Electromagnetic Radiation Safety

Scientific & policy developments regarding the biological & health effects of electromagnetic radiation from cell phones, cell towers, Wi-Fi, Smart Meters, electric vehicles & other wireless technology, including 5G. Website curated by Joel Moskowitz, Ph.D., School of Public Health, University of California, Berkeley.

Wednesday, October 14, 2026

Recent Research on Wireless Radiation and Electromagnetic Fields

I have been circulating abstracts of newly-published scientific papers on radio frequency and other non-ionizing electromagnetic fields (EMF) monthly since 2016. The complete collection contains more than 2500 abstracts with links to these papers. Several hundred EMF scientists around the world receive these updates.

To download Volume 3 which contains abstracts of papers published since 2024 (including the new papers listed below) click on the following link (763 page pdf)**:**

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The abstracts for recently published papers appear below.

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<5×10-8) 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≥0.115). 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 flelds 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.

Open access:
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

URL: 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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https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=11704817&isnumber=6514899

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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.

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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.

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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.

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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.

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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.

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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.

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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.

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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/