Summaries and assessments of selected studies

In the period from mid of October 2020 to beginning of February 2021, 122 new publications have been identified, and six 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) Human experimental studies

No impairment of sleep-dependent memory consolidation by 2.45 GHz Wi-Fi exposure (Bueno-Lopez et al. *2020)*

Bueno-Lopez *et al.* (2020) investigated the effects of one night of Wi-Fi exposure on sleep-dependent memory consolidation and associated neurophysiological correlates. For this purpose, the authors analyzed data of thirty healthy young male adults who had participated in the study by Danker-Hopfe *et al.* (2020)[1] (see Newsletter 23). The participants were exposed to a Wi-Fi (2.45 GHz) or a sham signal during sleep. A control night was followed by one night of exposure (real or sham), and the procedure was repeated after one week with the other condition (double-blind and randomized). The peak temporal SAR_{10g} at the head was below 25 mW/kg and the temporal mean over 6 min was below 6.4 mW/kg. Declarative, emotional, and procedural memory performances were assessed by using a word pair, a face recognition and a sequential finger tapping task. In addition, learning-associated sleep EEG parameters (EEG power for slow oscillations [0.5-1 Hz] and sleep spindles [12-14 Hz and 11-16 Hz] in non-REM sleep) were analyzed.

Emotional and procedural memory performance were not affected by Wi-Fi exposure. For the declarative task, the overnight improvement in memory performance was slightly more pronounced in the Wi-Fi condition than in the control condition. However, none of the sleep EEG parameters was affected by exposure.

Since none of the sleep EEG parameters assumed to be related to learning was affected, the slightly more pronounced overnight improvement in the word-pair association task with Wi-Fi radiation could be a chance finding. In any case, one night of Wi-Fi radiation did not result in impaired cognitive performance.

2) Epidemiological studies

Cohort study on the impact of mobile phone exposure on fertility and sperm quality (Hatch et al. *2021)*

In order to investigate the impact of RF-EMF exposure on fertility and sperm quality, Hatch *et al.* (2021) analyzed data from two prospective preconception cohort studies conducted between 2012 and 2020 in Denmark and North America. About 3,000 men were asked whether and where they carry a mobile

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[1] Danker-Hopfe H, Bueno-Lopez A, Dorn H, Schmid G, Hirtl R, Eggert T (2020): **Spending the night next to a router - Results from the first human experimental study investigating the impact of Wi-Fi exposure on sleep.** Int J Hyg Environ Health. 2020 May 11;228:113550. https://www.ncbi.nlm.nih.gov/pubmed/32408065

phone for how long on their body. The time to pregnancy in the female partners was assessed using bi-monthly follow-up questionnaires up to a maximum of 12 months or until reported conception. Overall, there was little evidence that carrying a mobile phone in a front pants pocket affected male fertility. Only in underweight and normal-weight men (body mass index (BMI) <25 kg/m²) carrying a mobile phone in the front pants pocket was associated with a longer time to successful pregnancy. However, a dose-response relationship was not evident with respect to how long the mobile phone was carried in the front pants pocket. Analysis of almost 800 sperm samples in a subgroup of these cohorts showed no effect of the mobile phone in the front pants pocket on sperm quality (volume, concentration and motility).

This study accounted for a number of potential confounding variables: Ethnicity, education, male and female BMI, household income, frequency of sexual intercourse, and female age. For men, the study also took into account smoking, sleep, work, age, history of sexually transmitted diseases, physical activity, and consumption of sugar-sweetened drinks as potential confounders. Exposure assessment was done prospectively. For these reasons, this study is substantially more informative than all previous epidemiological studies on sperm quality. The association found in men with relatively low or normal BMI could be a chance finding. However, the authors also speculate that in relatively slim men, the distance between mobile phone and testes is small, and their testes are thus more RF-EMF-exposed than those of other study participants. Overall, the exposure quantification is a weakness of this study. Regarding RF-EMF exposure of the reproductive organs, there are no data to date quantifying the RF-EMF exposure contribution from carrying a mobile phone in the front pants pocket. It should also be noted that the study participants tested the sperm quality with a self-test at home. It is unclear whether this had a negative impact on data quality.

Symptoms related to RF-EMF from mobile phone base station (Martin et al. *2021)*

The association between RF-EMF from mobile phone base stations and non-specific symptoms as well as sleep problems was examined in a cross-sectional survey conducted between 2015 and 2017 in five large cities in France (Martin *et al.* 2021). In total, 2,641 adults were contacted who were living in buildings located in the main beam of a mobile phone base station at a distance of 250 m or less. The mobile phone base stations were selected based on having been in operation for more than two years and not having been the subject of complaints by local residents at the time of their installation. The 354 individuals who consented to participate in the study were interviewed by telephone about environmental concerns, symptoms in relation to environmental exposures, anxiety, as well as non-specific symptoms and sleep problems. With regard to environmental concerns, the study participants were classified into three subgroups: worried, slightly concerned, and participants who described themselves as uninformed. RF-EMF exposure was measured at five points in each home using a broadband field-meter (100 kHz - 6 GHz), followed by a spectral analysis at the point of highest exposure to obtain source-specific exposure contributions. The median exposure from mobile phone base stations was 0.27 V/m (0.44 V/m for total RF-EMF), ranging from 0.03 V/m to 3.58 V/m. The mobile phone base station was the main source of exposure for 64% of the homes. Overall, no association between RF-EMF from the base station and non-specific symptoms or sleep problems was observed in the study sample. Regarding sleep problems, a significant interaction was found between RF-EMF exposure from mobile phone base stations and environmental concerns: risk for sleep problems increased with RF-EMF exposure among worried and uninformed participants, but not among slightly concerned participants.

The fact that exposure measurements were performed at the home of the study participants is a strength of this study. The chosen recruitment strategy was appropriate for maximizing the exposure contrast in the study collective. Consequently, exposure levels from mobile phone base stations in this study were slightly higher than those in previous similar studies. However, the relative small sample, low participation rate and the cross-sectional design are limitations of this study. Overall, the study does not indicate an association between symptoms and RF-EMF from mobile phone base stations in the general population. However, it does indicate a positive association between sleep problems and exposure in the subgroup with environmental concerns, both in the subgroup with general environmental concerns and in the subgroup attributing its complaints to RF-EMF. These observed interactions might reflect an attribution bias, meaning some worried individuals were aware of their higher exposure status and therefore rated their sleep problems as more severe. In contrast, the increased risk among uninformed participants is interesting, because the analysis in these individuals is unlikely to be biased by knowledge of their exposure status. Further studies need to confirm whether this observation is causal or due to chance or some other type of bias.

3) Dosimetrical studies

Computer simulation study of the penetration of pulsed 30, 60 and 90 GHz radiation into the human ear (Vilagosh et al. *2020)*

The coupling of pulsed electromagnetic waves in the frequency range between 30 and 90 GHz in the human auditory canal was investigated in the computer simulation study of Vilagosh *et al.* (2020). The frequency range from 30-90 GHz is increasingly being considered for applications in automotive technology, 5G mobile communications, and small-scale local area networks. At these frequencies, electromagnetic waves are absorbed within the first few millimeters of tissue. In the latest draft ICNIRP recommendations for the 10-300 GHz frequency range, the proposed limits therefore focus on absorption in the skin, eye, and ear canal. The limits are determined with respect to the power density of the incident wave.

The study uses simulation models of the ear canal including the tympanic membrane (eardrum). The eardrum has a high blood perfusion rate, contains many nerve endings, and is sensitive to inflammation and mechanical injury. The electromagnetic waves in the simulation were modeled as 100 picosecond or 20 picosecond pulsed waves from one of three incident angles (orthogonal, 30° anterior, and 45° superior to the ear canal). The ear canal including the eardrum and part of the inner ear together with part of the external structures were modeled according to an average anatomy. The corresponding dielectric tissue properties were derived from published data.

Since the first section of the ear canal can be assumed to be approximately cylindrical, the propagation of electromagnetic waves can be estimated in terms of a cylindrical waveguide. Consequently, based on the dimensions, penetration of waves below 30 GHz can be ruled out. Above 30 GHz, however, waves can propagate within the ear canal and be transmitted into the inner part of the ear, all the way to the eardrum.

The results of the study demonstrate the relationship between the incident power density at the entrance of the ear canal and at the eardrum for the different scenarios investigated. For an orthogonal incident pulsed wave at 30 GHz, only 0.2% of the incident power density reaches the eardrum. At 90 GHz, the respective rate is 13.8%. For a power density as permitted for occupational exposure at 90 GHz, a temperature increase of 0.032°C (+20% / -50%) was calculated. The authors recommend more detailed studies of the exposure of the eardrum and the structures located behind it for frequencies above 60 GHz, to assist the process of setting standards.

The study provides a first numerical assessment of the potential effects of exposure of the eardrum to electromagnetic waves in the frequency range above 10 GHz. The study uses a section of the human ear canal with the tissues contained therein as a numerical model. The dielectric and thermal tissue properties are derived from the limited available data. The study has been conducted very carefully and is considering a range of different scenarios. Follow-up studies conducted by the authors have evaluated new methods for determining thermal tissue properties in the THz range.[2,3] According to the authors, significant health effects in the range of expected public exposure are unlikely to occur. However, they point out that at higher power densities, effects on the inner ear may well be expected.s

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List of abbreviations (pdf)