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MOBILE PHONES AND CHILDREN

Abstract: *Daily use of wireless devices, especially mobile phones, has caused great concern among the public about the possible health effects of electromagnetic radiation to which the users of these devices, primarily children, are exposed. This paper summarizes the habit of using mobile phones by children and teenagers and its connection with possible harmful biological effects of electromagnetic radiation of these devices. This paper describes the procedure of creating models of adult and child heads that are used for numerical calculation of electromagnetic field penetration and the absorbed energy. As we know, the human body consists of many different tissues and organs, so each of them needs to be described by the appropriate electromagnetic characteristics.*

Key words: mobile phone, electromagnetic characteristics of tissues, model of child head, specific absorption rate.

INTRODUCTION

The development of wireless devices has opened a whole new array of options for voice transmission and images at any time in any place. Because of the content richness, smartphones are used by all age groups. Because of the intensive use of mobile phones, the question of the effect of electromagnetic radiation on humans, especially on children, has become very important.

The electromagnetic waves emitted by mobile phones occur within the so-called radio frequency (RF) range of non-ionizing electromagnetic radiation. RF radiation forms waves with frequencies ranging from about 3kHz to 300GHz, used in telecommunications services, including radio and television broadcasting, mobile communications, GPS receivers, radio communications for the police and fire brigades, and satellite communications. Most mobile phones in current use operate at frequencies between 800 and 2700MHz, with a maximum force range from 0.1 to 2W.

Exposure to electromagnetic radiation depends on the signal strength of the phone model. Exposure to electromagnetic radiation emitted by a mobile phone depends on the phone model, the configuration of the antenna, and signal strength. Weak signal results in higher levels of exposure, because the device automatically requires more power.

Despite concerns about the health effects of long-term exposure to RF radiation, the popularity of the use of wireless devices among young children is growing rapidly, even in case of very young children (Figure 1 and Figure 2). Nineteen per cent of children aged two to five would be more likely to use a smartphone than to spend time doing some other activities. Almost the same number of children aged two to three (17%) use smart applications, as well as children aged four to five (21%). One quarter of all children aged two to five know how to make a call using mobile phones. Many phones are specially designed for small children, some even with applications for pre-school children [1].

A large selection of different applications is available to smartphone owners. The most popular types of applications for children are certainly games and social networking applications. On average, smartphone owners usually spend up to eight hours per month playing games. According to one study, it was shown that iPhone users play games for almost fifteen hours each month, while those with Android devices play games for about nine hours per month [2, 3].

Figure 1. *Fisher-Price iPad for babies*

Figure 2. *Fisher-Price baby chair with iPad*

Smart phones have become an integral part of school activities. The design of educational applications has led to the adoption of smartphones in many schools and colleges among pupils and students.

Teachers and administrators also use smartphone apps to check class presence, for surveys in the classroom, for sending information about homework, exams, school events, and much more.

Today's children will certainly have much more exposure to cell phone radiation during their lives than adults [4].

Many classrooms include wireless routers, which are a source of RF radiation, even for those who do not use wireless devices.

A concern about the health risks for children from mobile phone radiation has led to the prohibition of the use of mobile phones in schools in France and throughout Europe. In particular, France prohibits the use of mobile phones in kindergartens, elementary schools, and colleges as a precaution to minimize the potential health risks.

However, smartphones are attributed to have caused the educational revolution, so most parents support their use. As many as 67% of parents in the United States would buy a mobile phone for their child to use at school if the school allows it, and 61% support the idea of students who use mobile devices to access textbooks [5].

Most studies dealing with the influence of electromagnetic radiation from mobile phones focused on determining the absorbed energy in the standard models of the adult head.

Standards and guidelines about the limits of exposure to electromagnetic fields are developed based on research for adults, as well [6]. Therefore, it is necessary to determine whether these safety margins are also sufficiently valid for children.

The International Agency for Research on Cancer (IARC) has classified the radiation of electromagnetic fields in group 2B, so they are classified as possibly carcinogenic to human, based on an increased risk of a malignant type of brain cancer. In this category there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals [7].

ELECTROMAGNETIC PROPERTIES OF TISSUES

The physical quantity used to determine the possible harmful effects of electromagnetic fields on human health is the Specific Absorption Rate (SAR). SAR is directly dependent on the electromagnetic properties of tissues and organs and is defined as:

$$\mathrm{SAR} = \frac{\sigma |E|^2}{\rho} \qquad (1)$$

where E is the maximum value of the internal electric field, σ is the conductivity of the tissue, and ρ is the density of the tissue. Maximum values of SAR that must not be exceeded are defined in the Regulation of the limits of exposure to non-ionizing radiation. This regulation defines the limits of exposure to non-ionizing radiation, or the basic restrictions and reference boundary levels of the population exposure to electric, magnetic, and electromagnetic fields of different frequencies [8].

It is evident from the previous term that, in order to determine the SAR values, it is necessary to know the electromagnetic characteristics of tissues and organs. Biological tissues are inhomogeneous, nonlinear, and dispersive. Since the human body consists of multiple different tissues and organs, each of them needs to be described by the appropriate electromagnetic parameters. These electromagnetic parameters are the relative dielectric constant ε_r, conductivity σ, and relative magnetic permeability μ_r [9].

MODELS OF HUMAN HEAD

Due to ethical considerations, the exposure of humans to electromagnetic fields for experimental purposes is limited. It is more convenient to develop a realistic model of the human head through numerical simulation.

Determination of the effects of electromagnetic radiation from mobile phones involves determining the electromagnetic field penetration within the human head and the absorption of electromagnetic energy, which results in an increase in temperature inside the head. The shape of the anatomical models of the human head also plays an important role in the absorption of electromagnetic energy, in addition to operating frequency and the distance between the source and the object. Exposure of children to electromagnetic radiation is higher than that of adults. In addition to differences in morphology and composition of the tissue, the essential difference is in the size and shape of the child head compared to the adult head. This primarily refers to the thinner tissue and organs, especially the skull and the ears.

According to some authors, higher SAR values in the child head are due to thinner earlobes and therefore due to the position of the antenna, which is closer to the head. Likewise, with reduction of the thickness of earlobes, the absorption of RF energy in the surface tissues reduces and the value of SAR in the deeper tissues potentially increases [10, 11].

However, the true-to-life degree of the model and the source of electromagnetic radiation vary from one research to another.

In early studies of electromagnetic field distribution and SAR within the human head, the models used were simple human head models. The first model was modelled in the form of a phantom and it included a layer that simulated the skin and an inner layer that had the electromagnetic characteristics of the brain (Figure 3). Thus, the obtained results did not reflect reality because they did not take into consideration the actual structure of the head. Therefore, the actual characteristics of tissues and organs as well as the

boundary conditions during the propagation of electromagnetic waves through the different tissues and organs were not taken into consideration [12, 13].

In some studies, the child head models were designed by scaling the existing adult head models (Figure 4) [14, 15].

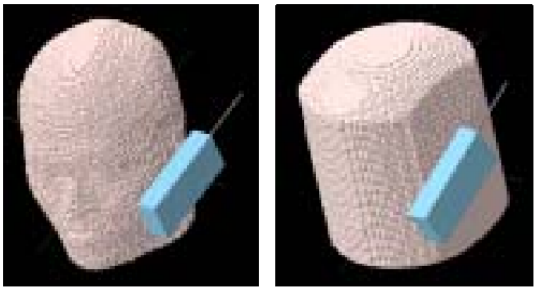

Figure 3. *A simple model of the human head in the form of a phantom [13]*

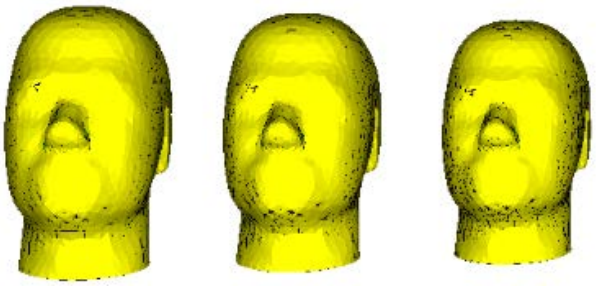

Figure 4. *Scaling the adult head in order to obtain a model of the child head [14]*

More complex models of the human head are created from multiple layers that simulate tissues or organs (Figure 5) or by creating any tissues and organs separately and joining them into a single model (Figure 6).

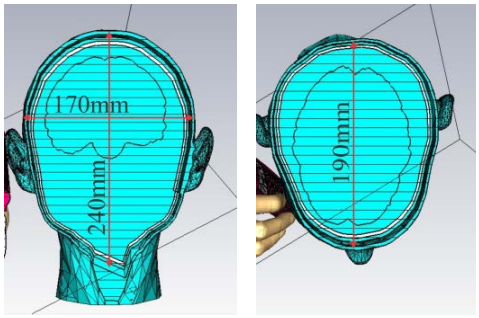

Figure 5. *Multilayered model [16]*

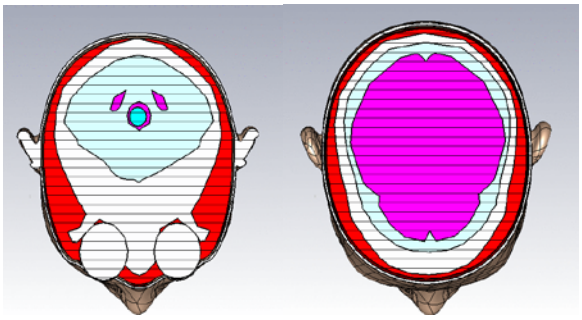

Figure 6. *Model composed of various tissues and organs [17]*

Since the obtained results are closer to the actual values, it is necessary to make a 3D model of the child head that corresponds to an actual child's head with its anatomical and morphological characteristics.

BIOLOGICAL EFFECTS

Tissues are more sensitive to the impact of external factors during development, including the influence of artificially generated electromagnetic fields. Regardless of whether children or adults are exposed, a large number of studies have shown that electromagnetic radiation can adversely affect the health of all. Based on their research, some Russian and East European scientists reported that exposure to low level RF radiation can cause a wide range of health effects, including changes in behaviour, the impact on the immune system, reproductive effects, changes in the level of hormones, headaches, irritability, fatigue, and cardiovascular effects.

Due to the RF-EM field emitted by the mobile phone that is located near the head, the possibility of brain tumour occurrence used to cause and still causes serious concern. Most studies focus on the potential correlation between the use of mobile phones and several types of brain tumours.

According to several Swedish studies of mobile phones and tumours, researchers have been using the Swedish Cancer Registry to find a consistent pattern of conclusive increase of the risk of acoustic neuroma and glioma after 10 years of mobile phone use. Bearing in mind that the evidence of risks from extended use of mobile phones and wireless phones is quite strong, the researchers conclude that "For people who have used these devices for 10 years or longer, and when they are mainly used on the one side of the head, the risk of malignant brain tumors is doubled, and even higher in case of people who have begun to use mobile phone before their 20 years" [18, 19, 20, 21, 22].

Some of the effects in humans after exposure to pulsed electromagnetic fields include a reduction in cognitive performance [23] as well as the need for more time to respond to the tasks (male subjects) when they were exposed to RF radiation of a standard GSM mobile phone positioned close to the head [24].

Several studies examined the effects of RF electromagnetic fields on the male reproductive system. They examined the quality of sperm and possible changes related to exposure to RF electromagnetic fields. Sperm exposed to RF electromagnetic waves emitted from mobile phones had higher levels of harmful free radicals, lower mobility, lower viability, and possible increased oxidative stress [25, 26].

Some researchers examined the impact of mobile phones on DNA. A mobile phone was placed at a distance of one meter from human cells. They found a decrease in DNA repair in cells with damaged double-stranded DNA. The strongest effects were observed in stem cells. Since stem cells are more active in children,

the researchers argue that children may be at increased risk of cancer due to exposure to electromagnetic radiation from mobile phones [27].

Swedish neuroscientists studied the effects of RF-EM fields on neurons of young rats. They placed a mobile phone on the side of the cage holding young rats and thus simulated the exposure to electromagnetic radiation similar to phone usage in case of humans. On that occasion, they found damage to neurons in the brain of young rats after 50 days of exposure over the interval of two hours per week [28, 29, 30, 31].

Children can potentially be subject to RF effects due to their nervous systems still developing, increasing levels of cell division, undeveloped immune systems, thinner skulls, and higher conductivity of brain tissue. The RF penetration in case of children is greater in relation to the size of the head and they are more exposed to radiation in their lifetime compared to adults [32].

At the first international conference about mobile phones and health in 2008, it was reported that the people who started using a mobile phone before age 20 had a more than five times increase in glioma incidence. Those who started using mobile phones when they were young were also five times more likely to develop acoustic neuroma [33].

According to one study, brain metabolism in the region closest to the antenna of mobile phone was significantly higher and it correlated with the estimated higher EMF. The mobile phone model used in the study had a SAR of 0.901W/kg for the head, which is below the limit of SAR for a mobile phone. Although the health impacts of this study are not known, the study demonstrates that exposure to RF electromagnetic fields from mobile phones affects brain function in case of humans at the levels that are below the prescribed value of SAR [34].

CONCLUSION

During a conversation on a mobile phone, the user's head is in the near field, so there is induction of electromagnetic field within the head. Electromagnetic field and absorbed energy are substantially localized near the antenna, while the part of the energy transfers deeper inside different layers of tissue.

In general situations involving near-field exposure, it is well known that exposure conditions such as operating frequency and the distance between the electromagnetic source and the exposed object play an important role in the absorption of electromagnetic energy.

The calculated values of SAR depend on the distance of the antenna relative to the head, as well as on the anatomical and morphological characteristics of the head of each individual. Thinner skulls of young children as well as thinner ears allow mobile phone radiation to penetrate deeper into the brain than in the case of adults. In case of children and foetuses, the nervous system develops rapidly and, because of their higher rate of cell division and longer potential exposure, the risks of adverse health effects are increased.

Today's teenagers are the first generation to grow up using wireless devices daily, so they are exposed to RF radiation from an early age. Concerns about exposure to RF radiation during childhood are numerous. For instance, the brain of a child absorbs much higher radiation than the brain of an adult, and anatomical differences in case of children may provide greater exposure of their brain regions to RF radiation from mobile phones due to the difference in the dielectric constants and electrical conductivity of their tissues and organs.

The depth of penetration of the electromagnetic field is greater at lower frequencies, resulting in higher value of SAR not only in the surface layers of the child head model but also deeper in the brain inside the model. As the frequency increases, the penetration depth decreases, so most of the electromagnetic energy is absorbed in the surface layers of the child head closer to the source of radiation.

In order to reduce the influence of electromagnetic radiation, it is necessary to keep a wireless device at enough distance from the body during use. People who use wireless devices to send text messages and access the Internet or those who use "hands-free" devices will have less exposure to electromagnetic energy than those who hold the mobile phone close to the head. Likewise, if the mobile phone is carried in one's bag, exposure will be far lower than if the same phone is carried in one's pocket. This is true even in the case of mobile phones in standby mode, because the devices are constantly in communication with a base station.

Finally, it is important to note that mobile phones, tablets, and laptop computers are not toys.

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BIOGRAPHY

Vladimir B. STANKOVIĆ was born in Niš, Serbia, in 1978. He received the Master degree from the University of Niš, Faculty of Electronic Engineering, Department of Telecommunications. His main areas of research include electromagnetic radiation. He is employed at the Faculty of Occupational Safety as a teaching assistant. He is currently a PhD student at the Department of Telecommunications.

MOBILNI TELEFONI I DECA

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Apstrakt: *Svakodnevna upotrebe bežičnih uređaja, pre svega mobilnih telefona, izazvala je veliku zabrinutost kod javnosti zbog mogućih štetnih efekata elektromagnetnog zračenja kojim su izloženi korisnici ovih uređaja, prevashodno deca. Ovaj rad sumira navike korišćenja mobilnih telefona kod dece i tinejdžera i vezu sa mogućim štetnim biološkim efektima elektromagnetnog zračenja ovih uređaja. Opisan je postupak kreiranja modela glave odraslih osoba i dece koji se koriste za numerički proračun prodrlog elektromagnetnog polja i apsorbovane energije. Kako se ljudsko telo sastoji od više različitih tkiva i organa, svaki od njih je neophodno opisati odgovarajućim elektromagnetnim karakteristikama.*

Ključne reči: mobilni telefon, elektromagnetne karakteristike tkiva, model glave deteta, specifična brzina apsorpcije