hippocampus, thus promoting neuronal health. In conclusion, this study showed that MWR induces apoptosis and oxidative stress in the brain, while ASW reduces excessive ROS production, prevents neurodegeneration and promotes neuronal health.

Excerpt

Birds were exposed to 2.45 GHz of MW irradiation using Ruckus R310 Wi-fi router with maximum transmission strength of 25dbm at the middle of the cage. Average power density obtained within each partition of cage was found to be 0.1264 mw/cm$^2$ and overall specific absorption rate (SAR) obtained per bird was determined to be 0.9978 W/Kg.

https://pubmed.ncbi.nlm.nih.gov/38506951/

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**Does Microwave Exposure at Different Doses in the Pre/Postnatal Period Affect Growing Rat Bone Development?**

Karadayi A, Sarsmaz H, Çigel A, Engiz B, Ünal N, Ürkmez S, Gürgen S. Does Microwave Exposure at Different Doses in the Pre/Postnatal Period Affect Growing Rat Bone Development? Physiol Res. 2024 Mar 11;73(1):157-172.

Abstract

Effects of pre/postnatal 2.45 GHz continuous wave (CW), Wireless-Fidelity (Wi-Fi) Microwave (MW) irradiation on bone have yet to be well defined. The present study used biochemical and histological methods to investigate effects on bone formation and resorption in the serum and the tibia bone tissues

of growing rats exposed to MW irradiation during the pre/postnatal period. Six groups were created: one control group and five experimental groups subjected to low-level different electromagnetic fields (EMF) of growing male rats born from pregnant rats. During the experiment, the bodies of all five groups were exposed to 2.45 GHz CW-MW for one hour/day. EMF exposure started after fertilization in the experimental group. When the growing male rats were 45 days old in the postnatal period, the control and five experimental groups' growing male and maternal rats were sacrificed, and their tibia tissues were removed. Maternal rats were not included in the study. No differences were observed between the control and five experimental groups in Receptor Activator Nuclear factor-kB (RANK) biochemical results. In contrast, there was a statistically significant increase in soluble Receptor Activator of Nuclear factor-kB Ligand (sRANKL) and Osteoprotegerin (OPG) for 10 V/m and 15 V/m EMF values. Histologically, changes in the same groups supported biochemical results. These results indicate that pre/postnatal exposure to 2.45 GHz EMF at 10 and 15 V/m potentially affects bone development.

Excerpt

In the present study, the effects of 2.45 GHz MW radiation on the bone of healthy rat tibia exposed to different doses of EMF during the prenatal and postnatal period were investigated using biochemical methods such as RANK, RANKL, OPG, and histopathological methods such as Tunel and immunohistochemical straining. Our findings showed that 2.45 GHz low-level MW radiation at 10 V/m (the peak SAR 10g value 14.4 mW/kg) and 15 V/m (the peak SAR 10g value 33.8 mW/kg) could cause changes in the bone. To our knowledge, our study seems to be the first investigation in literature focusing on effects on the bone of 2.45 GHz low-level MW radiation at different EMF values. Additionally, this research is the first article to determine the level of thermal and non-thermal effects on bone.

Open access paper: http://www.biomed.cas.cz/physiolres/pdf/73/73_157.pdf

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**The neuroprotective effects of baobab and black seed on the rat hippocampus exposed to a 900-MHz electromagnetic field**

Mohamed H, Deniz OG, Kaplan S. The neuroprotective effects of baobab and black seed on the rat hippocampus exposed to a 900-MHz electromagnetic field. J Chem Neuroanat. 2024 Mar 4;137:102405. doi: 10.1016/j.jchemneu.2024.102405.

Abstract

This study investigated the potential effects on the hippocampus of electromagnetic fields (EMFs) disseminated by mobile phones and the roles of baobab (Adansonia digitata) (AD) and black seed (Nigella sativa) (BS) in mitigating these. Fifty-six male, 12-week-old Wistar albino rats were divided into eight groups of seven animals each. No EMF exposure was applied to the control, AD or BS groups, while the rats in the Sham group were placed in an EMF system with no exposure. A 900-MHz EMF was applied to the EMF+AD, EMF+BS, EMF+AD+BS and EMF groups for 1 hour a day for 28 days. Pyramidal neurons in the hippocampus were subsequently counted using the optical fractionator technique, one of the unbiased stereological methods. Tissue sections were also evaluated histopathologically under light and electron microscopy. The activities of the enzymes catalase (CAT) and superoxide dismutase (SOD) were also determined in blood serum samples. Analysis of the stereological data revealed no statistically significant differences between the EMF and control or sham groups in terms of pyramidal neuron

numbers ($p>0.05$). However, stereological examination revealed a crucial difference in the entire hippocampus between the control group and the AD ($p<0.01$) and BS ($p<0.05$) groups. Moreover, exposure to 900-MHz EMF produced adverse changes in the structures of neurons at histopathological analysis. Qualitative examinations suggest that a combination of herbal products such as AD and BS exerts a protective effect against such EMF side-effects.

https://pubmed.ncbi.nlm.nih.gov/38447905/

Conclusion

We suggest that using appropriate quantities of natural antioxidants in combination with foodstuffs can inhibit or reduce the harmful effects of EMF radiation on the neurons of the brain. The human population, and especially children, should also be protected against exposure to radiation, especially that emitted from mobile phones. To the best of our knowledge, no prior study has demonstrated the effect of AD and BS in the EMF exposed rat hippocampus. Further studies focusing on the effect mechanism of antioxidants, especially AD and BS, that may represent novel protective substances against the side-effects of EMF radiation in the hippocampus, are now needed. Research involving different methods, durations and doses is therefore required.

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**Health and environmental effects to wildlife from radio telemetry and tracking devices—state of the science and best management practices**

Manville AM, Levitt BB, Lai HC. Health and environmental effects to wildlife from radio telemetry and tracking devices—state of the science and best management practices. Frontiers in Veterinary Science, 11. 2024. doi: 10.3389/fvets.2024.1283709.

Abstract

This paper discusses the potential health risks and benefits to tagged wildlife from the use of radio tracking, radio telemetry, and related microchip and data-logger technologies used to study, monitor and track mostly wildlife in their native habitats. Domestic pets, especially canids, are briefly discussed as radio-tagging devices are also used on/in them. Radio tracking uses very high frequency (VHF), ultra-high frequency (UHF), and global positioning system (GPS) technologies, including via satellites where platform terminal transmitters (PTTs) are used, as well as geo-locating capabilities using satellites, radio-frequency identification (RFID) chips, and passive integrated responder (PIT) tags, among others. Such tracking technologies have resulted in cutting-edge findings worldwide that have served to protect and better understand the behaviors of myriad wildlife species. As a result, scientists, field researchers, technicians, fish and wildlife biologists and managers, plus wildlife and other veterinarian specialists, frequently opt for its use without fully understanding the ramifications to target species and their behaviors. These include negative physiological effects from electromagnetic fields (EMF) to which many nonhuman species are exquisitely sensitive, as well as direct placement/use-attachment impacts from radio collars, transmitters, and implants themselves. This paper provides pertinent studies, suggests best management practices, and compares technologies currently available to those considering and/or using such technologies. The primary focus is on the health and environmental risk/benefit decisions

that should come into play, including ethical considerations, along with recommendations for more caution in the wildlife and veterinarian communities before such technologies are used in the first place.

Open access paper: https://www.frontiersin.org/articles/10.3389/fvets.2024.1283709

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**Electromagnetic fields regulate iron metabolism in living organisms: A review of effects and mechanism**

Zhen C, Zhang G, Wang S, Wang J, Shang P. Electromagnetic fields regulate iron metabolism in living organisms: A review of effects and mechanism. Prog Biophys Mol Biol. 2024 Mar 4:S0079-6107(24)00023-3. doi: 10.1016/j.pbiomolbio.2024.03.001.

Abstract

The emergence, evolution, and spread of life on Earth have all occurred in the geomagnetic field, and its extensive biological effects on living organisms have been documented. The charged characteristics of metal ions in biological fluids determine that they are affected by electromagnetic field forces, thus affecting life activities. Iron metabolism, as one of the important metal metabolic pathways, keeps iron absorption and excretion in a relatively balanced state, and this process is precisely and completely controlled. It is worth paying attention to how the iron metabolism process of living organisms is changed when exposed to electromagnetic fields. In this paper, the processes of iron absorption, storage and excretion in animals (mammals, fish, arthropods), plants and microorganisms exposed to electromagnetic field were summarized in detail as far as possible, in order to discover the regulation of iron metabolism by electromagnetic field. Studies and data on the effects of electromagnetic field exposure on iron metabolism in organisms show that exposure profiles vary widely across species and cell lines. This process involves a variety of factors, and the complexity of the results is not only related to the magnetic flux density/operating frequency/exposure time and the heterogeneity of the observed object. A systematic review of the biological regulation of iron metabolism by electromagnetic field exposure will not only contributes to a more comprehensive understanding of its biological effects and mechanism, but also is necessary to improve human awareness of the health related risks of electromagnetic field exposure.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0079610724000233?via%3Dihub

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**0.263 terahertz irradiation induced genes expression changes in *Caenorhabditis elegans (roundworm)***

Shang S, Gao F, Zhang Q, Song T, Wang W, Liu D, Gong Y, Lu X. 0.263 terahertz irradiation induced genes expression changes in *Caenorhabditis elegans*. iScience. 2024 Mar 2;27(4):109391. doi: 10.1016/j.isci.2024.109391.

Abstract

The biosafety of terahertz (THz) waves has emerged as a new area of concern with the gradual application of terahertz radiation. Even though many studies have been conducted to investigate the

influence of THz radiation on living organisms, the biological effects of terahertz waves have not yet been fully revealed. In this study, *Caenorhabditis elegans* (*C. elegans*) was used to evaluate the biological consequences of whole-body exposure to 0.263 THz irradiation. The integration of transcriptome sequencing and behavioral tests of *C. elegans* revealed that high-power THz irradiation damaged the epidermal ultrastructures, inhibited the expression of the cuticle collagen genes, and impaired the movement of *C. elegans*. Moreover, the genes involved in the immune system and the neural system were dramatically down-regulated by high-power THz irradiation. Our findings offer fresh perspectives on the biological impacts of high-power THz radiation that could cause epidermal damage and provoke a systemic response.

Open access paper: https://www.cell.com/iscience/fulltext/S2589-0042(24)00612-6

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**Environmental Pollution and Risk of Childhood Cancer: A Scoping Review of Evidence from the Last Decade**

Navarrete-Meneses MdP, Salas-Labadía C, Gómez-Chávez F, Pérez-Vera P. Environmental Pollution and Risk of Childhood Cancer: A Scoping Review of Evidence from the Last Decade. *International Journal of Molecular Sciences*. 2024; 25(6):3284. doi: 10.3390/ijms25063284.

Abstract

The long-term effects of environmental pollution have been of concern as several pollutants are carcinogenic, potentially inducing a variety of cancers, including childhood cancer, which is a leading cause of death around the world and, thus, is a public health issue. The present scoping review aimed to update and summarize the available literature to detect specific environmental pollutants and their association with certain types of childhood cancer. Studies published from 2013 to 2023 regarding environmental pollution and childhood cancer were retrieved from the PubMed database. A total of 174 studies were eligible for this review and were analyzed. Our search strategy brought up most of the articles that evaluated air pollution (29%) and pesticides (28%). Indoor exposure to chemicals (11%), alcohol and tobacco use during pregnancy (16%), electromagnetic fields (12%), and radon (4%) were the subjects of less research. We found a particularly high percentage of positive associations between prenatal and postnatal exposure to indoor (84%) and outdoor (79%) air pollution, as well as to pesticides (82%), and childhood cancer. Positive associations were found between leukemia and pesticides and air pollution (33% and 27%); CNS tumors and neuroblastoma and pesticides (53% and 43%); and Wilms tumor and other rare cancers were found in association with air pollution (50%). Indoor air pollution was mostly reported in studies assessing several types of cancer (26%). Further studies are needed to investigate the mechanisms underlying the potential associations between indoor/outdoor air pollution and pesticide exposure with childhood cancer risk as more preventable measures could be taken.

Open access paper: https://www.mdpi.com/1422-0067/25/6/3284

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**A broadband multi-frequency microwave combined biological exposure setup**

Zhao X, Li Z, Liu X, Wang Y, Dong G, Liu Q, Wang C. A broadband multi-frequency microwave combined biological exposure setup. *Rev. Sci. Instrum.* 1 April 2024; 95 (4): 044702. doi: 10.1063/5.0196908

Abstract

With the rapid popularization of wireless electronic devices, there has been an increasing concern about the impacts of the electromagnetic environment on health. However, most research reports on the biological effects of microwaves have focused on a single frequency point. In reality, people are exposed to complex electromagnetic environments that consist of multiple frequency microwave signals in their daily lives. It is important to investigate whether multi-frequency combined microwave energies have different biological effects compared with single frequency microwave energy. Unfortunately, there are limited reports on this topic due to the lack of suitable platforms for research on multi-frequency microwave energy combined with biological exposure. To address this issue, this study presents a setup that has a very wide working frequency bandwidth and can be compatible with single frequency and multi-frequency microwave combined exposure. Moreover, it can achieve relatively equal exposure to multiple biological samples at any frequency point in the working frequency range, which is crucial for electromagnetic biology research. The experimental results are in good agreement with the simulation results, confirming its capability to facilitate the study of complex electromagnetic environment effects on organisms.

Open access paper: https://pubs.aip.org/aip/rsi/article/95/4/044702/3280194/A-broadband-multi-frequency-microwave-combined

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**The effects of radiofrequency electromagnetic fields exposure on tinnitus, migraine and non-specific symptoms in the general and working population: A systematic review and meta-analysis on human observational studies**

My note: Numerous problems have been identified with this paper and other systematic reviews commissioned by the WHO for an upcoming monograph on radio frequency effects.

Röösli M, Dongus S, Jalilian H, Eyers J, Esu E, Oringanje CM, Meremikwu M, Bosch-Capblanch X. The effects of radiofrequency electromagnetic fields exposure on tinnitus, migraine and non-specific symptoms in the general and working population: A systematic review and meta-analysis on human observational studies. Environ Int. 2024 Jan;183:108338. doi: 10.1016/j.envint.2023.108338.

Abstract

Background: Applications emitting radiofrequency electromagnetic fields (RF-EMF; 100 kHz to 300 GHz) are widely used for communication (e.g. mobile phones), in medicine (diathermy) and in industry (RF heaters).

Objectives: The objective is to systematically review the effects of longer-term or repeated local and whole human body radiofrequency electromagnetic field (RF-EMF) exposure on the occurrence of symptoms. Primary hypotheses were tinnitus, migraine and headaches in relation to RF-EMF exposure of the brain, sleep disturbances and composite symptom scores in relation to whole-body RF-EMF exposure.

Methods: Eligibility criteria: We included case-control and prospective cohort studies in the general population or workers estimating local or whole-body RF-EMF exposure for at least one week.

Information sources: We conducted a systematic literature search in various databases including Web of Science and Medline. Risk of bias: We used the Risk of Bias (RoB) tool developed by OHAT adapted to the topic of this review.

Synthesis of results: We synthesized studies using random effects meta-analysis.

Results: Included studies: We included 13 papers from eight distinct cohort and one case-control studies with a total of 486,558 participants conducted exclusively in Europe. Tinnitus is addressed in three papers, migraine in one, headaches in six, sleep disturbances in five, and composite symptom scores in five papers. Only one study addressed occupational exposure.

Synthesis of results: For all five priority hypotheses, available research suggests that RF-EMF exposure below guideline values does not cause symptoms, but the evidence is very uncertain. The very low certainty evidence is due the low number of studies, possible risk of bias in some studies, inconsistencies, indirectness, and imprecision. In terms of non-priority hypotheses numerous exposure-outcome combinations were addressed in the 13 eligible papers without indication for an association related to a specific symptom or exposure source.

Discussion: Limitations of evidence: This review topic includes various challenges related to confounding control and exposure assessment. Many of these aspects are inherently present and not easy to be solved in future research. Since near-field exposure from wireless communication devices is related to lifestyle, a particular challenge is to differentiate between potential biophysical effects and other potential effects from extensive use of wireless communication devices that may compete with healthy behaviour such as sleeping or physical activity. Future research needs novel and innovative methods to differentiate between these two hypothetical mechanisms.

Interpretation: This is currently the best available evidence to underpin safety of RF-EMF. There is no indication that RF-EMF below guideline values causes symptoms. However, inherent limitations of the research results in substantial uncertainty.

Other: Funding: This review was partially funded by the WHO radioprotection programme.

Registration: The protocol for this review has been registered in Prospero (reg no CRD42021239432) and published in Environment International (Röösli et al., 2021).

Declaration of competing interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Martin Röösli's research is entirely funded by public or not-for-profit foundations. He has served as advisor to a number of national and international public advisory and research steering groups concerning the potential health effects of exposure to nonionizing radiation, including the World Health Organization, the International Agency for Research on Cancer, the International Commission on Non-Ionizing Radiation Protection, the Swiss Government (member of the working group "mobile phone and radiation" and chair of the expert group BERENIS), the German Radiation Protection Commission

(member of the committee Non-ionizing Radiation (A6) and member of the working group 5G (A630)) and the Independent Expert Group of the Swedish Radiation Safety Authority.

https://www.sciencedirect.com/science/article/pii/S0160412023006116?via%3Dihub

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**Effects of radiofrequency electromagnetic field (RF-EMF) exposure on male fertility: A systematic review of experimental studies on non-human mammals and human sperm in vitro (SR 4)**

My note: Numerous problems have been identified with this paper and other systematic reviews commissioned by the WHO for an upcoming monograph on radio frequency effects.

Cordelli E, Ardoino L, Benassi B, Consales C, Eleuteri P, Marino C, Sciortino M, Villani P, Brinkworth MH, Chen G, McNamee JP, Wood AW, Belackova L, Verbeek J, Pacchierotti F. Effects of radiofrequency electromagnetic field (RF-EMF) exposure on male fertility: A systematic review of experimental studies on non-human mammals and human sperm in vitro. Environment International. 2024, doi: 10.1016/j.envint.2024.108509. Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024000953

Highlights

Risk of bias, inconsistency, publication bias weakened the certainty of results
RF-EMF is unlike to decrease the fecundity of exposed male rodents.
RF-EMF may affect testicular tissue and sperm quality but the evidence is uncertain.
Impact on surrogate markers of fertility may not translate into functional effects.

Abstract

Background  The World Health Organization is coordinating an international project aimed at systematically reviewing the evidence regarding the association between radiofrequency electromagnetic field (RF-EMF) exposure and adverse health effects. Reproductive health outcomes have been identified among the priority topics to be addressed.

Objectives  To evaluate the effect of RF-EMF exposure on male fertility of experimental mammals and on human sperm exposed in vitro.

Methods  Three electronic databases (PubMed, Scopus and EMF Portal) were last searched on September 17, 2022. Two independent reviewers screened the studies, which were considered eligible if met the following criteria: 1) Peer-reviewed publications of sham controlled experimental studies, 2) Non-human male mammals exposed at any stage of development or human sperm exposed in vitro, 3) RF-EMF exposure within the frequency range of 100 kHz-300 GHz, including electromagnetic pulses (EMP), 4) one of the following indicators of reproductive system impairment:•decrease of fertility: rate of infertile males, rate of nonpregnant females, litter size and in vitro fertilization rate;•effects on semen quality: in animal studies sperm count, in both animal and in vitro studies sperm vitality, morphology and DNA/chromatin alterations;•reproductive organ toxicity: testis-epididymis weight, testis or epididymis histology, testis histomorphometry, testicular cell death, estimated testicular cell

production;•hormonal effects: testosterone level.Two reviewers extracted study characteristics and outcome data. We assessed risk of bias (RoB) using the Office of Health Assessment and Translation (OHAT) guidelines. We categorized studies into 3 levels of overall RoB: low, some or high concern. We pooled study results in a random effects meta-analysis comparing average exposure to no-exposure and in a dose–response meta-analysis using all exposure doses. For experimental animal studies, we conducted subgroup analyses for species, Specific Absorption Rate (SAR) and temperature increase. We grouped studies on human sperm exposed in vitro by the fertility status of sample donors and SAR. We assessed the certainty of the evidence using the GRADE approach after excluding studies that were rated as "high concern" for RoB.

Results  One-hundred and seventeen papers on animal studies and 10 papers on human sperm exposed in vitro were included in this review. Only few studies were rated as "low concern" because most studies were at RoB for exposure and/or outcome assessment. Subgrouping the experimental animal studies by species, SAR, and temperature increase partly accounted for the heterogeneity of individual studies in about one third of the meta-analyses. In no case was it possible to conduct a subgroup analysis of the few human sperm in vitro studies because there were always 1 or more groups including less than 3 studies. Among all the considered endpoints, the meta-analyses of animal studies provided evidence of adverse effects of RF-EMF exposure in all cases but the rate of infertile males and the size of the sired litters. The assessment of certainty according to the GRADE methodology assigned a moderate certainty to the reduction of pregnancy rate and to the evidence of no-effect on litter size, a low certainty to the reduction of sperm count, and a very low certainty to all the other meta-analysis results. Studies on human sperm exposed in vitro indicated a small detrimental effect of RF-EMF exposure on vitality and no-effect on DNA/chromatin alterations. According to GRADE, a very low certainty was attributed to these results. The few studies that used EMP exposure did not show effects on the outcomes. A low to very low certainty was attributed to these results.

Discussion  Many of the studies examined suffered of severe limitations that led to the attribution of uncertainty to the results of the meta-analyses and did not allow to draw firm conclusions on most of the endpoints. Nevertheless, the associations between RF-EMF exposure and decrease of pregnancy rate and sperm count, to which moderate and low certainty were attributed, are not negligible, also in view of the indications that in Western countries human male fertility potential seems to be progressively declining. It was beyond the scope of our systematic review to determine the shape of the dose–response relationship or to identify a minimum effective exposure level. The subgroup and the dose–response fitting analyses did not show a consistent relationship between the exposure levels and the observed effects. Notably, most studies evaluated RF-EMF exposure levels that were higher than the levels to which human populations are typically exposed, and the limits set in international guidelines. For these reasons we cannot provide suggestions to confirm or reconsider current human exposure limits. Considering the outcomes of this systematic review and taking into account the limitations found in several of the studies, we suggest that further investigations with better characterization of exposure and dosimetry including several exposure levels and blinded outcome assessment were conducted. Protocol registration: Protocols for the systematic reviews of animal studies and of human sperm in vitro studies were published in Pacchierotti et al., 2021. The former was also registered in PROSPERO (CRD42021227729 https://www.crd.york.ac.uk/prospero/display_record.php?RecordID = 227729) and the latter in Open Science Framework (OSF Registration DOI https://doi.org/10.17605/OSF.IO/7MUS3).

**Excerpts**

4.4. Implications for policy and research

In conclusion, our systematic review and *meta*-analyses indicate a possible detrimental effect of RF-EMF exposure on pregnancy rate and sperm count in experimental mammals, whereas the *meta*-analysis of data on litter size was consistent with null.

Although sperm count is not a functional indicator of male fertility, it is a well-standardised analysis routinely applied in clinical andrology. RF-EMF emitting devices are widely applied and epidemiological surveys seem to indicate that, in Western countries, male fertility potential is declining (Auger et al., 2022, Boulicault et al., 2022, Levine et al., 2017). For these reasons the results of our meta-analyses should not be overlooked at a policy level.

It was beyond the scope of our systematic review to determine the shape of the dose–response relationship or to identify a minimum effective exposure level. For these reasons, we cannot provide suggestions to confirm or reconsider current human exposure limits. Nevertheless, it is of note that most studies on male fertility, semen quality and reproductive organ toxicity investigated exposure levels which were rather high with respect to those relevant for human populations: 75–80 % tested exposure levels above 0.4 W/kg (ICNIRP basic restriction for workers) and 46–53 % tested exposure levels above 4 W/kg (ICNIRP health effect level) (ICNIRP, 2020). Thus, it is not known the extent to which the conclusions of the SR meta-analysis can be applied to human exposure levels. Similarly, it is unknown how much our conclusion can be extrapolated to frequencies below 100 MHz and above 10000 MHz, for which only very few studies were retrieved.

During the systematic review, we identified several methodological limitations in the studies that should be overcome to improve the quality of future research. In particular, blinding during experiment performance and outcome assessment should always be applied to minimize bias, an adequate number of cytological or histological preparations should be analysed, automated methods of analysis should be applied whenever possible, a more standardized and complete reporting of technical methods and results should be adopted. Many studies had to be excluded from the systematic review because of insufficient exposure characterization and a large proportion of included studies were rated at either 'some' or 'high concern' for RoB for similar reasons. We would recommend that future studies bear the reasons for exclusion or RoB concerns in mind in study design and implementation. There are several papers in the research literature with recommendations on how exposure characterisation concerns can be mitigated, for example Kuster and Schonborn (2000). Finally, studies investigating not just a single level but several exposure levels, spanning from low levels comparable to human exposure to higher levels where mild hyperthermic effects could be expected, should be conducted under the same experimental conditions and target tissue temperature monitoring should be employed.

As a final suggestion for future research, we consider it a priority to obtain a scientifically solid database of possible RF-EMF effects on the best predictive surrogate markers of male infertility in experimental rodents. Based on the results of this research, the possibility of testing directly the RF-EMF impact on male reproductive performance could be considered. In view of the limitations of the approach applying *in vitro* exposure of human sperm, we do not recommend further studies of this kind. Conversely, we suggest exploiting semen quality analysis in human biomonitoring investigations of RF-EMF exposed populations....

Other reviews assessing the impact of RF-EMF exposure on male fertility have recently been published, but these only partially assessed the available literature data (Kesari et al., 2018, Sciorio et al., 2022, Sterling et al., 2022, Vornoli et al., 2019). The few recently published systematic reviews on this topic suffered from some methodological limitations such as the lack of a Risk of Bias analysis (Jaffar et al.,

2019, Kim et al., 2021), they limited analysis to only assess effects on semen parameters or were limited to exposure conditions relevant to mobile phone exposures thereby imposing a SAR cut-off (Yu et al., 2021). International committees on human health protection from electromagnetic fields were unable to draw firm conclusions on the possibility of an adverse effect of RF-EMF on male fertility at exposure levels where humans are typically exposed (ICNIRP, 2020, SCENIHR, 2015)....

We considered only original, controlled experimental studies published in peer-reviewed journals. We excluded non-experimental studies (e.g., human epidemiologic or other observational studies), and studies of exposure of both males and females of a mating pair (additional decision and change from protocol, see Section 4.5.2). We excluded papers reporting reviews, opinions, proceedings or meeting abstracts. We did not impose any year-of-publication or language restriction....

For each endpoint, we first conducted a meta-analysis of exposed vs sham control comparisons. When a study had several exposure groups matched to the same comparator, the means and standard deviations of these exposed groups were combined into one exposed group using the formulas provided in the paragraph 6.5.2.10 of the Cochrane Handbook (Higgins and Li, 2022), so that each study was entered only once into the meta-analysis. The exposure level assigned to that combined exposed group was calculated as the average SAR of the exposed groups in that study weighed by the number of animals in each exposed group. In the forest plots this is indicated with an asterisk after the study ID. Studies that compared each exposed group to another separate sham control group were entered as separate studies in the meta-analysis. When multiple studies were reported in the same paper, this is indicated with a number after the study ID in the forest plot....

All data subject to a *meta*-analysis were graphically synthesized by forest plots. A forest plot was drawn in which the studies were divided according to their overall RoB level as “low or some concern” or “high concern”. We decided to exclude from the assessment of the pooled effect sizes the studies rated at “high concern” for RoB in order to draw conclusions based upon the most robust data (see Section 4.5.2)....

After reading the full text, 175 papers on animal studies were excluded. They are listed in Supplementary File 1a with a justification of the exclusion rationale together with those not retrieved or not translated. Over 45 % of the animal studies were excluded because essential information was missing regarding exposure set-up and/or dosimetry, e.g., details on how the exposure system output was established and maintained or exposure frequency. A further 27 % of the studies were excluded because outcome data were deemed out-of-scope or invalid....

Regarding studies on human sperm in vitro, we excluded 33 papers after reading the full text (Supplementary File 1b). Most papers were excluded because they did not report peer-reviewed original results. Other papers could not be included in the systematic review because exposure conditions and/or dosimetry were insufficiently reported or because the exposure conditions did not provide a sufficient exposure contrast between RF-EMF exposed and sham-exposed samples....

4.1. Summary of the evidence and interpretation of the results  From experimental animal studies there is moderate certainty of evidence that RF-EMF exposure reduces rate of pregnancy, moderate certainty of evidence that exposure does not reduce litter size, and low certainty of evidence that exposure lowers sperm count. All other results of animal studies and all results on human sperm exposed *in vitro* have very low certainty. We retrieved few independent studies reporting male reproductive effects after experimental animal exposure to EMP. For this source of exposure, results on pregnancy rate, litter size

and sperm count, all consistent with null, have a low certainty. All other results have a very low certainty.

It can be asked whether the results of our *meta*-analyses are consistent with the hypothesis that higher exposure levels, especially those inducing an hyperthermic effect, are more biologically effective than lower exposure levels. The result on the decrease of pregnancy rate is consistent with this hypothesis, as shown by the observation that the pooled effect size is statistically significant only in the subgroup of studies exposed to SAR equal to or higher than 5 W/kg and the statistically significant slope of the linear dose–response relationship. On the other hand, the results on sperm count do not show an increase of the detrimental effect with increasing SAR and all the models of dose–response relationship tested fit the data poorly. Also for other endpoints (the results of which were rated at very low certainty), a direct relationship between the effect and the exposure level is not evident by the subgroup and dose–response analyses and, in some cases, even the possibility of an inverse relationship is suggested by the data. However, this suggestion is not sustained by a solid adverse outcome pathway, and, in some cases, it is based only on few independent studies. We tested if other variables unequally distributed among the subgroups could have a role in increasing the heterogeneity of the observed results and could confound any underlying dose–effect relationship. Indeed, we showed that the absence of blinding during outcome assessment could strongly influence the results for those endpoints that were not measured by automated methods, thus supporting this hypothesis.

4.2. Limitations in the evidence  Of all the papers included in the database of animal studies after the title/abstract evaluation, about 60 % had to be excluded for different reasons, with poor exposure characterization accounting for about 45 % of them....

Financial support  This project was partially funded by the World Health Organization (contracts 2020/1026306–0, 2022/1275453–1). WHO provided the basis for the protocol and methodological support throughout the review process. Additional in-kind funds were provided by ENEA, Health Canada and Swinburne University of Technology.

Declaration of competing interest  The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments  We are grateful to Emilie van Deventer, Maria Rosaria Scarfì and Eric van Rongen for advice regarding the protocols draft and for discussions to ensure consistency in approaches across the multiple ongoing WHO systematic reviews. We wish to thank Flavio Di Marzio for his appreciated graphical help.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024000953

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**Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study**

My note: This cohort study suffers from numerous methodological problems that undermine the authors' results and conclusions.

Feychting M, Schüz J, Toledano MB, Vermeulen R, Auvinen A, Poulsen AH, Deltour I, Smith RB, Heller J, Kromhout H, Huss A, Johansen C, Tettamanti G, Paul Elliott P. Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study. Environment International. 2024, doi: 10.1016/j.envint.2024.108552.

Abstract

Background  Each new generation of mobile phone technology has triggered discussions about potential carcinogenicity from exposure to radiofrequency electromagnetic fields (RF-EMF). Available evidence has been insufficient to conclude about long-term and heavy mobile phone use, limited by differential recall and selection bias, or crude exposure assessment. The Cohort Study on Mobile Phones and Health (COSMOS) was specifically designed to overcome these shortcomings.

Methods  We recruited participants in Denmark, Finland, the Netherlands, Sweden, and the UK 2007–2012. The baseline questionnaire assessed lifetime history of mobile phone use. Participants were followed through population-based cancer registers to identify glioma, meningioma, and acoustic neuroma cases during follow-up. Non-differential exposure misclassification was reduced by adjusting estimates of mobile phone call-time through regression calibration methods based on self-reported data and objective operator-recorded information at baseline. Hazard ratios (HR) and 95% confidence intervals (CI) for glioma, meningioma, and acoustic neuroma in relation to lifetime history of mobile phone use were estimated with Cox regression models with attained age as the underlying time-scale, adjusted for country, sex, educational level, and marital status.

Results  264,574 participants accrued 1,836,479 person-years. During a median follow-up of 7.12 years, 149 glioma, 89 meningioma, and 29 incident cases of acoustic neuroma were diagnosed. The adjusted HR per 100 regression-calibrated cumulative hours of mobile phone call-time was 1.00 (95 % CI 0.98–1.02) for glioma, 1.01 (95 % CI 0.96–1.06) for meningioma, and 1.02 (95 % CI 0.99–1.06) for acoustic neuroma. For glioma, the HR for ≥ 1908 regression-calibrated cumulative hours (90th percentile cut-point) was 1.07 (95 % CI 0.62–1.86). Over 15 years of mobile phone use was not associated with an increased tumour risk; for glioma the HR was 0.97 (95 % CI 0.62–1.52).

Conclusions  Our findings suggest that the cumulative amount of mobile phone use is not associated with the risk of developing glioma, meningioma, or acoustic neuroma.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024001387

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**Headache in the international cohort study of mobile phone use and health (COSMOS) in the Netherlands and the United Kingdom**

My note: This cohort study suffers from numerous methodological problems that undermine the authors' results and conclusions.

Traini E, Smith RB, Vermeulen R, Kromhout H, Schüz J, Feychting M, Auvinen A, Poulsen AH, Deltour I, Muller DC, Heller J, Tettamanti G, Elliott P, Huss A, Toledano MB. Headache in the international cohort study of mobile phone use and health (COSMOS) in the Netherlands and the United Kingdom. Environmental Research. 2024. doi: 10.1016/j.envres.2024.118290.

Highlights

- Prospective study exploring the relationship between mobile phone use and headache.
- Associations with call-time were largely explained by texting.
- Associations likely to reflect behavioural aspects of mobile phone use.

Abstract

Headache is a common condition with a substantial burden of disease worldwide. Concerns have been raised over the potential impact of long-term mobile phone use on headache due to radiofrequency electromagnetic fields (RF-EMFs). We explored prospectively the association between mobile phone use at baseline (2009–2012) and headache at follow-up (2015–2018) by analysing pooled data consisting of the Dutch and UK cohorts of the Cohort Study of Mobile Phone Use and Health (COSMOS) (N = 78,437). Frequency of headache, migraine, and information on mobile phone use, including use of hands-free devices and frequency of texting, were self-reported. We collected objective operator data to obtain regression calibrated estimates of voice call duration. In the model mutually adjusted for call-time and text messaging, participants in the high category of call-time showed an adjusted odds ratio (OR) of 1.04 (95 % CI: 0.94–1.15), with no clear trend of reporting headache with increasing call-time. However, we found an increased risk of weekly headache (OR = 1.40, 95 % CI: 1.25–1.56) in the high category of text messaging, with a clear increase in reporting headache with increasing texting. Due to the negligible exposure to RF-EMFs from texting, our results suggest that mechanisms other than RF-EMFs are responsible for the increased risk of headache that we found among mobile phone users.

Excerpts

A study conducted in Sweden and Finland as part of COSMOS found limited evidence for an association between weekly headache and the highest level of mobile phone use and no clear trend with increasing call-time (Auvinen et al., 2019). The association of headache with call-time appeared stronger for calls via the Universal Mobile Telecommunication System (UMTS) (3G) network than via the older Global System for Mobile (GSM) (2G) telecommunications technology, despite the latter involving higher RF-EMF exposure levels to the head (van Wel et al., 2021) ....

Headache has been linked to excessive mobile phone use, but the mechanism by which mobile phone use may cause symptoms is not properly understood (Wang et al., 2017; Cerutti et al., 2016; Frey, 1998; Hocking, 1998; Oftedal et al., 2000; Schoeni et al., 2015). Previous research in adolescents has suggested that other exposures related to mobile phone use, but not exposure to RF-EMFs, should be considered the causal factor for various symptoms, as the strongest associations were found with activities that cause minimal RF-EMF exposure to the head, such as texting or gaming (Schoeni et al., 2017). Other studies have indicated that stress or unfavourable usage, such as late-night use, may be associated with an increase in reported health symptoms, such as headache (Szyjkowska et al., 2014; Röösli, 2008; Thomée et al., 2011). It is therefore crucial to distinguish between using a mobile phone for calling and other activities that expose the brain to RF-EMFs at lower levels, such as Internet browsing (Cabré-Riera et al., 2022a; SSM's Scientific Council on Electromagnetic Fields, 2020).

Our study attempted to disentangle the exposure-outcome gradient by considering call-time as a proxy for RF-EMF exposure and texting as a proxy for usage with negligible RF-EMF exposure to the brain (Wall

et al., 2019). This study's mobile phone usage data was gathered between 2009 and 2012. During those years, texting was the most popular activity unrelated to RF-EMF exposure.....

The Headache Impact Test (HIT-6) score with a cut-off of 56 points defined severe weekly headache. The HIT-6 is a tool used to measure the impact headaches have on one's ability to function in various aspects of daily life, including work, school, home, and social contexts. The score, ranging from 36 to 78 points, provides a measure of the degree to which headaches affect daily life and functioning, with higher scores indicating a more significant impact on the participant's overall life (Kosinski et al., 2003)....

Results from two-exposure models mutually adjusting for both call-time and texting at baseline, showed substantially lower risk estimates for weekly headache in the high call-time (RC-hfa) category (OR = 1.04, 95 % CI: 0.94–1.15), and no evidence of a trend (P trend = 0.292) (Table 2). Associations with texting were robust to adjustment for call-time: we observed an increased risk of weekly headache in the high category of texting (OR = 1.40, 95 % CI: 1.25–1.56) and a trend of increasing risk with increasing texting frequency (P trend<0.001), in line with results from the single-exposure model (Table 3)....

In this large international prospective cohort of mobile phone users in the Netherlands and the UK, mobile phone use for calling and texting at baseline was associated with headaches at follow-up. Mutually adjusting for both call-time and texting considerably attenuated risk estimates for call-time, while associations with texting were still strong and robust to adjustment, with a clear exposure-outcome gradient.

Headache has been linked to excessive mobile phone use, but the mechanism by which mobile phone use may cause symptoms is not properly understood (Wang et al., 2017; Cerutti et al., 2016; Frey, 1998; Hocking, 1998; Oftedal et al., 2000; Schoeni et al., 2015). Previous research in adolescents has suggested that other exposures related to mobile phone use, but not exposure to RF-EMFs, should be considered the causal factor for various symptoms, as the strongest associations were found with activities that cause minimal RF-EMF exposure to the head, such as texting or gaming (Schoeni et al., 2017)....

Our study attempted to disentangle the exposure-outcome gradient by considering call-time as a proxy for RF-EMF exposure and texting as a proxy for usage with negligible RF-EMF exposure to the brain (Wall et al., 2019). This study's mobile phone usage data was gathered between 2009 and 2012. During those years, texting was the most popular activity unrelated to RF-EMF exposure.

In both scenarios, we found an increased risk of headache in the high exposure category of mobile phone use with a positive exposure-outcome gradient confirmed by the test for trend. The attenuated risk estimates for call-time in the mutually adjusted model argue against an effect of exposure to RF-EMFs due to the negligible exposure attributed to texting. This conclusion is also supported by comparing call-time analyses with and without hands-free adjustment, where no risk reduction was found among users for the adjusted exposure metrics....

Regarding secondary health outcomes, we found consistent patterns of results for severe weekly headache and migraine at follow-up in terms of increased risk estimates and significant trends. Increasing risk of daily headache was associated with increasing texting (P trend<0.001) but not with increasing call-time (P trend = 0.448) (Table 2, Table 3).

In both scenarios, we found an increased risk of headache in the high exposure category of mobile phone use with a positive exposure-outcome gradient confirmed by the test for trend. The attenuated risk estimates for call-time in the mutually adjusted model argue against an effect of exposure to RF-EMFs due to the negligible exposure attributed to texting. This conclusion is also supported by comparing call-time analyses with and without hands-free adjustment, where no risk reduction was found among users for the adjusted exposure metrics.

In this study, the distribution of the exposure, specifically regarding call-time, differed between Dutch and UK participants. Mobile phone usage behaviour across countries cannot be assumed to be identical due to various factors such as cultural, economic, technological, and market dynamics (Böhm, 2015). To assess the consistency of our findings, we showed that defining the top exposure category for call-time based on the 80th percentile cut-off, thereby ensuring the inclusion of Dutch participants in the "high" exposure category, yielded results consistent with those obtained using the 90th percentile as a cut-off. These findings suggested that the association we found between call-time and headache was driven not only by UK but also Dutch participants. Of note, all analyses were adjusted for country of residence....

Our study also has limitations. First, we did not have information about "true" RF-EMF exposure. Exposure to RF-EMFs emitted by wireless devices is difficult to quantify, particularly in large populations and over extended periods, as it depends on different factors, such as reception quality or other factors influencing signal strength. In our study, we calculated several exposure metrics as proxies for RF-EMF exposure, which allowed us to estimate the average individual RF-EMF exposure in the population. Additionally, information on other aspects of usage, such as screen time, blue light exposure or unfavourable use at night, may be helpful to include in future studies.

For highly transient and acute symptoms such as headache, using the peak of RF-EMF exposure might be theoretically preferable over the weekly exposure assessed in our study. However, adopting this approach would require substantially different exposure assessment methods that are impractical for large cohort studies, such as asking participants to regularly fill in a detailed usage diary. Given the study design and methodology used to assess RF-EMF exposure in COSMOS, the analysis of the association between RF-EMF peak exposure and reporting of headache symptoms was precluded. In light of the transient nature of headaches, future research may explore the potential effect of peak RF-EMF exposure on symptom onset more thoroughly.

The composition of the Dutch cohort is not representative of the adult population of the Netherlands with respect to sex and age....

Conclusions

In summary, we found that the use of mobile phones, particularly texting, is associated with headaches and migraines, and the associations with call-time were largely explained by texting. As the associations are driven more by text messaging than call-time, they do not appear to be explained by RF-EMF exposure from the mobile device but are likely to reflect lifestyle, other exposures, or behavioural factors associated with mobile phone use.

Declaration of competing interest [Note that text is missing from this paragraph.]

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Maria Feychting reports financial support was provided by Swedish Research Council. Maria Feychting reports financial support was provided by AFA Insurance. Maria Feychting reports financial support was provided by Swedish Research Council for Health, Working Life and Welfare. Maria Feychting reports financial support was provided by Swedish Radiation Safety Authority. Maria Feychting reports financial support was provided by Sweden's Innovation Agency. Paul Elliott reports financial support was provided by Mobile Telecommunications and Health Research. Paul Elliott reports financial support was provided by National Institute for Health and Care Research Health Protection Research Unit. Anssi Auvinen reports financial support was provided by National Technology Agency (TEKES). Anssi Auvinen reports financial support was provided by Pirkanmaa Hospital District. Anssi Auvinen reports financial support was provided by Yrjö Jahnsson Foundation. Anssi Auvinen reports financial support was provided by Mobile Manufacturers Forum. Roel Vermeulen reports financial support was provided by Netherlands Organisation for Health Research and Development. Aslak Harbo Poulsen reports financial support was provided by the Danish Strategic Research Council. Joachim Schuz reports financial support was provided by French Agency for Food, Environmental and Occupational Health & Safety (ANSES). Maria Feychting reports a relationship with World Health Organization that includes:. Maria Feychting reports a relationship with Public Health England Advisory Group on Non-ionizing Radiation that includes:. Maria Feychting reports a relationship with Norwegian Institute of Public Health that includes:. Maria Feychting reports a relationship with Forskningsrådet för hälsa arbetsliv och välfärd that includes:. Maria Feychting reports a relationship with Swedish Radiation Safety Authority that includes:. Maria Feychting reports a relationship with International Commission on Non-Ionizing Radiation Protection that includes:. Aslak Harbo Poulsen reports a relationship with Swedish Radiation Safety Authority that includes:. Anssi Auvinen reports a relationship with International Commission on Non-Ionizing Radiation Protection that includes:. Anssi Auvinen reports a relationship with Scientific Committee on Emerging and Newly Identified Health Risks that includes:. Anssi Auvinen reports a relationship with European Commission, Swedish Radiation Safety Authority that includes:. Anssi Auvinen reports a relationship with World Health Organization that includes:. Anke Huss reports a relationship with Swedish Radiation Safety Authority that includes:. Anke Huss reports a relationship with International Commission on Non-Ionizing Radiation Protection that includes:. Anke Huss reports a relationship with BioEM society that includes:. Anke Huss reports a relationship with Gezondheidsraad that includes:. Anke Huss reports a relationship with Swiss Research Foundation for Electricity and Mobile Communication that includes:. Hans Kromhout reports a relationship with Gezondheidsraad that includes:. Hans Kromhout reports a relationship with World Health Organization that includes:. Mireille B Toledano reports a relationship with UK Committee on Medical Aspects of Radiation in the Environment (COMARE) that includes:.

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**Personal exposure to radiofrequency electromagnetic fields: A comparative analysis of international, national, and regional guidelines**

My note: This paper suffers from problems that undermine the authors' results and conclusions.

Ramirez-Vazquez R, Escobar I, Vandenbosch GAE, Arribas E. Personal exposure to radiofrequency electromagnetic fields: A comparative analysis of international, national, and regional guidelines. Environmental Research. 2024. doi: 10.1016/j.envres.2024.118124.

Highlights

- International, National and Regional exposure limits for RF-EMF.
- RF-EMF limits are based on the ALARA (As Low As Reasonably Achievable) Principle.
- Maximum exposure limit must be scientific related, not political or in any other way.
- New technologies and new smartphones require less intensity than previous model

Abstract

A worldwide overview and analysis for the existing limits of human exposure to Radiofrequency Electromagnetic Fields (RF-EMF) is given in this paper. These reference levels have been established by different national and even regional governments, which can be based on the guidelines provided by the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the International Committee on Electromagnetic Safety of the Institute of Electrical and Electronics Engineers (IEEE), and even in the United States of the Federal Communications Commission (FCC), as well as, are based on the so-called precautionary principle. Explicit reference is made to the exposure limits adopted in countries or regions, such as Canada, Italy, Poland, Switzerland, China, Russia, France, and regions of Belgium (Brussels, Flanders, Wallonia), where the limits are much lower than the international standards. The limits are compared to a selected set of in-situ measurements. This clearly shows that the measured values are typically very small compared to the international standards but could be somewhat higher compared to the reduced limits. Based on this observation and the reasonable assumption that the sensitivity of people to Electromagnetic Fields (EMF) is the same everywhere (whole-body), we propose the idea to establish a worldwide reference limit for the general public, thus applicable in all countries, if the ICNIRP considers it appropriate. Research must continue to generate measurement data that demonstrate the levels of exposure to which we are really exposed, and with this, provide arguments to the organizations that established the guidelines, especially the ICNIRP, to evaluate whether the current limits are too much. High and can be modified when considered pertinent. To the best of our knowledge, at no time has the reference level for the general public been exceeded.

Conclusion

The duality of limits in the same country does not seem appropriate, because people who live in one area or another have more or less the same interaction with RF-EMF waves. Therefore, the limits should be the same, following the ALARA principle – As Low As Reasonably Achievable. The reasons for setting the maximum exposure limit should only be scientific related, not political or in any other way.

In this paper, we provided an overview, analyze, and discuss existing limits to RF-EMF. The international reference levels established by ICNIRP are also recommended by WHO, IEEE and FCC, and are adopted by most countries. However, some countries such as Canada, Italy, Poland, Switzerland, China, Russia, France, and regions of Belgium establish more restrictive limits than the international ones. The case of Belgium is rather specific because it establishes three very strict and different limits in Brussels, Flanders, and Wallonia.

In addition to the international limits, we have commented on the BioInitiative Limit, based on the Precautionary Principle as a preventive action, an excessively restrictive value that leaves aside more than 60 % of the personal exposure studies to RF-EMF.

There should be a trend towards unifying the limits of exposure to RF-EMF in all countries. This would allow decisions to be made in a scientific and consensual manner. The solutions could follow the ones from the International Union for Pure and Applied Physics (IUPAP), which is an international organization that has sixty member countries and is in charge, among other things, of the correct use of the International System of Units and of reviewing the measurement units of the physical magnitudes.

Based on the observation and analysis of measured levels that in most cases, the measured levels are very small, we propose that a reference limit be established for the general public, reasonable and applied to all countries, if the ICNIRP considers it appropriate. Therefore, research must continue to generate measurement data that demonstrate the levels of exposure to which we are really exposed, and with this, provide arguments to the organizations that established the guidelines, especially the ICNIRP, so that they evaluate whether the current limits are too high and can be modified, when considered pertinent. To the best of our knowledge, at no time has the reference level been exceeded for the general public, and we believe that it will not be exceeded, since the new smartphones require much less intensity than previous models, and the same goes for new technologies, 5G, 6G.

https://www.sciencedirect.com/science/article/pii/S0013935124000288

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**How to improve IARC's RF-EMF cancer hazard communication**

My note: This paper suffers from problems that undermine the authors' analysis.

Wiedemann PM, Croft RJ. How to improve IARC's RF-EMF cancer hazard communication. Bioelectromagnetics. 2024 Feb 13. doi: 10.1002/bem.22499.

Abstract

A crucial aspect of IARC's evaluation of the relative carcinogenicity of agents is the communication of its conclusions. The present paper addressed the experimental risk perception literature pertaining to IARC's radiofrequency electromagnetic field evaluation communication, and derived specific recommendations for improving it.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22499

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**Molecular biomarkers in Electrohypersensitivity and Multiple Chemical Sensitivity: How They Can Help Diagnosis, Follow-Up, and in Etiopathologic Understanding**

Irigaray P, Awaida N, Belpomme D. Molecular biomarkers in Electrohypersensitivity and Multiple Chemical Sensitivity: How They Can Help Diagnosis, Follow-Up, and in Etiopathologic Understanding. Medical Research Archives, [S.l.], 12(1), 2024. doi: 10.18103/mra.v12i1.4771.

Abstract

Electrohypersensitivty (EHS) and multiple chemical sensitivity (MCS) are new worldwide emerging neurologic disorders in the framework of sensitivity-related environmental pathology. We have recently extended and confirmed our previous observation showing that EHS and MCS share clinically identical symptoms and may co-exist as a unique, common, sensitivity-related neurologic syndrome in 25% of the cases. There is presently no published biological study of these disorders, except the one we have previously published as preliminary. In the present study, we show that EHS and MCS and the combined syndrome share identical biochemical changes. More precisely, by measuring levels of peripheral blood and urine molecular biomarkers in a cohort of 2,018 consecutive cases, we show that both disorders and the combined syndrome can be objectively characterized, in about 90% of the cases, by a decrease in the production of 6-hydroxymelatonin sulfate in urine, while in 30-50% they are characterized by increased levels of histamine and of heat shock proteins (HSP) 27 and/or 70, and of protein S100B and nitrotyrosine in the peripheral blood. Increased levels of histamine and HSP are indicators of low grade inflammation while increased levels of protein S100B and nitrotyrosine are indicators of blood-brain barrier disruption/opening. In addition, we show that in about 15% of the cases anti-myelin autoantibodies can be detected in the peripheral blood, accounting for the occurrence of an autoimmune response. Sensitivity, specificity and reproducibility of the biochemical tests are discussed, as well as the role of these indicators used as biomarkers for the diagnosis and follow-up of patients. We also discuss cases with undetectable biological change for which they can be nevertheless diagnosed by cerebral neurotransmitters analysis in urine and brain imaging. On the basis of these biological data it is suggested that EHS and/or MCS are new brain disorders, generated via a common etiopathogenic mechanism.

https://esmed.org/MRA/mra/article/view/4771

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**Environmental Health Ecosystem Sustainability in The Era of Electromagnetic Radiation Contamination**

Matthew UO, Bakare KM, Oyekunle D, Nkeiruka AM, Ebong GN (2024) Environmental Health Ecosystem Sustainability in The Era of Electromagnetic Radiation Contamination. J Comm Med and Pub Health Rep 5(02): doi: 10.38207/JCMPHR/2024/JAN05020418.

Abstract

The primary environmental health sub-disciplines that address the best approaches to environmental health, ecosystem sustainability, and natural habitats are environmental science, toxicology, environmental epidemiology, and occupational and environmental medicine. The intimate connection between environmental toxins and human health gained increased public attention at the beginning of the new millennium. Radiation, chemical, and biological agents are the three primary ecological contaminants. There is contamination in the soil, water, food, and air. The increasing adoption of 5G wireless networks has recently raised interest in its potential to support several digital and critical infrastructures. However, concerns have been raised over the potential health risks associated with fifth-generation wireless networks due to the claims that the electromagnetic radiation in the 5G carrier signal is more potent than in any prior networks. As a subject of public health, environmental health studies the whole range of effects that artificial technology and natural environments have on the general well-being of society-wide space. It establishes the prerequisites for a wholesome atmosphere

as essential in managing factors that may negatively impact the sustainability of ecosystems and the environment's well-being. This study observed that the multistage carcinogenic process, which includes carcinogen activation, oxidative DNA damage, and tumor growth, is aided by hydrogen peroxide formation during the breakdown of water molecules due to 5G electromagnetic frequency radiation as an environmental contaminant.

https://www.acquaintpublications.com/article/environmental_health_ecosystem_sustainability_in_the_era_of_electromagnetic_radiation_contamination

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**Assessment of Radio Frequency Electromagnetic Field Exposure Induced by Base Stations in Several Micro-Environments in France**

W. B. Chikha et al. Assessment of Radio Frequency Electromagnetic Field Exposure Induced by Base Stations in Several Micro-Environments in France. IEEE Access, vol. 12, pp. 21610-21620, 2024, doi: 10.1109/ACCESS.2024.3363914.

Abstract

Recently, the monitoring of the radiofrequency electromagnetic field (RF-EMF) exposure induced by cellular networks has received a great deal of attention. In this work, a set of 70 microenvironments (MEs) located in urban and rural areas are selected in France under, on the one hand, the French Beyond5G project, and on the other hand, the 5G expOsure, causaL effects and rIsk perception through citizen engagement (GOLIAT) EU project. The purpose of this study is to assess the RF-EMF DL exposure in residential areas, downtowns, business areas, train stations, and public transport rides. For that, we employ the personal ExpoM-RF4 dosimeter placed inside a backpack to perform the measurements in different MEs. To take into consideration the effect of the presence of the human body near the dosimeter, we propose a correction approach that is mainly based on comparing the measurements given by ExpoM-RF4 to the ones provided by a reference system using the Tektronix real-time spectrum analyzer (RTSA) far from the body. Then, we use metrics, such as the quadratic mean, standard deviation, and median of the electric (E) field to carry out a comparative study between different MEs with different RF bands. It was found that the RF-EMF exposure levels for all MEs are well below the maximum allowable exposure limit prescribed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). In addition, we perform clustering analyses using the K-Means technique to group the MEs with comparable exposure levels. The results show that the exposure level is low, but generally higher in MEs located in Paris than in the other considered areas (i.e., Massy and three villages, namely Igny, Bures-sur-Yvette and Gif-Sur-Yvette). For example, we observe that outdoor MEs can be grouped into three clusters, where the average total E fields (ATEFs) are 0.77 V/m, 0.35 V/m, and 0.08 V/m for the MEs belonging to the first, second and third clusters, respectively. Note that the first cluster here mainly contains the MEs located in Paris. This can be explained by the important number of antennas deployed in that area to serve the huge amount of users. We also observe few locations with exceptions confirming the presence of heterogeneous environments in the vicinity of some areas. For instance, three MEs in Paris among fifteen have an exposure level similar to Massy MEs in outdoor

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10424982&isnumber=10380310

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**Electromagnetic Exposure Level of a Pure Electric Vehicle Inverter Based on a Real Human Body**

Dong X, Gao Y, Lu M. The Electromagnetic Exposure Level of a Pure Electric Vehicle Inverter Based on a Real Human Body. *Applied Sciences*. 2024; 14(1):32. https://doi.org/10.3390/app14010032.

Abstract

In order to quantitatively analyze the electromagnetic exposure dose of an inverter in a pure electric vehicle to the driver's body and assess the safety of the electromagnetic exposure, based on a real human anatomy model in the virtual home project, a real human model with several organs and tissues, including muscles, bones, a heart, lungs, a liver, kidneys, a bladder, a skull, a scalp, white matter, and a cerebellum, was constructed. The inverter of a pure electric vehicle is considered to be the electromagnetic exposure source; for this study, an equivalent electromagnetic environment model composed of a real human body, an inverter, and a vehicle body was built. The distribution of induced fields in the driver's tissues and organs was calculated and analyzed using the finite element method. The results show that the distribution of the magnetic flux density, induced electric field, and induced current density in the driver's body was affected by the spatial distance of the inverter. The farther the distance was, the weaker the value was. Specifically, due to the different dielectric properties of the different tissues, the induced field in the different tissues was significantly different. However, the maximum magnetic flux density over the space occupied by the driver's body and induced electric field in the driver's trunk and central nervous system satisfied the exposure limits of the International Commission on Non-Ionization Radiation Protection, indicating that the electromagnetic environments generated by the inverter proposed in this paper are safe for the vehicle driver's health. The numerical results of this study could also effectively supplement the study of the electromagnetic environments of pure electric vehicles and provide some references for protecting the drivers of pure electric vehicles from electromagnetic radiation.

Conclusions

Based on the numerical results, we found that although the B-field in the central region of the inverter exceeds the reference level of the ICNIRP for general public exposure, when the distance from the inverter is increased, the B-field values sharply decrease. The maximum B-field over the space occupied by the driver's body and the E-field in the driver's trunk and CNS are all below the exposure limits defined by the ICNIRP for general public exposure. The electromagnetic environment generated by the inverter adopted in this study (12 kW, Semikron, Germany), at its rated state in the paper, is therefore safe and would not affect the PEV driver's health. Additionally, the results of this study could effectively supplement research regarding the electromagnetic environment of PEVs and provide references for the formulation of industry standards for electromagnetic exposure and the design of vehicles that are safe in terms of electromagnetic exposure.

Open access paper: https://www.mdpi.com/2076-3417/14/1/32

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**SAR Estimations in a Child Due to RF Exposures from Several Laptops in a Classroom Environment**

Soares NE, Bulla G, Fernandez-Rodriguez CE, de Salles AAA. SAR Estimations in a Child Due to RF Exposures from Several Laptops in a Classroom Environment. *2023 IEEE MTT-S Latin America Microwave Conference (LAMC)*, San José, Costa Rica, 2023, pp. 58-60, doi: 10.1109/LAMC59011.2023.10375589.

Abstract

This research provides a detailed examination of the exposure to electromagnetic fields (EMF) in a classroom environment. The study is driven by the escalating integration of electronic devices in educational settings and the subsequent necessity to estimate the implications of this on the overall exposure. The employed methodology simulates a classroom filled with several 7-year-old girls realistic models, each using a laptop, which are the primary sources of electromagnetic radiation. The 1g and 10g peak spatial Specific Absorption Rate (psSAR) are calculated for various parts of the child model, including the head, back, and hands. It is observed that, when several laptops are used, the psSAR can be substantially increased (e.g. up to 40-fold). One objective of this study is to enhance the understanding of potential EMF exposure effects in relation to age and to provide guidelines for the design of safer classrooms in the context of widespread laptop usage.

https://ieeexplore.ieee.org/document/10375589

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**Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue**

Bektas H, Dasdag S, Altindag F, Akdag MZ, Yegin K, Algul S. Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue. *Bioelectromagnetics* 1–9 (2024). doi: 10.1002/bem.22498.

Highlights

- 3.5 GHz radiofrequency radiation (RFR) may induce alterations in hormones regulating energy metabolism.
- 3.5 GHz RFR may lead to alterations in total antioxidant, total oxidant, and hydrogen peroxide levels.
- Particularly in conjunction with diabetes, 3.5 GHz RFR may result in adverse effects on energy metabolism.
- Although there were changes of the hormone levels in the exposed group, the actual values remained for both sham and exposed groups within the normal range.

Abstract

In recent years exposure of living beings to radiofrequency radiation (RFR) emitted from wireless equipment has increased. In this study, we investigated the effects of 3.5-GHz RFR on hormones that regulate energy metabolism in the body. Twenty-eight rats were divided into four groups: healthy sham ($n$ = 7), healthy RFR ($n$ = 7), diabetic sham ($n$ = 7), and diabetic RFR ($n$ = 7). Over a month, each group spent 2 h/day in a Plexiglas carousel. The rats in the experimental group were exposed to RFR, but the sham groups were not. At the end of the experiment, blood and adipose tissues were collected from euthanized rats. Total antioxidant, total oxidant, hydrogen peroxide, ghrelin, nesfatin-1, and irisin were

determined. Insulin expression in pancreatic tissues was examined by immunohistochemical analysis. Whole body specific absorption rate was 37 mW/kg. For the parameters analyzed in blood and fat, the estimated effect size varied within the ranges of 0.215–0.929 and 0.503–0.839, respectively. The blood and adipose nesfatin-1 ($p = 0.002$), blood and pancreatic insulin are decreased, ($p = 0.001$), gherelin ($p = 0.020$), irisin ($p = 0.020$), and blood glucose ($p = 0.040$) are increased in healthy and diabetic rats exposed to RFR. While nesfatin-1 are negatively correlated with oxidative stress, hyperglycemia and insulin, ghrelin and irisin are positively correlated with oxidative stress and hyperglycemia. Thus, RFR may have deleterious effects on energy metabolism, particularly in the presence of diabetes.

https://onlinelibrary.wiley.com/doi/10.1002/bem.22498

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**Genetic profiling of rat gliomas and cardiac schwannomas from life-time radiofrequency radiation exposure study using a targeted next-generation sequencing gene panel**

Brooks AM, Vornoli A, Kovi RC, Ton TVT, Xu M, Mashal A, Tibaldi E, Gnudi F, Li JL, Sills RC, Bucher JR, Mandrioli D, Belpoggi F, Pandiri AR. Genetic profiling of rat gliomas and cardiac schwannomas from life-time radiofrequency radiation exposure study using a targeted next-generation sequencing gene panel. PLoS One. 2024 Jan 17;19(1):e0296699. doi: 10.1371/journal.pone.0296699.

Abstract

The cancer hazard associated with lifetime exposure to radiofrequency radiation (RFR) was examined in Sprague Dawley (SD) rats at the Ramazzini Institute (RI), Italy. There were increased incidences of gliomas and cardiac schwannomas. The translational relevance of these rare rat tumors for human disease is poorly understood. We examined the genetic alterations in RFR-derived rat tumors through molecular characterization of important cancer genes relevant for human gliomagenesis. A targeted next-generation sequencing (NGS) panel was designed for rats based on the top 23 orthologous human glioma-related genes. Single-nucleotide variants (SNVs) and small insertion and deletions (indels) were characterized in the rat gliomas and cardiac schwannomas. Translational relevance of these genetic alterations in rat tumors to human disease was determined through comparison with the Catalogue of Somatic Mutations in Cancer (COSMIC) database. These data suggest that rat gliomas resulting from life-time exposure to RFR histologically resemble low grade human gliomas but surprisingly no mutations were detected in rat gliomas that had homology to the human IDH1 p.R132 or IDH2 p.R172 suggesting that rat gliomas are primarily wild-type for IDH hotspot mutations implicated in human gliomas. The rat gliomas appear to share some genetic alterations with IDH1 wildtype human gliomas and rat cardiac schwannomas also harbor mutations in some of the queried cancer genes. These data demonstrate that targeted NGS panels based on tumor specific orthologous human cancer driver genes are an important tool to examine the translational relevance of rodent tumors resulting from chronic/life-time rodent bioassays.

Excerpts

In this study we have demonstrated that the gliomas and cardiac schwannomas in rats resulting from lifetime exposure to low dose far field RFR that are used for cellular telephone communications, are morphologically similar to low grade human gliomas and that about 25% of the mutations seen in these tumors have corresponding alterations in homologs of human cancer genes. Surprisingly, none of the rat

gliomas examined in this study harbored mutations in *Idh1/2* genes that are common in human gliomas....

In summary, our results demonstrate that regardless of their etiology (due to lifetime RFR exposure or arising spontaneously), rat gliomas are primarily *Idh*1/2 wild type unlike most human gliomas. Histologically, most of the rat gliomas resemble diffuse low-grade gliomas in humans and such gliomas that do not harbor *IDH1/2* mutations in humans are known to have poor prognosis. The genetic alterations in other cancer genes evaluated in this panel provide novel insights into tumor progression in rat gliomas and cardiac schwannomas. The relevance of specific mutations to human cancers is variable, with some genes (*Tp53*, *Cdkn2a*, *Erbb2*, *Chek2*, *Kras* and *Pik3r1*) harboring many alterations with COSMIC relevance while the opposite is true for other target genes (*Idh1/2*, *Atrx*, *Notch1*, *Pten*, *Rb1* and *Setd2*). Several of these conserved mutations in rat tumors do not have comparable alterations in the COSMIC database, suggesting that the orthologous mutations could have different functional consequences in rat carcinogenesis and deserve further study. An important consideration is that molecular differences underlying mutational processes contribute to distinct mutational patterns which could be the result of similar etiology, albeit by different mechanisms.

Several of the variants that were detected in gliomas were also observed in non-tumor brain tissues from interim time point providing an insight into the molecular pathogenesis in rodent carcinogenicity studies and these strategies may be utilized to potentially estimate the cancer hazard risk in shorter term animal studies. Finally, this targeted mutation panel may be refined using data from whole genome or exome sequencing of rat tumors and performing error corrected duplex sequencing to increase the sensitivity to detect rare mutations in exposed non-tumor tissues from early time points.

Open access paper: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0296699

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**Understanding the public voices and researchers speaking into the 5G narrative**

Weller S, McCredden J. Understanding the public voices and researchers speaking into the 5G narrative. Front. Public Health. Vol. 11. 2023 doi: 10.3389/fpubh.2023.1339513.

Abstract

The many different voices speaking into the current narrative surrounding the health effects of 5G technologies necessitate an exploration of the background of the various published author spokespersons and their potential motives. This has been attempted recently by de Vocht and Albers. However, that opinion piece used a narrow investigative lens, resulting in an undermining of both the rationality of the concerned general public and the motives of specific researchers. At the same time, biases, conflicts of interest, and flaws found in "independent" reviews were not considered. To address these oversights, an evidence-based appraisal of public opinion and the scientific caliber of authors involved in the 5G health discussion is warranted. Subsequently, this review article presents an analysis of the available Australian data representing public voices, while also conducting a broader investigation of the level of expertise of the recent author-spokespersons based on their experience as scientists, particularly in the area of health effects of radiofrequency electromagnetic fields. This review thus attempts to more clearly illustrate for the reader the caliber and motives of the voices speaking into the

5G narrative. The article concludes with a set of questions that need to be answered to enable scientists to advise policy makers more effectively on matters of 5G and public health.

Open access paper: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1339513/abstract

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**Effects of 700 and 3500 MHz 5G radiofrequency exposure on developing zebrafish embryos**

Torres-Ruiz M, Suárez OJ, López V, Marina P, Sanchis A, Liste I, de Alba M, Ramos V. Effects of 700 and 3500 MHz 5G radiofrequency exposure on developing zebrafish embryos. Sci Total Environ. 2024 Jan 8:169475. doi: 10.1016/j.scitotenv.2023.169475.

Abstract

Telecommunications industries are rapidly deploying the fifth generation (5G) spectrum and there is public concern about the safety and health impacts of this type of Radio Frequency Radiation (RFR), in part because of the lack of comparable scientific evidence. In this study we have used a validated commercially available setting producing a uniform field to expose zebrafish embryos (ZFe) to unmodulated 700 and 3500 MHz frequencies. We have combined a battery of toxicity, developmental and behavioral assays to further explore potential RFR effects. Our neurobehavioral profiles include a tail coiling assay, a light/dark activity assay, two thigmotaxis anxiety assays (auditory and visual stimuli), and a startle response - habituation assay in response to auditory stimuli. ZFe were exposed for 1 and 4 h during the blastula period of development and endpoints evaluated up to 120 h post fertilization (hpf). Our results show no effects on mortality, hatching or body length. However, we have demonstrated specific organ morphological effects, and behavioral effects in activity, anxiety-like behavior, and habituation that lasted in larvae exposed during the early embryonic period. A decrease in acetylcholinesterase activity was also observed and could explain some of the observed behavioral alterations. Interestingly, effects were more pronounced in ZFe exposed to the 700 MHz frequency, and especially for the 4 h exposure period. In addition, we have demonstrated that our exposure setup is robust, flexible with regard to frequency and power testing, and highly comparable. Future work will include exposure of ZFe to 5G modulated signals for different time periods to better understand the potential health effects of novel 5G RFR.

https://pubmed.ncbi.nlm.nih.gov/38199355/

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**Effects of radiofrequency field from 5G communication on fecal microbiome and metabolome profiles in mice**

Wang, X., Zhou, G., Lin, J. *et al.* Effects of radiofrequency field from 5G communication on fecal microbiome and metabolome profiles in mice. *Sci Rep* **14**, 3571 (2024). https://doi.org/10.1038/s41598-024-53842-2

Abstract

With the rapid development of 5G networks, the influence of the radiofrequency field (RF) generated from 5G communication equipment on human health is drawing increasing attention in public. The study aimed at assessing the effects of long-term exposure to 4.9 GHz (one of the working frequencies of 5G communication) RF field on fecal microbiome and metabolome profiles in adult male C57BL/6 mice. The animals were divided into Sham group and radiofrequency group (RF group). For RF group, the mice were whole body exposed to 4.9 GHz RF field for three weeks, 1 h/d, at average power density (PD) of 50 $W/m^2$. After RF exposure, the mice fecal samples were collected to detect gut microorganisms and metabolites by 16S rRNA gene sequencing and LC–MS method, respectively. The results showed that intestinal microbial compositions were altered in RF group, as evidenced by reduced microbial diversity and changed microbial community distribution. Metabolomics profiling identified 258 significantly differentially abundant metabolites in RF group, 57 of which can be classified to Kyoto Encyclopedia of Genes and Genomes (KEGG) pathways. Besides, functional correlation analysis showed that changes in gut microbiota genera were significantly correlated with changes in fecal metabolites. In summary, the results suggested that altered gut microbiota and metabolic profile are associated with 4.9 GHz radiofrequency exposure.

Open access paper: https://www.nature.com/articles/s41598-024-53842-2

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**Estimation of SAR Average in Rats during 5G NR Chronic Exposure**

Makhmanazarov R, Tseplyaev I, Shipilov S, Krivova N. Estimation of SAR Average in Rats during 5G NR Chronic Exposure. *Applied Sciences*. 2024; 14(1):208. doi: 10.3390/app14010208.

Abstract

To study physiological reactions in the brain and skin of higher mammals exposed to chronic radiofrequency radiation, specific absorption ratio (SAR) determination is required and time-consuming numerical methods are used. The paper deals with the estimation of the whole-body specific absorption rate (SAR) in rats chronically exposed to external electromagnetic fields, as well as the development of a laboratory setup simulating the operation of a fifth-generation 5G New Radio base station (with a signal bandwidth of 15 MHz and a carrier frequency of 2.4 GHz). The paper presents a modified method for theoretical SAR estimation for one-sided irradiation and distributed absorption. Mean whole-body SAR values were estimated by the proposed method and numerically modeled with the CST Microwave Studio simulation software 2020package using primitive rat models. Dielectric parameters in the numerical simulation were used from the software library. The IEEE/IEC 62704-1 algorithm was used to investigate SAR in numerical simulations. The theoretical estimates and numerical simulations were compared for different SAR distributions and were found to be qualitatively comparable. The differences between approximate theoretical estimates and numerical simulations are 7% and 10% for distributed and non-distributed absorptions, respectively. The proposed method, which takes into account the decreasing power flux density, can be used to estimate the approximate whole-body SAR during chronic electromagnetic field exposure in rats.

Open access paper: https://www.mdpi.com/2076-3417/14/1/208

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**The thermal sensation threshold and its reliability induced by the exposure to 28 GHz millimeter-wave**

Akiko Y, Shintaro U, Kazuki U, Sachiko K, Norika A, Akimasa H, Yohei O. The thermal sensation threshold and its reliability induced by the exposure to 28 GHz millimeter-wave. Frontiers in Neuroscience. 18. 2024. doi: 10.3389/fnins.2024.1331416.

Abstract

The application of 28 GHz millimeter-wave is prevalent owing to the global spread of fifth-generation wireless communication systems. Its thermal effect is a dominant factor which potentially causes pain and tissue damage to the body parts exposed to the millimeter waves. However, the threshold of this thermal sensation, that is, the degree of change in skin temperature from the baseline at which the first subjective response to the thermal effects of the millimeter waves occurs, remains unclear. Here, we investigated the thermal sensation threshold and assessed its reliability when exposed to millimeter waves. Twenty healthy adults were exposed to 28 GHz millimeter-wave on their left middle fingertip at five levels of antenna input power: 0.2, 1.1, 1.6, 2.1, and 3.4 W (incident power density: 27–399 mW/cm<sup>2</sup>). This measurement session was repeated twice on the same day to evaluate the threshold reliability. The intraclass correlation coefficient (ICC) and Bland–Altman analysis were used as proxies for the relative and absolute reliability, respectively. The number of participants who perceived a sensation during the two sessions at each exposure level was also counted as the perception rate. Mean thermal sensation thresholds were within 0.9°C–1.0°C for the 126–399 mW/cm<sup>2</sup> conditions, while that was 0.2°C for the 27 mW/cm<sup>2</sup> condition. The ICCs for the threshold at 27 and 126 mW/cm<sup>2</sup> were interpreted as poor and fair, respectively, while those at higher exposure levels were moderate to substantial. Apart from a proportional bias in the 191 mW/cm<sup>2</sup> condition, there was no fixed bias. All participants perceived a thermal sensation at 399 mW/cm<sup>2</sup> in both sessions, and the perception rate gradually decreased with lower exposure levels. Importantly, two-thirds of the participants answered that they felt a thermal sensation in both or one of the sessions at 27 mW/cm<sup>2</sup>, despite the low-temperature increase. These results suggest that the thermal sensation threshold is around 1.0°C, consistent across exposure levels, while its reliability increases with higher exposure levels. Furthermore, the perception of thermal sensation may be inherently ambiguous owing to the nature of human perception.

Open access paper:
https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2024.1331416

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**The impact of radiofrequency exposure on Aedes aegypti (Diptera: Culicidae) development [mosquitos]**

Nik Abdull Halim NMH, Mohd Jamili AF, Che Dom N, Abd Rahman NH, Jamal Kareem Z, Dapari R. The impact of radiofrequency exposure on Aedes aegypti (Diptera: Culicidae) development. PLoS One. 2024 Feb 27;19(2):e0298738. doi: 10.1371/journal.pone.0298738.

Abstract

Introduction  Wireless communication connects billions of people worldwide, relying on radiofrequency electromagnetic fields (RF-EMF). Generally, fifth-generation (5G) networks shift RF carriers to higher frequencies. Although radio, cell phones, and television have benefited humans for decades, higher carrier frequencies can present potential health risks. Insects closely associated with humans (such as mosquitoes) can undergo increased RF absorption and dielectric heating. This process inadvertently impacts the insects' behaviour, morphology, and physiology, which can influence their spread. Therefore, this study examined the impact of RF exposure on Ae. aegypti mosquitoes, which are prevalent in indoor environments with higher RF exposure risk. The morphologies of Ae. aegypti eggs and their developments into Ae. aegypti mosquitoes were investigated.

Methods  A total of 30 eggs were exposed to RF radiation at three frequencies: baseline, 900 MHz, and 18 GHz. Each frequency was tested in triplicate. Several parameters were assessed through daily observations in an insectarium, including hatching responses, development times, larval numbers, and pupation periods until the emergence of adult insects.

Results  This study revealed that the hatching rate for the 900 MHz group was the highest (79 ± 10.54%) compared to other exposures ($p = 0.87$). The adult emergence rate for the 900 MHz group was also the lowest at 33 ± 2.77%. A significant difference between the groups was demonstrated in the statistical analysis ($p = 0.03$).

Conclusion  This work highlighted the morphology sensitivity of Ae. aegypti eggs and their developments in the aquatic phase to RF radiation, potentially altering their life cycle.

This study successfully comprehended the influence of RF exposure on the development of *Aedes* mosquitoes. The 900 MHz RF exposure accelerated the hatching process of *Ae*. *aegypti* mosquitoes and increased the percentage of adult emergence. These findings represented an essential initial stage in understanding the impact of RF radiation on *Aedes* mosquito populations, providing vital insights into the population dynamics. Nevertheless, the potential variability results under distinct study conditions involving RF exposure variation types and the mosquito species studied were necessary. Thus, additional investigation was desirable and crucial to understand the consequences of RF exposure comprehensively on *Ae*. *albopictus* and determine the most efficient approaches for identifying the most effective strategies for dengue vector control. Studies are actively investigating the influence of RF exposure on insects (particularly mosquitoes) due to data suggesting that it can impact hatching and developmental processes. Hence, further studies should be conducted to fully comprehend the scope of these effects and clarify their practical relevance in preventing dengue spread. These ongoing studies are pivotal in learning the potential utility of RF exposure to mitigate the spread of dengue disease and in establishing the most efficacious approaches for translating this knowledge into practical control measures.

Open access paper:  https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0298738

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**Detrimental impact of cell phone radiation on sperm DNA integrity (Review)**

Koohestanidehaghi Y, Khalili MA, Dehghanpour F, Seify M. Detrimental impact of cell phone radiation on sperm DNA integrity. Clin Exp Reprod Med. 2024 Jan 24. doi: 10.5653/cerm.2023.06121.

Abstract

Radiofrequency electromagnetic radiation (RF-EMR) from various sources may impact health due to the generation of frequency bands. Broad pulses emitted within frequency bands can be absorbed by cells, influencing their function. Numerous laboratory studies have demonstrated that mobile phones-generally the most widely used devices-can have harmful effects on sex cells, such as sperm and oocytes, by producing RF-EMR. Moreover, some research has indicated that RF-EMR generated by mobile phones can influence sperm parameters, including motility, morphology, viability, and (most critically) DNA structure. Consequently, RF-EMR can disrupt both sperm function and fertilization. However, other studies have reported that exposure of spermatozoa to RF-EMR does not affect the functional parameters or genetic structure of sperm. These conflicting results likely stem from differences among studies in the duration and exposure distance, as well as the species of animal used. This report was undertaken to review the existing research discussing the effects of RF-EMR on the DNA integrity of mammalian spermatozoa.

EMW can induce oxidative stress, which subsequently leads to disorders such as reduced mobility, morphological changes, acrosome disturbances, and ultimately, damage to the nucleus and genetic material. This oxidative damage to DNA can result in the breakdown of both single-stranded and double-stranded DNA structures, culminating in fragmentation. If the DNA is not repaired and the damage accumulates, the sperm may undergo apoptosis. Damage to the sperm genome can ultimately impact fertility, potentially leading to infertility. Therefore, it is advisable to limit daily exposure to these sources to prevent irreversible damage caused by EMWs. Many men carry their cell phones in their trouser pockets or clipped to their belts, and the use of Bluetooth can increase their susceptibility to RF-EMR exposure. This exposure can induce changes in sperm quality through oxidative stress, potentially leading to infertility. Agarwal et al. [11] suggested that carrying a cell phone in a pocket could lead to a decline in sperm quality. However, it is important to note that the phone and male reproductive organs are separated by multiple tissue layers. Therefore, extrapolating these in vitro effects to real-life conditions requires further studies [11].

In July 2021, the European Parliament commissioned a research report titled “Health impact of 5G.” The report concluded that the commonly used RF-EMFs are likely carcinogenic to humans and have a definitive impact on male fertility. It also suggested potential adverse effects on the development of embryos, fetuses, and newborns. To mitigate these adverse effects, the organization proposed several strategies. These include favoring non-wireless connections, increasing distance from the source of RF-EMFs, switching off devices when not in use, and practicing safe phone usage [55].

Open access paper: https://ecerm.org/journal/view.php?doi=10.5653/cerm.2023.06121

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**Acute exposure of microwave impairs attention process by activating microglial inflammation**

Jiang S, Ma Y, Shi Y, *et al.* Acute exposure of microwave impairs attention process by activating microglial inflammation. *Cell Biosci* **14**, 2 (2024). doi: 10.1186/s13578-023-01162-9.

Abstract

Background  Attention provides the foundation for cognitions, which was shown to be affected by microwave (MW) radiation. With the ubiquitous of microwaves, public concerns regarding the impact of MW radiation on attention has hence been increased. Our study aims to investigate the potential effect and mechanism of acute microwave exposure on attention.

Results  We identified obvious impairment of attention in mice by the five-choice serial reaction time (5-CSRT) task. Proteomic analysis of the cerebrospinal fluid (CSF) revealed neuroinflammation and microglial activation potentially due to acute MW exposure. Moreover, biochemical analysis further confirmed microglial activation in the prefrontal cortex (PFC) of mice subjected to acute MW exposure. Finally, minocycline, a commercially available anti-inflammatory compound, attenuated neuroinflammation, inhibited the upregulation of N-methyl-D-aspartic acid receptor (NMDAR) including NR2A and NR2B, and also accelerated the attentional recovery after MW exposure.

Conclusions  We believe that microglial activation and NMDAR upregulation likely contribute to inattention induced by acute MW exposure, and we found that minocycline may be effective in preventing such process

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10768366/

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**Detrimental effects of electromagnetic radiation emitted from cell phone on embryo morphokinetics and blastocyst viability in mice**

Seify M, Khalili MA, Anbari F, Koohestanidehaghi Y. Detrimental effects of electromagnetic radiation emitted from cell phone on embryo morphokinetics and blastocyst viability in mice. Zygote. Published online 2024:1-5. doi:10.1017/S0967199424000042

Abstract

Electromagnetic radiation (EMR) has deleterious effects on sperm motility and viability, as well as oocyte membrane and organelle structure. The aim was to assess the effects of cell phone radiation on preimplantation embryo morphokinetics and blastocyst viability in mice. For superovulation, 20 female mice were treated with intraperitoneal (IP) injections of 10 IU pregnant mare's serum gonadotropin (Folligon® PMSG), followed by 10 IU of human chorionic gonadotropin (hCG) after 48 h. The zygotes (n = 150) from the control group were incubated for 4 days. The experimental zygotes (n = 150) were exposed to a cell phone emitting EMR with a frequency range 900–1800 MHz for 30 min on day 1. Then, all embryos were cultured in the time-lapse system and annotated based on time points from the 2-cell stage (t2) to hatched blastocyst (tHDyz), as well as abnormal cleavage patterns. Blastocyst viability was assessed using Hoechst and propidium iodide staining. Significant increases ($P < 0.05$) were observed in the cleavage division time points of t2, t8, t10, and t12 of the experimental group compared with the controls. In terms of blastocyst formation parameters, a delay in embryo development was observed in the experimental group compared with the controls. Data analysis of the time intervals between the two groups showed a significant difference in the s3 time interval ($P < 0.05$). Also, the rates of fragmentation, reverse cleavage, vacuole formation, and embryo arrest were significantly higher in the experimental group ($P < 0.05$). Furthermore, the cell survival rate in the experimental group was lower than the control group ($P < 0.05$). Exposure to EMR has detrimental consequences for preimplantation embryo

development in mice. These effects can manifest as defects in the cleavage stage and impaired blastocyst formation, leading to lower cell viability.

https://www.cambridge.org/core/journals/zygote/article/abs/detrimental-effects-of-electromagnetic-radiation-emitted-from-cell-phone-on-embryo-morphokinetics-and-blastocyst-viability-in-mice/BC3E03A74EC2E5E9C97D6CF6E22253A3

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**Radio-tracking systems emit pulsed waves that could affect the health and alter the orientation of animals**

Balmori A. Radio-tracking systems emit pulsed waves that could affect the health and alter the orientation of animals. Journal for Nature Conservation. Vol. 77. 2024, doi: 10.1016/j.jnc.2023.126520.

Abstract

Any study carried out with a given technique must avoid causing harmful effects on the experimental subjects, in order to avoid altering the survival rates of the animals or causing bias in the results of the study. Radio tagging is undoubtedly a very useful technique, and in many cases is the only option available to obtain information on the ecology and movements of wild animals, but unfortunately it has been used indiscriminately, without regard to the problems it can cause. The most well-known of these are the effects from the weight of the device and the harness, but there are others that have not yet been taken into account and that have not been sufficiently studied, such as the non-thermal effects of modulated and/or pulsed electromagnetic fields on the health and orientation of radio-tracked animals. This commentary provides a brief overview of the scientific evidence on the effects of electromagnetic fields, and underlines the importance of carrying out relevant studies in order to check for the possible effects of radio transmitters on animals.

https://www.sciencedirect.com/science/article/pii/S1617138123001917

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**A study on effects of cell phone tower-emitted non-ionizing radiations in an Allium cepa test system**

Sharma A, Sharma S, Bahel S, Katnoria JK. A study on effects of cell phone tower-emitted non-ionizing radiations in an Allium cepa test system. Environ Monit Assess. 2024 Feb 13;196(3):261. doi: 10.1007/s10661-024-12435-2.

Abstract

Considering enormous growth in population, technical advancement, and added reliance on electronic devices leading to adverse health effects, *in situ* simulations were made to evaluate effects of non-ionizing radiations emitted from three cell phone towers (T1, T2, and T3) of frequency bands (800, 1800, 2300 MHz), (900, 1800, 2300 MHz), and (1800 MHz), respectively. Five sites (S1–S5) were selected near cell phone towers exhibiting different power densities. The site with zero power density was considered

as control. Effects of radiations were studied on morphology; protein content; antioxidant enzymes like ascorbate peroxidase (APX), superoxide dismutase (SOD), glutathione-S-transferase (GST), guaiacol peroxidase (POD), and glutathione reductase (GR); and genotoxicity using *Allium cepa*. Mean power density ($\mu W/cm^2$) was recorded as 1.05, 1.18, 1.6, 2.73, and 12.9 for sites 1, 2, 3, 4, and 5, respectively. A significant change in morphology, root length, fresh weight, and dry weight in *Allium cepa* was observed under the exposure at different sites. Protein content of roots showed significant difference for samples at all sites while bulbs at sites S4 and S5 when compared to control. Antioxidant activity for root in terms of APX, GST, and POD showed significant changes at S4 and S5 and GR at site S5 and SOD at S1, S2, S3, S4, and S5. Similarly, bulbs showed significant changes at sites S4 and S5 for APX while at sites S3, S4, and S5 for POD and S2, S3, S4, and S5 for SOD and S5 for GR and GST. Genotoxicity study has shown induction of abnormalities at different stages of the cell cycle in *Allium cepa* root tips. The samples under exposure to radiation with maximum power density have shown maximum induction of oxidative stress and genotoxicity.

https://pubmed.ncbi.nlm.nih.gov/38349609/

Excerpts

Specific locations with cell phone towers were identified using the Tarang Sanchar portal. The power density ($\mu W/cm^2$) at different sites near towers was noted manually using an electromagnetic radiation detector (model: PCE-EM 29; make: PCE instruments, UK). Five sites were selected following the criteria of high-power density exposure and site with convenient experimental setup. Cell phone towers emitting radiations of different frequency bands, viz., 800, 1800, and 2300 MHz, for Reliance Jio 900, 1800 and 2300 MHz for Airtel, and 1800 MHz for Vodafone Idea (VI), were located at the sites of experiment. Depending upon the distance from the cell towers, five sites near towers showed the increasing order of their power density with decreasing distance. Site 1 showed a mean power density of 1.05 $\mu W/cm^2$ at a distance of 20 m from cell towers, with an angle of $\angle 16.67°$. Meanwhile, site 2 recorded a mean power density of 1.18 $\mu W/cm^2$ at a distance of 15 m, with an angle of $\angle 21.77°$. Site 3 exhibited a mean power density of 1.6 $\mu W/cm^2$ at a distance of 10 m and an angle of $\angle 30.94°$. Site 4 showed a mean power density of 2.73 $\mu W/cm^2$ at a distance of 5 m and an angle of $\angle 50.19°$. In contrast, site 5 displayed a higher mean power density of 12.9 $\mu W/cm^2$ at distance of 1 m and an angle of $\angle 80.21°$ with an average temperature recorded to be 20–24 °C and relative humidity of 45–50%. The specifics regarding the selection of the exposure sites are provided in Fig. 1. Keeping all other environmental conditions constant and altering only one parameter that is power density, the site with zero power density is designated as the control at a distance of 50 m and an angle of $\angle 6.818°$.

Conclusion

The present study clearly revealed that plant samples under exposure to electromagnetic radiations generated from cell phone towers at varied frequencies and maximum power densities had altered morphological and biochemical characteristics. The enhanced level of antioxidative enzymes like APX, GST, GR, POD, and SOD during the present study indicate the enhancement of oxidative stress and genotoxicity. The harmful effects of exposure to non-ionizing radiations were also witnessed through reduced protein content in test samples as compared to that of control. The genotoxicity studies revealed that the damage by exposure to radiations was high for root samples as compared to bulb samples indicating that root tip cells of *Allium cepa* were sensitive bioindicators to reveal toxicity of radiation pollution. This study is the first of its kind conducted in the field and reveals that further

advance research is the need of an hour for in-depth understanding and devising the effective protective measures for mitigation of the detrimental effects of radiations.

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**A systematic review on cellular responses of Escherichia coli to nonthermal electromagnetic irradiation**

Askaripour K, Żak A. A systematic review on cellular responses of Escherichia coli to nonthermal electromagnetic irradiation. Bioelectromagnetics. 2024 Jan;45(1):16-29. doi: 10.1002/bem.22484.

Highlights

- The present review aims to systematically evaluate literature to reach a firm conclusion on the causality between nonthermal electromagnetic radiation of alternating current and biological effects in *Escherichia coli*.
- The systematic review methodology by OHAT and the risk of bias tool evaluating the validity of experimental design and conduct within research works were followed.
- With 25 of the 114 records screened meeting the eligibility criteria, the evidence summation was performed regarding growth rate, morphology, and gene expression under exposure of extremely low frequency, intermediate frequency, or radio frequency.
- With 85% of experiments in the included studies focusing on the extremely low-frequency range, effects on growth rate, morphology, and gene expression were supported in 74%, 80%, and 33% of the experiments, respectively.

Abstract

Investigation of Escherichia coli under electromagnetic fields is of significance in human studies owing to its short doubling time and human-like DNA mechanisms. The present review aims to systematically evaluate the literature to conclude causality between 0 and 300 GHz electromagnetic fields and biological effects in E. coli. To that end, the OHAT methodology and risk of bias tool were employed. Exponentially growing cells exposed for over 30 min at temperatures up to 37◦C with fluctuations below 1◦C were included from the Web-of-Knowledge, PubMed, or EMF-Portal databases. Out of 904 records identified, 25 articles satisfied the selection criteria, with four excluded during internal validation. These articles examined cell growth (11 studies), morphology (three studies), and gene regulation (11 studies). Most experiments (85%) in the included studies focused on the extremely low-frequency (ELF) range, with 60% specifically at 50 Hz. Changes in growth rate were observed in 74% of ELF experiments and 71% of radio frequency (RF) experiments. Additionally, 80% of ELF experiments showed morphology changes, while gene expression changes were seen in 33% (ELF) and 50% (RF) experiments. Due to the limited number of studies, especially in the intermediate frequency and RF ranges, establishing correlations between EMF exposure and biological effects on E. coli is not possible.

https://pubmed.ncbi.nlm.nih.gov/37807247/

Conclusions

The present review systemically evaluates whether the current literature, passing through the risk of bias tool, while fulfilling the selection criteria defined in the PECO statement, supports an association between nonthermal electromagnetic fields and alterations in the biological composition and functioning of *E. coli* strains. The findings from the 21 included studies are dependent on the specific endpoints assessed, which include cell growth, morphology, and gene expression. The conclusions are subject to certain limitations, as the review focuses on exponentially growing strains that were exposed to nonthermal EMFs of frequencies 0–300 GHz for a minimum duration of 30 min.

In each study, it is possible that multiple experiments were conducted. Among these studies, 85% of experiments (16 articles) focused on the extremely low-frequency range, with 60% specifically examining 50 Hz. Additionally, 5% of experiments (one article) addressed the IF range, while 10% of experiments (four articles) addressed the RF range. In the investigation of nonthermal effects of extremely low-frequency electromagnetic fields (ELF-EMF), 74% of the experiments supported the effects on growth rate (investigated in nine articles), 80% supported the effects on morphology (investigated in three articles), and 33% supported the effects on gene expression (investigated in eight articles). Within the IF range, nonthermal effects on growth rate were observed in 100% of experiments (conducted in one article), but no experiments supported such effects on gene expression (investigated in one article). In the RF range, 71% of experiments supported nonthermal effects on growth rate (conducted in two articles), while 50% supported nonthermal effects on gene expression (conducted in two articles). Therefore, due to the limited number of studies available on the IF and RF ranges, the reliability of the results may primarily apply to ELF-EMF, particularly at 50 Hz.

When experiments demonstrated biological effects, the observed pattern varied as either beneficial or detrimental, depending on the exposure conditions and experimental setup. For example, out of 38 experiments on growth rate, 12 showed beneficial effects while 16 showed detrimental effects. This controversy can be explained by the concept of the *biological window*, in which EMF may contribute to positive physiological processes. However, if the accumulated exposure exceeds the cell-specific energy limit, detrimental effects may prevail. Several sources exhibited inconsistencies when observing these effects.

In terms of exposure parameters, continuity, referring to intermittent or continuous status, had a significant effect on the results, with pulsed signals showing a greater impact compared to sinusoidal signals. Extremely low frequencies and radio frequencies had a major impact on the investigated endpoints, while intermediate frequencies have received limited research attention. The intensity and duration of exposure influenced the absorbed energy levels, resulting in varying effects ranging from beneficial to neutral or detrimental. Modulation may introduce significant differences compared to unmodulated signals, depending on the modulation frequency. The optimal measurement time point depends on the specific endpoint and necessitates mechanistic understanding for accurate identification.

Special attention is needed regarding sufficient and clear reports on the amount of electromagnetic irradiation absorbed by the strains, as it can make the quantitative comparison between studies possible, and discriminate between nondetrimental or detrimental effects. Besides, special attention to the background electromagnetic irradiation as a confounder and the measurement time point for allowing the outcome to develop is required. Deficiencies associated with the risk of bias including *research personnel blinded to the study group*, *randomization of exposure*, *allocation concealment*, *attrition/exclusion bias*, and their possible effect on the outcome should be considered. More mechanistic investigations regarding cellular processes and their related genes are demanded.

Based on the limited number of studies encompassing three different frequency ranges and three different endpoints, the systematic review does not establish a conclusive correlation between nonthermal exposure to electromagnetic fields and cellular alterations in *E. coli* strains. However, future research could explore this correlation more specifically, considering the similarity of endpoints and levels of exposure between *E. coli* and humans. This exploration would help shed light on the potential implications of these effects on human health.

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**On the Quasistationarity of the Ambient Electromagnetic Field Generated by Wi-Fi Sources**

Tuță L, Roșu G, Andone A, Spandole-Dinu S, Fichte LO. On the Quasistationarity of the Ambient Electromagnetic Field Generated by Wi-Fi Sources. *Electronics*. 2024; 13(2):301. doi:10.3390/electronics13020301.

Abstract

In recent decades, the widespread use of mobile phones and wireless technologies has led to a significant increase in radiofrequency electromagnetic fields (RF-EMFs), raising concerns about continuous RF-EMF exposure among the general population. Recent research indicates that real-life RF signals are more biologically active than controlled laboratory signals with a low variability, suggesting that living organisms can adapt to EMF exposure when the pattern has a low variability. However, using real-life sources with unpredictable variation signals in biological experiments contradicts the principle of experiment controllability. This paper aims to investigate the nature of signals generated by current sources of ambient EMFs in terms of stationarity, with the goal of replicating them in biological experiments to study the effects of EMF exposure. Employing a range of statistical methodologies, starting with descriptive statistical analysis and progressing to the advanced APDP and APTF methods, an examination is conducted on a collection of Wi-Fi signal recordings across various operating modes, with particular attention given to video streaming. The chosen datasets are scrutinized with respect to their adherence to a Gaussian distribution and the concept of stationarity. The results indicate that the observed Wi-Fi signals lack stationarity in both the time and frequency domains. However, based on the analytical findings, it is possible to generate signals in frequency that authentically replicate Wi-Fi signals, accounting for nonstationarity considerations.

Conclusions

The stationarity of electromagnetic emission sources, particularly those generating time-varying EMFs, can significantly impact living organisms. Exposure to nonstationary sources with dynamic signals limits an organism's ability to adapt to the changing stimulus. The consideration that real-life source signals may be more biologically active raises concerns about the accuracy and relevance of laboratory sources in experiments studying the effects of RF-EMF exposure. However, using real-life sources with unpredictable variations contradicts the principle of experiment controllability. The investigation into the impact of Wi-Fi routers on living organisms is crucial, as these emission sources exhibit either weak stationarity or nonstationarity, potentially leading to adverse effects on human health.

The paper describes the examination of temporal variations in ambient electromagnetic exposure emanating from Wi-Fi communication devices which involves the application of diverse statistical

methodologies. The objective is to ascertain the stationarity of these signals. The ultimate outcome aims to produce laboratory-controlled signals that faithfully replicate the authentic variability observed in real-life signals generated by Wi-Fi communication devices.

Several datasets were obtained from various frequency-domain measurements with a spectrum analyzer. A stationarity analysis was performed for the measured datasets, in both time and frequency domains, using the ADPD and APTF methods.

The findings derived from the analysis using APTF and APDP indicate that the observed Wi-Fi signals lack stationarity in both the time and frequency domains. This outcome poses a challenge with respect to simulating Wi-Fi signals, suggesting that the incorporation of modulations exclusive to the 802.11 standards (OFDM and DSSS), along with the introduction of Gaussian noise, may prove insufficient for an accurate emulation of authentic Wi-Fi signals.

We suggest, in this case, simulating the spectrum analyzer measurement by generating vectors from the Pearson system of distributions, with statistical parameters that correspond to practical measurements. The quality of these simulated Wi-Fi waveforms will depend on the measurements used to train the algorithm. These waveforms could be used for further EMF investigation by generating them using a portable SDR device, without requiring a Wi-Fi router with Internet access.

Open access paper: https://www.mdpi.com/2079-9292/13/2/301

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**Changes in honey bee nutrition after exposure to radiofrequency electromagnetic field**

Migdal P, Plotnik M, Bieńkowski P, Murawska A, Berbeć E, Sobkiewicz P, Zarębski K, Latarowski K (2024). Changes in honey bee nutrition after exposure to radiofrequency electromagnetic field. The European Zoological Journal, 91:1, 172-179. doi: 10.1080/24750263.2024.2308550.

Abstract

Urban beekeeping has gained interest in recent years. Bees placed in cities, on the roofs of buildings, are exposed to many different sources of electromagnetic fields of different frequencies and intensities. Knowledge about the impact of electromagnetic fields on the physiology and behavior of insects (including honey bees) is limited. Hence, one of the first steps was to check how radiofrequency electromagnetic fields affect honey bees' nutrition. The level of total proteins, glucose, triglycerides, and TAS activity in bee hemolymph was analyzed. This is because they indicate the honey bee's nutrition level. The experiment involved 2-day-old Carniolan worker honey bees (*Apis mellifera carnica* L.). The bees were exposed to fields of 12 V/m, 28 V/m, and 61 V/m for 0.25, 1 and 3 h. Hemolymph was taken from 40 alive worker honey bees from each group immediately after exposure, by removing the antennae with sterile tweezers. The activity of biochemical markers (total proteins, TAS, and triglycerides) in the bee hemolymph in 12 V/m and 28 V/m groups showed statistically significant differences compared to the control group in most cases. According to our own research, radiofrequency electromagnetic fields disturb honey bee nutrition. The changes in the analyzed indicators may have long-term effects.

Open access paper: https://www.tandfonline.com/doi/full/10.1080/24750263.2024.2308550

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**Studies of the Electromagnetic Background at the Antarctic Vostok Station**

Shurshakov VA, Belov EV, Ilyin EA, *et al.* Studies of the Electromagnetic Background at the Antarctic Vostok Station. *Hum Physiol* **49**, 906–909 (2023). doi: 10.1134/S0362119723070216.

Abstract

The electromagnetic background was measured in the living quarters of the Vostok Station located on the Antarctic plateau distant from the potential sources of technogenic electromagnetic fields. The level of E-radiation in the range from 0.8 to 8 GHz was determined using a MERA integral dosimeter. Based on the results of long-term continuous (one to 4 months) measurements, the mean flux density was equal to 1.5 ± 0.8 nWt/cm, which is nearly 7000 times lower than the admissible level for population adopted in Russia. The Antarctic Vostok Station can be considered as a plausible location for biomedical investigations into the effects of low-frequency electromagnetic radiation.

Conclusions

(1) The EFD values of technogenic EMR in the living quarters of the Vostok Station are 7 thousand times below the regulatory standards for EMR in the Russian Federation. This fact indicates that the long-term stay of people at the Vostok Station is safe as regards the sanitary standards for EMR. [The Russian regulatory standards for EMR 0.3–300 GHz are 1000 μW/cm$^2$ for personnel and 10 μW/cm$^2$ for the population.]

(2) The daily dynamics of the main frequencies in EMR EFD variability and its dependence on solar activity have been revealed.

(3) Since the members of polar expeditions at the Vostok Station perform daily outdoor work (up to 1.5 h), it would be reasonable for future expeditions to measure the EFD of EMR in an open area, which will allow estimating the natural (background) level of EMR EFD in the vicinity of the station.

The Antarctic Vostok Station can be considered as one of the possible places for conducting biomedical research under the conditions of reduced electromagnetic radiation flux.

Open access paper: https://link.springer.com/article/10.1134/S0362119723070216

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**Shortwave radiation-induced reproductive organ damage in male rats by enhanced expression of molecules associated with the calpain/Cdk5 pathway and oxidative stress**

Yao B, Men J, Liu S, Bai Y, Yu C, Gao Y, Xu X, Zhao L, Zhang J, Wang H, Li Y, Peng R. Shortwave radiation-induced reproductive organ damage in male rats by enhanced expression of molecules associated with the calpain/Cdk5 pathway and oxidative stress. Electromagn Biol Med. 2023 Oct 2;42(4):150-162. doi: 10.1080/15368378.2023.2296896.

Abstract

Shortwave radiation has been reported to have harmful effects on several organs in humans and animals. However, the biological effects of 27 MHz shortwave on the reproductive system are not clear. In this study, we investigated the effects of shortwave whole-body exposure at a frequency of 27 MHz on structural and functional changes in the testis. Male Wistar rats were exposed to **27 MHz continuous shortwaves at average power densities of 0, 5, 10, or 30 mW/cm$^2$ for 6 min**. The levels of insulin-like factor 3 (INSL3) and anti-sperm antibodies (AsAb) in the peripheral serum, sperm motility, sperm malformation rate, and testicular tissue structure of rats were analyzed. Furthermore, the activity of superoxide dismutase (SOD), catalase (CAT), malondialdehyde (MDA) content, calpain, and Cdk5 expression were analyzed at 1, 7, 14, and 28 days after exposure. We observed that the rats after radiation had decreased serum INSL3 levels ($p < 0.01$), increased AsAb levels ($p < 0.05$), decreased percentage of class A+B sperm ($p < 0.01$ or $p < 0.05$), increased sperm malformation ($p < 0.01$ or $p < 0.05$), injured testicular tissue structure, decreased SOD and CAT activities ($p < 0.01$ or $p < 0.05$), increased MDA content ($p < 0.01$), and testicular tissue expressions of calpain1, calpain2, and Cdk5 were increased ($p < 0.01$ or $p < 0.05$). In conclusion, Shortwave radiation caused functional and structural damage to the reproductive organs of male rats. Furthermore, oxidative stress and key molecules in the calpain/Cdk5 pathway are likely involved in this process.

Plain language summary

Shortwave radiation has been used in communications, medical and military applications, and its damaging effects on several organs of the human body have been reported in the literature. However, the biological effects of shortwave radiation on the male reproductive system are unknown. The present study, by constructing an animal model of short-wave radiation and analyzing the experimental results, revealed that shortwave radiation could cause functional and structural damage to the reproductive organs of male rats, and that oxidative stress and key molecules in the calpain/Cdk5 pathway might be involved in this process. It will provide organizational data for further studies on the mechanisms of male reproductive damage by shortwave radiation.

https://pubmed.ncbi.nlm.nih.gov/38155529/

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**Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue**

Bektas H, Dasdag S, Altindag F, Akdag MZ, Yegin K, Algul S. Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue. Bioelectromagnetics. 2024 Feb 18. doi: 10.1002/bem.22498.

Abstract

In recent years exposure of living beings to radiofrequency radiation (RFR) emitted from wireless equipment has increased. In this study, we investigated the effects of 3.5-GHz RFR on hormones that regulate energy metabolism in the body. Twenty-eight rats were divided into four groups: healthy sham (n = 7), healthy RFR (n = 7), diabetic sham (n = 7), and diabetic RFR (n = 7). Over a month, each group

spent 2 h/day in a Plexiglas carousel. The rats in the experimental group were exposed to RFR, but the sham groups were not. At the end of the experiment, blood and adipose tissues were collected from euthanized rats. Total antioxidant, total oxidant, hydrogen peroxide, ghrelin, nesfatin-1, and irisin were determined. Insulin expression in pancreatic tissues was examined by immunohistochemical analysis. Whole body specific absorption rate was 37 mW/kg. For the parameters analyzed in blood and fat, the estimated effect size varied within the ranges of 0.215-0.929 and 0.503-0.839, respectively. The blood and adipose nesfatin-1 ($p = 0.002$), blood and pancreatic insulin are decreased, ($p = 0.001$), gherelin ($p = 0.020$), irisin ($p = 0.020$), and blood glucose ($p = 0.040$) are increased in healthy and diabetic rats exposed to RFR. While nesfatin-1 are negatively correlated with oxidative stress, hyperglycemia and insulin, ghrelin and irisin are positively correlated with oxidative stress and hyperglycemia. Thus, RFR may have deleterious effects on energy metabolism, particularly in the presence of diabetes.

https://pubmed.ncbi.nlm.nih.gov/38369591/

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**Evidence of spatial clustering of childhood acute lymphoblastic leukemia cases in Greater Mexico City: report from the Mexican Inter-Institutional Group for the identification of the causes of childhood leukemia**

Duarte-Rodríguez DA, Flores-Lujano J, McNally RJQ, Pérez-Saldivar ML, Jiménez-Hernández E, Martín-Trejo JA, Espinoza-Hernández LE, Medina-Sanson A, Paredes-Aguilera R, Merino-Pasaye LE, Velázquez-Aviña MM, Torres-Nava JR, Espinosa-Elizondo RM, Amador-Sánchez R, Dosta-Herrera JJ, Mondragón-García JA, González-Ulibarri JE, Martínez-Silva SI, Espinoza-Anrubio G, Paz-Bribiesca MM, Salcedo-Lozada P, Landa-García RÁ, Ramírez-Colorado R, Hernández-Mora L, Santamaría-Ascencio M, López-Loyola A, Godoy-Esquivel AH, García-López LR, Anguiano-Ávalos AI, Mora-Rico K, Castañeda-Echevarría A, Rodríguez-Jiménez R, Cibrian-Cruz JA, Solís-Labastida KA, Cárdenas-Cardos R, López-Santiago N, Flores-Villegas LV, Peñaloza-González JG, González-Ávila AI, Sánchez-Ruiz M, Rivera-Luna R, Rodríguez-Villalobos LR, Hernández-Pérez F, Olvera-Durán JÁ, García-Cortés LR, Mata-Rocha M, Sepúlveda-Robles OA, Bekker-Méndez VC, Jiménez-Morales S, Meléndez-Zajgla J, Rosas-Vargas H, Vega E, Núñez-Enríquez JC, Mejía-Aranguré JM. Evidence of spatial clustering of childhood acute lymphoblastic leukemia cases in Greater Mexico City: report from the Mexican Inter-Institutional Group for the identification of the causes of childhood leukemia. Front Oncol. 2024 Feb 14;14:1304633. doi: 10.3389/fonc.2024.1304633

Abstract

Background: A heterogeneous geographic distribution of childhood acute lymphoblastic leukemia (ALL) cases has been described, possibly, related to the presence of different environmental factors. The aim of the present study was to explore the geographical distribution of childhood ALL cases in Greater Mexico City (GMC).

Methods: A population-based case-control study was conducted. Children <18 years old, newly diagnosed with ALL and residents of GMC were included. Controls were patients without leukemia recruited from second-level public hospitals, frequency-matched by sex, age, and health institution with the cases. The residence address where the patients lived during the last year before diagnosis (cases) or the interview (controls) was used for geolocation. Kulldorff's spatial scan statistic was used to detect spatial clusters (SCs). Relative risks (RR), associated p-value and number of cases included for each cluster were obtained.

Results: A total of 1054 cases with ALL were analyzed. Of these, 408 (38.7%) were distributed across eight SCs detected. A relative risk of 1.61 ($p<0.0001$) was observed for the main cluster. Similar results were noted for the remaining seven ones. Additionally, a proximity between SCs, electrical installations and petrochemical facilities was observed.

Conclusions: The identification of SCs in certain regions of GMC suggest the possible role of environmental factors in the etiology of childhood ALL.

Open access paper:
https://www.frontiersin.org/journals/oncology/articles/10.3389/fonc.2024.1304633/full

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**International study of childhood leukemia in residences near electrical transformer rooms**

Crespi CM, Sudan M, Juutilainen J, Roivainen P, Hareuveny R, Huss A, Kandel S, Karim-Kos HE, Thuróczy G, Jakab Z, Spycher BD, Flueckiger B, Vermeulen R, Vergara X, Kheifets L. International study of childhood leukemia in residences near electrical transformer rooms. Environ Res. 2024 Feb 10:118459. doi: 10.1016/j.envres.2024.118459.

Abstract

Objectives: New epidemiologic approaches are needed to reduce the scientific uncertainty surrounding the association between extremely low frequency magnetic fields (ELF-MF) and childhood leukemia. While most previous studies focused on power lines, the Transformer Exposure study sought to assess this association using a multi-country study of children who had lived in buildings with built-in electrical transformers. ELF-MF in apartments above built-in transformers can be 5 times higher than in other apartments in the same building. This novel study design aimed to maximize the inclusion of highly exposed children while minimising the potential for selection bias.

Methods: We assessed associations between residential proximity to transformers and risk of childhood leukemia using registry based matched case-control data collected in five countries. Exposure was based on the location of the subject's apartment relative to the transformer, coded as high (above or adjacent to transformer), intermediate (same floor as apartments in high category), or unexposed (other apartments). Relative risk (RR) for childhood leukemia was estimated using conditional logistic and mixed logistic regression with a random effect for case-control set.

Results: Data pooling across countries yielded 16 intermediate and 3 highly exposed cases. RRs were 1.0 (95% CI: 0.5, 1.9) for intermediate and 1.1 (95% CI: 0.3, 3.8) for high exposure in the conditional logistic model. In the mixed logistic model, RRs were 1.4 (95% CI: 0.8, 2.5) for intermediate and 1.3 (95% CI: 0.4, 4.4) for high. Data of the most influential country showed RRs of 1.1 (95% CI: 0.5, 2.4) and 1.7 (95% CI: 0.4, 7.2) for intermediate (8 cases) and high (2 cases) exposure.

Discussion: Overall, evidence for an elevated risk was weak. However, small numbers and wide confidence intervals preclude strong conclusions and a risk of the magnitude observed in power line studies cannot be excluded.

https://pubmed.ncbi.nlm.nih.gov/38346482/

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**The role of curcumin during pregnancy on the exposed fetuses' tissues of Wistar rats to electromagnetic field**

Kalantar MH, Bayat PD, Ghaffari Khaligh S, Soleimani H. The role of curcumin during pregnancy on the exposed fetuses' tissues of Wistar rats to electromagnetic field. Electromagn Biol Med. 2024 Feb 17:1-10. doi: 10.1080/15368378.2024.2315214.

Abstract

To investigate curcumin (CUR) as the protector against the harmful effects of low-frequency electromagnetic field(LF- EMF, 50 Hz) during pregnancy period, 5 males and 15 females of Wistar rat mated and vaginal plaques were observed. Then, the pregnant rats were divided into six groups. During pregnancy(21 days), the EMF group was exposed to EMF for 30 min/day, the CUR group received a single dose of 50 mg/kg/daily CUR intraperitoneal, the EMF+CUR group was injected CUR and exposed to EMF daily. The DMSO(dimethyl sulfoxide) group was injected solvent of CUR (DMSO) intraperitoneal with the same volume of CUR solvent, the sham group was placed through the solenoid in the same conditions as the first group without exposure and the control group was kept in their cage in normal condition. After four weeks, babies born were divided according to the mother groups and sacrificed. Then, the three tissues injuries were investigated. EMF exposure led to an increase in outstanding necrotic areas in hippocampal tissue, an increase in the amount of hyperemia($p$ = 0.017) and necrotic($p$ = 0.005) in kidneys, and degeneration in liver tissue($p$ = 0.007) in the EMF group compared with EMF+CUR groups. A single dose of CUR daily during pregnancy can protect these tissues from injuries caused by LF-EMF exposure in rat fetuses.

Plain language summary

Electromagnetic fields (EMFs) are able to penetrate and be absorbed by the body. The researchers showed that these radiations might be harmful and lead to cancers, cardiovascular diseases, mental disorders, and fetal abnormalities. Curcumin as an active component in turmeric has anti-inflammatory, antioxidant and anti-hyperlipidemia properties. It can protect the body against diseases such as arthritis, anxiety, and metabolic syndrome. This study examined the effects of curcumin as the protector against the harmful effects of EMF (50Hz) during pregnancy period. So the pregnant rats were divided into six groups. During pregnancy, a group was exposed to EMF for 30 min/day, the second group was injected a dose of curcumin 50mg/kg/daily, the third group was injected curcumin and exposed to EMF daily. The fourth group was injected a curcumin solvent dose, the sham group was placed through the field generator in the same conditions as the first group without exposure and the control group was kept in their cage in normal condition. After four weeks, babies born were divided according to the mother groups and sacrificed. Then, the liver, kidney, and hippocampal tissues were investigated. EMF exposure led to an outstanding increase in necrotic areas in hippocampal tissue, a notable increase in the amount of hyperemia and necrosis in kidneys, and degeneration in liver tissue($p$=0.007) in the EMF group compared with the third group that was exposed to EMF and received curcumin. A single dose of curcumin daily during pregnancy can protect these tissues from injuries caused by EMF(50Hz) exposure in rat fetuses.

https://pubmed.ncbi.nlm.nih.gov/38366892/

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**Extremely low-frequency EMF facilitate both osteoblast and osteoclast activity through Wnt/β-catenin signaling in the zebrafish scale**

Kobayashi-Sun J, Kobayashi I, Kashima M, Hirayama J, Kakikawa M, Yamada S, Suzuki N. Extremely low-frequency electromagnetic fields facilitate both osteoblast and osteoclast activity through Wnt/β-catenin signaling in the zebrafish scale. Front Cell Dev Biol. 2024 Feb 7;12:1340089. doi: 10.3389/fcell.2024.1340089.

Abstract

Electromagnetic fields (EMFs) have received widespread attention as effective, noninvasive, and safe therapies across a range of clinical applications for bone disorders. However, due to the various frequencies of devices, their effects on tissues/cells are vary, which has been a bottleneck in understanding the effects of EMFs on bone tissue. Here, we developed an *in vivo* model system using zebrafish scales to investigate the effects of extremely low-frequency EMFs (ELF-EMFs) on fracture healing. Exposure to 10 millitesla (mT) of ELF-EMFs at 60 Hz increased the number of both osteoblasts and osteoclasts in the fractured scale, whereas 3 or 30 mT did not. Gene expression analysis revealed that exposure to 10 mT ELF-EMFs upregulated *wnt10b* and Wnt target genes in the fractured scale. Moreover, *β*-catenin expression was enhanced by ELF-EMFs predominantly at the fracture site of the zebrafish scale. Inhibition of Wnt/*β*-catenin signaling by IWR-1-endo treatment reduced both osteoblasts and osteoclasts in the fractured scale exposed to ELF-EMFs. These results suggest that ELF-EMFs promote both osteoblast and osteoclast activity through activation of Wnt/*β*-catenin signaling in fracture healing. Our data provide *in vivo* evidence that ELF-EMFs generated with a widely used commercial AC power supply have a facilitative effect on fracture healing.

Open access paper: https://www.frontiersin.org/articles/10.3389/fcell.2024.1340089/full

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**Influence of Magnetic Fields, Including the Planetary Magnetic Field, on Complex Life Forms: How Do Biological Systems Function in This Field and in Electromagnetic Fields?**

Hart DA. The Influence of Magnetic Fields, Including the Planetary Magnetic Field, on Complex Life Forms: How Do Biological Systems Function in This Field and in Electromagnetic Fields? *Biophysica*. 2024; 4(1):1-21. doi: 10.3390/biophysica4010001.

Abstract
Life on Earth evolved to accommodate the biochemical and biophysical boundary conditions of the planet millions of years ago. The former includes nutrients, water, and the ability to synthesize other needed chemicals. The latter includes the 1 g gravity of the planet, radiation, and the geomagnetic field (GMF) of the planet. How complex life forms have accommodated the GMF is not known in detail, considering that Homo sapiens evolved a neurological system, a neuromuscular system, and a cardiovascular system that developed electromagnetic fields as part of their functioning. Therefore, all

of these could be impacted by magnetic fields. In addition, many proteins and physiologic processes utilize iron ions, which exhibit magnetic properties. Thus, complex organisms, such as humans, generate magnetic fields, contain significant quantities of iron ions, and respond to exogenous static and electromagnetic fields. Given the current body of literature, it remains somewhat unclear if Homo sapiens use exogenous magnetic fields to regulate function and what can happen if the boundary condition of the GMF no longer exerts an effect. Proposed deep space flights to destinations such as Mars will provide some insights, as space flight could not have been anticipated by evolution. The results of such space flight "experiments" will provide new insights into the role of magnetic fields on human functioning. This review will discuss the literature regarding the involvement of magnetic fields in various normal and disturbed processes in humans while on Earth and then further discuss potential outcomes when the GMF is no longer present to impact host systems, as well as the limitations in the current knowledge. The GMF has been present throughout evolution, but many details of its role in human functioning remain to be elucidated, and how humans have adapted to such fields in order to develop and retain function remains to be elucidated. Why this understudied area has not received the attention required to elucidate the critical information remains a conundrum for both health professionals and those embarking on space flight. However, proposed deep space flights to destinations such as Mars may provide the environments to test and assess the potential roles of magnetic fields in human functioning.

Open access paper: https://www.mdpi.com/2673-4125/4/1/1

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**Do electromagnetic fields from subsea power cables effect benthic elasmobranch behaviour? A risk-based approach for the Dutch Continental Shelf**

Hermans A, Winter HV, Gill AB, Murk AJ. Do electromagnetic fields from subsea power cables effect benthic elasmobranch behaviour? A risk-based approach for the Dutch Continental Shelf. Environ Pollut. 2024 Feb 13:123570. doi: 10.1016/j.envpol.2024.123570.

Abstract

Subsea power cables cause electromagnetic fields (EMFs) into the marine environment. Elasmobranchs (rays, skates, sharks) are particularly sensitive to EMFs as they use electromagnetic-receptive sensory systems for orientation, navigation, and locating conspecifics or buried prey. Cables may intersect with egg laying sites, mating, pupping, and nursery grounds, foraging habitat and migration routes of elasmobranchs and the effects of encountering EMFs on species of elasmobranchs are largely unknown. Demonstrated behavioural effects are attraction, disturbance and indifference, depending on EMF characteristics, exposed life stage, exposure level and duration. We estimated exposure levels of elasmobranchs to subsea power cable EMFs, based on modelled magnetic fields in the Dutch Continental Shelf and compared these to reported elasmobranch sensory sensitivity ranges and experimental effect levels. We conclude that the risk from subsea power cables has a large uncertainty and varies per life stage and species ecology. Based on estimated no-observed effect levels (from $10^{-3}$ to $10^{-1}$ μT) we discuss what will probably be the most affected species and life stage for six common benthic elasmobranchs in the Southern North Sea. We then identify critical knowledge gaps for reducing the uncertainty in the risk assessments for EMFs effects on benthic elasmobranchs.

https://pubmed.ncbi.nlm.nih.gov/38360387/

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**A Boundary Element Method of Bidomain Modeling for Predicting Cellular Responses to Electromagnetic Fields**

Czerwonky DM, Aberra AS, Gomez LJ. A Boundary Element Method of Bidomain Modeling for Predicting Cellular Responses to Electromagnetic Fields. bioRxiv [Preprint]. 2023 Dec 16:2023.12.15.571917. doi: 10.1101/2023.12.15.571917. (preprint, not peer-reviewed)

Abstract
Objective: Commonly used cable equation-based approaches for determining the effects of electromagnetic fields on excitable cells make several simplifying assumptions that could limit their predictive power. Bidomain or "whole" finite element methods have been developed to fully couple cells and electric fields for more realistic neuron modeling. Here, we introduce a novel bidomain integral equation designed for determining the full electromagnetic coupling between stimulation devices and the intracellular, membrane, and extracellular regions of neurons.

Methods: Our proposed boundary element formulation offers a solution to an integral equation that connects the device, tissue inhomogeneity, and cell membrane-induced E-fields. We solve this integral equation using first-order nodal elements and an unconditionally stable Crank-Nicholson time-stepping scheme. To validate and demonstrate our approach, we simulated cylindrical Hodgkin-Huxley axons and spherical cells in multiple brain stimulation scenarios.

Main results: Comparison studies show that a boundary element approach produces accurate results for both electric and magnetic stimulation. Unlike bidomain finite element methods, the bidomain boundary element method does not require volume meshes containing features at multiple scales. As a result, modeling cells, or tightly packed populations of cells, with microscale features embedded in a macroscale head model, is made computationally tractable, and the relative placement of devices and cells can be varied without the need to generate a new mesh.

Significance: Device-induced electromagnetic fields are commonly used to modulate brain activity for research and therapeutic applications. Bidomain solvers allow for the full incorporation of realistic cell geometries, device E-fields, and neuron populations. Thus, multi-cell studies of advanced neuronal mechanisms would greatly benefit from the development of fast-bidomain solvers to ensure scalability and the practical execution of neural network simulations with realistic neuron morphologies.

Open access paper: https://www.biorxiv.org/content/10.1101/2023.12.15.571917v1

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**Static magnetic fields as a factor in modification of tissue and cell structure: a review**

Saletnik BA, Puchalska-Sarna A, Saletnik A, Lipa T, Dobrzański B, Puchalski C. Static magnetic fields as a factor in modification of tissue and cell structure: a review. *Int. Agrophys.* 2024;38(1):43-75. doi:10.31545/intagr/176998.

Highlights

- The static magnetic field (SMF) is an indispensable factor in the natural environment.
- A moderate SMF in the most commonly used range of 2–80 mT has a potential application in the formation and re-modeling of plants and animals, including human cells.
- SMFs can significantly change the potential of the cell membrane, and thus can have a significant impact on the properties of the cell.

Abstract

This review is intended to contribute to the evidence of the effects of static magnetic field on cells and tissue, as well as to present research results that will elucidate the complex matters involved in the formation and remodeling of cells. The cell characteristics studied in the papers that are reviewed include cell viability and proliferation, aggregation and their differentiation, structure and membrane potential. A moderate static magnetic field in the most commonly used range of 2-80 mT has potential application in the formation and remodeling of plant and human cells. However, in the case of cancer cells, the range of fields commonly used was 0.2-9 T. Magnetism promotes changes in plant cell growth, which prompts the cell to proliferate, thereby ensuring an increased rate of biomass production. Some research presented the enhancement of the differentiation of plant cells and skeletal muscle tissue by over 30% at 80 mT static magnetic field. Changes in the cell cycle and growth reflect directly on the cell number and viability and provide useful information to detect modifications in the cell machinery. Static magnetic field, depending on its intensity, enhances cell proliferation and thus may improve, among other processes, tissue regeneration, wound healing and the inhibition of cancer cell proliferation. Researchers showed, among other things, that cells under the influence of static magnetic field changed their shape, had a larger chloroplast, stiffer cell wall, density of the cytoskeleton and cytoplasm contained several mitochondria. Numerous studies also discussed the behavior of the cell membrane of plant and animal organisms, including humans, under the influence of a static magnetic field. The effects of static magnetic field on the cell membrane of plant and human cells were similar. The research results indicate that static magnetic fields can significantly change membrane depolarization and its potential that regulates ion movement and thus can have a significant impact on the properties and biological functionality of the cell. Studies have shown that continuous application of static magnetic field caused deformation and damage of cell membrane. Based on the theoretical analyses presented also in this review, it can be concluded that static magnetic field affects cells and tissue, giving them changes in properties and behaviors and modulates, e.g. in the activity of ion channels. Thus it may produce effects leading to changes in the functioning of the cell. It is possible to formulate directions for further research aimed at using static magnetic fields for the non-invasive remodeling and formation of plant and human cells.

Open access paper: http://www.international-agrophysics.org/Static-magnetic-fields-as-a-factor-in-modification-of-tissue-and-cell-structure-a,176998,0,2.html

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**The biological effects of terahertz wave radiation-induced injury on neural stem cells**

Wang Y, Xiong Y, Chen M, Liu F, He H, Ma Q, Gao P, Xiang G, Zhang L. The biological effects of terahertz wave radiation-induced injury on neural stem cells. iScience. 2023 Jul 18;26(10):107418. doi: 10.1016/j.isci.2023.107418.

Abstract

Terahertz (THz) is an electromagnetic wave with a radiation wavelength range of 30-3000 μm and a frequency of 0.1-10 THz. With the development of new THz sources and devices, THz has been widely applied in various fields. However, there are few studies on biological effects of THz irradiation on the human neural stem cells (hNSCs) and mouse neural stem cells (mNSCs), which need to be further studied. We studied the biological effects of THz radiation on hNSCs and mNSCs. The effects of THz irradiation time and average output power on the proliferation, apoptosis, and DNA damage of NSCs were analyzed by flow cytometry and immunofluorescence. The results showed that the proliferation and apoptosis of NSCs were dose-dependently affected by THz irradiation time and average output power. The proliferation of hNSCs was more vulnerable to damage and apoptosis was more serious under the same terahertz irradiation conditions compared to those of mNSCs.

Open access paper: https://www.cell.com/iscience/fulltext/S2589-0042(23)01495-5