

Wireless Device Emissions: Inadequate Exposure Limits for Cancer & Reproductive Risks

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National Toxicology Program

The mission of the **NTP** is to identify and characterize health effects of environmental agents based on state-of-the-art toxicological research methods.

In this way, the **NTP** provides the scientific basis for public health policies that can lead to disease prevention.



Why do Health Agencies Use Animal Studies to Assess Human Cancer Risk?

- **Similar biological processes of disease induction**
- **Unethical to intentionally test for carcinogenicity in humans**
- **Every known human carcinogen is carcinogenic in animals when adequately tested**
- **Controlled exposures eliminate potential confounders**
- **Animal studies can eliminate the need to wait for sufficient human cancer data before implementing public health protective strategies**

FDA's Center for Devices and Radiological Health Nomination of RF Radiation to the NTP

- **“Existing exposure guidelines are based on protection from acute injury from thermal effects of RFR exposure, and may not be protective against any non-thermal effects of chronic exposures”**
- **Request to NTP: toxicity and carcinogenicity studies of cell phone RF radiation in experimental animals “to provide the basis to assess the risk to human health”**

Exposure Limits to RF Radiation from Wireless Devices

Behavioral studies on RF-EMF conducted by the US Navy Department in the early 1980s

- 8 male rats¹ and 5 male monkeys², trained to depress a lever to deliver food pellets, were exposed to radiofrequency radiation (RFR) at various intensities during 40- to 60-minute sessions
 - Response rates were decreased at calculated specific absorption rates (SARs) of approximately 4 W/kg and higher
 - This exposure level was also associated with colonic temperature increase of $\sim 1^{\circ}\text{C}$

¹De Lorge and Ezell, Bioelectromagnetics (1980), 1:183–198.

²De Lorge, Bioelectromagnetics (1984), 5:233-246

FCC and ICNIRP Exposure Guidelines (1996/1997) for Radiofrequency Radiation

- SAR of 4 W/kg adopted as threshold dose; guidelines were designed to protect against adverse effects that might occur due to increases in body temperature of 1°C
- Whole body exposure limits, expressed as SAR
 - Workers (threshold $\div$ 10): 0.4 W/kg
 - General public (threshold $\div$ 50): 0.08 W/kg
- Local tissue exposure limits, expressed as SAR
 - Workers: 8 W/kg over any 1-gram cube of tissue (FCC)
 - General public 1.6 W/kg averaged over any 1-gram cube of tissue (FCC)

FCC and ICNIRP Assumptions

- No adverse effects would occur below the putative threshold SAR of 4 W/kg
- Any reported biological effects are due to excessive tissue heating, the only possible biological effect of nonionizing radiation
 - RFR does not have sufficient energy to break chemical bonds or ionize molecules, and therefore cannot damage DNA

IARC Classification of RF Radiation

RF- Electromagnetic Fields: Possibly Carcinogenic to Humans* (IARC)

*Classification
based mainly on
human studies



Epidemiological Studies of Cancer Risk in Cell Phone Users

- **Prior to IARC, 2011**
 - **Case-control studies**
 - Significant increases of brain gliomas and acoustic neuromas (Interphone; Hardell et al.)
 - Further increase in risk with ipsilateral use
 - Potential recall bias
 - **Cohort studies**
 - IARC, 2011: serious methodological shortcomings, including exposure misclassifications (Danish cohort study)
- **After IARC, 2011**
 - Significant increase in brain gliomas Coureau et al.
 - Multiple meta-analyses demonstrate increased risk of glioma, e.g., Moon et al, 2024
 - WHO systematic analyses/meta-analyses

IARC Evaluation on the Carcinogenicity of RF Radiation

Monograph Volume 102 (2013)

- **Limited evidence in humans:** positive associations have been observed from exposure to RF radiation from wireless phones and glioma and acoustic neuroma
 - ▶ Negative cohort studies: potential misclassifications of exposure
 - ▶ Positive case-control studies: potential selection and recall bias
- **Limited evidence in experimental animals**
- **Overall:** RF-EMFs are possibly carcinogenic to humans (Group 2B)

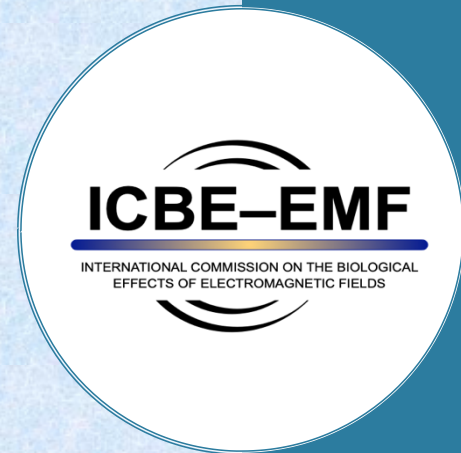
2018-2020

- **NTP study (2018):** “Clear evidence” for heart schwannomas and “some evidence” for brain gliomas with CDMA- or GSM-modulated RF radiation, plus preneoplastic lesions in the heart (Schwann cells) and brain (glial cells). Same cell types affected in human cancer studies
 - Cardiomyopathy
 - DNA strand breaks in brains of rats and mice
- **Ramazzini study (2018):** increased incidences of heart schwannomas and brain gliomas
- **Philips et al (2018):** glioblastoma multiforme incidence increasing in England between 1995 and 2015, and reduced incidence of lower grade brain tumors
- **ICNIRP and FCC** reaffirm previous exposure limits to RF radiation
- **ICBE-EMF** examines basis for exposure limits in relation to scientific studies conducted over the past 25 years, and challenges the validity of assumptions that underlie ICNIRP’s and FCC’s exposure limit

ICBE Evaluates RF Radiation Exposure Limits

International Commission on the Biological Effects of Electromagnetic Fields

- A multi-disciplinary consortium of scientists, doctors and related professionals who are, or have been, involved with research related to the biological and health effects of EMFs.
- Purpose: to make recommendations to ensure the protection of humans and other species from harmful effects of non-ionizing radiation.



<https://icbe-emf.org>

COMMENT

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Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: implications for 5G

International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF)*

Abstract

In the late-1990s, the FCC and ICNIRP adopted radiofrequency radiation (RFR) exposure limits to protect the public and workers from adverse effects of RFR. These limits were based on results from behavioral studies conducted in the 1980s involving 40–60-minute exposures in 5 monkeys and 8 rats, and then applying arbitrary safety factors to an apparent threshold specific absorption rate (SAR) of 4W/kg. The limits were also based on two major assumptions: any biological effects were due to excessive tissue heating and no effects would occur below the putative threshold SAR, as well as twelve assumptions that were not specified by either the FCC or ICNIRP. In this paper, we show how the past 25 years of extensive research on RFR demonstrates that the assumptions underlying the FCC's and ICNIRP's exposure limits are invalid and continue to present a public health harm. Adverse effects observed at exposures below the assumed threshold SAR include non-thermal induction of reactive oxygen species, DNA damage, cardiomyopathy, carcinogenicity, sperm damage, and neurological effects, including electromagnetic hypersensitivity. Also, multiple human studies have found statistically significant associations between RFR exposure and increased brain and thyroid cancer risk. Yet, in 2020, and in light of the body of evidence reviewed in this article, the FCC and ICNIRP reaffirmed the same limits that were established in the 1990s. Consequently, these exposure limits, which are based on false suppositions, do not adequately protect workers, children, hypersensitive individuals, and the general population from short-term or long-term RFR exposures. Thus, urgently needed are health protective exposure limits for humans and the environment. These limits must be based on scientific evidence rather than on erroneous assumptions, especially given the increasing worldwide exposures of people and the environment to RFR, including novel forms of radiation from 5G telecommunications for which there are no adequate health effects studies.

Assumptions (*Invalid*) Underlying the FCC/ICNIRP Exposure Limits for RF Radiation

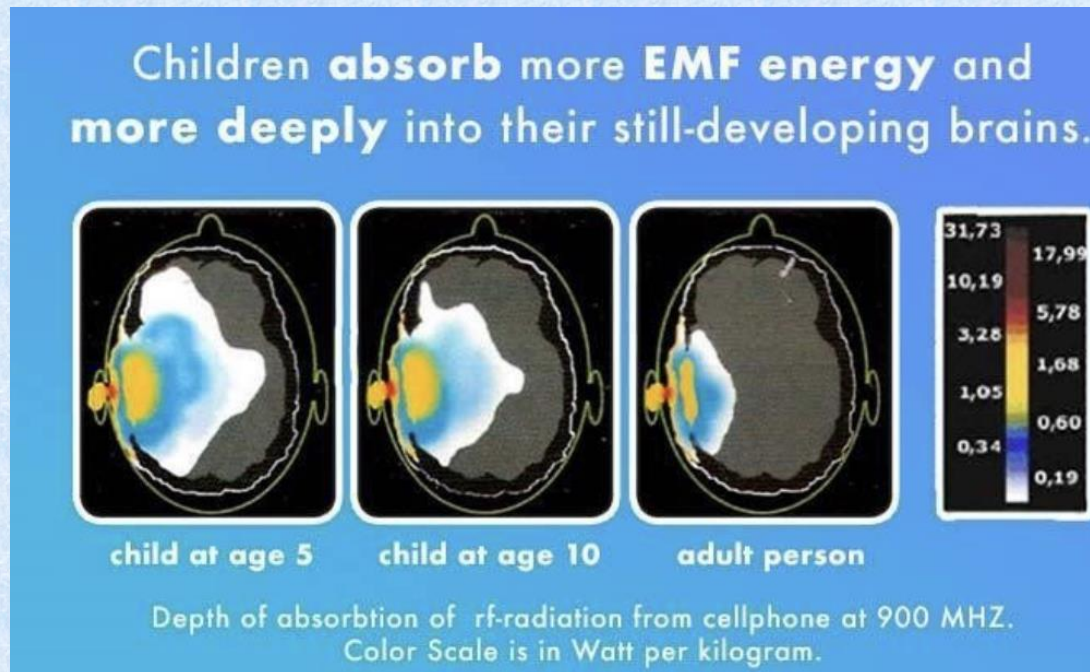
- 1) There is a threshold exposure for any adverse health effect caused by RF radiation; in the frequency range of 100 kHz to 6 GHz it is a whole-body exposure that exceeds an SAR of 4 W/kg. Any biological effect of RF radiation above the threshold exposure is due to tissue heating.
- 2) RF radiation is incapable of causing DNA damage other than by heating; there is no mechanism for non-thermal DNA damage
- 3) Two to seven exposures to RF radiation for up to one hour duration are sufficient to exclude adverse effects for any duration of exposure including chronic exposures.
- 4) No additional effects would occur from RF radiation with co-exposure to other environmental agents.
- 5) Health effects are dependent only on the SAR value; carrier wave modulations, frequency, or pulsing do not matter except as they influence the SAR.
- 6) The multiple human studies that find associations between exposure to cell phone RF radiation and increases in brain cancer risk are flawed because of biases in the published case-control studies, and because brain cancer rates have remained steady since the time that use of wireless communication devices became widespread.

Assumptions continued

- 7) There are no differences among individuals, including children, in the absorption of RF-EMF and susceptibility to this radiation.
- 8) There are no differences among individuals in their sensitivity to RF radiation-induced health effects.
- 9) A 50-fold safety factor for whole body exposure to RF radiation is adequate for protecting the general population to any health risks from RF radiation.
- 10) A 10-fold safety factor for whole body exposure to RF radiation is adequate for protecting workers to any health risks from RF radiation.
- 11) Exposure of any gram of cube-shaped tissue up to 1.6 W/kg, or 10 grams of cube-shaped tissue up to 2 W/kg, (duration not specified) will not increase the risk of that tissue to any toxic or carcinogenic effects in the general population.
- 12) Exposure of any gram of cube-shaped tissue up to 8 W/kg, or 10 grams of cube-shaped tissue up to 10 W/kg, (duration not specified) will not increase the risk of that tissue to any toxic or carcinogenic effects in workers.
- 13) There is no concern for environmental effects of RF radiation or for effects on wildlife or household pets.
- 14) No health effects data are needed for exposures to 5G; safety is assumed because penetration is limited to the skin (“minimal body penetration”).

Special Concern for Effects of RF Radiation in Children

- Absorb more radiation
- Deeper penetration
- Developing organs are more susceptible to tissue damaging agents
- Lifetime exposure



RF Radiation Exposure Limits: Accounting for Cancer Risk and Reproductive Toxicity

Two WHO-sponsored Reviews On Effects of RF-EMF Exposure were Rated as High Certainty of Evidence (HCE)*

- Cancer in laboratory animal studies (Mevissen et al., 2025).
 - Included benchmark dose analyses
- Male fertility reduced in non-human mammals (Cordelli et al., 2024)
 - Linear dose-response relationship, with significant increase of 3% per W/kg

*** HCE: the reported effect is highly likely to be due to exposure to RF radiation**

RESEARCH

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Exposure limits to radiofrequency EMF do not account for cancer risk or reproductive toxicity assessed from data in experimental animals



Ronald L. Melnick^{1*}, and Joel M. Moskowitz² on behalf of

The International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF)

Abstract

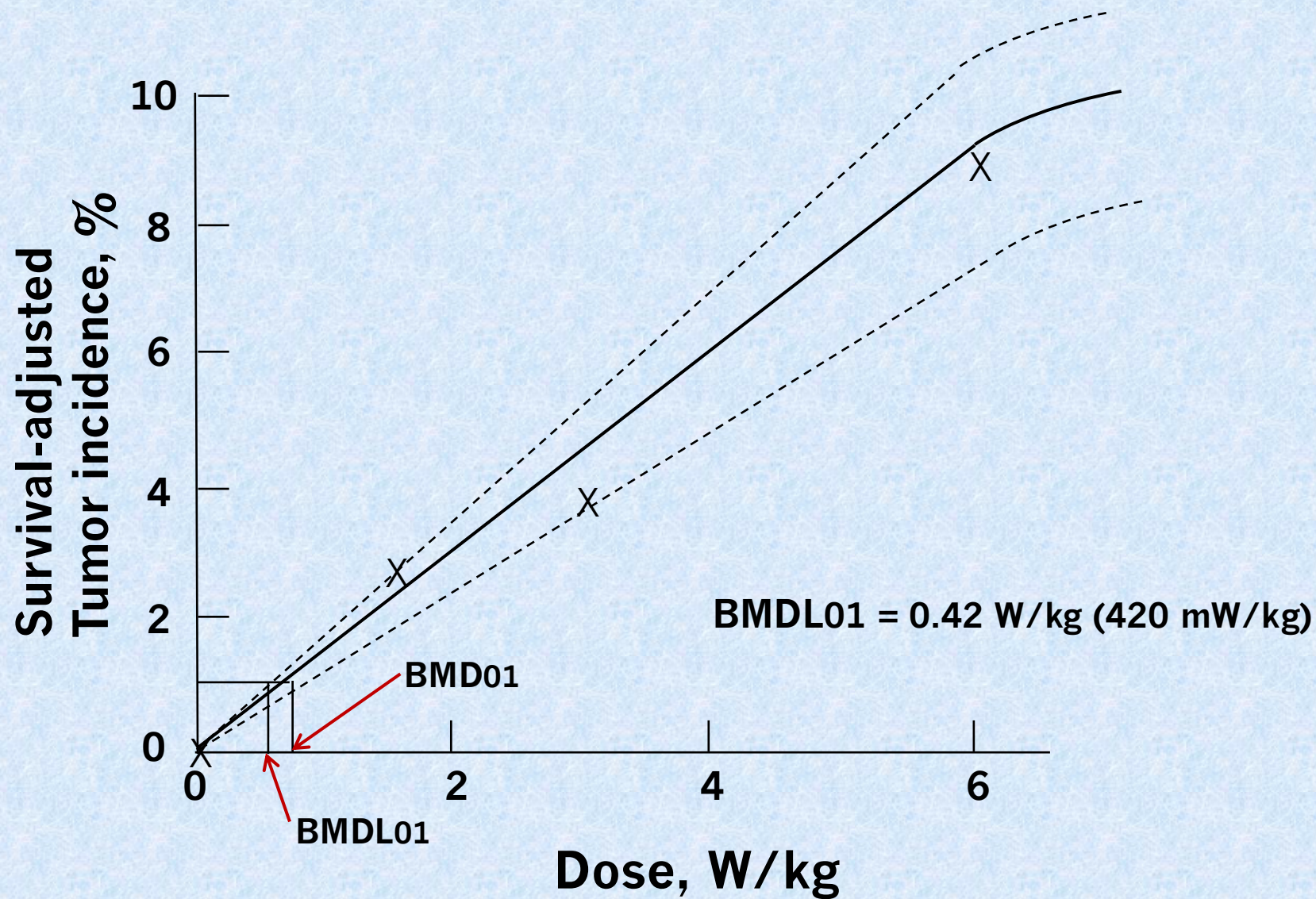
Background Recent WHO-commissioned systematic reviews have concluded with “high certainty” that exposure to radiofrequency electromagnetic fields (RF-EMF) increases cancer risk and reduces male fertility in experimental animals.

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.

Benchmark Dose Analysis



Risk Assessment of Heart Schwannomas from NTP Study of CDMA-modulated RF-EMF (9hr/day)

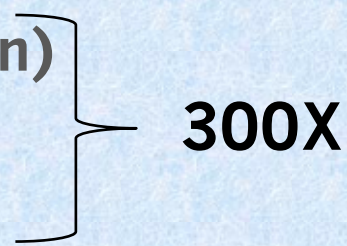
Exposure (hr/day)	SAR (mW/kg) ¹	ICNIRP/FCC ² vs NTP
1	3.8	21
4	0.95	84
8	0.47	170 ³

¹ Time-adjusted SAR value associated with additional risk of 1 per 100,000

² The ICNIRP/FCC whole-body exposure limit to RF-EMF for the general public is 0.08 W/kg = 80 mW/kg. This value is also the additional lifetime cancer risk per 100,000 based on ICNIRP/FCC guidelines

³ For heart schwannoma or brain glioma, the 8 hr/day SAR value at 1×10^{-5} risk is 205 times lower than the ICNIRP/FCC exposure limit

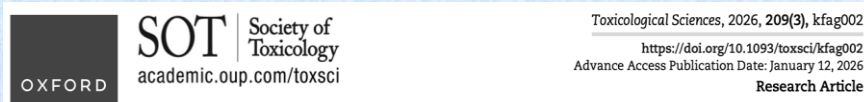
ICNIRP/FCC Exposure Limit to RF Radiation vs Reduced Male Fertility

- Reduced male fertility was linear with increasing SAR; potency = 3% per W/kg (Cordelli et al, 2024)
- Applied uncertainty factors
 - 10X interspecies (animal to human)
 - 10X intraspecies
 - 3X lack of a NOAEL

300X
- SAR of $1 \text{ W/kg} / 300 = 3.3 \text{ mW/kg}$
- ICNIRP/FCC limit vs calculated SAR
 - $80 \text{ mW/kg} / 3.3 \text{ mW/kg} = 24$ for general public
 - $400 \text{ mW/kg} / 3.3 \text{ mW/kg} = 120$ for workers

New Carcinogenicity Studies and WHO's Systematic Reviews on RF Radiation

Carcinogenicity Studies of CDMA-modulated RF radiation Conducted in Japan and Korea*



The International Collaborative Animal Study of mobile phone radiofrequency radiation carcinogenicity and genotoxicity: the Japanese study

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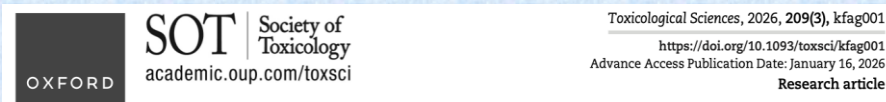
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Abstract

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 h and 20 min daily over 2 yr. The study included a 28-d preliminary toxicity study, genotoxicity assays (alkaline comet and micronucleus tests), and a 2-yr 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.



The International Collaborative Animal Study of the carcinogenicity and genotoxicity of mobile phone radiofrequency radiation: the Korean study

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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 h and 20 min each day, with 10-min on/off cycles. The project included a 28-d toxicity study, a 2-yr carcinogenicity study, and a 14-wk 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

* “to verify key findings from the NTP study using **identical protocols** and exposure systems.”

COMMENT

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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

Ronald L. Melnick^{1*}, Joel M. Moskowitz² and Paul Héroux³ on behalf of
International Commission on the Biological Effects of Electromagnetic Fields

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.

Comparison of 3 Carcinogenicity Studies of 900 MHz CDMA-modulated RF Radiation in Sprague-Dawley Rats Exposed in Reverberation Chambers

	NTP study				Japanese study		Korean study	
Dose, W/kg	0	1.5	3.0	6.0	0	4.0	0	4.0
Number of animals per group	90	90	90	90	70	68	70	70
Heart schwannoma incidence, %	0*	2.2	3.3	6.7*	1.4	1.5	0	2.9
Conclusion	“Clear evidence of carcinogenic activity,” based on significant (*) trend and pair-wise comparison at 6 W/kg				Not carcinogenic		Not carcinogenic	

Critique of Japanese and Korean Validation Studies of NTP Carcinogenicity Results of CDMA-modulated RF Radiation

- Did not include the dose group (6 W/kg) which had a significant increase in heart schwannomas in exposed animals compared to sham controls.
- Single dose study eliminated the ability to analyze trends, which are essential for interpreting experimental carcinogenicity data.
- Smaller number of animals per group limited the statistical power to detect a significant effect
 - Power calculation shows that 258 animals per group needed for 80% power and 320 animals per group for 90% power to find a significant effect at 4 W/kg.
- Strong influence of ICNIRP in the design and interpretation
 - “no reproducible carcinogenic potential of mobile phone-type RF exposure in rats”
 - Alternatives to ICNIRP “recommend[ed] exposure limits for RF radiation based on thermal effects” are inconclusive

WHO Systematic Reviews and Meta-analyses on Health Effects of Radiofrequency Radiation

- Cancer
 - Human observational studies
 - Studies in experimental animals
- Male fertility
 - Human observational studies
 - Studies in experimental animals and human sperm *in vitro*
- Female reproductive outcomes
 - Human observational studies
 - Pregnancy and birth outcomes in no-human mammals
- Cognition
 - Human observational studies
 - Human experimental studies
- Tinnitus, migraine, other reported symptoms
 - Human observational studies
 - Human experimental studies: Electromagnetic hypersensitivity
- Oxidative stress
- No reviews on heat-related effects

REVIEW

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The WHO-commissioned systematic reviews on health effects of radiofrequency radiation provide no assurance of safety

Ronald L. Melnick^{1*}, Joel M. Moskowitz², Paul Héroux³, Erica Mallery-Blythe⁴, Julie E. McCredde⁵, Martha Herbert⁶, Lennart Hardell⁷, Alasdair Philips⁸, Fiorella Belpoggi⁹, John W. Frank¹⁰, Theodora Scarato¹¹, Elizabeth Kelley¹² and On Behalf of the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF)

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.

ICBE-EMF Critique of WHO Systematic Reviews/ Meta-Analyses on Radiofrequency Radiation

- Many had relatively few primary studies for each meta-analysis, sometimes due to excessive subgrouping
- Lack of transparency
- Inconsistencies in ratings
- Weaknesses in many of the selected primary studies
- Many meta-analyses had high between-study heterogeneity
- The review of cancer studies in experimental animals did not conduct a meta-analysis due to methodological differences among available studies, e.g., frequency, modulation, etc.
- Conclusions of (very) low certainty of no association with RF radiation exposures do not provide proof of safety of cell phones or other wireless devices

Conclusions/Recommendations

- Exposure limits to RF radiation must be based on scientific evidence rather than on erroneous assumptions, especially given the increasing worldwide exposures of people and the environment. Our assessment shows that current exposure limits exceed public health protective levels by 20- to 200-fold.
- Numerous reports of harmful effects of RF radiation (e.g., cancer, reproductive toxicity, etc.) at doses below the threshold claimed by the FCC and ICNIRP demonstrate that current exposure limits provide no assurance of safety.
- An independent assessment of the health effects and risks of RF radiation is urgently needed, with the aim of developing health protective exposure standards for workers and the general public, especially for children and pregnant women.
- Public health and regulatory agencies need to inform the public of health risks of RF radiation and promote precautionary actions to reduce exposures.
- The principle of ALARA (As Low As Reasonably Achievable) should be applied to wireless devices.

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