

A study on the effect of prolonged mobile phone use on pure tone audiometry thresholds of medical students of Sikkim

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ABSTRACT

Introduction: Mobile phones have become indispensable for daily activities, and people are exposed to them from an early age. There is, however, concern about the harmful effect of the electromagnetic radiation emitted from the mobile phones. **Objective:** The objective of the study was to study the effect of mobile phone on average pure tone audiometry (PTA) threshold of the person and to study the changes in the pure tone threshold at high frequencies such as 2 kHz, 4 kHz, and 8 kHz among the students with prolonged exposure to mobile phones. **Methodology:** A cross-sectional study was conducted among the medical students who have been using mobile phones for the past 5 years. The effect of mobile phones on the PTA threshold in the exposed ear and the nonexposed ear was assessed. **Results:** The study shows that there is a significant difference in average air conduction (AC) and bone conduction (BC) hearing threshold among the exposed and the nonexposed ears ($P < 0.05$). A significant rise of both AC and BC threshold at individual frequencies between the exposed and the nonexposed ear is also noted in this study. **Conclusion:** The study conducted shows changes in the hearing threshold of the exposed ear when compared with the nonexposed ear. There are however lot of unanswered questions which provide an interesting avenue for further research. Till concrete evidence is available the only feasible way to control its exposure is to limit the duration of usage of mobile phones.

KEY WORDS: Electromagnetic radiation, harmful effect, hearing threshold, mobile phones, radiofrequency

Received : 15-10-2016
Review completed : 22-12-2016
Accepted : 01-01-2017

Introduction

Mobile phones have become an integral part of our daily activities. The use of mobile phones started in the early eighties, and since then it has increased exponentially. In 2014, the World Health Organization estimated 6.9 billion users of mobile phones globally.^[1] India is considered the second largest market for smartphones and is expected to have 650 million users of smartphones by 2019.^[2] With the advancement of technology, the role of mobile phones is not limited to only making or receiving calls. Present day smartphones support a wide range of services such as text messaging, internet access, short-range wireless communications (infrared,

Bluetooth), business applications, gaming, and photography. Research has shown that approximately 40%–55% of the radiofrequency output from mobile phones is absorbed in the user's head.^[3] International Agency for Research on Cancer classified mobile phone radiation as a possible carcinogenic to humans.^[1] Adverse effects of mobile phone use on health include the possible link to increased risk of vehicular accidents, leukemias, sleep disturbances, and brain tumors.^[4] The thermal effects of electromagnetic radiation (EMR) include headache, sensation of warmth or burning around the ear, burning sensation on the facial skin and alteration of the blood–brain barrier.^[4]

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How to cite this article: Das S, Chakraborty S, Mahanta B. A study on the effect of prolonged mobile phone use on pure tone audiometry thresholds of medical students of Sikkim. J Postgrad Med 2017;63:221-5.

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Quick Response Code:	Website: www.jpgmonline.com
	DOI: 10.4103/0022-3859.201419

The operating frequencies of most mobile phone are around 900–1800 mHz. Although this frequency is within the acceptable range yet data on its long-term cumulative effect and influence on cellular damage is lacking. The ear, remain closest to the mobile phone and is the direct recipient of the noise, thermal energy, and EMR waves emitted by the phone.^[5] There is a concern that this may damage the sensitive outer hair cells in the organ of Corti. Various studies have been undertaken to assess the hearing status in long-term mobile phone users, but results are inconclusive.^[6-8]

The aims and objective of the study was to study the effect of mobile phone on average pure tone audiometry (PTA) threshold of the person and to study the changes in the pure tone threshold at high frequencies such as 2 kHz, 4 kHz, and 8 kHz among the students with prolonged exposure to mobile phones.

Methodology

The study was carried out at the Department of ENT of the institute. Clearance was obtained from the Institutional Ethics Committee before starting the study.

The study population comprised the medical students of the institute within the age group of 18–30 years and who were using mobile phones for the past 5 years or more. Individuals not willing to consent for the study, individuals with preexisting ear disorders, history of sudden loud noise or chronic noise exposure, using headphones for recreational purpose for more than 1 h/day or individuals with any systemic diseases such as diabetes, hypertension were also excluded. Individuals with a history of taking ototoxic medications in the past, those with a history of measles, mumps, rubella, jaundice, etc., were also excluded. Those with a history of alcohol abuse were also excluded from the study.

The students were first screened randomly with a predesigned and pretested questionnaire, and a thorough clinical examination was carried out. Duration of use of mobile phones for making and receiving calls was cross-examined by taking into consideration the average duration of call log for randomly selected 2 days in the preceding week. This was based on the findings of the study by Ahn *et al.* which shows that contrary to popular prediction the difference in usage pattern of mobile phones between weekdays and weekend is small.^[9] The selected candidates were subjected to impedance audiometry to rule out any middle ear pathology. PTA was then performed for both air conduction (AC) and bone conduction (BC) as per American Speech-Language-Hearing Association guidelines^[10] and the thresholds at various frequencies noted. The average pure tone threshold for AC and BC were calculated by taking the average of the hearing threshold at 500 Hz, 1000 Hz, and 2000 Hz.

It has been observed in a study by Seidman *et al.* that handedness of individual determines the pattern of use of mobile phones. In the same study, it was seen that 68% of right-handed persons used their mobile phones in the right ear while only 25% used in the opposite ear while 7% had no

preference.^[11] As such in most scenario, one ear is predominantly exposed to mobile phones as compared to the other ear. The dominant ear (the ear predominantly used while making or receiving a call) was considered the exposed ear and the other ear (nondominant ear) was considered the nonexposed ear. Individuals who had no preference and had both ears exposed during call were excluded. A cutoff duration of usage of mobile phones for more than or equal to 2 h/day was taken for comparison of the threshold of hearing between the exposed ear and the nonexposed ear. Statistical analysis was carried out using SPSS version 16 (Chicago, SPSS Inc.). Among users of mobiles for the duration of more than or equal to 2 h, a paired *t*-test (two-tailed) was used to analyze the significance between the exposed and nonexposed ears for the average AC and BC threshold and the AC and BC threshold at individual frequencies. The confidence limit of the test was fixed at 95%, and $P < 0.05$ was considered statistically significant.

Audiometric assessment

PTA was performed bilaterally for both AC and BC threshold. AC threshold was evaluated at frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz and 12,000 Hz. BC threshold was assessed at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. BC threshold at 250 Hz was not taken into consideration due to the possibility of vibrotactile responses. The audiologist was blinded while doing the audiometry and was unaware of the exposed and the nonexposed ear. The students undergoing the audiometry were unaware of the exposed and nonexposed ears. A calibrated Grason-Stadler 61 pure tone audiometer was used for PTA and Impedance audiometry was carried out using Interacoustic AT325 Impedance Audiometer.

Results and Observations

A total of 100 students were screened randomly. All the participants used Global System for Mobile Communication (GSM) network for mobile communication, and all of them were using smartphones of different manufacturers. The specific absorption rate of the handset ranged from 0.27 to 1.28 W/Kg for the head region for a different model of handset. Eighteen students were excluded on the basis of the exclusion criteria. The study population was finally limited to 82 students (males 29, females 53). Out of the total 82 students, 61 students (74.4%) were right handed and used their right ear predominantly, while 21 students (25.6%) used their left ear predominantly for making or receiving calls. Forty-two students (51%) used mobile phones for more than or equal to 2 h whereas 40 students (49%) used mobile phones for < 2 h. The final analysis of data was done among the 42 students who used mobile phones for more than or equal to 2 h/day. The average PTA threshold for AC and BC between exposed ear was higher than the nonexposed ear and the difference was significant ($P < 0.05$) [Tables 1 and 2]. Analysis of AC and BC threshold at individual frequencies also revealed a statistically significant difference between the exposed and the nonexposed ear with a higher threshold in the exposed ear [Tables 1, 2 and Figures 1, 2]. There was no statistically significant difference in threshold for AC at 250 Hz between the exposed and nonexposed ears.

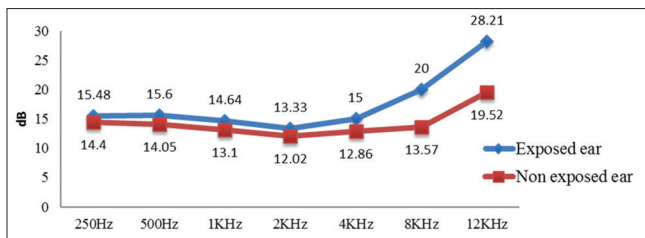


Figure 1: Mean air conduction threshold of exposed and nonexposed ears at different frequencies

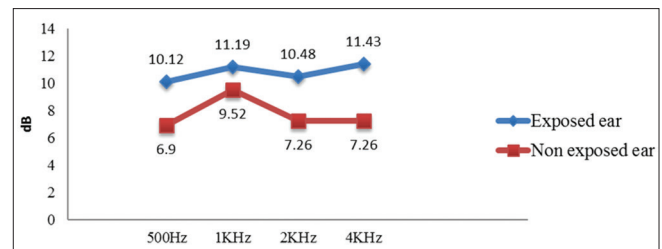


Figure 2: Mean bone conduction threshold of exposed and nonexposed ear at different frequencies

Table 1: Statistical analysis of air conduction threshold

	Exposed ear versus nonexposed ear					t	Significance (two-tailed)
	Paired differences						
	Mean	SD	SEM	95% CI of the difference			
				Lower	Upper		
Average AC threshold	1.467	0.136	0.078	1.129	1.804	18.711	0.003
Threshold at 250 Hz	1.071	4.353	0.672	−0.285	2.428	1.595	0.118
Threshold at 500 Hz	1.548	3.402	0.525	0.488	2.608	2.949	0.005
Threshold at 1 kHz	1.548	3.743	0.578	0.381	2.714	2.680	0.011
Threshold at 2 kHz	1.310	3.672	0.567	0.165	2.454	2.311	0.026
Threshold at 4 kHz	2.143	4.572	0.706	0.718	3.568	3.037	0.004
Threshold at 8 kHz	6.429	6.077	0.938	4.535	8.322	6.855	0.0000003
Threshold at 12 kHz	8.690	8.342	1.287	6.091	11.290	6.752	0.00000004

AC: Air conduction, SD: Standard deviation, SEM: Standard error of mean, CI: Confidence interval

Table 2: Statistical analysis of bone conduction threshold

	Exposed ear versus nonexposed ear					t	Significance (two-tailed)
	Paired differences						
	Mean	SD	SEM	95% CI of the difference			
				Lower	Upper		
Average BC threshold	2.703	0.895	0.517	0.480	4.926	5.232	0.035
Threshold at 500 Hz	3.214	3.280	0.506	2.192	4.236	6.351	0.0000001
Threshold at 1 kHz	1.667	2.629	0.406	0.847	2.486	4.109	0.0002
Threshold at 2 kHz	3.214	3.280	0.506	2.192	4.236	6.351	0.0000001
Threshold at 4 kHz	4.167	3.298	0.509	3.139	5.194	8.189	0.000000001

BC: Bone conduction, SD: Standard deviation, SEM: Standard error of mean, CI: Confidence interval

Discussion

There has been a substantial concern worldwide regarding the effect of long-term exposure to EMR. Various studies have

been undertaken to investigate the damage caused to the inner ear by the EMR from mobile phones. A study by Ramya *et al.* demonstrated a significant increase in hearing threshold with an increase in duration of use of mobile phones.^[12] Oktay and Dasdag found no difference in the threshold of hearing among users who used mobiles for 10–20 min/day but found higher threshold in users who talked over mobile phones for more than 2 h/day.^[13] Khullar *et al.* found a significant increase in auditory brainstem response threshold in people using GSM mobile phones for more than 30 min/day for the past 10 years.^[14]

In the present study, a significant difference of PTA threshold for AC was found between the exposed and the nonexposed ears. The average PTA thresholds of the exposed ears were higher compared to the nonexposed ear ($P < 0.05$). There is also a significant difference of AC thresholds between the exposed and nonexposed ears at frequencies of 2 kHz, 4 kHz, 8 kHz, and 12 kHz ($P < 0.05$) [Table 1]. The BC threshold of the exposed ear and nonexposed ear show statistically significant difference at the average threshold and threshold of all frequencies. These findings are similar to studies conducted by Ramya *et al.*,^[12] Prajapati *et al.*,^[15] Velayutham *et al.*,^[16] and Panda *et al.*^[17] and suggest a possible inner ear damage caused by prolonged usage of mobile phones.^[17] All the students in this study used GSM phones and any comparison with code division multiple access (CDMA) phones could not be done. Panda *et al.*^[18] in their study found the damage to the inner ear to be same for both GSM and CDMA users. The same study found a higher speech frequency threshold and absent distortion product otoacoustic emission among prolonged mobile phone users and concluded that extensive use of mobile phones caused damage to both cochlea and the auditory cortex.^[18] There is an elevated risk of developing tinnitus after use of mobile phones for more than 4 years.^[19] However, in the present study, none of the participants complained of tinnitus. There is a report of mobile phone induced sensorineural hearing loss which reversed to normal on discontinuation of the exposure.^[20] It is possible that prolonged exposure to EMR may cause an increase in the audiological threshold as seen in this study.

The effect of EMRs on human body has been an area of research. Bhatia *et al.* reviewed the neuropsychiatric effects of the mobile phones and reported that regular usage had harmful effects which included a headache, nausea dizziness, sleep disturbance, mood swing, memory loss, lack of concentration and coordination and fatigue.^[21] Mobile handset can cause a sensation of warmth around the ears, but the temperature change

is usually not more 0.11°C.^[22] The effects of radiofrequency have been studied *in vitro* and research has shown that low-level radiofrequency affects the structural and functional properties of cell membrane.^[23] Chronic radiofrequency exposure may induce oncogenesis by inhibiting cell apoptosis and affect DNA directly.^[22,23] There has been a concern regarding increased risk of acoustic neuroma and other brain tumors after prolonged exposure to mobile phones, but conclusive evidence is lacking till now.^[4,24] Various studies have failed to demonstrate any noticeable effect on the auditory function after short exposure to EMR.^[5,25,26]

It is important to consider that in the present scenario exposure to mobile phones are rarely short. A study conducted among adolescents reveal that average duration of use of mobile phones is about 199.8 ± 127.4 min/day.^[27] Ramya *et al.* found a significant increase in the hearing threshold among those using mobile phones for more than 30 min/day for more than 5 years.^[12] The data from the present study also point toward raised threshold of hearing among prolonged users of mobile phones.

Mobile phones have become an integral part of modern day functioning. As the global market of cell phones rise every year, people are exposed to cell phone use from an early age. At present, there is no data on the effects of radiofrequency on children and those with compromised auditory function.^[22] The effect of EMR on auditory function is a controversial issue, and its long-term outcome on hearing status is yet to be revealed.^[22]

Conclusion

The present study shows an increase in the hearing threshold of the ear exposed to the prolonged use of mobile phones. It is not known whether this threshold shift is temporary or permanent. Scientific data are lacking on the molecular and biochemical alterations caused by the EMRs in the organ of Corti. Definite conclusions on the effect of mobile phones on the auditory function can only be derived from studying the ultrastructure of the cochlea and the hair cell after prolonged exposure to the mobile phones. As such this area provides an interesting avenue for further research.

Acknowledgment

We would like to thank the STS Programme of Indian Council of Medical Research under which the research was carried out. We would also like to thank Dr. J. Mahanta for his valuable suggestions on statistical analysis of the study. We acknowledge the help and support of Ms. Kinga Choden Chewang who meticulously performed the audiological tests in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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