



Bundesamt
für Strahlenschutz

Spotlight on EMF Research

Spotlight on “Exposure to radiofrequency electromagnetic fields and IARC carcinogen assessment: Risk of Bias preliminary literature assessment for 10 key characteristics of human carcinogens” by Simkó et al. in Mutation Research (2025)

Category [radiofrequency, review]

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Competence Centre for Electromagnetic Fields (KEMF)

1 Context

In May 2011, the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) analysed the current knowledge of radiofrequency electromagnetic fields (RF-EMF) and cancer illnesses and classified these fields into Group 2B “possibly carcinogenic” on the IARC scale [2]. This classification is based on limited evidence from epidemiological studies on humans and on limited evidence from laboratory tests on animals. In April 2024 the *IARC Monographs Advisory Group* published a recommendation for future IARC evaluations. According to this recommendation, the IARC plans to reassess RF-EMF [3]. The evaluation has been given high priority and is planned to be conducted until 2029. Since the last classification, the IARC advisory group has changed the name of the monograph series to “IARC Monographs on the Identification of Carcinogenic Hazards to Humans” [4]. This change reflects the important distinction between hazard and risk: hazard refers to the strength of the evidence that an agent is a carcinogen, whereas risk refers to the probability that a given exposure to a carcinogen will result in cancer. Additionally, a greater weight is given to mechanistic evidence of carcinogenicity, resulting in the definition of ten key characteristics of a carcinogen [4].

2 Results and conclusions from the perspective of Simkó et al.

The purpose of this review [1] was to establish whether there is evidence that RF-EMF could fulfil the criteria of the ten key characteristics of human carcinogens defined by IARC [4] thus increasing the cancer risk in organisms exposed to them. The literature search considered *in vitro* and *in vivo* studies involving RF-EMF exposure within the frequency range between 300 MHz and 300 GHz. The search was conducted in the databases EMF-Portal, Web of Science and Google Scholar up to 30 June 2023. Publications were limited to those written in English and published in peer-reviewed scientific journals. Exposures above 4 W/kg SAR were excluded and studies using mobile phones or similar devices as exposure sources were not considered due to dosimetry limitations. Two key characteristics, genotoxicity and oxidative stress, were excluded as they had been covered by recent systematic reviews [5, 6].

The risk of bias (RoB) was evaluated according to six criteria relevant to RF-EMF studies, as developed by Simkó et al. in an earlier publication [7]: use of sham controls, use of positive controls, use of negative controls, appropriate temperature control, blinding, appropriate dosimetry. These criteria were not evaluated in a graded manner, but rather using simple yes/no questions. They address the internal validity of studies, i.e., whether the reported changes associated with exposure appear to be causally related to the exposure.

Table 1 summarises for each of the eight key characteristics the total number of *in vivo* and *in vitro* studies, and the number of studies showing at least one statistically significant effect of RF-EMF exposure. Only one characteristic (alteration of cell proliferation, cell death or nutrient supply) had a comparable number of studies to those examined in the previously published systematic reviews [5, 6]. The reported statistically significant effects showed no apparent dependency on frequencies or exposure levels.

Overall, 179 studies (43 *in vivo* and 136 *in vitro*) were assessed, 68 (38%) of which reported statistically significant findings, however, only 3 (10%) of a total of 29 high-quality studies (meeting at least 5 RoB criteria) showed statistically significant effects. For the key characteristic “alters cell proliferation, cell death or nutrient supply”, 129 studies were identified (19 *in vivo*, 110 *in vitro*), with 30 (23%) reporting statistically significant effects; but none of these was of high quality.

Of the 43 *in vivo* studies only 3 (7%) were of high quality and none of these studies showed statistically significant effects. Twenty-six (19%) of 163 *in vitro* studies were of high quality; however, only 3 of them reported statistically significant effects. Overall, the vast majority of higher-quality studies produced negative results. However, the studies generally had low statistical power; therefore, small effects may not have been discovered.

Simkó et al. conclude that the present database of *in vitro* and *in vivo* studies on the eight examined key characteristics is very diverse in its outcomes and variable in quality. They point out that any conclusions

Key characteristic	In vivo studies		In vitro studies	
	Total	With statistically significant effects	Total	With statistically significant effects
Is electrophilic or can be metabolically activated to an electrophile (e.g., is able to form adducts on nucleic acids and proteins)	1	1	0	0
Is genotoxic	Covered by Romeo et al. [6]			
Alters DNA repair or causes genomic instability	4	4	5	5
Induces epigenetic alterations (e.g., methylation)	1	1	1	1
Induces oxidative stress	Covered by Meyer et al. [5]			
Induces chronic inflammation	0	0	10	8
Is immunosuppressive	17	12	0	0
Modulates receptor-mediated effects	1	1	2	2
Causes immortalization (cells escape senescence and can reproduce indefinitely)	0	0	8	3
Alters cell proliferation, cell death or nutrient supply	19	9	110	21
Total	43	28	136	40

Table 1: Summary of results

from systematic reviews dedicated to these topics would have very low confidence in the evidence. Robust, higher-quality studies investigating RF-EMF bioeffects on these key characteristics are thus needed. The few statistically significant results from the high-quality studies identified in the two published systematic reviews [5, 6] and in this review [1] require closer examination and replication.

3 Comments by the BfS

Simkó et al. point out that their review [1] is neither a PRISMA-compliant systematic review nor a scoping review. However, it provides an important and broad overview of the current scientific literature dedicated to a possible association between RF-EMF exposure and carcinogenicity that considers all 10 key characteristics [4] as well as a traceable RoB assessment of the included studies. The author's assessment that at present systematic reviews aiming at assessing the current evidence base on most key characteristics of carcinogenicity would likely conclude with low certainty of the evidence thus appears very convincing.

Two of the 10 key characteristics have already been the subject of systematic reviews [5, 6] and commented in spotlight articles (Jan/2025 No. 3, Oct/2025 No. 1). Seven of the remaining key characteristics have rarely been investigated. For one characteristic (alteration of cell proliferation, cell death or nutrient supply) a greater number of published in vivo and in vitro studies were identified, some of which fulfilled the criteria for low risk of bias defined by Simkó et al. [7]. Here, a systematic Review and Meta-analysis might provide additional value.

By systematically mapping and structuring the highly heterogeneous evidence on mechanistic pathways linking RF-EMF exposure and carcinogenesis, this review provides a valuable basis for assessing the carcinogenic potential of RF-EMF exposure.

References

- [1] Simko, M, Repacholi, MH, Foster, KR, Mattsson, MO, Croft, RJ, Scarfi, MR, Vijayalaxmi. Exposure to radiofrequency electromagnetic fields and IARC carcinogen assessment: Risk of Bias preliminary literature assessment for 10 key characteristics of human carcinogens. *Mutation Research. Reviews in Mutation Research*. 2025; 796:108545.
DOI: <https://doi.org/10.1016/j.mrrev.2025.108545>.
- [2] *Non-ionizing radiation, part 2: radiofrequency electromagnetic fields*. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans 102. Lyon: IARC, 2013.
URL: <https://publications.iarc.who.int/126>.
- [3] Berrington de Gonzalez, A, Masten, SA, Bhatti, P, et al. Advisory Group recommendations on priorities for the IARC Monographs. *Lancet Oncology*. 2024; 25(5):546–548.
DOI: [https://doi.org/10.1016/S1470-2045\(24\)00208-0](https://doi.org/10.1016/S1470-2045(24)00208-0).
- [4] Samet, JM, Chiu, WA, Cogliano, V, et al. The IARC Monographs : updated procedures for modern and transparent evidence synthesis in cancer hazard identification. *Journal of the National Cancer Institute*. 2020; 112(1):30–37.
DOI: <https://doi.org/10.1093/jnci/djz169>.
- [5] Meyer, F, Bitsch, A, Forman, HJ, Fragoulis, A, Ghezzi, P, Henschenmacher, B, Kellner, R, Kuhne, J, Ludwig, T, Sachno, D, Schmid, G, Tsaïoun, K, Verbeek, J, Wright, R. The effects of radiofrequency electromagnetic field exposure on biomarkers of oxidative stress in vivo and in vitro: A systematic review of experimental studies. *Environment International*. 2024; 194:108940.
DOI: <https://doi.org/10.1016/j.envint.2024.108940>.
- [6] Romeo, S, Sannino, A, Rosaria Scarfi, M, Lagorio, S, Zeni, O. Genotoxicity of radiofrequency electromagnetic fields on mammalian cells in vitro: A systematic review with narrative synthesis. *Environment International*. 2024; 193:109104.
DOI: <https://doi.org/10.1016/j.envint.2024.109104>.
- [7] Simkó, M, Remondini, D, Zeni, O, Scarfi, MR. Quality matters: Systematic analysis of endpoints related to “cellular life” in vitro data of radiofrequency electromagnetic field exposure. *International Journal of Environmental Research and Public Health*. 2016; 13(7):701.
DOI: <https://doi.org/10.3390/ijerph13070701>.

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