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## Electromagnetic field exposure and health problems among college students

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### Abstract

Our aim in this study was to determine both the level of exposure to the electromagnetic radiation of the young population in their living areas and its relationship with their health problems. A questionnaire about the intensity of the electromagnetic field radiation exposure and their health problems was used on 705 college students. Participants were 40.2% male, 59.8% female with a median of 20 (17-41) years old. Some students have been living close to base stations and high voltage lines (30% and 18.7%, respectively). Students had an internet network (82.3%). Mobile phone and computer usage for more than 5 years were 83% and 66%, respectively. 73.1% had electrical/electronic devices in the bedroom. Exposure time to electrical/electronic systems in 44.7% of students was more than 5 hours per day. Some health problems mentioned were fatigue (75.2%), muscle pain (39%), difficulty in concentration (51.7%), stress (36.4%), eye discomfort (28.5%), light sensitivity (21.3%), and sleep disorder (%40). Chi-square analysis showed a significant relationship between daily electrical/electronic device exposure time and headache frequency, concentration difficulties, fatigue, muscle pain ( $P<0.01$ ,  $P<0.05$ ,  $P<0.001$ ,  $P<0.01$ , respectively). The presence of electronic devices in the bedroom showed a statistically significant relationship with a sleep disorder, concentration difficulties, stress, fatigue, dizziness, and tinnitus ( $P<0.01$ ,  $P<0.01$ ,  $P<0.001$ ,  $P<0.001$ ,  $P<0.05$ , and  $P<0.001$ , respectively). According to our results, there is considerable exposure to electromagnetic radiation from technological systems in our daily life. Although the long-term effects of electromagnetic radiation exposure in humans are unclear, our findings suggest that electromagnetic radiation may be associated with some health problems.

**Keywords:** Electromagnetic fields exposure, mobile phone, computer use, health effects

### Introduction

Electronic/electrical and wireless communication devices are the hallmarks of modern life. In line with human needs, constantly developing technology provides comfort to our lives. While these technological products, mobile phones, radio, internet, and television make our lives easier, they also emit electromagnetic radiation. This non-ionizing radiation generated by electromagnetic fields (EMF) is one of the physical factors affecting public health and has the potential to create several health problems [1-3]. Non-ionizing electromagnetic radiation consists of two separate frequency bands: ELF band emitted at extremely low frequency

from electronic/electrical devices, high-voltage lines and transformers; and, radio frequency (RF-MW) band emitted from base stations, mobile phones, and radio-television transmitters. Both have effects on human health [3-5]. Functional changes in nervous system activity such as hearing perception, balance, learning, and memory as well as synaptic plasticity and change in neurotransmitter release were observed in low-frequency EMF exposure [6-10].

In general, the biological effects of EMF radiation can be classified as thermal and non-thermal [11]. Thermal effects are associated with heat generated by electromagnetic radiation in tissue. At each interaction with living tissues, radiofrequency fields cause an energy transfer, which creates an increase in temperature. Non-thermal effects of RF (radiofrequency) energy were also observed [11, 12]. However, the net effects on cell biological processes cannot be fully explained. These effects might be related to an increase in the production of reactive oxygen species (ROS) [13, 14]. Non-ionizing radiation creates DNA damage due to oxidative

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stress in cells [15]. Due to its high metabolic activity, brain tissue is more susceptible to oxidative damage caused by free radicals [16]. Exposure to EMF can lead to neurological disorders [17]. Studies have also shown that exposure to EMF leads to some endocrine changes. 900 MHz EMF frequency produced by digital-cordless phones has been shown to reduce TSH and thyroid hormones [18]. It has been reported that there was a significant increase in fetal abnormalities and spontaneous abortion in pregnant women exposed to EMF radiation [19]. Children and adolescents are considered more susceptible to the effects of EMFs, due to the properties of their neurologic and skull bone tissues and using the device earlier in their life [7, 20-22]. Recent studies indicated children were more vulnerable to high Specific Absorption Rate (SAR) values than adults, but this issue is still controversial [23-25]. Since the devices that emit EMF radiation have entered into almost every area of our lives, it is necessary to investigate the possible effects of this non-ionizing radiation on our health. The 2006 World Health Organization Radio Frequency fields (WHO RF) (Research Agenda) had stated that the effects of non-ionizing radiation among children and adolescents with health consequences such as sleep, headaches, and cognitive problems need to be investigated. The 2010 version of the WHO RF expressed high-priority research needs in EMF related behavioral and neurological disorders among adolescents and recommended also the investigation of dose-response relationships [26]. In this study, we investigated the intensity of electromagnetic radiation exposure and its effects on the health of young college students.

## Material and Methods

A questionnaire about the intensity of electromagnetic radiation exposure from a mobile phone, computer, and other electrical/electronic devices in daily living and its effects on health was given to 705 college students from Sakarya University Medical School and Istanbul Gelişim University Vocational School of Health Services.

The questionnaire consisted of 39 questions and the areas and question numbers in each area investigated were as follows: 7 questions about exposure to EMF in social areas; 6 questions about exposure to EMF in personal areas; 3 questions about average daily exposure to EMF; 10 questions were about health problems; 6 questions were about the duration of daily computer and mobile phone use; 4 questions were about smoking, drinking habits and vitamin supplementation status; and 3 questions on demographic characteristics. Health-related symptoms were questioned as to the frequency during the last 12 months. The study protocol was approved by the Research Ethics Committee of Gelişim University and performed following the Declaration of Helsinki (77366270-199-E.4821).

## Statistical analysis

Data analysis was performed with statistical software "Statistical Package for the Social Sciences-SPSS 15.0 for Windows" [SPSS Inc, Chicago, IL, USA]. Data were presented and % of participants. Associations between categorical variables were evaluated using the Chi-square test. P-value <0.05 was considered statistically significant.

## Results

Participating students were 40.2% male and 59.8% female with a median age of 20 (17-41). The living place of students was close to base stations in 30%, high voltage lines (18.7%), and airport or radar system (33%). 73.1% had electrical/electronic devices in the bedroom. In house internet network and microwave, oven percentages were 82.3% and 43%, respectively. 18.5% of participants paid attention to SAR values when buying a computer; 82.9% of them turned off unnecessary lighting systems, 30.0% used to leave electrical/electronic devices in standby position (Table 1). Exposure times to electrical/electronic systems were more than 5 hours per day in 43%. Mobile phone and computer use for more than 5 years were 83% and 66%, respectively (Table 1). 30% of students talked with a cell phone for more than 2 hrs per day and 70% used of cell phone for social media and watching videos again for more than 2 h/ day (Table 2).

Most students complained of fatigue (75.2%) while more than half had difficulty in concentration (51.7%). Other health problems were presented in Table 1.

There was a significant association between exposure to high voltage lines and sleep disturbance and headache frequency ( $P<0.05$ ,  $P<0.05$ , respectively). There was also a significant association between the distance of residence to the airport and sleep disturbance, headache frequency, eye disturbance, losses in smell, musculoskeletal disorders, and light sensitivity ( $P<0.001$ ,  $P<0.001$ ,  $P<0.001$ ,  $P<0.01$ ,  $P<0.05$ ,  $P<0.01$  and  $P<0.05$ , respectively) (Table 3).

Chi-square analysis showed a significant relationship between daily electrical/electronic device exposure time and headache frequency, concentration difficulties, fatigue, muscle pain ( $P<0.01$ ,  $P<0.05$ ,  $P<0.001$ ,  $P<0.01$ , respectively). Similarly, the presence of electronic devices in the bedroom showed a statistically significant relationship with a sleep disorder, concentration difficulties, stress, fatigue, dizziness, and tinnitus ( $p<0.01$ ,  $P<0.01$ ,  $P<0.001$ ,  $P<0.001$ ,  $P<0.05$  and  $P<0.001$ , respectively). (Table 3).

The relationship between mobile phone usage habits of participants and health problems experienced was summarized in Table 4, whereas the association between computer usage and television watching habits and health problems was shown in Table 4. There was a relationship between cell phone usage duration (years) and headache frequency, eye discomfort, and forgetfulness ( $P<0.05$ ,  $P<0.01$ , and  $P<0.05$ , respectively). The relationship between daily mobile phone usage for speaking (hours/day) and headache frequency, eye discomfort, sleep disturbance, dizziness frequency, muscle pain, and losses in taste were statistically significant ( $P<0.05$ ,  $P<0.01$ ,  $P<0.01$ ,  $P<0.01$ ,  $P<0.05$  and  $P<0.05$ , respectively). There was a relationship between daily mobile phone usage for video /social media purposes and eye discomfort, fatigue, sleep disturbance, frequency of dizziness, muscle pain, tinnitus, dizziness, and concentration difficulties ( $P<0.001$ ,  $P<0.05$ ,  $P<0.001$ ,  $P<0.05$ ). 0.001,  $P<0.001$ ,  $P<0.01$ ,  $P<0.001$  and  $P<0.05$ , respectively). There was a relationship between daily computer usage duration (hours/day) and fatigue, losses in taste, and skin disorders ( $P<0.05$ ,  $P<0.001$ , and  $P<0.05$ , respectively). The relationship between computer usage duration (years) and eye disorder, musculoskeletal disturbance, dizziness, and tinnitus was statistically significant ( $P<0.01$ ,  $P<0.05$ ,  $P<0.05$ , and  $P<0.01$ , respectively). There was a relationship between TV watching

**Table 1.** Characteristics of living spaces and use of electrical / electronic devices and EMF related health problems

Characteristics of living spaces and use of electrical / electronic devices	%	EMF related health problems	%
Proximity of living place to the base station (5-10 km)	30.00	Fatigue	75.20
Proximity of living place to high voltage lines (5-10 km)	18.70	Forgetfulness	30.00
Proximity of living place to airport/radar systems (5-10 km)	33.00	Concentration difficulties	51.70
Number of floors in the building (1-5)	61.90	Sleep disorders	40.00
Knowing computer SAR (Specific Absorption Rate) values	18.50	Stress disorder	36.40
Knowing cell phone SAR (Specific Absorption Rate) values	19.90	Dizziness	13.00
Presence of internet network at home	82.70	Tinnitus	16.00
Keeping electrical / electronic devices in standby position	30.00	Headache	13.00
Turning off lighting systems not required	82.90	Muscle pain	39.00
Use of microwave oven in the kitchen	43.00	Eye discomfort	28.50
The presence of electrical/electronic equipment in the bedroom	73.10	Sensitivity to light	21.30
		Losses in taste	4.70
		Losses in smell	3.90
		Skin Disease	13.00
		Musculoskeletal disorders	11.90

**Table 2.** Distribution of individuals according to the duration of mobile phone usage, computer usage, mobile phone usage including talking, social media, and video watching

	Duration (Year/ Hours per day)	Percentage (%)
Beginning the computer usage	< 5 years	34
	5-10 years	30
	>10 years	36
Beginning the cell phone usage	< 5 years	17
	5-10 years	51
	>10 years	32
Daily talking with the cell phone	0-1 hour	40
	1-2 hours	30
	2-5 hours	18
	>5 hours	12
Daily use the cell phone for social media and video	0-1 hour	10
	1-2 hours	20
	2-5 hours	39
	>5 hours	31
Daily computer usage	0-1 hour	76
	1-2 hours	15
	2-5 hours	5
	>5	4

**Table 3.**Relationships between living spaces, electromagnetic field sources and health problems of individuals

	Exposure to electrical / electronic systems	Microwave usage	The presence of electrical/ electronic equipment in the bedroom	Keeping electrical / electronic devices in standby position	Proximity of living place to high voltage lines	Number of floors in the building	Time spent at shopping center	Proximity of living place to airport/radar systems
<b>Sleeping disorder</b>	NS	176.714***	24.085**	NS	7.510*	NS	NS	120.646***
<b>Frequency of headache</b>	27.519**	NS	NS	NS	8.438*	NS	NS	192.301***
<b>Eye discomfort</b>	NS	NS	NS	48.582***	NS	65.336***	48.323**	142.753***
<b>Concentration difficulties</b>	11.281*	NS	12.046**	NS	NS	6.371*	14.614**	39.057**
<b>Stress</b>	NS	NS	71.957***	NS	NS	NS	NS	30.957*
<b>Fatigue</b>	28.123***	686.822***	145.308***	NS	NS	NS	NS	36.891**
<b>Muscle pain</b>	14.251**	11.017**	NS	NS	NS	NS	NS	NS
<b>Musculoskeletal disorders</b>	NS	NS	NS	9.276**	NS	NS	NS	NS
<b>Losses in taste</b>	NS	28.501***	NS	NS	NS	NS	NS	31.773*
<b>Dizziness</b>	NS	25.015***	16.177*	NS	NS	NS	NS	NS
<b>Skin Disease</b>	NS	684.966***	NS	NS	NS	NS	NS	NS
<b>Tinnitus</b>	NS	NS	34.226***	NS	NS	NS	NS	NS

\*P&lt;0.05, \*\*P&lt;0.01, \*\*\*P&lt;0.001, NS: Not significant

**Table 4.**Relationship between duration of the mobile phone usage, computer usage, television watching and health problems of individuals

	Beginning the computer usage (Years)	Beginning the computer usage (Years)	Daily talking with the cell phone (Hours)	Daily use the cell phone for social media and video (Hours)	Daily computer usage (Hours)	Daily duration of watching TV (Hours)
<b>Concentration difficulties</b>	NS	NS	NS	9.243*	NS	7.651*
<b>Dizziness</b>	NS	NS	NS	29.510***	NS	NS
<b>Eye discomfort</b>	35.696**	10.444**	52.902**	49.018***	NS	NS
<b>Fatigue</b>	NS	NS	NS	19.217*	16.685*	NS
<b>Forgetfulness</b>	5.797*	NS	NS	NS	NS	NS
<b>Frequency of dizziness</b>	NS	9.726*	15.650**	29.510***	NS	17.181**
<b>Frequency of headache</b>	14.573*	NS	22.843*	NS	NS	NS
<b>Losses in taste</b>	NS	NS	9.308*	NS	16.271***	NS
<b>Muscle pain</b>	NS	NS	7.567*	19.769***	NS	7.894*
<b>Musculoskeletal disorders</b>	NS	6.466*	NS	NS	NS	NS
<b>Skin Disorders</b>	NS	NS	NS	NS	14.528*	NS
<b>Sleeping disorder</b>	NS	NS	25.000**	31.685***	NS	NS
<b>Tinnitus</b>	NS	13.995**	NS	15.435**	NS	14.738*

\*\*P&lt;0.05, \*\*P&lt;0.01, \*\*\*P&lt;0.001, NS: Not significant

duration (hours/day) and the frequency of dizziness, muscle pain, tinnitus, and concentration difficulties ( $P<0.01$ ,  $P<0.05$ ,  $P<0.05$ , and  $P<0.05$ , respectively).

## Discussion

Considering the development of technology, it is not possible to avoid technological systems in our life. Thus, it is also reasonable to question their effects on human beings. Scientific studies indicate the negative effects of these technological systems on human health due to electromagnetic radiation. In our study, we investigated both using habits of devices that emit electromagnetic radiation and also their possible effects on human health. We selected a young population as a subject since they can easily adapt to those technological systems and use them widely. The results of our survey suggest that exposure to electromagnetic fields is widespread in our both social and personal living spaces and it can be associated with some health problems such as fatigue, stress, concentration difficulties, muscle pain, skeletal system disorders, skin disorders, eye discomfort, and light sensitivity.

Our results showed that almost half of the participants are exposed to electrical/electronic systems for more than 5 hours per day. Three of the four participants have electronic devices in their bedroom suggesting that they are exposed to the electromagnetic field in their sleeping time in addition to exposure in their daily lives. In our statistical analysis, daily electrical/electronic device exposure times were very significantly related to headache frequency, concentration difficulties, fatigue, and muscle pain. Similarly, the presence of electronic devices in the bedroom was very significantly related to sleep disorder, concentration difficulties, stress, fatigue, dizziness, and tinnitus. Using a microwave oven and leaving the devices in standby position showed a statistically significant relationship with some health problems. In agreement with our results, a significant relationship between the use of cordless phones and difficulties in concentration difficulties was reported [27]. In another study, Mortazavi et al. found a significant relationship between mobile phone usage and headache, vertigo, and sleeping problems in elementary and junior high school students [28]. Kucer et al. found that users of mobile phones and computers more often complained of headache, joint and bone pain, hearing loss, vertigo/dizziness, tension-anxiety symptoms according to time of daily usage [29]. Also, it was determined that women from mobile phones and computer users had more headaches, vertigo, dizziness, fatigue, forgetfulness, and tension-anxiety than males [29]. These studies support our findings.

In our study, we investigated the effects of EMF from environmental sources at social living places. We found that residency close to high voltage lines and airports were showed a significant relationship with some health problems such as sleep disturbance, headache, eye discomforts, losses in smell, musculoskeletal disorders, and light sensitivity. We also found an association between the number of floors of living place; time spent in shopping centers and some health problems. While the causal relationship between these findings and EMF radiation could not be established in this study, the strong statistical associations between exposure and health problems suggest such a relationship.

The use of mobile phones and computers are issues needed to be addressed in particular as they are now central to modern life.

Our study showed an intense exposure to cellular phones and computers among college students. We showed that this exposure was associated with health problems and our findings agreed with the literature. Rööslü et al. reported a relationship between exposure to the mobile phone, base station, cordless phone, and power lines; and, sleep disorders, headache, nervousness or distress, fatigue, and concentration difficulties [30]. Durusoy et al. reported that there was an association between the headache, concentration difficulties, fatigue, sleep disorders, and ear warming and use of mobile phones; this association was dose-related [20]. The causal relationship of these findings with EMF still needs to be confirmed. One of the important contributions of our study in this area is that it provides the evaluation of behavioral patterns in the use of information and communication technologies in a group of university students. For example, it provides data regarding time spent on social media, mobile phone talking duration, desktop/laptop usage times. These data should be carefully evaluated. For instance, our results show that a group of these young people spends 5-7 hours or more a day with a mobile phone. We can assume that the proportion of this group is at least 31% of our population. Since it is not possible to escape or ignore information and communication technologies, the behavioral patterns of young people and children on this subject should be known correctly; its effects on both mental and physical health should not be overlooked, and society should be able to take corrective measures if necessary.

In a conclusion, our study suggests that the exposure to electromagnetic radiation due to technological systems is quite high and this exposure may be related to health problems such as fatigue, headache, insomnia, forgetfulness, weakness, concentration disorder, eye, skin, and musculoskeletal disorders. Since this is a survey study, it does not show a direct causal relationship. The effects of this exposure on biological systems and its causal relationships with electromagnetic radiation need to be further evaluated by in vivo and in vitro experimental studies.

## Conflict of interests

*The authors declare that they have no competing interests.*

## Financial Disclosure

*All authors declare no financial support.*

## Ethical approval

*The study protocol was previously reviewed and approved by the ethics committee of the Gelişim University and performed in accordance with the Declaration of Helsinki (77366270-199-E.4821).*

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