

Review

**ELECTROMAGNETIC FIELDS OF CELLULAR COMMUNICATION
AS A HEALTH RISK FACTOR FOR CHILDREN AND ADOLESCENTS (REVIEW)****N.I. Khorseva¹, P.E. Grigoriev²**¹Institute of Biochemical Physics of the Russian Academy of Sciences, 4 Kosygina Str., Moscow, 119334, Russian Federation²Sevastopol State University, 33 Universitetskaya Str., Sevastopol, 299053, Russian Federation

Modern telecommunication technologies rely on using radio-frequency electromagnetic field (RF EMF). They have brought many useful services into our life able to solve multiple issues. However, we should bear in mind that this exposure is open, uncontrollable and permanent. Given that, it seems relevant to investigate possible negative influence exerted by RF EMF on health of children and adolescents since this population group is the most vulnerable and sensitive to any external exposure.

This review analyzes Russian and foreign studies with their focus on chronic influence of RF EMF created by cellular communication means on health of children (aged 6–10 years) and adolescents (aged 11–16 years).

We have established several manifestations of health disorders in children and adolescents including asthenic syndrome (headache, irritability, increased fatigue, sleeping disorders, periodical pains in the heart and joints); mental deadadaptation (anxiety, stress, depression, etc.); as well as their combinations.

Along with all the aforementioned syndromes, effects produced by exposure to RF EMF become apparent through some indirect signs of memory and attention failure such as forgetfulness (inability to recall the necessary information in time) and inattention (inability to concentrate on an event or activity) and even through growing frequency of respiratory diseases.

Basing on the analyzed studies by Russian and foreign researchers, we can conclude that they provide solid evidence of negative influence of electromagnetic fields created by cell phones on health of children and adolescents.

Therefore, implementation of modern gadgets and their active use by children and adolescents should be accompanied with assessment of actual threats posed by them, health risk assessment, and development of scientifically substantiated standards for their safe use.

Keywords: *electromagnetic radiation, health, risk factor, asthenic syndrome, mental deadadaptation, mobile phones, children, adolescents.*

Radiofrequency electromagnetic fields (RF EMF) are a well-known anthropogenic environmental factor able to produce various negative health effects, as reported by M.H. Repacholi in his work as far back as in 1998 [1]. Undoubtedly, telecommunication technologies that rely on using RF EMF have brought many useful services into our life able to solve multiple tasks with just one ‘mouse click’. However, we should bear in mind that this exposure is open, uncontrollable and permanent: given that, a range of

negative outcomes caused by exposure to RF EMF is constantly growing.

Children and adolescents are the primary targets of this exposure; at present, these population groups are among the most active users of mobile devices and simultaneously the most vulnerable to their effects.

In 2009, V. Khurana and others reported in their work that children tended to start using a mobile phone (MP) at age 3 and this fact seemed sensational [2]; but later, H.K. Kabali with colleagues established in

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their study performed in the USA that more than one third of babies started to use a smartphone or a tablet already during infancy and at age 2 most children used mobile devices daily [3]. Similar findings were reported by A.O. Kılıç with colleagues in Turkey [4].

It is noteworthy that most publications on negative health effects of RF EMF on children and adolescents were issued in 2006–2013 and were mostly foreign. At present, the overwhelming majority of research that addresses RF EMF influence concentrates on youths and young adults; however, this review considers findings reported in studies concentrating exclusively on such age groups as children and adolescents.

Negative influence exerted by RF EMF on health of children and adolescents as the population group that is the most vulnerable to any environmental exposures has been repeatedly highlighted by Yu.G. Grigoryev in his publications [5–10].

Available data indicate that several target organs and systems are primarily affected by exposure to RF EMF created by modern technologies, in particular, mobile phones (MP) (2G–4G). First, negative effects are produced on the brain, genital system, and the entire intrauterine development; the thyroid gland is affected by using mobile devices with construction peculiarities of a new mobile generation (the antenna is usually located at the bottom of a smartphone) [11]. In addition, implementation of 5G technology produces negative effects on sclera and skin [12, 13].

Therefore, the aim of this review was to analyze studies that addressed effects of RF EMF on growing generations, specifically, on two separate age groups: children (between 3 and 10) and adolescents (between 11 and 16). However, some analyzed studies consider a rather wide age range that can cover several different age groups. This often creates certain difficulty in systematizing data when the results are analyzed.

Our analysis revealed that authors, as a rule, questioned either respondents them-

selves (children and adolescents) or their parents (when respondents were aged 3–10 years) in their studies. They also relied on a wide range of statistical analysis methods when analyzing their research results.

To describe basic effects produced by exposure to RF EMF on children and adolescents, we used a classification provided in the article [14], which specifies asthenic (headache, irritability, increased fatigue, sleep disturbances, periodical heart or joint pains), asthenovegetative (hypertension and bradycardia), and hypothalamic (neurocirculatory dystonia and hypertension) syndromes as well as mental deadadaptation (failure to adapt to living conditions).

We can conclude, basing on literature data, that most health effects were related to asthenic syndrome and to a lesser extent to mental deadadaptation.

Asthenic syndrome signs. Asthenic syndrome is known to be one of the most frequent health disorders; however, at present no conventional definitions, classifications, or concepts are available in literature that can fully explain its pathogenesis. Asthenia is a polymorph syndrome and can manifest both with specific symptoms such as headache, irritability, increased fatigue, sleep disturbances, and periodical pains in the heart and joints as well as with their combinations.

The prospect cohort study by S.Y. Kim with colleagues revealed that excessive use of smartphones (more than 1 hour a day) by children aged 5–8 years led to shorter sleep duration and its poorer quality (more frequent nocturnal waking) [15]. Unlike the study by S.Y. Kim with colleagues, O.A. Vyatleva and A.M. Kurganskiy did not identify any statistically significant correlations between MP use and frequency of sleep disturbances in primary schoolchildren (aged 6–10 years). However, the total duration of MP talks was considerably shorter in the analyzed cohort than in the study by S.Y. Kim with colleagues. [16]. Difficulty in falling asleep was statistically significantly associated with use of the mobile Internet [17].

The greatest number of asthenic syndrome manifestations has been identified for adolescents.

Thus, no significant correlation between MP use and sleep disturbances was identified for young adolescents (aged 10–12 years) [16]. Nevertheless, it was established that use of mobile phones at night was associated with some adverse health outcomes for sleep such as later waking, shorter duration of sleep, restless sleep and some others. These disorders were shown to be more intensive in case a gadget was used in darkness [18–20].

An association between MP usage and sleep disturbances was much more apparent in older adolescents [16, 21, 22], including MP usage late at night [23, 24] and when a MP was used for more than 5 hours a day [25].

In addition, it was established that the total duration of talks was statistically significantly longer among girls than among boys in all the age groups (between 6 and 18) and the greatest negative health outcomes occurred at the age of 14–15 years. In particular, intensity of MP use correlated with frequency of headaches for boys and with difficulty in falling asleep for girls [26].

However, the longitudinal study by J.E. Lee with colleagues established that long MP use increased the risk of poor sleep quality but not short sleep duration [27].

Such symptoms as headache and vertigo are also more frequent in adolescents and depend on MP usage. Thus, O.A. Vyatleva and A.M. Kurganskiy established a correlation between headache and MP usage. However, it was less apparent in adolescents aged 11–13 years than among those aged 14–16 years [16]. Nevertheless, a significant increase in the share of children who suffered from headaches was established when the total duration of MP talks ranged between 12 and 32 minutes a day [28].

Dose-response frequency of headache and warming of the ear depending on duration of MP-use was identified in the study by R. Durusoy and others [21]; tinnitus was identified in adolescents who used wire

headsets; wireless headsets involved headache and more frequent nocturnal waking [29]. It was also established that mobile phone use by adolescents could lead not only to headache but migraine and skin itch as well [30].

A statistically significant correlation between fatigue and MP usage was established for schoolchildren aged 9–12 years in the study by F. Zheng and others [31]. Similar findings were reported both for primary schoolchildren [32], including a correlation between feeling tired (the subjective feeling of fatigue, *comment by the authors*) and the number of mobile phone talks [28], and for senior adolescents [21, 22, 24], as well as rapid exhaustibility, headache, and physical ill-being [24].

Mental deadadaptation and other symptoms. Anxiety is an individual psychological peculiarity and the most widespread mental disorder in adolescents associated with growing up. In addition, contemporary children and adolescents tend to more frequently have such mental disorders as stress (psychophysiological tension) and depression (an affective mental disorder). As noted by many researchers, such short-term changes tend to often develop into various actual mental disorders. These events are caused by multiple reasons and intense use of various gadgets, mobile phones being certainly the leading ones, is one of them.

It is due to all the aforementioned that investigation of mobile phone use and severity of various mental dysfunctions is a quite relevant issue at present.

Anxiety in primary schoolchildren was shown to depend on MP use [28, 32]. It is interesting to note that the prospect cohort study with participating primary schoolchildren reported an association between growing anxiety levels and switching to smartphones as well as longer use of the mobile Internet [17].

Depression in adolescents intensifies in case they use a mobile phone for more than two hours a day spending this time in social

networks and online chats; the effect is much more apparent than that produced by Internet use, gaming or watching videos [25]. J. Liu with colleagues, having compared MP usage on weekdays and weekends, established that duration of mobile phone use longer than 2 h/day on weekdays and longer than 5 h/day on the weekend was associated with increased risk of depressive symptoms [33]. In addition, girls were established to be more susceptible to elevated risks of smartphone addiction and depression than boys [34].

It was also established that uncontrolled MP use by adolescents before sleep and at night could lead to some serious outcomes for their mental health such as suicidal feelings and greater proneness to self-injury [20].

However, it is noteworthy that anxiety, depression and mental disorders were estimated through questioning in all the studies, that is, they were subjectively estimated by participating respondents.

Active use of mobile phones has resulted in occurrence of new mental disorders (nomophobia, smartphone addiction, etc.); however, these issues have not been addressed in the present review.

In our opinion, studies where various health disorders in children and adolescents are identified in cohorts covering a wide age should be considered separately.

For example, children and adolescents aged between six and 16 years took part in the study by S.M.J. Mortazavi. In this study, statistically significant associations were found between the time mobile phones were used in talk mode and the number of headaches, vertigo, and sleeping problems per month [35]. Similar symptoms were identified for the cohort that included children from primary, middle and senior school who were active smartphone users (their age was between 6 and 18 years). In particular, among those overusing mobile devices (more than 4 hours a day), the most commonly experienced symptoms included headaches, sleep disturbances and neck/shoulder pain as well as poorer ability to concentrate [36]. How-

ever, data specific for each age group (primary, middle, or senior school) were analyzed in this study only for mobile phone use. All the remaining parameters were analyzed for the whole data array.

Sleep disturbances associated with using a mobile phone before sleep were identified by the online survey among adolescents of both sexes aged 12–19 years [37]. Similar findings were reported for adolescents aged 14–18 years [38].

Users of mobile phone and computer more often complained of headache, joint and bone pain, hearing loss, vertigo/dizziness, and tension-anxiety symptoms as it was established by the questioning of respondents older than 9 years. Female respondents complained more often of headache, vertigo/dizziness, fatigue, and tension-anxiety than male ones [39].

The study by A.J. Buabbas with colleagues provided direct evidence of a relationship between anxiety, stress and depression and smartphone use; it included middle and senior schoolchildren (aged between 11 and 21 years). In addition, anxiety, stress and depression caused by gadget overuse (more than 4 hours a day) were shown to be higher for females [40].

However, we believe all these studies to have a certain drawback, that is, they investigate health disorders in children and adolescents as per the whole age group without any division into specific age periods. This can substantially distort the results since health outcomes have their age-specific peculiarities, as it was previously shown in this review.

In conclusion, we should note that, apart from asthenic syndrome and mental deadadaptation, a correlation was established between MP use and some indirect signs of memory and attention failure such as forgetfulness (inability to recall the necessary information in time) and inattention (inability to concentrate on an event or activity) [17]. However, forgetfulness and inattention were established by questioning and, therefore,

were estimated subjectively rather than objectively.

In addition, it was shown that certain health risks (for example, risks of respiratory diseases) depended on a model of a mobile phone, its radiation level and mode of its use, as it was shown in the studies by O.A. Vyatleva and A.M. Kurganskiy for primary schoolchildren [16, 28, 32]; health risks related to a growing number of diseases that involved a fever were identified for senior adolescents [26].

Conclusion. Therefore, the research results give evidence of negative effects produced by RF EMF on health of children and adolescents. In this case, this does not concern some specific signs of somatic or mental dysfunctions in children or adolescents;

this is about the whole set of disorders that are able to deteriorate health of the growing generation. This should be realized quickly in this rapidly changing modern world of new telecommunication technologies that are changing our entire way of life. Implementation of new technologies should be accompanied with assessment of actual threats posed by using them and development of scientifically substantiated standards for their safe use, especially for children and adolescents.

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