## Summaries and assessments of selected studies

In the period from mid of October 2021 to mid of January 2022, 123 new publications have been identified, and eight of these were discussed in depth by BERENIS. Based on the selection criteria, four of these publications were selected as the most relevant ones. Their summaries and assessments are provided below.

### *1) Experimental animal and cell studies*

*Combined effect of environmental exposures: RF-EMF, heat acclimation and effects on anxiety and depression considering the gut-brain axis (Luo* et al. *2021)*

The gut microbiota affects the energy homeostasis, metabolism, blood-glucose balance and immune response. It also plays an important role in maintaining physiological functions of the brain. The gut microbiota contributes to behaviour, brain development, ageing, and the development or characteristics of neurodegenerative diseases. A change of the gut microbiota, for example, can lead to alterations of the brain's immune system, the microglia.

In the *in vivo* study by Luo *et al.* (2021), male mice (strain: C57BL/6J) were divided into four groups, with and without heat acclimation (35°C or 28°C) for the first 28 days followed by 5 weeks of subchronic RF-EMF exposure or sham exposure. In respect to the gut-brain axis of mice, the interaction between exposure to RF-EMF (2450 MHz, 2 µs/pulse, 500 pulses/second, 4 hours/day; whole-body SAR 2.5 W/kg) and heat acclimation (35°C instead of 28°C) was investigated. Behavioural tests were performed to assess anxiety and depression. In addition, the gut microbiota was determined by sequencing and serum parameters were analysed, i.e.: tryptophan and phenylalanine, and also cholesterol and fructose, which have been found to correlate with depression in other studies.

The behavioural tests did not indicate an impact on anxiety at any time point, while the animals showed increased signs of depression after five weeks of RF-EMF exposure. At the same time, the gene activities of various bacteria were altered. This was not the case with simultaneous heat acclimation, which also improved some of the serum parameters mentioned above. Pathway analysis of altered gene activities revealed an interaction with the tryptophan and pyrimidine metabolism and biosynthesis of amino acid. The authors concluded that the RF-EMF exposure leads to depression-like neurobehavioural disorders, possibly due to an imbalance of the gut microbiota. In addition, the data suggests that the gut microbiota is involved in heat acclimation.

Despite indications for an involvement of the gut-brain axis with regard to increased occurrence of depression in connection with changes in the gut microbiota (which could be reversed by heat acclimation), a causal relationship cannot be conclusively established on the basis of these findings; and thus, further studies are necessary. As the authors state, this would require a determination of the measurement parameters over time and, more importantly, inhibition of the relevant bacteria by means of antibiotics and/or fecal transplantation of specific gut microbiota.

***2) Epidemiological studies***

*Brain tumour risk from age 10 to 24 years and use of mobile and cordless phones (Castaño-Vinyals* et al. *2022)*

A large and elaborately designed case-control study ("MOBI-Kids") analysed data from 14 countries[1] to investigate whether the use of mobile and cordless phones and the resulting exposure to RF-EMF and ELF-MF increased the risk of brain tumours in young people (Castaño-Vinyals *et al.* 2022). The study population consisted of 899 persons aged 10 to 24 years who were diagnosed with a brain tumour between 2010 and 2015, and 1,910 control individuals of the same age and from the same region who had been operated for appendicitis at the corresponding time. Data on the use of mobile and cordless phones and other relevant factors were collected retrospectively by questionnaire interviews with the study participants and/or the parents. In addition, an EMF dose calculation was performed. Data were analysed separately for three age groups (10 to 14, 15-19 and 20 to 24 years) to account for age-related differences in mobile phone use.

According to the main analyses, an increase in the use of mobile and cordless phones correlated with a decrease in brain tumour risk, especially in the 15-19 year old group. Similarly, when the analysis was performed based on cumulative ELF-MF or RF-EMF dose at the tumour site, the results also showed decreasing risks with increasing dose. However, more detailed analyses indicate that this "protective" effect is likely not to be causal. When usage data within five years prior to diagnosis was not taken into account, and only information from the study participants, rather than from their parents, was considered, the "protective" effect was no longer statistically observable and there was no overall correlation between the occurrence of brain tumours and mobile and cordless phone use.

The authors conclude that the study does not provide evidence for a causal relationship between the use of mobile and cordless phones and the occurrence of brain tumours in the age group studied, even if a small residual risk cannot be completely excluded. The fact that apparently "protective" effects were observed was attributed, on the one hand, to inaccurate information on use provided by the parents and, on the other hand, to the fact that symptoms before diagnosis had led to reduced mobile and cordless phone use and not vice versa (reverse causality).

The MOBI-Kids study, relying on public funding from the participating countries and the EU, is the largest study conducted so far on the topic in this age group. Other strengths of the study are, for example, the fact that numerous sensitivity analyses were performed, and that both radiofrequency and extremely low frequency radiation were included. However, case-control studies are based on retrospectively collected information on exposure, which includes substantial uncertainties. Specifically, in this case, parents of healthy 15-19 year olds in particular seemed to overestimate mobile phone use in contrast to parents of sick children, which led to the paradoxical "protective" effects. Case-control studies cannot robustly detect small risks due to methodological shortcomings. Substantial brain tumour risks in this age group due to mobile phone use, however, should by now also be visible from higher case numbers in cancer registry data. In this age group, though, there has generally been no detectable increase in brain tumour risk since the introduction of mobile phones. Overall, the study supports results from other epidemiological studies and time series analyses of cancer registries that mobile phone radiation has so far not led to a substantially increased risk of brain tumours.

[1] Australia, Austria, Canada, France, Germany, Greece, India, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Spain

### *3) Human experimental studies*

*Waking brain activity and GSM exposure (Wallace* et al. *2021a,b)*

Most studies on RF-EMF exposure and brain activity have found that spontaneous alpha activity was altered, and both increases and decreases have been reported. Some studies also found no effects. The reasons for this heterogeneity of findings can be manifold: e.g., differences in the methodology, in the experimental protocols, in the applied frequencies and intensities, as well as in the study population.

Wallace *et al.* (2021a,b) studied 32 young and healthy participants (right-handed, 17 women). The participants were exposed to an RF-EMF (GSM, 900 MHz, 217 Hz modulation, 0.49 W/kg max. SAR (averaged over 10 grams of body tissue)) or sham exposure for 25.5 minutes. A mobile phone (active or sham) was placed against the left ear with a tubular bandage (double-blind, randomised, counter-balanced, crossover). The measurement protocol comprised a baseline, exposure, and post-exposure period. The electroencephalogram (EEG) and the electrocardiogram (ECG) were measured continuously. Furthermore, a magnetoencephalogram (MEG) was recorded during the baseline and post-exposure phases. The EEG records the electrical component of brain activity and the MEG its magnetic component. In addition, four saliva samples were taken (at the beginning, before and after exposure, and at the end) to test for possible stress effects.

In a first publication (32 participants analysed; Wallace *et al.* 2021a), the MEG and stress factors were analysed. In the MEG, the effect of exposure on alpha activity (8-12 Hz) after exposure was investigated. The results in the sensor and source space (assessing where the activity originates in the cerebral cortex) showed a significant decrease in MEG alpha activity after GSM exposure, with different cortical regions involved depending on whether the eyes were open or closed, probably due to the different level of attention with eyes open or closed. Measurements of heart rate, heart rate variability (HRV), biomarkers of stress and caffeine concentration showed no changes, which means that the results were hardly influenced by confounding factors such as stress behaviour or caffeine consumption before the experiment.

In a second publication (21 participants analysed, 10 of them women, Wallace *et al.* 2021b), the focus was on the EEG. EEG data (alpha activity) of the baseline and exposure phase were analysed. Alpha activity in the resting state (eyes open or closed) was not changed during GSM exposure compared to the sham condition.

The two publications by Wallace *et al.* showed both a decrease and no effect. However, it should be noted that the decrease in the MEG occurred after exposure, and that no effect was found in the EEG during exposure. It remains unclear why the EEG was not also analysed after exposure.

### *4) Information about other publications: reviews*

*WHO reviews*

The Word Health Organization (WHO) has commissioned a series of systematic reviews on health effects of RF-EMF exposure. While the reviews are still in progress, most of the corresponding protocols have already been published (August 2022: 10 of 11 protocols published). [2]

[2] https://www.sciencedirect.com/journal/environment-international/special-issue/109J1SL7CXT

*Statement of the German Commission on Radiological Protection*

The German Commission on Radiological Protection (Strahlenschutzkommission, SSK) has published a statement on EMF from mobile communications in the course of the current 5G network expansion, focusing on technical aspects and biological effects in the frequency range below approx. 7 GHz.[3]

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[3] SSK (2021): **Elektromagnetische Felder des Mobilfunks im Zuge des aktuellen 5G-Netzausbaus – Technische Aspekte und biologische Wirkungen im unteren Frequenzbereich (FR1, bis ca. 7 GHz).** Stellungnahme der Strahlenschutzkommission. Verabschiedet in der 317. Sitzung der Strahlenschutzkommission (SSK) am 09./10. Dezember 2021.
https://www.ssk.de/SharedDocs/Beratungsergebnisse/2021/2021-12-10_Stgn_5G_Mobilfunk.html

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Additional information:

BERENIS - Swiss expert group on electromagnetic fields and non-ionising radiation

List of abbreviations (pdf)