Environmental Health Engineering and Management Journal 2023, 10(2), 149–156
http://ehemj.com
doi 10.34172/EHEM.2023.17
Environmental Health Engineering and Management Journal
Original Article
Open Access Publish Free

Specific absorption rate of different phone brands and health students' awareness, attitude, and performance towards mobile phone hazards

Hiwa Hossaini[1], **Faranak Khodadoost**[2*], **Soma Goftari**[2*]

[1]Department of Environmental Health Engineering, Faculty of Public Health, Kermanshah University of Medical Sciences, Kermanshah, Iran
[2]Student Research Committee, Kermanshah University of Medical Sciences, Kermanshah, Iran

Abstract

Background: This study aimed to assess the specific absorption rate (SAR) due to the exposure to the radiations from different brands of cellphones, and to compare it with guideline values. The SAR is calculated using the mathematic equation based on the measured energy.

Methods: In this regard, 204 cellphones from different brands were randomly surveyed. A questionnaire composed of demographic and self-reported questions was designed to survey the students' awareness and attitude about cellphone brands, usage duration and observed health effects. The Kolmogorov-Smirnov test was used for statistical analysis at frequencies of 900 and 1800 MHz and the differences between brands were assessed by the Kruskal-Wallis test.

Results: According to the results, it was found that 46.7% and 8.4% of people used cellphones for less than 4 and more than 12 hours per day, respectively. According to the statistical tests, students with higher talk time, sent messages, and Internet usage, and those using wireless hands-free, had the most reported symptoms of headache, tinnitus, eye burning and eyestrain, sleep disturbances, and skin color changes.

Conclusion: The authors found that there was no significant difference between different brands based on the SAR values. However, Samsung and Nokia brands had the highest SAR values and ASUS brand had the lowest ones. Also, the type of game apps (online/offline) was significantly correlated with possible health effects. Therefore, regarding these cases, as well as the fact that many dangers of cellphone use are unknown, it is recommended to use cellphones cautiously.

Keywords: Cell phone, Students, Electromagnetic fields, Attention, Humans

Citation: Hossaini H, Khodadoost F, Goftari S. Specific absorption rate of different phone brands and health students' awareness, attitude, and performance towards mobile phone hazards. Environmental Health Engineering and Management Journal 2023; 10(2): 149–156. doi: 10.34172/EHEM.2023.17.

Article History:
Received: 21 June 2022
Accepted: 27 November 2022
ePublished: 9 April 2023

***Correspondence to:**
Faranak Khodadoost,
Email: khodadoost.faranak@gmail.com;
Soma Goftari,
Email: soma.goftari@yahoo.com

Introduction

Today, due to the advances in wireless technology, industrialized nations are exposed to a complex mix of electric and magnetic fields in the broadband frequency ranges from human-made sources (1,2). Electromagnetic fields (EMFs) are consisted of cosmic, gamma, X, ultraviolet, visible, infrared, microwave and radio waves (3-5). These radiations are divided into two types of ionizing and non-ionizing radiation (6). Ionizing radiation such as gamma, X, and ultraviolet rays are able to ionize and severely damage to biological materials like DNA (7). Non-ionizing radiations occupy a wide range of radio magnetic frequencies and are emitted from various electrical devices such as radars, high-voltage power lines, telecommunications devices (cell phones), television transmitters and more (3). Due to their low energy, non-ionizing radiations cannot produce negative effects immediately after exposure, while they only intensify in chronic contact. These radiations are safer than ionizing radiations (8).

Radiofrequency electromagnetic fields (RF-EMF) have a frequency range of 0-300 GHz according to the International Commission on Non-Ionizing Radiation Protection)ICNIRP(guidelines (2). Some indoor sources of RF-EMFs are cellphones, wireless telephones, and Wi-Fi access points, and some outdoor sources are cellular base stations and radio stations (9). Today, the use of cell phones is not limited to a specific age group but is widespread across all age groups, especially adults (10). To this end, the impact of EMF waves emitted by cell phones

© 2023 The Author(s). Published by Kerman University of Medical Sciences. This is an open-access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

on the life of organisms and human health has become one of the most important research topics (3). In general, electromagnetic waves have two major known effects on tissues, including thermal and non-thermal (chemical) effects (3). Non-thermal effects are cumulative over time and their risks become more pronounced after 8-10 years (11,12). Meanwhile, there is no known biological mechanism for the damaging effects of cellphone radiation, as the quantum energy used for mobile communication is far below the level that breaks chemical bonds. In fact, the only accepted mechanism for RF-EMF of cellphones that can have a detrimental effect on health is the generation of heat. Previous studies demonstrated that elevation of brain or ear channel temperature from 1.5 to 4.5ºC occurred after about half an hour continuous cell phone operation, which is also preventable by contact restrictions imposed by ICNIRP for ordinary people (10,12). The exposure to cellphone RF radiation has been reported to cause various symptoms such as fatigue, headache, sleep disturbances and poor sleep quality (6,13,14), and other neurovegetative symptoms such as damage accumulation, nausea, palpitations (15), earache, blurred vision, short-term memory loss, numbness, severe electromagnetic sensitivity and anxiety (6), and skin complications like redness, itching, and burning (15). However, some cohort studies have reported an inverse association between cellphone use and Alzheimer's disease, Parkinson's disease, and epilepsy among men (16). Other studies have emphasized the long-term development of brain tumors due to the effects of radiation on cerebral vessels and cells responsible for learning and motion memory (3,10). Lerchl et al reported increased incidence of brain tumors in the intensive use of cellphones (12). Sadetzki et al found that there was a relationship or association between long-term and intensive use of cellphones and the development of parotid glands tumor (17), the World Health Organization (WHO) has classified cell phone radiation as a Class 2B carcinogen (5).

Surveys show that the RF values generated by the cellphones depend on the number of cellular base stations around the area, mobile network traffic, and its distance from the base station (18). Cellphone technology, as an integral part of today's life, requires undeniable attention (19). In 2018, 59.97% of people used cell phones. Penetration is predicted to continue to grow, rounding up to 4.78 billion people in 2020 and it will certainly increase in 2022 (20). Accordingly, the peak spatial-average specific absorption rate (SAR) values of 2 W/kg and 10 W/kg for the exposure of the public and exposures in controlled environments over 10 g of tissue were introduced, respectively. Accordingly, for frequencies above 100 MHz, the radiation evaluation by the SAR calculation is important (12,21-23). The Institute of Electrical and Electronics Engineers (IEEE) and the WHO guideline value for SAR is 1.6 W/kg in 10 g of tissue. The guideline values for the electric field intensities at the 900 MHz and 1800 MHz are 41.25 V/m and 53.8 V/m, respectively (10,24). So, although many studies have been conducted today on the impact of electric fields on health and exacerbation of various diseases, little attention has been paid to the SAR of cellphones and awareness of people about the importance of cellphone SAR values. Although in few studies conducted in this regard, the SAR values of all cellphones were lower than the guideline values (10). The literature suggests that the harmful biological effects are initially on the brain at SAR level less than 0.001 W/kg, which accordingly increases the molecular stress response in cells (25).

Therefore, it is important for people to know the SAR values of the cellphones used. This study aimed to determine the students' information on the cellphones SAR values awareness in Kermanshah School of Public Health. In addition, cellphone radiation and SAR in 10 g of brain tissue (SAR10 g) were evaluated; the SAR of cellphones was compared with the ICNIRP guidelines, and their relationship with cellphone brand and number of active SIM cards was examined.

Materials and Methods

Measuring the electric field

This descriptive-analytical study was conducted in May-June 2021 at Kermanshah University of Medical Sciences in Iran. A total of 204 students were randomly selected according to Morgan table. A questionnaire including awareness, attitude and demographic and performance information was designed, and Cronbach's alpha was used to determine its reliability (95%) (Supplementary file). In addition, power density (mW/m^2) of cellphones were measured using the TM-196-AXIS RF Field Strength Meter (Tenmars Electronics Co., Ltd, Taiwan). All experiments were performed on the X, Y, Z axes, and to reduce interference from other sources of electromagnetic radiation, all experiments were performed in a 60 × 60 × 60 cm plexiglass box with 2 mm thickness and aluminum cladding, which is cases with 0.2 mm thickness. A plastic base was used to hold the cell phones. In each experiment, a cellphone was placed close to the sensor on a stand at an angle of 120 degrees in the box. The maximum and mean electric field and power density were measured for 60 seconds. To consider the effect of base radiation changes due to weather conditions or intensity of antennas, the base radiation measured and subtracted from the measured phone radiation.

Calculating the specific absorption rate

The SAR is defined as the loss of natural energy in the face of dense materials (10). Using the obtained power density values, SAR values at 900 and 1800 MHz were calculated using the following equation (25):

$$SAR = \frac{\sigma(E)2}{\rho m} = PA/\ \rho m$$

Where, *SAR* is the specific absorption rate of the electric field (W/kg), σ is the conductivity coefficient of human brain tissue, which was 0.7665 Ω/m and 1.1531 Ω/m at 900 and 1800 MHz, respectively, $|E|^2$ is magnitude of the electric field vector, and *P* is mass density of human brain tissue at 900 and 1800 MHz equal to 1030 kg/m^3.

Statistical analysis

The results were statistically analyzed using SPSS version16.0 and Excel 2016. First, the normality of data was checked, the Kolmogorov-Smirnov test was used for statistical analysis at frequencies of 900 and 1800 MHz. Due to the non-normality of SAR for all brands in the two mentioned frequencies, the differences between brands were assessed by the Kruskal-Wallis test. The SAR was compared with guidelines and standards at frequencies of 900 and 1800 MHz. In statistical tests, $P < 0.05$ was chosen at the significance level of α = 5% and the corresponding graphs were plotted.

Results

In this study, 204 cases were surveyed. Accordingly, after completing the questionnaire, demographic information, self-reported items including health effects, safety considerations, awareness, and attitude were assessed. As shown in Table 1, 75% of the participants were female and 25% were male. The frequency of brands among the examined phones was shown in Figure 1. As shown in this

Table 1. Relationship of demographic information with awareness and attitude

Variable		Frequency		Awareness		Level	Attitude		Level
		Number	Percent	Mean ± SD	*P* value		Mean ± SD	*P* value	
Gender	Female	158	75	6.91 ± 1.50	0.754	Good	29.33 ± 18.4	0.03	Good
	Male	55	25	6.83 ± 1.70		Good	16.26 ± 4.27		Good
Having body exercise	Yes	97	4.335	7.07 ± 1.52	0.102	Good	17.20 ± 4.24	0.08	Good
	No	117	5.674	6.73 ± 1.56		Good	25.48 ± 18.4		Good
Kind of workout	Regular	28	2.926	7.22 ± 1.69	0.463	Good	16.39 ± 4.42	0.20	Good
	Non-regular	76	7.083	6.97 ± 1.47		Good	17.58 ± 4.09		Good
Workout duration (h)	<0.5	58	5.316	7.09 ± 1.47	0.104	Good	17.96 ± 4.18	0.07	Good
	1-2	40	3.838	7.03 ± 1.54		Good	17.60 ± 4.06		Good
	2 -4	3	2.91	4.91 ± 1.37		Moderate	13.50 ± 3.50		Moderate
	>4	2	1.94	7.50 ± 0.35		Very good	13.37 ± 2.29		Moderate
Brands	iPhone	10	4.67	7.00 ± 2.38	0.716	Good	16.77 ± 4.86	0.06	Good
	Sony	41	1.169	7.01 ± 1.43		Good	17.77 ± 4.49		Good
	Huawei	21	9.81	6.83 ± 1.63		Good	16.85 ± 3.62		Good
	Nokia	37	1.297	6.97 ± 1.49		Good	19.38 ± 5.26		Good
	HTC	8	3.74	6.03 ± 1.27		Good	5.26 ± 1.067		Good
	Samsung	74	3.584	6.73 ± 1.61		Good	17.09 ± 3.84		Good
	Huawei and Nokia	3	1.40	7.50 ± 0.66		Very good	13.66 ± 4.16		Moderate
	Nokia and Samsung	4	1.87	7.37 ± 1.26		Good	18.37 ± 3.70		Good
	Sony and Nokia	4	1.87	6.45 ± 0.41		Good	18.40 ± 2.70		Good
	Sony and Samsung	2	0.93	7.87 ± 1.59		Very good	17.75 ± 3.88		Good
	Others	10	4.67	7.50 ± 1.53		Very good	21.27 ± 3.81		Good
Cellphone usage (h)	<4	100	4.736	6.80 ± 1.62	0.458	Good	18.09 ± 4.77	0.69	Good
	4-8	75	3.515	6.90 ± 1.57		Good	17.30 ± 3.91		Good
	8 -12	20	9.35	7.40 ± 1.24		Good	18.03 ± 4.08		Good
	>12	18	8.41	6.76 ± 1.31		Good	17.75 ± 4.60		Good
Number of active SIM cards	1	146	6.228	6.77 ± 1.66	0.274	Good	4.68 ± 17.84	0.85	Good
	2	63	2.449	7.14 ± 1.30		Good	17.55 ± 3.76		Good
	3	55	2.34	7.10 ± 0.84		Good	18.50 ± 3.56		Good
Sent and received messages	<5	66	3.281	6.60 ± 1.63	0.331	Good	4.81 ± 7.824	0.581	Good
	5-10	47	2.272	7.07 ± 1.68		Good	4.28 ± 17.13		Good
	10-15	19	9.00	6.89 ± 1.68		Good	4.62 ± 17.09		Good
	>15	79	3.447	7.01 ± 1.35		Good	3.94 ± 18.12		Good

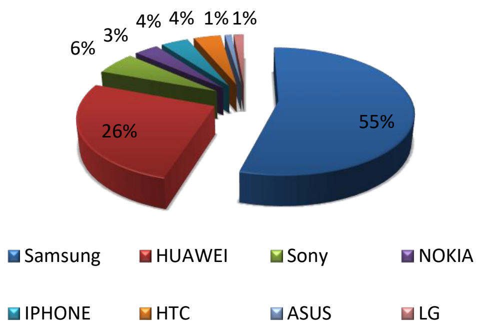

Figure 1. Frequency (%) of brands examined

figure, Samsung (55%) and LG and ASUS each with (1%) have the highest and lowest frequency, respectively.

The results observed in Table 1 showed that most students had only one active SIM card. Based on the self-reported data, 46.73% of students had a cellphone usage less than 4 hours, 35.51% used cellphones between 4-8 hours, 9.35% used cellphones between 8-12 hours, and 8.41% used cellphones higher than 12 hours per day. Among the surveyed cases, 76.89% did not use handsfree during conversations, and the remaining using handsfree, preferred wired handsfree. Most students used third-generation (3G) cellphones and offline games, and most of their online time was spent on social media. According to the results, more than 95% of the students did not have any information about SAR and most of them had non-regular exercises (body workout) less than 30 minutes per day.

In the section of the self-reported items that included health effects and safety considerations, there was no significant relationship between self-reported information (health effects and safety considerations) and students' awareness based on the statistical tests ($P > 0.05$). This means that students did not have enough information about the safety of cellphone use, which could be due to the lack of regular training programs and lack of interest in spending time on finding information about the effects of cellphone overuse (Table 1).

According to Table 1, the obtained scores of students showed a good general level of awareness and attitude. According to the results, subjects' awareness of the proper use of cellphones was at a good level. To investigate the relationship between variables, the questions were classified into demographics, and awareness, attitude and self-reported (practice) sections. After determining the normality of data, Pearson's test was used to investigate the relationship between normal parameters and Spearman's test was used to investigate the relationship between non-normal parameters. The Pearson's test showed a significant relationship between awareness and attitude ($P < 0.001$) and the Spearman's test showed no significant relationship between health and safety (practice) ($P = 0.547$).

Also, based on the Kolmogorov-Smirnov and Kruskal-Wallis tests, there were significant differences between male and female students' attitudes and demographic information including talk time, using handsfree during calls, cellphone's generation and students using and not using game apps ($P < 0.001$). According to the statistical tests, students with higher talk time, sent messages and Internet usage, and those using wireless handsfree, had the most reported symptoms of a headache, tinnitus, eye burning and eyestrain, sleep disturbances, and skin color changes ($P < 0.001$). Also, the type of game apps (online/offline) was significantly correlated with possible health effects ($P = 0.03$) (Table 2).

The next step was to measure the SAR of cell phones. Figure 2 shows the frequency of different cellphone brands that had an SAR value lower than the specified guideline values (2 W/kg).

According to Figure 2, SAR values were lower than guideline values at frequency of 900 MHz in 97.4% of Samsung cellphones and 100% of other brands; and at 1800 MHz, in 100% of cellphones of Sony, iPhone, ASUS, and LG brands; and in 97.3%, 98.1%, 85.7%, and 87.5% of the Samsung, Huawei, Nokia, and HTC brands, respectively.   summarizes the median, mean, standard deviation, and SAR values of cellphone brands examined at two frequencies of 900 and 1800 MHz.

According to Table 3, the highest mean SAR values were seen in Nokia (0.29 ± 0.64 and 0.87 ± 2.04 at 900 and 1800 MHz, respectively) and Samsung brands (0.27 ± 1.48 and 0.87 ± 6.29 at 900 and 1800 MHz, respectively); and the lowest SAR values were seen in ASUS brand (0.0002 ± 0.0002 and 0.1 ± 0.13 at 900 and 1800 MHz, respectively). Since scattering of data resulted in relatively large standard deviations for some brands, median is a more appropriate index to compare brands in terms of SAR. Therefore, the lowest median value was reported in ASUS at 900 MHz and the highest one was reported in LG, HTC, and Nokia brands at 1800 MHz, the median values for all brands are lower than the guideline values. As shown in this table, for iPhone at frequencies of 900 and 1800 MHz, the median and mean SAR values were reported 0.0995 and 0.1985, respectively. Also, for Samsung, the median SAR values at frequencies of 900 and 1800 MHz were 0.05 and 0.07, respectively. According to the reports in 2021, iPhone had an average radiation SAR of 1.166 W/kg whereas the Samsung devices had an average of 0.517 W/kg. In order to compare SAR values among brands, the normality of SAR values at 900 and 1800 MHz was first determined using the Kolmogorov-Smirnov test. Due to the non-normality of SAR for all brands in the two mentioned frequencies ($P > 0.05$), differences between brands were assessed by the Kruskal-Wallis test. According to the results, no significant difference was observed between measured brands ($P > 0.05$). However, there was a significant difference between Huawei and iPhone in terms of SAR ($P < 0.05$). In order to examine the

Table 2. Relationship of demographic information with awareness and attitude

Variable		Frequency		Awareness		Level	Attitude		Level
		Number	Percent	Mean±SD	*P* value		Mean±SD	*P* value	
Talk time (min)	<5	80	37.91	7.10±1.51	0.387	Good	18.92±4.62	0.018	Good
	5-10	78	36.97	6.72±1.56		Good	16.85±4.23		Good
	10 -40	35	16.59	6.92±1.48		Good	17.13±3.91		Good
	>40	18	8.53	6.61±1.59		Good	17.43±3.45		Good
Handsfree	Yes	49	23.11	7.06±1.67	0.340	Good	16.33±4.31	0.011	Good
	No	163	76.89	6.82±1.52		Good	18.13±4.29		Good
Wired handsfree	Yes	130	62.20	6.92±1.58	0.712	Good	17.33±4.10	0.075	Good
	No	79	37.80	6.75±1.53		Good	18.43±4.67		Good
Wireless handsfree	Yes	18	8.45	6.84±1.68	0.944	Good	16.76±4.34	0.304	Good
	No	189	88.73	6.87±1.55		Good	17.83±4.36		Good
Generation cellphones	2G	44	21.89	6.97±1.33	0.652	Good	19.80±4.66	0.001	Good
	3G	136	67.66	6.78±1.63		Good	16.83±4.00		Good
	4G	21	10.45	7.04±1.55		Good	17.59±4.17		Good
Duration of Internet usage (h)	<1	66	32.35	6.46±1.58	0.08	Good	17.20±4.64	0.394	Good
	1-3	58	28.43	7.36±1.47		Good	17.75±4.50		Good
	3-6	44	21.57	6.61±1.52		Good	17.21±3.48		Good
	>6	36	17.65	7.01±1.46		Good	18.62±4.39		Good
Playing games	Yes	70	32.86	6.73±1.65	0.303	Good	16.26±4.19	0.001	Good
	No	143	67.14	6.97±1.50		Good	18.50±4.32		Good
Duration of playing games (h)	<2	61	80.26	6.56±1.64	0.411	Good	16.64±4.24	0.960	Good
	2-5	11	14.47	7.27±1.80		Good	16.45 4.95		Good
	5-10	2	2.63	7.12±0.88		Good	15.00±0.00		Moderate
	<10	2	2.63	7.78±0.17		Very good	16.37±2.29		Good
Kind of Games	Online	12	16.67	7.18±1.70	0.208	Good	16.47±4.08	0.898	Good
	Offline	43	59.72	6.43±1.60		Good	16.58±4.34		Good
	Online and offline	17	23.61	7.13±1.80		Good	16.01±4.18		Good
Mostly use of cellphone	Call	36	16.90	6.61±1.61	0.678	Good	17.02±4.94	0.728	Good
	Sent messages	54	25.35	6.98±1.45		Good	17.99±4.70		Good
	Internet use	119	55.87	6.95±1.56		Good	17.92±4.13		Good
	Games	4	1.88	6.93±1.24		Good	17.87±3.60		Good
Do you know what SAR is?	Yes	25	11.74	7.45±1.55		Good	17.68±4.61		Good
	No	188	88.26	6.81±1.54	0.057	Good	17.78±4.38	0.915	Good
Information about cell phones' SAR values	Yes	9	4.23	7.08±1.67		Good	17.10±4.04		Good
	No	204	95.77	6.88±1.55	0.709	Good	17.79±4.09	0.690	Good
In permitted SAR limit	Yes	7	3.29	7.71±1.27	0.156	Very good	15.39±4.14	0.147	Good
	No	206	96.71	6.86±1.56		Good	17.84 4.39		Good
Check SAR when buying your cellphone	Yes	3	1.41	8±1.8	0.216	Very good	15.16±2.92	0.304	Good
	No	210	98.59	6.87±1.55		Good	17.80±4.41		Good

relationship between measured levels of power density and number of active SIM cards, normality of power density was examined by the Kolmogorov-Smirnov test. Due to non-normality of power density ($P > 0.05$), and also, as the number of active SIM cards consists of two groups (1 or 2 SIM cards), Mann-Whitney U test was used to examine the significant relationship between the power density level and the number of active SIM cards. According to the test results, there was no significant relationship between mean power density levels and the number of active SIM cards ($P > 0.05$).

Discussion

In a previous study, Fakhri and Majlessi conducted at 2, 25, and 50 cm distances in the three Ringing, Vibrating, and Silent modes of three brands of Samsung, Nokia, and

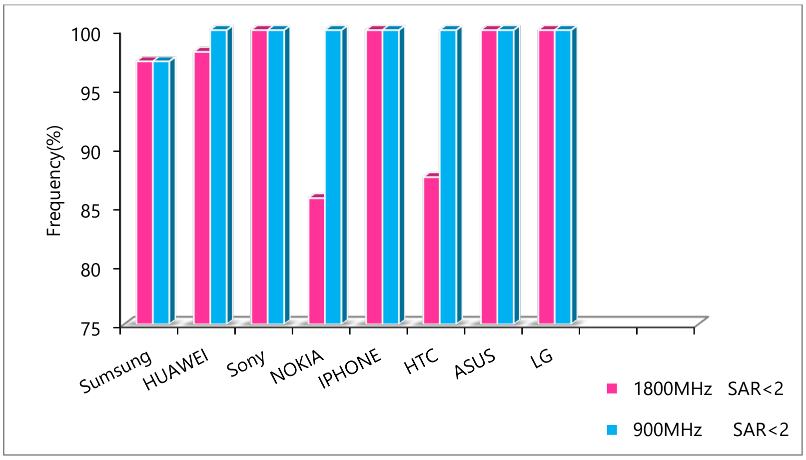

Figure 2. Frequency of cellphones with an SAR value below the guideline values in different brands

Table 3. Medium, Mean, Standard deviation, and SAR (W/kg) for different brands

Brands	Median		Mean		Standard Deviation	
	900 MHz	1800 MHz	900 MHz	1800 MHz	900 MHz	1800 MHz
Samsung	0.05	0.07	0.27	0.87	1.48	6.29
Huawei	0.007	0.009	0.08	0.14	0.25	0.48
Sony	0.04	0.08	0.05	0.09	0.045	0.09
Nokia	0.1	0.2	0.29	0.87	0.64	2.04
iPhone	0.0995	0.1985	0.0995	0.1985	0	0
HTC	0.1	0.2	0.15	0.8	0.26	1.93
ASUS	0.0002	0.1	0.0002	0.1	0.0002	0.13
LG	0.1	0.2	0.066	0.13	0.06	0.11

Sony, SAR values order was as Samsung < Sony < Nokia. In their study, SAR range in 8 Samsung models was 3.6E-04 - 4.0E-05 and 5.5E-0.4 - 4.0E-05 at frequencies of 900 and 1800 MHz, respectively; in 9 Nokia models, it was 2.6E-03 - 4.0E-05 and 3.9E-0.3 - 7.0E-0.5 at frequencies of 900 and 1800 MHz, respectively; and in 4 Sony models, it was 1.6E-03 - 4.0E-05 and 2.4E-03 - 7.0E-05 at frequencies of 900 and 1800 MHz, respectively. Based on these results, the SAR values were lower than those of the present study (10). In another study conducted on 8 models of Samsung and 5 models of Nokia and Sony smartphones, the mean SAR in Samsung and Nokia at 5 mm distance and in the alarms mode was 0.0024 ± 0.0005 W/kg and 0.0041 ± 0.0013 W/kg at frequency of 900 MHz, respectively; and 0.001 ± 0.004 and 0.0062 ± 0.002 at frequency of 1800 MHz, respectively. In addition, SAR values for Nokia were significantly higher than those for Samsung. The reported SAR values for these two brands were significantly lower than those reported in the present study ($P > 0.05$) (7). Such differences might be due to the measurement of the radiation during calls and the difference in the models studied, as well as antenna coverage. Martínez-Búrdalo et al demonstrated that SAR values of cellphones in 10 g of brain tissue at 2.2 cm from measuring device at frequencies of 900 and 1800 MHz in all three human head models was lower than the European guidelines (2 W/kg). For instance, the adult people scale was reported as 1.44 and 1.45 W/kg at frequencies of 900 and 1800 MHz, respectively (SAR 10 g). These values are generally lower than those of the present study, which can be due to the difference in measurement distance (26). However, according to the literature and Nokia and Samsung manufacturers, the mean SAR values in 116 models of Nokia cellphones were 0.75 ± 0.27 and in 96 models of Samsung cellphones were 0.65 ± 0.273, which are close to those reported in the present study (7).

According to the data obtained from this study, power density values, and subsequently, SAR values exceeded the guideline values only in a few cases, which could be due to factors such as cellphone models, poor antenna coverage, and etc. Also, comparing measurements in morning with evening showed that measurements in the evening hours gave significantly larger values than other times. This was approved by Dhami (25), in addition, in cloudy weather, power density measurements gave larger values.

Conclusion

SAR values were higher in all brands at frequency of 1800 MHz than at 900 MHz. Among the examined brands, Samsung and Nokia showed the highest mean SAR values, although this difference was not significant ($P > 0.05$). At both frequencies, cases with SAR values greater than the ICNIRP guidelines were found. According to the statistical tests, students with higher talk time, sent messages and Internet usage, and those using wireless handsfree, had the most reported symptoms of a headache, tinnitus, eye burning and eyestrain, sleep disturbances and skin color changes ($P < 0.001$). Also, the type of game apps (online/offline) was significantly correlated with possible health effects ($P = 0.03$). The questionnaire revealed that most people had poor information in all three areas, therefore, considering the results of this study and the potential dangers of cellphone use, more attention should be paid to the impact of cellphone use on human health.

Acknowledgements

The authors would like to gratitude all students who participated in this study.

Authors' contribution

Conceptualization: Hiwa Hossaini.
Data curation: Hiwa Hossaini.
Formal analysis: Hiwa Hossaini.
Funding acquisition: Hiwa Hossaini.
Investigation: Faranak Khodadoost.
Methodology: Hiwa Hossaini.
Project administration: Hiwa Hossaini.
Resources: Faranak Khodadoost.
Software: Faranak Khodadoost.
Supervision: Hiwa Hossaini.
Validation: Hiwa Hossaini.
Visualization: Soma Goftari.
Writing–original draft: Faranak Khodadoost.
Writing–review & editing: Soma Goftari.

Competing interests

The authors declare that there is no conflict of interest.

Ethical issues

The authors certify that all data collected during the present study are presented in this manuscript and no data from the study have been or will be published elsewhere separately.

Supplementary file

Supplementary file contains questionnaire including awareness, attitude and demographic and performance information.

References

1. Christopher B, Mary Y S, Khandaker MU, Jojo PJ. Empirical study on specific absorption rate of head tissues due to induced heating of 4G cell phone radiation. Radiat Phys Chem Oxf Engl 1993. 2021;178:108910. doi: 10.1016/j.radphyschem.2020.108910.
2. Fernández-García R, Gil I. Measurement of the environmental broadband electromagnetic waves in a mid-size European city. Environ Res. 2017;158:768-72. doi: 10.1016/j.envres.2017.07.040.
3. Kaplan S, Deniz OG, Önger ME, Türkmen AP, Yurt KK, Aydın I, et al. Electromagnetic field and brain development. J Chem Neuroanat. 2016;75(Pt B):52-61. doi: 10.1016/j.jchemneu.2015.11.005.
4. Borzoueisileh S, Shabestani Monfared A, Ghorbani H, Mortazavi SMJ, Zabihi E, Pouramir M, et al. Combined effects of radiofrequency electromagnetic fields and X-ray in renal tissue and function. Res Rep Urol. 2020;12:527-32. doi: 10.2147/rru.s257365.
5. World Health Organization (WHO). Establishing a Dialogue on Risks from Electromagnetic Fields. WHO; 2002.
6. Deepti B. Electromagnetic hypersensitivity syndrome. Int J Green Pharm. 2016;10(4):212-9. doi: 10.22377/ijgp.v10i04.758.
7. Fakhri Y, Alinejad A, Keramati H, Bay A, Avazpour M, Zandsalimi Y, et al. Survey on different Samsung with Nokia smart mobile phones in the specific absorption rate electrical field of head. Glob J Health Sci. 2016;8(9):53967. doi: 10.5539/gjhs.v8n9p251.
8. Guxens M, Vermeulen R, van Eijsden M, Beekhuizen J, Vrijkotte TGM, van Strien RT, et al. Outdoor and indoor sources of residential radiofrequency electromagnetic fields, personal cell phone and cordless phone use, and cognitive function in 5-6 years old children. Environ Res. 2016;150:364-74. doi: 10.1016/j.envres.2016.06.021.
9. Aly AA, Crum R. Research review for possible relation between mobile phone radiation and brain tumor. International Journal of Information Technology Convergence and Services. 2016;6(4):1-16. doi: 10.5121/ijitcs.2016.6401.
10. Fakhri Y, Majlessi M. Comparison Nokia, Samsung and Sony mobile phones in the specific absorption rate of head induced to electric field. Health Sci. 2016;5(7S):377-84.
11. Sivani S, Sudarsanam D. Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem-a review. Biol Med. 2012;4(4):202-16.
12. Lerchl A, Klose M, Grote K, Wilhelm AF, Spathmann O, Fiedler T, et al. Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. Biochem Biophys Res Commun. 2015;459(4):585-90. doi: 10.1016/j.bbrc.2015.02.151.
13. Al-Bayyari N. The effect of cell phone usage on semen quality and fertility among Jordanian males. Middle East Fertil Soc J. 2017;22(3):178-82. doi: 10.1016/j.mefs.2017.03.006.
14. Arnetz BB, Akerstedt T, Hillert L, Lowden A, Kuster N, Wiholm C. The effects of 884 MHz GSM wireless communication signals on self-reported symptom and sleep (EEG)-an experimental provocation study. Piers Online. 2007;3(7):1148-50. doi: 10.2529/piers060907172142.
15. Hillert L, Akerstedt T, Lowden A, Wiholm C, Kuster N, Ebert S, et al. The effects of 884 MHz GSM wireless communication signals on headache and other symptoms: an experimental provocation study. Bioelectromagnetics. 2008;29(3):185-96. doi: 10.1002/bem.20379.
16. Schüz J, Waldemar G, Olsen JH, Johansen C. Risks for central nervous system diseases among mobile phone subscribers: a Danish retrospective cohort study. PLoS One. 2009;4(2):e4389. doi: 10.1371/journal.pone.0004389.
17. Sadetzki S, Chetrit A, Jarus-Hakak A, Cardis E, Deutch Y, Duvdevani S, et al. Cellular phone use and risk of benign and malignant parotid gland tumors--a nationwide case-control study. Am J Epidemiol. 2008;167(4):457-67. doi: 10.1093/aje/kwm325.
18. Ghoneim FM, Arafat EA. Histological and histochemical study of the protective role of rosemary extract against harmful effect of cell phone electromagnetic radiation on the parotid glands. Acta Histochem. 2016;118(5):478-85. doi: 10.1016/j.acthis.2016.04.010.
19. Liu T, Mathrani A, Mbachu J. Hunting the popular construction apps. In: 2016 3rd Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE). Nadi, Fiji: IEEE; 2016. doi: 10.1109/APWC-on-

CSE.2016.042.

20. Number of Mobile Phone Users Worldwide from 2015 to 2020. November 23, 2022. Available from: https://www.statista.com/statistics/274774/forecast-of-mobile-phone-users-worldwide/.
21. Develi I, Sorgucu U. Prediction of temperature distribution in human BEL exposed to 900MHz mobile phone radiation using ANFIS. Appl Soft Comput. 2015;37:1029-36. doi: 10.1016/j.asoc.2015.04.055.
22. Anderson V, Joyner KH. Specific absorption rate levels measured in a phantom head exposed to radio frequency transmissions from analog hand-held mobile phones. Bioelectromagnetics. 1995;16(1):60-9. doi: 10.1002/bem.2250160112.
23. Bailey WH, Bodemann R, Bushberg J, Chou CK, Cleveland R, Faraone A, et al. Synopsis of IEEE Std C95. 1™-2019 "IEEE standard for safety levels with respect to human exposure to electric, magnetic, and electromagnetic fields, 0 Hz to 300 GHz". IEEE Access. 2019;7:171346-56. doi: 10.1109/ACCESS.2019.2954823.
24. Bhargava D, Leeprechanon N, Rattanadecho P, Wessapan T. Specific absorption rate and temperature elevation in the human head due to overexposure to mobile phone radiation with different usage patterns. Int J Heat Mass Transf. 2019;130:1178-88. doi: 10.1016/j.ijheatmasstransfer.2018.11.031.
25. Dhami AK. Study of electromagnetic radiation pollution in an Indian city. Environ Monit Assess. 2012;184(11):6507-12. doi: 10.1007/s10661-011-2436-5.
26. Martínez-Búrdalo M, Martín A, Anguiano M, Villar R. Comparison of FDTD-calculated specific absorption rate in adults and children when using a mobile phone at 900 and 1800 MHz. Phys Med Biol. 2004;49(2):345-54. doi: 10.1088/0031-9155/49/2/011.