Bundesamt
für Strahlenschutz

Spotlight on EMF Research

Spotlight on “The effects of radiofrequency electromagnetic fields exposure on tinnitus, migraine and non-specific symptoms in the general and working population: A systematic review and meta-analysis on human observational studies” by Röösli et al. in Environment International (2024)

Category [radiofrequency, epidemiology]

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Competence Centre Electromagnetic Fields (KEMF)

1 Putting the paper into context by the BfS

In 2018, the World Health Organisation (WHO) launched an international project with the aim of systematically reviewing the evidence for a possible link between exposure to radiofrequency electromagnetic fields (RF-EMF) and health effects. The aim is to comprehensively re-evaluate the risk and update the Environmental Health Criteria (EHC) monograph on RF-EMF, which was last published in 1993 (see also Spotlight - Apr/2024 no.2 [2]). To this end, key topics were identified in an expert survey, on which the WHO initiated systematic reviews in autumn 2019 [3]. The review by Röösli et al. [1] now published summarises the evidence regarding an association between exposure to RF-EMF in the frequency range 100 kHz to 300 GHz and tinnitus, migraine, headache, sleep disturbances and various non-specific symptoms from observational studies in humans. Another systematic review analyses the results of experimental studies in humans with regard to various symptoms [4].

2 Results and conclusions from the authors‘ perspective

The systematic review focuses on five primary hypotheses. Hypotheses 1-3 examine possible associations between tinnitus, migraine or headache and local exposure from near-field sources such as mobile phones or cordless phones. Hypotheses 4 and 5 examine possible associations between sleep disturbances or composite symptom scores and whole-body exposure, which is mostly focused on far-field sources such as radio antennas, mobile phone base stations or Wireless Local Area Network access points. The authors understand composite symptom scores as endpoints that were collected in the studies as score values through questionnaires that referred to various physical and/or psychological complaints. In addition to the outcomes of the primary hypotheses, other non-specific symptoms such as nervousness, fatigue, exhaustion and dizziness are also considered. In the previously published protocol [5], inclusion and exclusion criteria were specified to define the studies to be evaluated. Only observational studies that follow a time course (longitudinal design) were included. The target population includes the general population, occupationally exposed persons or persons who state to be electromagnetic hypersensitive.

After a literature search in the databases Medline, Web of Science, PsycInfo, Cochrane Library, Epistemonikos and Embase, 13 studies were identified according to the inclusion criteria applied, after excluding duplicates from 3,887 identified studies. The oldest of the included papers dates back to 2009 [6] and the three most recent papers are from 2019 and 2020 [7-9]. Two of them report results from the international COSMOS study (Cohort Study on Mobile Phones and Health) initiated in 2010 on the effects of EMF from mobile phone use.

To assess the quality of the studies, the risk of bias was evaluated (see also Spotlight - Apr/2024 no. 2 [2]). Half of the evaluated combinations of endpoint, exposure, exposure assessment method and population type had a low risk of bias (Tier 1 study) and half had a high risk of bias (Tier 3 study).

If several studies were available for the primary outcome exposure combinations, random-effects meta-analyses were performed for the pooled analyses of the effect measures from the studies. A relative risk (RR) was calculated as meta-estimate for tinnitus and standardised mean differences (SMDs) for headaches, sleep disturbances and symptom scores. The results are shown in Table 1.

For synthesizing evidence, Röösli et al. rated the confidence in the evidence of the effect estimates for the primary hypotheses (last column in Table 1). The rating started from a moderate confidence in the evidence and was downgraded in cases of high risk of bias in the studies, strong inconsistency (heterogeneity) of results between studies, indirectness of the exposure measurement, low precision of the effect estimates (imprecision) and strong indications of publication bias. Possible reasons for increasing the confidence in the evidence would have been large magnitude of effect, the presence of a consistent RF-EMF exposure-effect relationship (a consistent exposure-response-gradient) and an unlikely bias due to unconsidered or insufficiently controlled confounding factors (residual confounding), but these reasons did not apply to the data set.

If more than one study was available on possible associations between primary endpoints and other sources of exposure, meta-analyses were also performed for these endpoint-exposure combinations in the systematic review. For other endpoints that were also addressed in the 13 studies, no meta-analysis could be performed because there are too few comparable combinations of exposure and outcome. For most of these combinations, the associations are not statistically significant. The few statistically significant estimates show both directions of effect (increase or decrease in symptoms).

Table 1: Summary of the results

Outcome	No. of studies	Exposure (site/measure)	Effect measure, effect size (95% CI)	Statistically significant effects	Confidence in the evidence
Results for the primary hypotheses					
Tinnitus	3	local brain exposure	RR 1.43 (0.94 – 2.18) per 100 min call duration per week	no	very low
Migraine*	1	local brain exposure	RR 1.2 (1.1 – 1.3) per 100 min call duration per week	increased risk	very low
Headache	4	local brain exposure	SMD -0.64 (-2.38 – 1.10) per 100 min call duration per week	no	very low
Sleep disturbances	3	whole-body exposure	SMD 1.51 (-2.00 – 5.03) per 1 V/m increase	no	very low
Composite symptom scores	4	whole-body exposure	SMD 1.13 (-0.94 – 3.20) per 1 V/m increase	no	very low

CI – Confidence Interval, RR – relative risk, SMD – standardised mean difference

* Results of a single study, no meta-analysis was performed because only one study was available.

For the five primary hypotheses, the authors conclude that there is very low confidence in the evidence of association of RF-EMF and considered non-specific symptoms. For the other hypotheses, the authors conclude that there is no indication for an association related to a specific symptom or a specific exposure source.

In several passages, Röösli et al. address various *aspects of exposure assessment* as causal for the very low confidence in the evidence for the primary findings. These aspects result from the inherent difficulties in directly measuring RF-EMF exposure and the limitations associated with the use of more or less suitable proxies. Therefore, all observational epidemiological studies are typically affected by these difficulties. For four of the five primary hypotheses, a high or very high risk of bias resulted in a downgrading of confidence in the evidence by one or two points. The critical risk of bias assessment was made because the effect measures were partly, mostly or exclusively derived from Tier 3 studies, which in turn were always due to *errors in exposure assessment*. The inconsistency (heterogeneity) of the study results led to a downgrading of the confidence in the evidence for all primary endpoints. The authors suggest plausible causes for the heterogeneity in the different study methodologies in terms *of exposure assessment methods* and due to confounding. For the primary outcome tinnitus, migraine and headache in relation to local brain exposure, also *the indirectness of the exposure measurement* led to a downgrading of the confidence in the evidence. According to the protocol, specific absorption rate (SAR) calculated as a time-weighted average or cumulative is the primary exposure of interest. However, this was measured only in one study. The studies used the duration of mobile phone use as a surrogate. However, the use of mobile phones is not only associated with RF-EMF, but also with many other aspects that may influence the risk for the endpoints considered. Furthermore, the actual exposure to RF-EMF can only be very imprecisely derived from data on the duration of mobile phone use. In addition, mobile phone use in the studies is often only available as self-reported mobile phone use and not as mobile phone use recorded and verified by the operators, which leads to the above-mentioned *errors in exposure assessment*.

3 Comments by the BfS

This systematic review is important from a radiation protection perspective and is of interest to both the scientific community and the general public. Well-established guidelines and methods for conducting systematic reviews [10-14] were used (see also Spotlight - Apr/2024 no.2 [2]). It provides a transparent, high-quality analysis of the current evidence from human observational studies on possible associations between RF-EMF exposure and tinnitus, migraine and other non-specific symptoms.

After examining the inclusion criteria, only 13 studies were included in the systematic review. The inclusion criteria regarding study design and study objective, which severely limit the database, are well justified and comprehensible. 23 cross-sectional studies, which differ from longitudinal studies in that they refer to a single point in time, were excluded from the analysis. This was because it is challenging to draw causal conclusions and identify confounding factors without considering the temporal sequence of events. The inclusion of panel and cross-sectional studies in the discussion section would certainly have enriched it and could possibly have been a source of additional evidence.

The studies evaluated in the review provide inadequate evidence for or against possible associations between RF-EMF and non-specific symptoms. As Röösli et al. note, the results do not provide any evidence that RF-EMF exposures below guideline values of the International Commission on Non-Ionising Radiation Protection (ICNIRP) cause the symptoms examined. However, when considered in isolation, they also do not prove that RF-EMF exposures below the limits do not cause these symptoms. For a more extensive evaluation, the results of experimental studies must also be taken into account, along with questions of biological plausibility (underlying mechanisms of action). A recently published systematic review of experimental studies in humans, also commissioned by WHO, also found no effects under the experimental conditions used [4]. Therefore, a causal relationship between low level RF-EMF exposure and the non-specific symptoms under consideration seems highly unlikely at this time.

The BfS agrees with the authors that further epidemiological research can only be expected to provide new insights if methodological developments take place. There is a particular need for this with regard to exposure assessment, which is facing considerable challenges, especially due to the rapid technical development of mobile phone technology. It is currently unclear to what extent it will be possible in the future to reliably assess the RF-EMF exposure of study participants on a large scale, even over long periods of observation.

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Bundesamt für Strahlenschutz
Postfach 10 01 49
38201 Salzgitter

Tel.: +49 30 18333-0
Fax: +49 30 18333-1885
E-Mail: spotlight@bfs.de
De-Mail: epost@bfs.de-mail.de

www.bfs.de

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