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Original Research Article

AUDITORY DISTURBANCES ACCOMPANYING THE USE OF MOBILE PHONES AMONG MEDICAL STUDENTS- A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Mobile telephony has emerged as one of the greatest technological accomplishments of the present century. Their inadvertent use puts millions, especially youngsters at a risk of developing noise-induced hearing loss (NIHL). This study was aimed to assess the auditory disturbances accompanying the use of mobile phones among medical students. **Methods:** The study was conducted in the Department of Otorhinolaryngology and Head & Neck Surgery at Mahatma Gandhi Medical College and Hospital, Jaipur, on a total of 290 medical students. A detailed history of all participants was taken, followed by a meticulous clinical examination. A detailed questionnaire enquiring about the pattern of use of mobile phones was distributed to all the students. Assessment of hearing was done by pure tone audiometry (PTA). **Results:** The study included 144 (49.7%) students who were males and 146 (50.3%) who were females. The mean age of the students was 21.47±1.72 years. The mean hearing thresholds in both ears, at all frequencies, were correlated with daily usage hours and years of use. They were found to be significantly correlating at 4000 Hz ($P<0.05$). This correlation was not found to be significant at other frequencies ($p >0.05$). The mean hearing thresholds in both ears at all frequencies were also correlated between males and females. A significant correlation was found at 4000 Hz ($P=0.001$). This correlation was not found to be significant at other frequencies ($p>0.05$). **Conclusions:** The permanence of noise-induced hearing loss underlines the importance of noise damage prevention caused by the use of mobile phones, by making small changes in daily routine right from early days before irreversible changes start.

Keywords: Hearing thresholds; Mobile phones; Noise-induced hearing loss (NIHL); Pure Tone Audiometry (PTA).

INTRODUCTION

Hearing loss is the most common sensory deficit in humans in the present time leading to disability **(1).** Prolonged exposure to high levels of noise leads to a permanent hearing loss, termed as noise-induced hearing loss (NIHL). Noise-induced hearing loss is the second most common cause of acquired hearing loss **(2).** According to a WHO report, some 1.1 billion teenagers and young adults are at risk of developing noise-induced hearing loss due to the unsafe use of smartphones **(3).** The incidence of NIHL is increasing in youngsters. As per a study by Lees RE et al., 40% of students between the ages of 16 to 25 years were found to have audiological evidence of NIHL **(4)**.

Mobile telephony has emerged as one of the greatest technological accomplishments of the present century. Mobile telephones have been available in the market since 1983 **(5)**. According to Global System for Mobile Communications data, there are exactly 5.13 billion people in the world who own mobile phones, which makes 66.5% of the world's population. The increased accessibility, integration of personal music systems in smartphones, portability with long battery life, large storage capacity, lower prices, and technical improvement

regarding sound quality has made the use of smartphones extremely common worldwide. Their inadvertent use puts millions of youngsters at a risk of developing permanent hearing loss in long term **(6).**

Mobile phones cause harm to the body in two ways. First, they transmit radio signals and secondly, they are a source of the noise. Mobile phones transmit and receive signals using electromagnetic fields in the radiofrequency band. At high power levels, radiofrequency wave exposure can rapidly heat tissue and cause visible damage, such as burns. Mobile phones operate at power levels well below the level at which such overt heating effects occur. Consequently, the mobile phone health issue has generally focused on non-thermal effects from frequent and long-term exposure to low-level radiofrequency wave emission **(7).** Currently, GSM, UMTS, and LTE bands are the technologies that are used in mobile phone network services in India. These services operate at 850 to 2300 MHz frequency bands. Humans can hear sounds that range from about 20 to 20000 Hertz (Hz). Speech frequencies are roughly located between 300-8000 Hz. Low frequencies (300- 3000 Hz) are used to (listening) hear people. High frequencies (3000-8000 Hz) are used to understand speech.

The inner ear is the first and main organ that receives the full impact of mobile phones due to its close proximity, thus making it the most vulnerable organ compared to other parts of the body. The delicate hair cells in the organ of Corti do not have regenerative properties, thus noise-induced damages are often permanent with little chance of recovery in advanced stages. The higher frequencies are the first to be affected **(8).** The physiological changes to the ear are also reflected through the development of other problems such as tinnitus, headache, dizziness, fatigue, etc.

This study was aimed to assess the auditory disturbances accompanying the use of mobile phones among medical students.

MATERIALS AND METHODS

This cross-sectional study was conducted in the Department of Otorhinolaryngology and Head & Neck Surgery at Mahatma Gandhi Medical College and Hospital, Jaipur, India, from April 2019 to February 2020. A total of 300 medical students between the ages of 18 to 24 years, who were using mobile phones on regular basis, for at least an hour a day, for more than a year were selected for the study. Subjects with a history of chronic ear disease or chronic ear discharge, previous ear surgery, history of intake of drugs known for being ototoxic, history of systemic diseases affecting the ear, those with previously diagnosed hearing impairment or using hearing aids, having reported hearing difficulties within the immediate family and those having constant exposure to loud noise such as those living near an airport were excluded from the study. Informed consent was obtained from all the participants and the study was approved by the institution's Ethics board.

A detailed history of all participants was taken which was followed by a meticulous clinical examination. A thorough examination of the ear using an otoscope and under a microscope was done. A detailed questionnaire enquiring about the pattern of use of mobile phones was distributed to all the students.

Assessment of hearing

All the students underwent pure tone audiometry (PTA). The audiometry was carried out in a soundproof room with minimal ambient noise, with an ALPS-advanced digital audiometer (AD2100) using the Modified Hughson-Westlake Procedure. Sennheiser HDA 300 headphones were used for measuring air conduction thresholds. The bone conduction was done with bone conductor Radio Ear B71 (Radioear, USA). Hearing thresholds were measured at octave frequencies (250 Hz –8000 Hz, calibrated in dB HL) for both ears. Appropriate graphs were plotted.

Statistical analysis

All statistical analyses were done using SPSS version 20 (IBM SPSS Statistics Inc., Chicago, Illinois, USA) Windows software program. Descriptive statistics included the computation of percentages, means, and standard deviations. The unpaired t-test (for quantitative data to compare two independent groups), paired t-test (for quantitative data to compare before and after observations), and analysis of variance (ANOVA) [for quantitative data within three groups] were used to compare quantitative data of all clinical indicators. The level of significance was set at $p \leq 0.05$.

RESULTS

A total of 290 students were included in the study after applying the inclusion and exclusion criteria. Of them, 144 (49.7%) were males and 146 (50.3%) were females. The mean age of the study population was 21.47±1.72 years.

On analyzing the usage pattern of mobile phones, it was found that 63 (21.7%) students spent 1-3 hours daily on their mobile phones, 111 (38.3%) students spent 4-6 hours daily and a majority of them i.e. 116 (40.0%), spent more than 6 hours daily on their devices.

Overall, 50 (17.2%) students had been using mobile phones for 1-3 years and 85 (29.4%) students for 4-6 years. The remaining majority i.e. 155 (53.4%) of them, had been using mobile phones for more than 6 years.

On analyzing the audiometric results, the maximum hearing threshold was found to be 25 dB in both right as well as left ears, seen at 4000 Hz. The maximum mean hearing threshold was 19.40 ± 4.29 dB in right ear and 17.98 ± 4.28 dB in left ear, both seen at 4000 Hz (Table 1 and Graph 1).

The mean hearing thresholds in both the ears, at all frequencies were correlated with daily usage hours. The number of hours daily spent on mobile phones was found to be significantly correlating with increasing hearing thresholds at 4000 Hz ($P<0.05$). As the daily usage increased, the hearing thresholds also increased significantly. This correlation between the daily usage hours and the hearing threshold was not found to be significant at other frequencies ($p >0.05$) (Table 2-A,2-B and Graph 2-A,2-B).

Table 1: Hearing Threshold (dB HL) on Pure Tone Audiometry

Frequency (Hz)	Ear	Minimum (dB HL)	Maximum (dB HL)	Mean (dB HL)	Std. Dev.
250 Hz	Right	0	10	7.47	2.538
	Left	0	10	7.45	2.538
500 Hz	Right	0	15	9.41	2.038
	Left	0	15	9.40	1.968
1000 Hz	Right	5	15	10.31	1.634
	Left	5	15	10.19	1.458
2000 Hz	Right	5	15	10.19	1.334
	Left	5	15	10.09	1.279
4000 Hz	Right	10	25	19.40	4.290
	Left	10	25	17.98	4.280
8000 Hz	Right	5	15	8.52	2.539
	Left	5	15	8.45	2.531

Graph 1: Mean Hearing Threshold (dB HL) on Pure Tone Audiometry

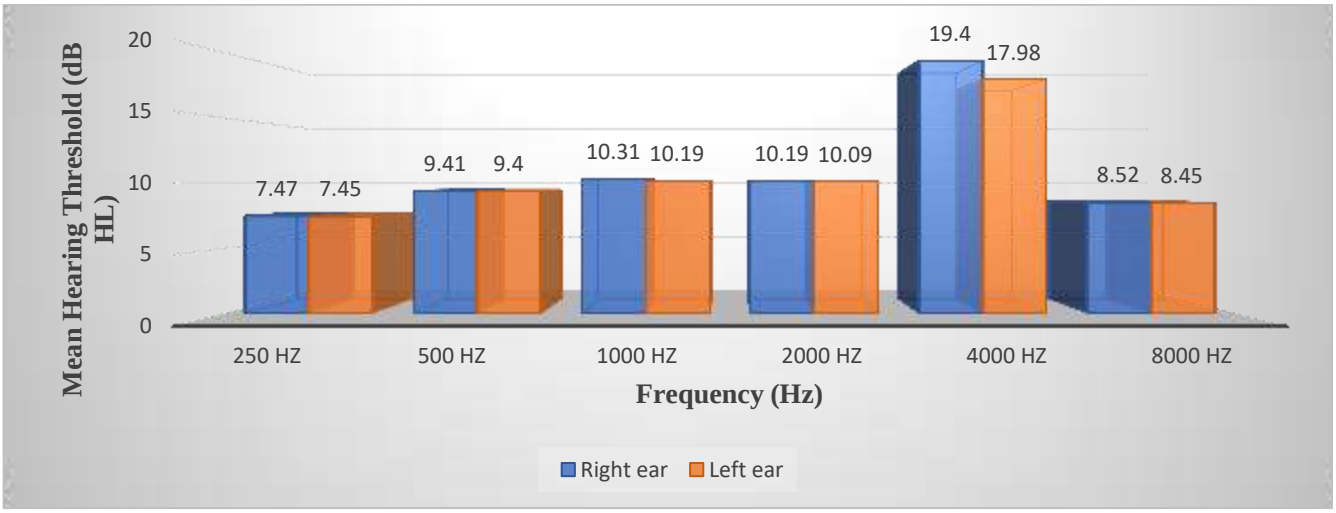


Table 2-A: Correlation of Hearing Threshold (dB HL) With Daily Usage Hours- Right Ear

Frequency (Hz)	1-3 hours		4-6 hours		>6 hours		P-value
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
250 Hz	7.22	2.661	7.84	2.488	7.24	2.497	0.14
500 Hz	8.89	2.280	9.68	1.549	9.44	2.262	0.40
1000 Hz	10.08	1.418	10.23	1.042	10.52	2.124	0.18
2000 Hz	10.08	1.678	10.18	0.936	10.26	1.451	0.69
4000 Hz	16.83	4.427	19.77	4.177	20.43	3.763	0.001
8000 Hz	8.33	2.540	8.87	2.305	8.28	2.727	0.16

Graph 2-A: Correlation of Hearing Threshold (dB HL) With Daily Usage Hours- Right Ear

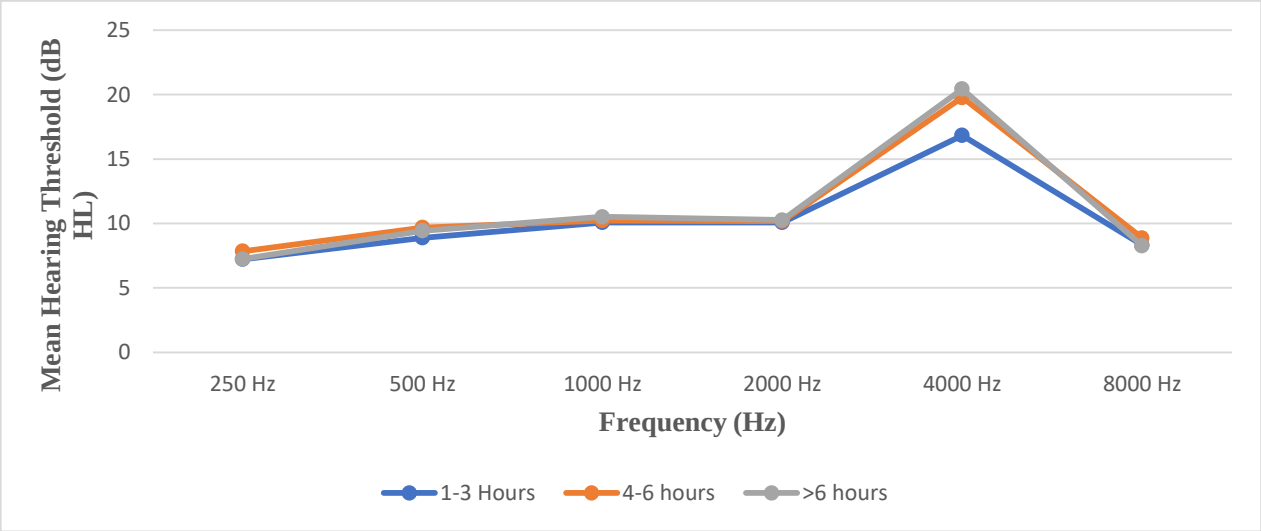
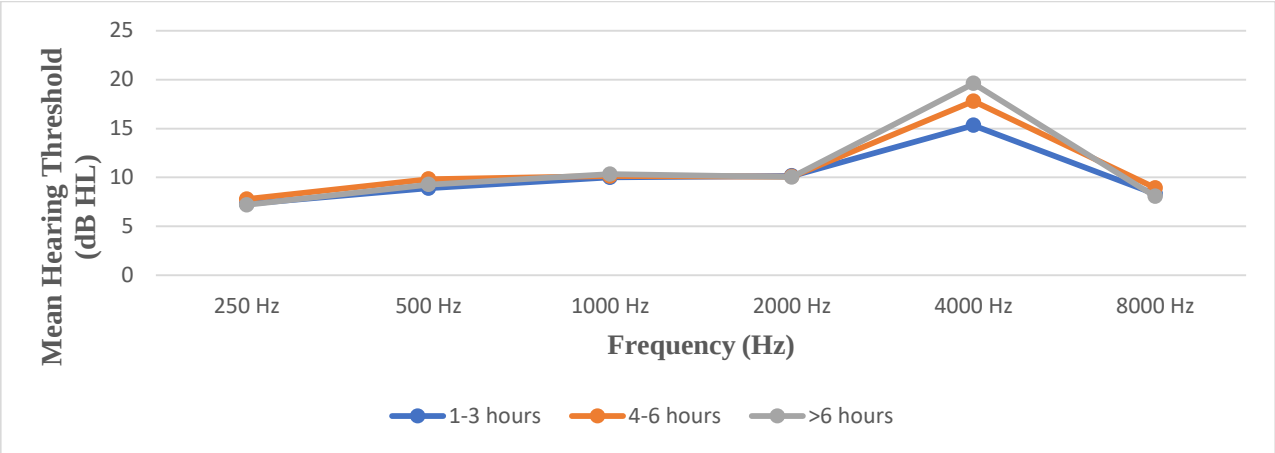


Table 2-B: Correlation of Hearing Threshold (dB HL) With Daily Usage Hours- Left Ear

Frequency (Hz)	1-3 hours		4-6 hours		>6 hours		P-value
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
250 Hz	7.30	2.668	7.79	2.494	7.20	2.492	0.18
500 Hz	8.89	2.280	9.82	1.641	9.27	2.006	0.07
1000 Hz	10.00	1.270	10.14	0.814	10.34	1.948	0.28
2000 Hz	10.16	1.789	10.09	0.668	10.04	1.398	0.84
4000 Hz	15.32	4.295	17.79	3.971	19.61	3.797	0.01
8000 Hz	8.33	2.540	8.92	2.068	8.06	2.857	0.33

Graph 2-B: Correlation of Hearing Threshold (dB HL) With Daily Usage Hours- Left Ear



The mean hearing thresholds in both ears at all frequencies were correlated with years of use of mobile phones. The number of years of use was found to be significantly correlating with increasing hearing thresholds at 4000 Hz (P=0.001). As the years of use increased, the hearing thresholds also increased significantly. This correlation between years of use and hearing threshold was not found to be significant at other frequencies (p >0.05) (Table 3-A,3-B and Graph 3-A,3-B).

The mean hearing thresholds in both ears at all frequencies were correlated between males and females. A significant correlation was found at 4000 Hz (P=0.001). This correlation was not found to be significant at other frequencies (Table 4-A,4-B and Graph 4-A,4-B).

Table 3-A: Correlation of Hearing Threshold (dB HL) With Years of Use-Right Ear

Frequency (Hz)	1-3 Years		4-6 Years		>6 Years		P-value
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
250 Hz	7.50	2.720	7.00	2.464	7.71	2.499	0.16
500 Hz	8.90	2.323	9.76	2.169	9.39	1.832	0.05
1000 Hz	10.00	1.429	10.82	1.866	10.13	1.502	0.07
2000 Hz	9.80	1.414	10.29	1.183	10.26	1.372	0.07
4000 Hz	14.10	3.144	19.12	3.871	21.26	3.253	0.001
8000 Hz	8.20	2.424	8.12	2.670	8.84	2.472	0.06

Graph 3-A: Correlation of Hearing Threshold (dB HL) With Years of Use-Right Ear

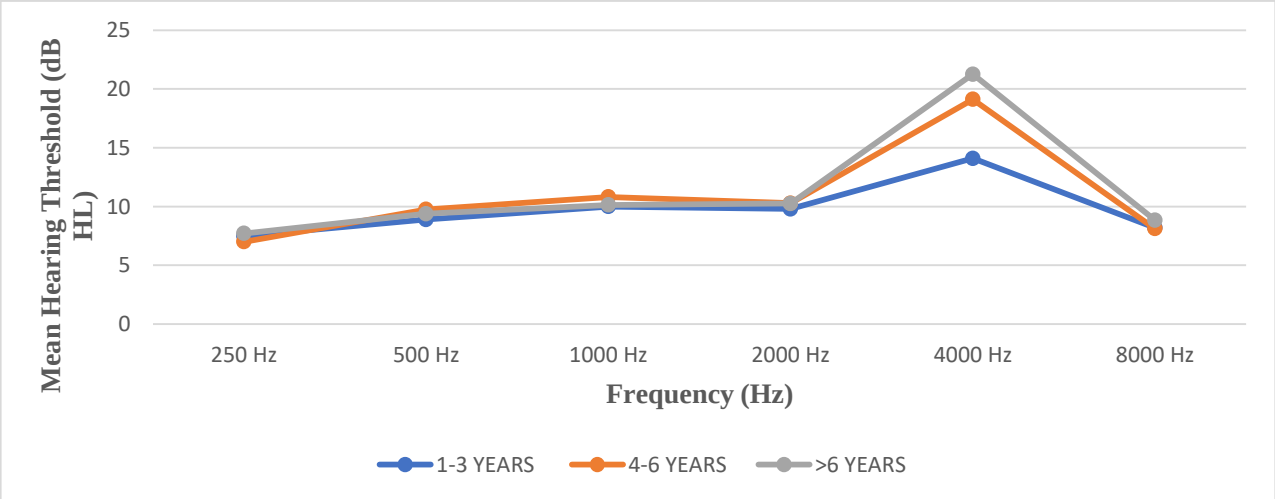


Table 3-B: Correlation of Hearing Threshold (dB HL) With Years of Use-Left Ear

Frequency (Hz)	1-3 Years Mean	Std. Dev.	4-6 Years Mean	Std. Dev.	>6 Years Mean	Std. Dev.	P-value
250 Hz	7.50	2.720	7.06	2.475	7.65	2.504	0.22
500 Hz	8.90	2.323	9.59	1.923	9.45	1.852	0.12
1000 Hz	9.90	1.233	10.65	1.688	10.03	1.336	0.2
2000 Hz	9.90	1.594	10.00	0.003	10.19	1.495	0.28
4000 Hz	12.80	3.220	17.71	3.582	19.81	3.461	0.001
8000 Hz	8.20	2.424	7.94	2.475	8.81	2.554	0.56

Graph 3-B: Correlation of Hearing Threshold (dB HL) With Years of Use-Left Ear

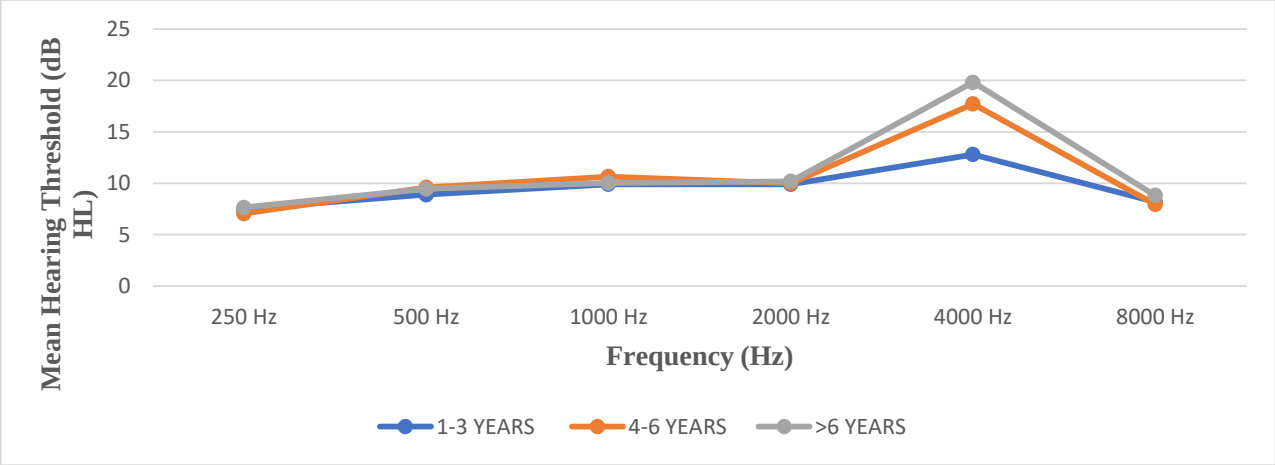


Table 4-A: Comparison of Hearing Threshold between Males and Females (dB HL) - Right Ear

Frequency (Hz)	Male Mean	Std. Dev.	Female Mean	Std. Dev.	P-value
250 Hz	7.22	2.493	7.71	2.568	0.1
500 Hz	9.27	2.210	9.55	1.850	0.23
1000 Hz	10.49	1.900	10.14	1.306	0.06
2000 Hz	10.35	1.525	10.03	1.098	0.06
4000 Hz	20.52	4.127	18.29	4.170	0.001
8000 Hz	8.58	2.752	8.46	2.317	0.69

Graph 4-A: Comparison of Hearing Threshold between Males and Females (dB HL) - Right Ear

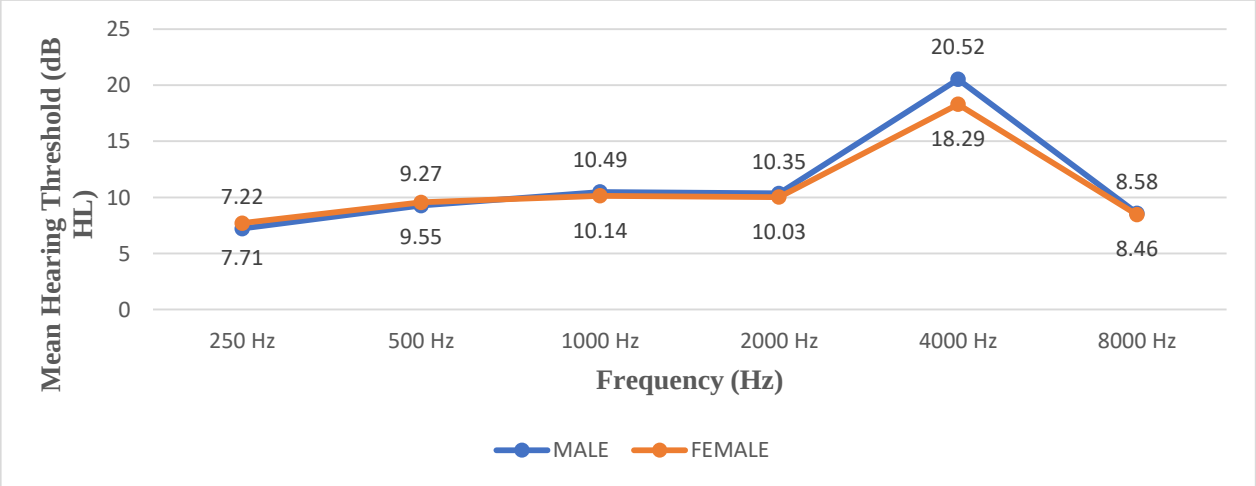
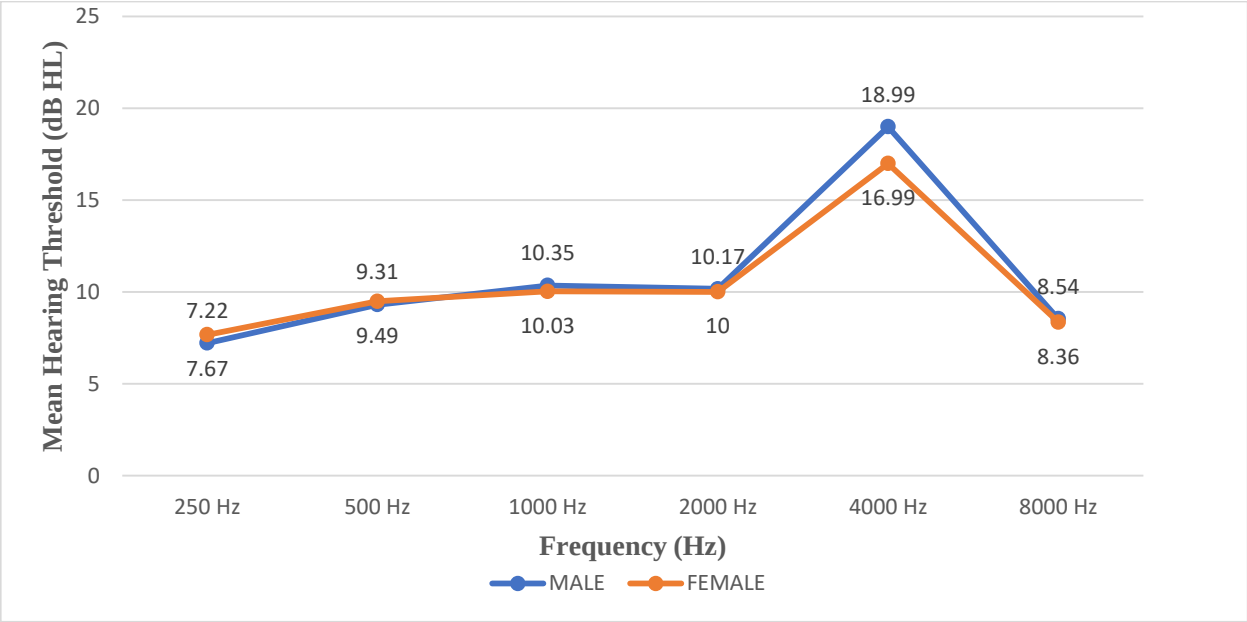


Table 4-B: Comparison of Hearing Threshold Between Males And Females (dB HL) - Left Ear

Frequency (Hz)	Male Mean	Std. Dev.	Female Mean	Std. Dev.	P-value
250 Hz	7.22	2.493	7.67	2.571	0.13
500 Hz	9.31	2.182	9.49	1.735	0.43
1000 Hz	10.35	1.739	10.03	1.098	0.06
2000 Hz	10.17	1.497	10.00	1.017	0.24
4000 Hz	18.99	4.288	16.99	4.046	0.001
8000 Hz	8.54	2.702	8.36	2.357	0.53

Graph 4-B: Comparison of Hearing Threshold Between Males And Females (dB HL) - Left Ear



DISCUSSION

Rapid technological advancements during the past few decades have significantly increased the intensity of exposure to environmental electromagnetic fields (EMFs). The widespread use of mobile communications raises several questions about the effects of these EMFs in the human body, specifically on the auditory system. There is a growing concern that the increased noise exposure through these technological developments might negatively impact hearing, particularly among young people, who are highly exposed to these devices **(9).**

Early-stage hearing damage could eventually lead to permanent noise-induced hearing loss (NIHL). Therefore, it is crucial to carefully characterize the early effects of these devices on hearing, using appropriate tools which could detect hearing damage at the initial subclinical stage.

Our study focused on medical students who represent an academically inclined section of society. The surge of online study programs, online streaming services, and social media have made the youth vulnerable to the inexpedient use of mobile phones. This puts them at a risk of developing auditory problems in the long term. Several similar studies have been carried out on youngsters. The mean age in our study was 21.47 (±1.72) years. In the study to assess the effect of chronic use of the mobile phone on hearing of young adults by Prajapati et al (2015), the mean age was 26.17 (± 2.65) years **(10).** In another similar study by Magda Youssef et al (2016), conducted on medical students, the mean age was 20.5 years **(11).**

On analyzing the audiometric data collected in our study, we found higher hearing thresholds at 4000 Hz, in both ears. A drop in hearing sensitivity

between 3000 and 6000 Hz is a typical characteristic of noise-induced hearing loss **(12,13).** Although our results showed a 7 to 9 dB threshold increase at 4000 Hz, this does not constitute a clinically relevant manifestation of NIHL but rather a potential early indication of the disease. Clinically relevant NIHL typically manifests itself after many years of exposure to noise; even at high exposure levels, a 10 dB threshold shift is expected only after approximately 10 years down the line **(12,13,14).** The findings in our study are very concerning in light of the participants' young age. Several previous studies have reported similar findings. Timon Hussain et al in their study about Early Indication of Noise-Induced Hearing Loss in Young Adult Users of Personal Listening Devices, found significantly increased hearing threshold at 4000 and 6000 Hz with pure tone audiometry **(15).** Kumar et al found significant differences at 3000 Hz, 4000Hz, and 6000 Hz suggesting noise-induced hearing loss **(16).**

In our study, we found that majority of students spent more than six hours on their devices daily. The amount of total time spent daily on mobile phones is important since we found that the mean hearing thresholds specifically at 4000 Hz, increased as the daily usage increased amongst the students. Several other studies have yielded similar findings. Prajapati et al showed an increase in mean hearing loss (especially at higher frequencies) with an increase in the duration of daily mobile phone usage **(10).** Meyer-Bisch C also found mean hearing thresholds significantly higher at several frequencies (2–12 kHz) in PLD users (12–30 years old) listening for more than 7 hours/week compared with those listening for 2–7 hours/week and controls **(17).**

The present generation youngsters have grown up using mobile phones, as reflected in our study, where we found that the majority of students, had been using mobile phones for more than six years. Not surprisingly, but we also found higher hearing thresholds at 4000 Hz amongst the long-term users. This is in agreement with other studies. Prajapati et al showed an increase in mean hearing loss (especially at higher frequencies) with an increase in total years of mobile phone usage **(10).** A similar study by Panda et al states that high-frequency hearing loss was observed with an increase in the duration of mobile phone use **(18,19).** Thus, cumulative long-term use of these devices has a debilitative effect on hearing **(19,20).**

In our study, we also compared the hearing thresholds of males and females. A significant correlation was found at 4000 Hz, in both ears. Male students were having higher hearing thresholds than female students. This finding is in agreement with several other studies. Myung et al too showed significantly higher hearing thresholds at 4000 Hz among the male students in both the left and right ears than female students **(21).** This may be probably due to the higher listening volume preferred by males as compared to females.

There were certain limitations in our study. A larger population-based study could better help us to know the full impact of the problem. Since mobile phones form part of new technological trends seen over the past few decades, there is a lack of evidence available on the long-term auditory changes resulting from their use. Therefore further long-duration studies are needed to be carried out, to strengthen our knowledge on the effects of long-term and intensive mobile phone use on hearing. This is crucial since they have become an essential part of our lives.

CONCLUSION

Auditory system damage is a cumulative process. The damaging effects are gradual, continue long after noise exposure has ceased and they are irreversible. However, noise-induced hearing loss is the only type of hearing loss, which is absolutely preventable. Thus, the permanence of noise-induced hearing loss underlines the importance of noise damage prevention caused by the use of mobile phones, by making small changes in daily routine right from early days before irreversible changes start. Social awareness should be increased through health promotion activities, such as public presentations or group discussions, and via electronic and printed media sources. We would like to suggest some recommendations such as, set the lowest volume, having shorter usage periods, and using mobile phones with low EMF emissions.

Declarations

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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