

Current Understanding of the Health Effects of Electromagnetic Fields

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ABSTRACT

There has been an exponential increase in the use of electronic devices over the past few decades. This has led to increased exposure to electromagnetic fields (EMF). Electric fields result from differences in voltage, whereas magnetic fields result from the flow of electric current. Higher-frequency waves of EMF have more energy than lower-frequency waves, and thus generally tend to be more harmful. An EMF activates cellular stress response and also causes breaks in DNA strands. There are many methodological barriers to effectively measuring the associations of EMF and childhood cancers. The consensus from multiple studies is that there is no causal role of extremely low-frequency EMFs in childhood cancers, including brain cancer. A recent study showed a link between EMF radiation and the development of malignant tumors in rats. In light of that study, the American Academy of Pediatrics set out new recommendations to decrease the adverse effects of cellphone exposure on children. [*Pediatr Ann.* 2017;46(4):e172-e174.]

In today's world, everyone seems to have a cell phone. From fourth-grade students with smart phones to older adults with basic flip phones, cellphones have become a vital part of our existence. We use our cellphones for everything from making phone calls and checking emails to booking flights and making hotel reservations. In addition to cell phones, the use of electronic tablets and laptops has increased as well. Because of this extensive use of technology, the safety and health effects of electronic equipment have been questioned and studied. This review article discusses the current

evidence and opinions on the effect of electromagnetic fields (EMFs) on human health.

BACKGROUND

The first cell phone was invented in 1973 by engineer Martin Cooper.¹ It weighed 1.1 kg, could be used for approximately 30 minutes, and took 10 hours to charge. Ten years later, Motorola released its first commercial mobile phone. In the early 1990s, cell phones were primarily used by wealthy businessmen rather than the average person. However, by the late 1990s, mobile devices became the norm for

the average person, as the size of the handsets and their price grew smaller.¹ However, with the increased use of mobile devices, their possible harmful effects came into question. One of the questions that has been raised is if the EMF radiation produced by cell phones and other electronic devices causes an increase in childhood brain cancer and leukemia.

Electric fields result from differences in voltage, whereas magnetic fields result from the flow of electric current. Thus, the greater the current, the stronger the magnetic field will be. Electric fields are created by a local build-up of electric charges, so EMFs are essentially present everywhere in the environment. The main quality that differentiates EMFs is frequency. The different frequencies of EMFs have distinct health effects. Higher-frequency waves have more energy than lower-frequency waves, and thus generally tend to be more harmful.²

Different devices emit different frequencies of EMF. Of the common devices we use today, AM radios tend to emit the lowest frequencies (600 kHz-1.6 MHz), whereas medical imaging machines such as X-rays (80 keV) and positron emission tomography scans (511 keV) tend to emit the highest. Other devices, such as cell phones (900 MHz-2.4 GHz), televisions (54-700 MHz), microwaves (2.4 GHz), and tanning beds (290-400 nm) tend to fall in between.³

How do EMFs, whether at an extremely low-frequency (ELF) range

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or at a radio frequency (RF) range, lead to increased incidence and risk of cancer? EMF activates cellular stress responses. Once activated, the stress response induces the expression of stress response genes, such as heat shock protein 70 (*HSP70*), leading to an increased level of stress proteins.⁴ The stress proteins act as chaperones by helping repair and refold damaged proteins and transport them across cell membranes. To induce this stress response, DNA must be activated, and despite the large energy differences between ELF and RF, they activate the same cellular pathways. Specific DNA sequences on the promoter of the *HSP70* stress gene are responsive to EMF, and it has been suggested that EMFs could also interact directly with electrons in DNA.⁴ However, EMFs with energy in the RF range can lead to breaks in the DNA strand.⁴ Thus, any extensive damage or changes to DNA that need repair may increase the risk of developing cancerous cells.

HEALTH EFFECTS OF EMFS

The consensus from a review of multiple studies in humans is that there seems to be no causal role of ELF and RF-EMFs in the development of childhood cancers.⁵⁻⁷ Mezei et al.⁵ performed a meta-analysis of 13 studies and reported that no increase in childhood brain cancer risk was evident from EMF exposure. The study used an inverse variance-weighted method and calculated summary effect estimates separately for distance, wire codes, and measured and calculated magnetic fields.⁵ Kheifets et al.⁶ performed a pooled analysis (considered the gold standard for synthesis of results from multiple studies), and on subanalyses, their results suggest an increase in cancer incidence with EMF exposure. However, these increases were small, highly dependent

on the particular studies included in the subset, and inconsistent with regard to increasing exposure for all models chosen. Overall, their results provided little evidence for an association between ELF-MF exposure and childhood brain tumors. Results from another epidemiologic study of childhood brain cancer provided no strong evidence for an increase in risk with residential exposure to ELF-EMFs.⁶ However, the suggestion of a moderate-risk increase of childhood brain cancer at higher EMF exposure levels (>0.4 mT) could not be excluded (odds ratio of 1.68, 95% confidence interval: 0.83-3.43).⁶ A study by Schüz et al.⁷ measured nighttime bedroom exposure to ELF-EMFs because it was thought that it may represent a more accurate reflection of exposure and have a greater biologic relevance. However, based on the odds ratios for nighttime ELF-EMF exposures, the results do not support the hypotheses that nighttime measures are more appropriate. Thus, this study also did not support any association between EMF and cancer.

Recently, the National Toxicology Program published a multiyear, peer-reviewed study that found a low incidence of two types of tumors (gliomas and schwannomas of the heart) in male rats exposed to ELF-EMFs.⁸ It must be noted that not all biological effects observed in animals apply to humans. In this study, more than 2,500 rats were exposed to two common types of wireless technologies (Global System for Mobile Communication and Code Division Multiple Access Channel) at 900 MHz for approximately 9 hours a day. There seemed to be a cancer association in male rats but not in female rats; the reasons for which remain unclear. Furthermore, rats that were exposed to ELF-EMFs in-utero exhibited slightly lower birth weights. The complete results of this study will be released later

in 2017. This newfound link between ELF-EMF exposure and cancer in rats further necessitates a more concrete conclusion about ELF-EMF exposure and cancer in humans.

In light of recent findings of the link of EMF radiation and the development of malignant tumors in rats, the American Academy of Pediatrics (AAP) set out a few recommendations to decrease the adverse effects of cell phone exposure on children.⁹ These recommendations include encouraging children to use text messaging when possible, make only short and essential calls on cellular phones, use hand free kits and wired headsets, and hold the cell phone an inch or more away from the head. Furthermore, the AAP also encourages parents to limit cell phone and television use in children to 2 hours or less per day. These are a few small, but nonetheless important, measures we can take to reduce excessive EMF exposure in children until more definitive research is available.

DIFFICULTIES WITH STUDYING THE EFFECTS OF EMFS ON HEALTH

There are many methodologic barriers to effectively measuring the associations of ELF-EMF and childhood cancers. Kheifets and Shimkhada,¹⁰ stated that epidemiologic studies of ELF-EMFs and childhood leukemia are difficult to design, conduct, and interpret due to the fact that EMFs are imperceptible, ubiquitous, have multiple sources, and can vary greatly over time and short distances. Also, the small number of cases of leukemia in any given population necessitates retrospective design, making exposure assessment even more difficult.¹⁰ Furthermore, Kheifets and Shimkhada¹⁰ discuss that a selection bias exists and can only be resolved with large, well-conducted cohort studies or with case-control studies in which ex-

posure information can be collected independently.¹⁰

Despite these various existing barriers, some studies have managed to overcome many of the difficulties by designing a thorough, well-controlled study protocol. Sadetzki et al.¹¹ have designed a project called MOBI-Kids to assess the potential carcinogenic effects of childhood and adolescent exposure to radio RF-EMFs from mobile telephones on the central nervous system. An advantage of MOBI-Kids is its large sample size; it is the largest study to date on this topic in young people, with 14 participating countries. Participants are being identified and recruited in a time period in which mobile phone use in young people has become more prevalent, thus increasing the statistical power and overall generalizability of the results. In addition, MOBI-Kids includes extensive exposure assessment work and validation studies using both historical provider records and software-modified smartphones to counteract potential recall bias. Despite the various challenges faced by the study team, their experience thus far in the development and implementation of the study protocol indicates that MOBI-Kids is feasible and will generate results contributing to

the understanding of potential brain tumor risks associated with use of mobile phones and other wireless communication technologies among young people.

CONCLUSION

Overall, according to the literature review, there does not seem to be an association between ELF-EMFs or RF-EMFs and childhood cancers. However, these results present short-term data and to obtain a definitive answer, we need to conduct long-term studies and follow up on the results of the MOBI-Kids study. Furthermore, we need to assess the effects of ELF-EMF on younger children due to recent increased use of electronic devices among the younger population.

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