Original Research

PRECLINICAL COCHLEAR DYSFUNCTION DETECTION THROUGH INTRA-INDIVIDUAL EAR COMPARISON IN HABITUAL MOBILE PHONE USERS: A PURE TONE AUDIOMETRY STUDY AMONG MEDICAL STUDENTS

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ABSTRACT

Introduction: Prolonged mobile phone use has generated apprehensions about subtle auditory effects resulting from chronic unilateral exposure to radiofrequency electromagnetic fields (RF-EMF) and acoustic stimulation. Identifying early cochlear dysfunction prior to the manifestation of clinically significant hearing loss continues to be a public health imperative. This study sought to identify preclinical cochlear alterations by comparing hearing thresholds between the predominantly exposed ear and the contralateral ear in habitual mobile phone users.

Methods: A cross-sectional observational study was performed. A pretested, structured questionnaire was given to all participants to collect data. Self-reported auditory complaints, such as tinnitus, ear discomfort, or perceived hearing difficulties, were collected within the questionnaire. Tympanometry and pure tone audiometry was conducted as a part of audiology testing. Paired t-test was used to compare the pure tone hearing thresholds of the exposed and unexposed ear. A p-value of less than 0.05 was considered to be statistically significant.

Results: At higher and speech-related frequencies, the predominantly exposed ear exhibited significantly increased thresholds ($p<0.05$), indicating early cochlear stress, although the values remained within clinically normal limits. Correlation analysis revealed a weak yet statistically significant positive correlation between the duration of daily mobile phone usage and hearing thresholds in the predominantly exposed ear (Pearson's $r = 0.28$, $p = 0.006$).

Conclusion: The present study shows that the ear that is mostly exposed to mobile phones in medical students who use them frequently has much higher hearing thresholds than the ear that is not exposed to mobile phones.

Keywords: Cell Phone, Hearing Loss, Audiometry.

INTRODUCTION

Teenagers and young adults, especially students, use cell phones as they are necessary for doing schoolwork, talking to other people, and having fun. The International Telecommunication Union (ITU) reported that there are above 8.5 billion cell phone subscriptions round the world right now. The user base in India is one of the largest and is expanding at the fastest rate[1]. [1] A subgroup of people who are characterized by prolonged and frequent exposure to mobile phones areis medical students. These students frequently engage in extended voice calls, which require them to repeatedly position the handset in a unilateral position next to their ear.

Both sound waves and radiofrequency electromagnetic fields (RF-EMF) are transmitted to the ears of individuals who are involved in the act of speaking on the phone.The World Health Organization (WHO) has classified radiofrequency electromagnetic fields (RF-EMF) as "possibly carcinogenic to humans" (Group 2B)[2].[2] This classification underscores the growing concern regarding the potential non-thermal biological effects of RF-EMF, such as hearing damage. In addition to systemic factors, there has been a growing view on the auditory system, where extended or repetitive exposure has been related to symptoms like tinnitus and auditory fatigue, along with subtle changes in hearing thresholds[3].[3]

www.ajmrhs.com
eISSN: 2583-7761

Date of Received: 26-12-2025
Date Acceptance: 05-01-2026
Date of Publication: 07-02-2026

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These changes might predict initial cochlear stress rather than clinically evident hearing loss.

Evidence indicates that unilateral exposure during mobile phone usage may lead to asymmetrical auditory effects, with the predominantly exposed ear possibly demonstrating early functional alterations[4,5].[4,5] While few studies have found significant changes in the hearing threshold of the dominant ear, others have failed to establish any obvious difference[6,7].[6,7] Additionally, most of the available data is from Western populations, with scant evidence from developing countries such as India, where mobile phone usage patterns and environmental exposures may vary.

The current literature about the auditory impacts of mobile phone usage has primarily concentrated on overt hearing loss or comparative analyses between users and non-users, frequently producing inconsistent findings and neglecting subtle, early cochlear alterations. Significantly, there is a scarcity of research investigating preclinical cochlear impairment by intra-individual ear comparison, especially in young, asymptomatic cohorts like medical students, when confounding variables such as occupational noise exposure are negligible. This gap restricts the early identification of cochlear changes that may not be apparent in standard inter-group analyses. The main goal of this study was to utilize intra-individual comparison through pure tone audiometry to detect early, subclinical cochlear alterations potentially linked to regular mobile phone usage, thus offering a more sensitive and clinically pertinent method for early auditory risk evaluation.

From a public health standpoint, the prompt recognition of auditory alterations in young adults is crucial, as subclinical cochlear dysfunction may precede irreversible hearing loss. In alignment with Indian Council of Medical Research (ICMR) priorities that stress early detection and preventive measures, this study seeks to evaluate preclinical cochlear dysfunction by comparing pure tone hearing thresholds between the predominantly exposed ear and the contralateral ear among frequent mobile phone users in a cohort of medical students at a tertiary care hospital in North India. The results may facilitate early auditory monitoring and evidence-based guidelines for safer mobile phone usage among young, high-exposure demographics.

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional observational study was conducted over six months in the Department of Otorhinolaryngology at a tertiary care teaching hospital in North India. Before the study started, the Institutional Ethics Committee reviewed and approved the study protocol. The study was conducted in accordance with declaration of Helsinki.. Before enrolling, written informed consent was obtained from all participants.

Study Population

The study population had undergraduate medical students enrolled in the Bachelor of Medicine and Bachelor of Surgery (MBBS) program at the institution. Participants aged 18 to 25 years were selected through a stratified random sampling method to guarantee proportional representation from each academic year. The study included 100 students who met the eligibility

Inclusion Criteria

Age range of 18 to 25 years old was a requirement for inclusion. The other inclusion criteria were as follows: the use of a mobile phone for more than an hour on a daily basis for atleast a year; otolaryngological findings that were typical, as well as the firmness of the tympanic membrane.

Exclusion Criteria

The exclusion criteria encompassed a history of hearing impairment, chronic ear conditions, previous aural surgeries, utilization of ototoxic pharmaceuticals, exposure to occupational or recreational noise, hearing disorders of neurological or systemic nature, and daily use of headphones or earbuds exceeding one hour.

Data Acquisition

A pretested, structured questionnaire was given to all participants to collect data. Basic demographic details, frequency, time duration of using mobile phone, frequently used ear for phone calls, any other hearing difficulty present was recorded in the questionnaire. The most commonly used ear for phone calls was considered the frequently used ear and the other one was considered the contralateral ear.

Audiology Tests

Pure Tone Audiometry

With the use of an audiometer, an educated audiologist conducted pure tone audiometry test for the participants. Starting from 250 Hz to 8000 Hz was applied to find out the threshold for conduction of air in each ear. To evaluate early cochlear alterations, intra-individual comparisons were conducted between the predominantly exposed ear and the contralateral ear.

Tympanometry

All participants underwent audiometry (tympanometry) to assess middle ear and rule out conductive pathology. The final results included only study participants with normal (Type A) tympanograms.

Outcome Measures

The primary outcome was the difference in pure tone hearing thresholds between the predominantly exposed ear and the contralateral ear, indicative of preclinical cochlear dysfunction. For analytical purposes, mean hearing thresholds at speech

frequencies (500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) were calculated and compared intra-individually.

Statistical Analysis

The data was recorded in Microsoft excel and SPSS version 25 was used for analysis. Descriptive statistics was used to sum up the basic demographic information, patterns of mobile phone use, and audiometric parameters. The mean ± standard deviation was used to show continuous variables.

Paired t-test was used to compare the pure tone hearing thresholds of the ear that was mostly exposed to sound with the ear that was not. This was done for each participant, so they were their own control. The study looked at both the average hearing thresholds at speech frequencies (500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) and the individual test frequencies. A p-value of less than 0.05 was considered to be statistically significant.

RESULTS

Demographic Characteristics and Mobile Phone Usage

The final analysis included 100 undergraduate medical students. There were 58 males (58%) and 42 females (42%) among these. The participants' average age was 21.4 years. All participants indicated regular mobile phone usage for voice communication, averaging 2.8 ± 1.2 hours daily, with a minimum of one hour per day. The average length of time people owned a cell phone was 5.6 ± 1.4 years (Table 1).

Table 1: Baseline Demographic and Mobile Phone Usage Characteristics

Variable	Category / Unit	n (%) / Mean ± SD
Total participants	---	100 (100%)
Gender	Male	58 (58%)
	Female	42 (42%)
Mean age	Years	21.4
Daily mobile phone usage	Hours per day	2.8 ± 1.2
Minimum reported usage	Hours per day	≥ 1 hour
Duration of cell phone ownership	Years	5.6 ± 1.4

Among the 100 participants: 81% indicated right ear usage during phone calls; 19% indicated a predominant usage of their left ear. Sixty-four percent of individuals use their smartphones for both voice communication and additional media consumption. Sixteen percent reported experiencing auditory issues, such as ear discomfort or tinnitus, during prolonged phone conversations.

Audiometric Findings

Pure Tone Audiometry

Intra-individual comparisons of air conduction thresholds demonstrated consistently elevated hearing thresholds in the predominantly exposed ear relative to the contralateral ear across the majority of tested frequencies. At frequencies of 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz, there were statistically significant differences ($p < 0.05$). There was no significant variation at 250 Hz. At 250 Hz, the average hearing threshold was 10.1 ± 3.2 dB HL in the ear that was mostly exposed and 9.8 ± 3.1 dB HL in the other ear ($p = 0.12$). At higher and speech-related frequencies, the predominantly exposed ear exhibited significantly increased thresholds, indicating early cochlear stress, even though the findings remained within clinically normal limits (Table 2).

Table 2: Intra-Individual Comparison of Pure Tone Hearing Thresholds between Ears

Frequency (Hz)	Predominantly Exposed Ear (dB HL)	Contralateral Ear (dB HL)	p-value
250	10.1 ± 3.2	9.8 ± 3.1	0.12
500	11.5 ± 3.4	10.8 ± 3.3	0.03
1000	12.2 ± 3.7	11.4 ± 3.6	0.02
2000	13.6 ± 4.1	12.5 ± 3.9	0.01
4000	15.1 ± 4.5	13.8 ± 4.2	0.01
8000	16.4 ± 5.0	15.1 ± 4.7	0.04

Tympanometric Findings

All participants exhibited Type A tympanograms bilaterally, signifying normal middle ear pressure and compliance. These findings ruled out conductive or middle ear pathology as a potential confounding variable in the observed threshold differences.

Correlation between Mobile Phone Use Duration and Hearing Thresholds

Correlation analysis revealed a weak but still a significant positive correlation between the duration of everyday mobile phone usage and hearing thresholds in the predominantly exposed ear (Pearson's r = 0.28, p = 0.006). This finding signifies that unilateral mobile phone exposure for a longer duration may correlate with an early increase in hearing thresholds, aligning with preclinical cochlear dysfunction (Table 3)

Table 3: Correlation between Daily Mobile Phone Use Duration and Hearing Thresholds

Variable	Pearson's Correlation Coefficient (r)	p-value	Interpretation
Daily mobile phone use (hours) vs. hearing threshold (dB HL) in predominantly exposed ear	0.28	0.006	Weak positive correlation

DISCUSSION

The present study aimed at preclinical cochlear dysfunction in people who frequently use mobile phones by comparing the hearing thresholds between the ear that was mostly exposed and the ear on the other side. As young adults, especially students, who become more reliant on mobile phones, it is important for public health to understand the possible early effects on hearing. The results depict that there are statistically significant differences in pure tone hearing thresholds over various frequencies within the same person. The ear that was mostly exposed had consistently higher thresholds, which shows that using a mobile phone on one side of the head may have affected the cochlea early on.

When comparing ears within the same person, it was found that threshold elevations were strongest at speech frequencies (500 Hz, 1000 Hz, and 2000 Hz) and higher frequencies (4000 Hz and 8000 Hz). Even though these threshold differences were still within clinically normal limits, their consistent presence across frequencies suggests subtle cochlear stress rather than established hearing loss. These findings corroborate the hypothesis that alterations in auditory perception occurring prior to the manifestation of symptoms or clinical indicators of impairment may precede them, particularly in individuals subjected to prolonged unilateral exposure.

The findings of the present study are in line with what other studies have found about mobile phone users having uneven changes in their hearing. Oktay and Dasdag found that heavy mobile phone users had much higher hearing thresholds in the ear they used the most for calls. This suggests that long-term exposure to radiofrequency electromagnetic fields (RF-EMF) and sound stimulation can have cumulative effects [8]. Panda et al. also found that people who used mobile phones for a long time had higher thresholds and hearing problems, such as tinnitus [3]. It has been suggested that repeated exposure to RF-EMF may result in oxidative stress, alterations in microvasculature, or impairment of cochlear hair cell function [9].

There was a weak but still a significant positive correlation between the length of time spent using a mobile phone every day and hearing thresholds in the ear that was mostly exposed. This suggests a possible dose–response relationship. This link, while weak, suggests that prolonged exposure on one side may gradually lead to cochlear stress or auditory fatigue. This is important for young adults because early changes can build up over time and make them highly likely to lose their hearing in the future.

The literature reports various results, which is intriguing. Sözen et al. did not show any significant differences in hearing between ears or between teens who used mobile phones and those who didn't[7]. Differences in age groups, length of exposure, study design, and analysis methods might be the reason for these differences. On the other side, the current study included adult medical students who had more consistent and longer exposure, which may have made them more sensitive to picking up on small preclinical changes. Das et al. showed that Indian college students who used their phones for more than two hours a day had higher hearing thresholds in the ear they used most for phone calls[5]. These results align with the present study's findings and highlight the importance of examining auditory effects in populations with significant mobile phone dependency.

The exact biological mechanisms responsible for alterations in cochlear function among frequent mobile phone users have not yet been fully elucidated. Nevertheless, several plausible explanations have been proposed in the literature, primarily focusing on the effects of radiofrequency electromagnetic fields (RF-EMF). These effects are generally categorized into thermal and non-thermal mechanisms. From a thermal perspective, RF-EMF exposure may alter cochlear blood flow and cause localized heating of neural tissues, potentially reducing cochlear sensitivity to acoustic stimulation. In contrast, non-thermal mechanisms such as oxidative stress, increased free radical formation, and microvascular dysfunction have been suggested to disrupt outer hair cell activity

and cochlear homeostasis [10,11]. Importantly, even prolonged exposure to relatively low levels of stress may cumulatively influence cochlear physiology over time.

Apart from RF-EMF exposure, acoustic output from mobile phone speakers represents an additional stressor to the auditory system. This concern becomes more pronounced during prolonged phone use or when devices are operated in noisy environments that necessitate higher volume levels. Although existing regulations aim to restrict output within safe auditory limits, extended exposure may still result in temporary threshold shifts or early manifestations of cochlear fatigue [12].

In the present study, higher hearing threshold values were consistently observed in the ear more frequently exposed to mobile phone use. This finding suggests that habitual unilateral phone usage may lead to localized accumulation of RF-EMF and acoustic energy, thereby predisposing the dominant ear to early cochlear stress. Alternating phone use between ears may help minimize this asymmetrical exposure and reduce the risk of unilateral cochlear damage. Failure to adopt such practices could potentially contribute to long-term auditory impairment. Therefore, prudent mobile phone usage is recommended, including limiting continuous usage duration, utilizing speaker or hands-free options, and undergoing periodic audiological assessments, particularly among individuals with high daily exposure.

A notable strength of the present study lies in the audiometric assessments being conducted in a sound-treated environment, along with intra-individual ear comparisons to minimize confounding variables. Additionally, the homogeneity of the study population further enhances the internal validity of the findings.

Due to the fact that the study was conducted using a cross-sectional methodology, it is not possible to make any inferences of a causal nature. Due to the fact that the participants themselves gave the information regarding their mobile phone usage patterns and ear preference, there is a possibility that recall bias occurred. There was no low-exposure or non-user control group, so it is difficult to compare the results.Also, extended high-frequency audiometry (>8000 Hz), which might be better at finding early cochlear damage, was not done.

Subsequent investigations ought to incorporate longitudinal cohort designs to ascertain if these preclinical auditory alterations advance to clinically pertinent hearing loss. Utilizing advanced audiological assessments, including otoacoustic emissions and extended high-frequency audiometry, may enhance the early identification of cochlear dysfunction. Comparative studies assessing various communication modalities, such as wired earphones, bluetooth devices, and speakerphone utilization, could enhance evidence-based public health recommendations.

CONCLUSION

The current study shows that the ear which is mostly exposed to mobile phones in medical students has much higher hearing thresholds than the ear that is not exposed to mobile phones. Even though these differences were still within clinically normal limits, they show that there is preclinical cochlear dysfunction, probably because of long-term exposure to RF-EMF and sound from mobile devices. This shows how weak the auditory system is, even in young, otherwise healthy people. These findings underscore the necessity of advocating safe listening practices, such as alternating ears during phone calls, restricting call duration, utilizing hands-free or speakerphone options, and eschewing high-volume usage. To validate these initial findings and elucidate the enduring auditory effects of prolonged mobile phone exposure, subsequent research must utilize longitudinal study designs with expanded sample sizes and integrate more sensitive audiological evaluations, including otoacoustic emissions and extended high-frequency audiometry.

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How to cite this article: Anchal Gupta, Neharika Pathak, PRECLINICAL COCHLEAR DYSFUNCTION DETECTION THROUGH INTRA-INDIVIDUAL EAR COMPARISON IN HABITUAL MOBILE PHONE USERS: A PURE TONE AUDIOMETRY STUDY AMONG MEDICAL STUDENTS, Asian J. Med. Res. Health Sci., 2026; 4 (1):26-31.
Source of Support: Nil, Conflicts of Interest: None declared.