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RESEARCH ARTICLE

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Complications of nonionizing radiofrequency on divided attention

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Abstract

Exposure to electromagnetic fields is considered as a potential hazard for biological systems. The objective of our investigation is the study of probable consequences of radiofrequency electromagnetic fields from Wi-Fi router devices on the short-term memory, and attention's levels. A population consisting of 312 female college students (14 to 17 years old) was elected by cluster random sampling. Teenagers were divided into two groups of control group (Wi-Fi nonusers; n = 138), and experiment group (Wi-Fi users; n = 174). Both groups have been examined using short-term memory tests; selective attention, and also divided attention tests. According to the results, there was no significant difference between using Wi-Fi router devices on levels of selective attentions and short-term memory of the sample students with the control group. However, analyses revealed that there is a significant correlation between the use of Wi-Fi routers and declining levels of divided attentions. Our investigation has demonstrated the adverse consequences of 2.4-2.48 GHz radio-frequency electromagnetic fields of Wi-Fi router devices on divided attention levels of female university students that should be mentioned as a technological risk factor and taken into account by healthcare organizations.

KEYWORDS

electromagnetic fields, radiofrequency, short-term memory

1 | INTRODUCTION

The Internet networks are rapidly becoming the main source of information and communication, worldwide.[1] During the recent years, wireless networks are increasingly common in work environments, public areas, schools, and homes. The benefits of these technologies are not negligible in daily life; however, there have been concerns about possible health consequences of radiofrequency electromagnetic fields (RF-EMFs) exposure generated by wireless devices.[2,3]

Human brain is the main affected organ for the RF-EMFs. Public concerns, regarding both physical and mental complications caused by being exposed to RF-EMFs, has been increased. In 2011, the International Agency for Research on Cancer (IARC) of World Health Organization (WHO), classified RF-EMFs as a group 2B, that means it is considered a possible human carcinogen. Also, the Council of Europe has proposed restrictions on internet access and cell phone usage in all schools to protect the teenagers from potentially harmful RF-EMFs.[4]

Thus far, few studies have explored the effect of RF-EMFs on brain function.[5-9] Hardell et al, demonstrated a correlation between malignant brain tumors and exposure to RF-EMFs.[2] Furthermore, Mortazavi et al shows a significant association between cordless phone usage and headache, fatigue, difficulties in concentration, nervousness, attention disorders, palpitation, myalgia, and tinnitus.[10] In addition, they reported a gender association with women having significantly higher rates of headache, myalgia, dizziness, and nervousness than men (in each case $P < 0.001$).[10]

Another study by Redmayne et al on a group of the 15-19-year-old individuals in New Zealand indicated that the time duration of phone calls by the cordless and cell phones could be associated with increasing the risk of getting headache, depression, and sleep disorders.[11] Kwon et al have investigated the possible health effects of RF-EMFs emitted by wideband code division multiple access (WCDMA) mobile phones in humans.[12] In this study, two groups of self-reported electromagnetic hypersensitivity (EHS) and non-EHS volunteers were investigated for physiological symptoms (heart rate, heart rate variability, and respiratory rate) and eight subjective symptoms. However, from this study they did not conclude any significant physiological changes or subjective symptoms in either group by RF-EMFs generated by WCDMA.[12] This is interesting because in diseases such as bipolar, depressive disorders, and schizophrenia, increasing evidence is showing a relationship between glucose metabolism, and mitochondrial dysfunction with such mental diseases.[13,14]

2 | METHODS

This study was primarily started with inclusion of 406 female teenager volunteers in Estahban, Fars province (Iran) with ages from 14 to 17 years old. Subjects were selected using a cluster sampling method out of 950 teenager female volunteers. After describing the purpose of the study and obtaining the consent of the individuals, Anxiety Inventory (BAI), a survey-based data collection method was used to determine and exclude the individuals with potentially significant anxiety levels (n = 48). A total score >36 in BAI test considered as high anxiety levels that exhibit impaired cognitive abilities that will interfere with the mental health test in our study, so we excluded the subjects with the total score of 36 and above (data not shown). Depression levels of the elected students were assessed (data not presented) and analyses revealed that the differences are negligible. Then, information regarding exposure to main RF-EMF sources at home was collected using a detailed questionnaire administered to the female teens. The questionnaire included questions about the history of using Wi-Fi at home, the average duration of daily usage of Wi-Fi routers, and the location of the devices. Only subjects, who fully filled in the questionnaire were included for further analysis (n = 312). In this study, all teenagers, who had no Wi-Fi device at home, were considered as nonusers and those teenagers who had Wi-Fi device at home for more than a year were considered as users. Then, both groups were examined by digit span as a measure of short-term memory capacity, selective attention test, and divided attention test.[15,16] It should be noted that all symptoms were self-reported and there was no medical examinations. Students were almost similar in different situations of their lifestyles including the culture, wealth, educations' levels of families, and the job of their parents, and so on. All statistical analyses were performed using SPSS 20.0 (SPSS Inc., Chicago, IL). Student *t* tests were used for comparison of obtained scores of three different tests in two groups of Wi-Fi users, and nonusers. Also, Fisher's exact test was applied to different groups based on duration of Wi-Fi usage, location of Wi-Fi modems, and Wi-Fi from cell phones. *P*-values <0.05 ($P < 0.05$) were considered as significant difference level in obtained results.

3 | RESULTS

Analyses showing that 55.8% of teenagers were Wi-Fi users and 66.7% of teenagers are cell phone users. In 44.8% of records Wi-Fi modem is located in bedroom and only 8.0% of teenagers using Wi-Fi at home for 4 years or more.

All collected data from short-term memory; selective, and divided attention of high school female teenagers exposing to RF-EMFs emitted from Wi-Fi devices were analyzed. Figure 1 shows the distribution of all obtained scores of three different psychological tests by both groups of Wi-Fi users and Wi-Fi nonusers. A clear difference is presented in divided memory tests' results. Based on the results, the Wi-Fi users group showing lower mean values in both selective and divided attention

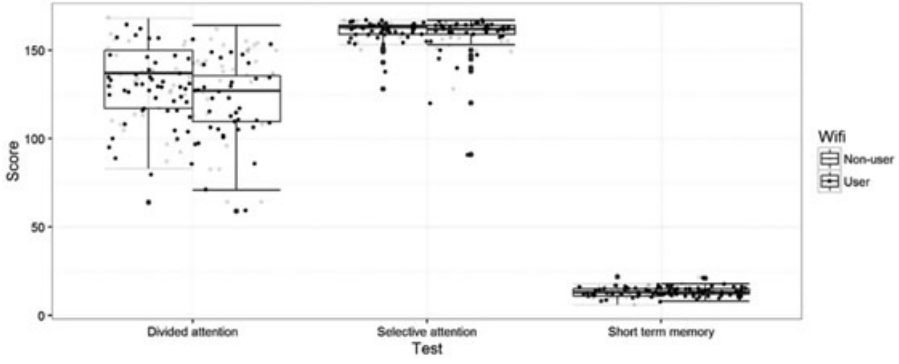


FIGURE 1 Box plot comparison of obtained scores of short-term memory test, selective attention, and divided attention tests by Wi-Fi users and nonusers

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and short-term memory results. However, the only significant difference between both groups of Wi-Fi users and Wi-Fi nonusers is determined in divided attention results (Figure 1). In addition, Fisher's exact test's results have demonstrated no significant differences in different defined groups based on duration of Wi-Fi usage, location of Wi-Fi modems, and Wi-Fi from cell phones (data not shown).

4 | DISCUSSION

All kinds of free radical creation due to extrinsic sources such as exposure to high-energy radiations, and intrinsically induction in normal biochemical reactions are potentially harmful. EMFs even at very low strengths are also able to produce free radicals in biological systems.[17] However, available reported data do not provide any consistent evidence that EMFs affect biological systems via free radical production. For such reasons, EMFs effect on biological subjects continue to be a subject of research.[18] On the other hand, numerous studies have been focused on the effect of RF-EMFs emitted from Wi-Fi devices on different parameters including fertility, immune system development, brain development, stress, and fetal development.[19-22]

Psychological health hazards of exposure to RF-EMFs is another important research area that is recently explored by scientists in the field.[23-25] It is known that RF-EMFs effects are at least sensitive to the gender and age of subjects.[10,24,26] Therefore, we targeted female teenagers in a narrow range of age, that is, 14- to 17-year-old. As a result, it is observed that the long-term exposure to Wi-Fi radiofrequency radiation caused a significant decrease in the divided attention of female teenagers. Our study can help the public health policy makers by increase their awareness to potential effects of Wi-Fi usage on divided attention of female teenagers.

AUTHORS' CONTRIBUTIONS

All authors contributed to the work the same as each other.

CONFLICTS OF INTEREST

We declare that there are no conflicts of interest.

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