RESEARCH PAPER

Assessment of Sensorineural Hearing Loss in Individuals With Prolonged Exposure to Earphone Music – A Comparative Analysis Using Pure Tone Audiometry and Otoacoustic Emissions

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ABSTRACT

Introduction: The increasing use of personal listening devices has raised concerns regarding recreational noise-induced hearing loss, particularly among young adults. Prolonged exposure to high-intensity earphone music may result in early cochlear damage that often remains undetected by conventional hearing assessment. This study evaluated sensorineural hearing loss in individuals with prolonged earphone use using pure tone audiometry (PTA) and otoacoustic emission (OAE) testing.

Materials and Methods: A comparative cross-sectional study was conducted in the Department of Otorhinolaryngology, Adichunchanagiri Institute of Medical Sciences, Karnataka, India, from July 2024 to January 2026. A total of 120 participants aged 20–40 years were enrolled and divided into two groups: 60 prolonged earphone users (>3–4 hours/day for at least one year) and 60 non-/minimal earphone users (<3 hours/day). All participants underwent otoscopic examination, PTA, and OAE testing. Data were analyzed using SPSS version 31.0, with $p<0.05$ considered statistically significant.

Results: The study groups were comparable in terms of age and gender ($p>0.05$). The exposed group demonstrated significantly higher hearing thresholds at all tested frequencies, with the greatest elevations observed at 4000 Hz (34.6 ± 8.9 vs. 20.3 ± 5.8 dB) and 6000 Hz (38.2 ± 9.4 vs. 22.1 ± 6.2 dB) ($p<0.001$). The mean PTA threshold was significantly higher among prolonged earphone users (29.4 ± 8.1 vs. 18.7 ± 5.6 dB; $p<0.001$). Minimal and moderate hearing loss were more prevalent in the exposed group ($p<0.001$). Abnormal OAE ("Refer") results were also significantly more frequent among prolonged earphone users than controls (28.3% vs. 8.3%; $p=0.004$), indicating greater cochlear outer hair cell dysfunction.

Conclusion: Prolonged earphone use is associated with early cochlear dysfunction and significant deterioration in hearing sensitivity, particularly at higher frequencies. The combined use of PTA and OAE facilitates early detection of noise-induced auditory damage and may be valuable for routine screening and preventive hearing health programs among frequent earphone users.

Keywords: Earphone use; Sensorineural hearing loss; Pure tone audiometry; Otoacoustic emissions; Noise-induced hearing loss.

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INTRODUCTION

Hearing is an essential sensory function that plays a fundamental role in communication, learning, social interaction, and overall quality of life [1]. The auditory system comprises the external ear, middle ear, inner ear, auditory nerve, and central auditory pathways, all of which work in coordination to convert sound waves into neural impulses perceived by the brain [2]. Damage at any level of this pathway may result in hearing impairment, with sensorineural hearing loss (SNHL) being the most common form of permanent hearing loss [3]. SNHL primarily results from damage to the cochlear hair cells or

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auditory nerve, and excessive noise exposure remains one of the leading preventable causes worldwide [4,5].

The widespread use of smartphones and personal listening devices has markedly increased recreational noise exposure, particularly among adolescents and young adults [6]. Earphones and headphones enable prolonged listening at high sound intensities, often exceeding internationally recommended safe exposure limits [7]. Unlike environmental noise, earphones deliver sound directly into the external auditory canal, generating higher sound pressure levels at the tympanic membrane and increasing the risk of cochlear injury [8]. Chronic exposure to high-intensity sound induces metabolic stress, oxidative damage, and apoptosis of cochlear outer hair cells, predominantly affecting the basal turn of the cochlea and resulting in early high-frequency hearing loss characteristic of noise-induced hearing loss [8,9].

Pure tone audiometry (PTA) is the gold standard for assessing hearing thresholds and diagnosing hearing loss; however, it is a subjective test that depends on patient cooperation and may fail to detect early cochlear dysfunction before measurable threshold shifts occur [10]. In contrast, otoacoustic emissions (OAEs), particularly distortion product otoacoustic emissions, provide an objective assessment of outer hair cell integrity and are capable of identifying subclinical cochlear damage even in individuals with normal audiometric thresholds [11,12]. The complementary use of PTA and OAE testing offers a more comprehensive evaluation of auditory function and facilitates early detection of noise-induced cochlear injury before irreversible hearing impairment develops [13,14].

Noise-induced hearing loss has emerged as an important public health concern owing to the increasing use of personal listening devices and the potential for preventable permanent hearing impairment among young adults [12]. Although several studies have independently evaluated audiometric thresholds or otoacoustic emissions in recreational noise exposure, comparative evidence integrating both modalities remains limited. Such an approach may improve the identification of early cochlear changes and support timely preventive interventions. Therefore, the present study aimed to assess sensorineural hearing loss in individuals with prolonged exposure to earphone music using pure tone audiometry and otoacoustic emission testing and to compare the auditory findings with those of non- or minimal-earphone users.

MATERIALS AND METHODS

This comparative cross-sectional study was conducted in the Department of Otorhinolaryngology, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, Mandya District, Karnataka, India, over a period of 18 months from July 2024 to January 2026. The study aimed to assess sensorineural hearing loss among individuals with prolonged exposure to earphone music using pure tone audiometry (PTA) and otoacoustic emission (OAE) testing. Ethical approval was obtained from the Institutional Ethics Committee prior to commencement of the study, and written informed consent was obtained from all participants before enrolment.

A total of 120 participants aged 20–40 years were recruited from the outpatient Department of Otorhinolaryngology using simple random sampling. Based on the duration of daily earphone use, participants were categorized into two equal groups: an exposed group comprising 60 individuals with prolonged earphone use (>3–4 hours/day for at least one year) and a non-exposed group comprising 60 individuals with minimal earphone use (<3 hours/day). Individuals with a normal otoscopic examination were eligible for inclusion. Participants with a history of occupational or industrial noise exposure, previous ear surgery, active or chronic middle ear disease, tympanic membrane perforation, ototoxic drug intake, diabetes mellitus, pre-eclampsia, psychiatric illness, or congenital or childhood-onset hearing loss were excluded from the study.

The sample size was calculated using the two-proportion formula based on an expected prevalence of 22% in the exposed group and 4% in the non-exposed group, with a 95% confidence interval ($Z\alpha/2 = 1.96$) and 80% study power ($Z\beta = 0.84$). After accounting for an anticipated 10% non-response rate, the required sample size was determined to be 60 participants in each group, resulting in a total sample size of 120 subjects.

Following informed consent, demographic details and relevant clinical history were obtained using a predesigned structured questionnaire. All participants underwent a detailed otoscopic examination to confirm eligibility. Hearing assessment was subsequently performed using pure tone audiometry to determine air-conduction hearing thresholds at standard test frequencies, followed by otoacoustic emission testing to evaluate cochlear outer hair cell function. Data were entered into Microsoft Excel and analyzed using SPSS version 31.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Normality of continuous variables was assessed using the Shapiro–Wilk test. Comparisons between groups were performed using the independent samples t-test or Mann–Whitney U test, as appropriate, whereas categorical variables were analyzed using the Chi-square test. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 120 participants were included in the study, with 60 individuals in the exposed group and 60 in the non-exposed group. The mean age of participants in the exposed group was 28.6 ± 5.2 years, while that of the non-exposed group was 27.9 ± 4.8 years. The difference in age between the two groups was not statistically significant ($p=0.442$), indicating comparable age distribution. Similarly, the gender distribution was well matched between the groups, with males accounting for 53.3% and females for 46.7% in the exposed group, compared with 50.0% males and 50.0% females in the non-exposed group ($p=0.715$). These findings demonstrate that the baseline demographic characteristics were comparable between the study groups. (Table 1)

Table 1. Baseline characteristics of the study population

Variable	Exposed (n=60)	Non-exposed (n=60)	p-value
Age (years), Mean ± SD	28.6 ± 5.2	27.9 ± 4.8	0.442
Male, n (%)	32 (53.3)	30 (50.0)	0.715
Female, n (%)	28 (46.7)	30 (50.0)	

Pure tone audiometry demonstrated significantly higher hearing thresholds in the exposed group across all tested frequencies. At 1000 Hz, the mean hearing threshold was 22.4 ± 6.1 dB in the exposed group compared with 16.8 ± 4.2 dB in the non-exposed group ($p<0.001$). Similar significant differences were observed at 2000 Hz (25.7 ± 7.4 vs. 18.9 ± 5.1 dB), 4000 Hz (34.6 ± 8.9 vs. 20.3 ± 5.8 dB), and 6000 Hz (38.2 ± 9.4 vs. 22.1 ± 6.2 dB), with all comparisons showing highly significant differences ($p<0.001$). The greatest elevation in hearing thresholds was observed at the higher frequencies of 4000 Hz and 6000 Hz, suggesting greater susceptibility of high-frequency hearing to prolonged earphone exposure. (Table 2)

Table 2. Comparison of pure tone audiometry thresholds at different frequencies

Frequency (Hz)	Exposed (Mean ± SD)	Non-exposed (Mean ± SD)	Mean Difference	p-value
1000	22.4 ± 6.1	16.8 ± 4.2	5.6	<0.001
2000	25.7 ± 7.4	18.9 ± 5.1	6.8	<0.001
4000	34.6 ± 8.9	20.3 ± 5.8	14.3	<0.001
6000	38.2 ± 9.4	22.1 ± 6.2	16.1	<0.001

The overall mean pure tone audiometry threshold was significantly higher among individuals with prolonged earphone exposure than among non-exposed participants. The exposed group demonstrated a mean PTA threshold of 29.4 ± 8.1 dB compared with 18.7 ± 5.6 dB in the non-exposed group. This difference was highly statistically significant ($p<0.001$), indicating poorer overall hearing sensitivity among participants with prolonged exposure to earphone music. (Table 3)

Table 3. Comparison of mean pure tone audiometry threshold between study groups

Study Group	Mean PTA Threshold (dB), Mean ± SD	p-value
Exposed (n=60)	29.4 ± 8.1	<0.001
Non-exposed (n=60)	18.7 ± 5.6	

Assessment of hearing loss severity according to the Goodman classification revealed marked differences between the two groups. Normal hearing was observed in 40.0% of the exposed group compared with 83.3% of the non-exposed group. Minimal hearing loss was considerably more frequent among exposed participants (43.3%) than non-exposed participants (11.7%). Mild hearing loss was observed in 5.0% of participants in both groups, whereas moderate hearing loss was identified exclusively in the exposed group (11.7%). Overall, the distribution of hearing loss severity differed significantly between the two groups ($p<0.001$), indicating an increased prevalence and severity of hearing impairment among individuals with prolonged earphone exposure. (Table 4)

Table 4. Comparison of degree of hearing loss according to Goodman classification

Degree of Hearing Loss	Exposed n (%)	Non-exposed n (%)	Total n (%)	p-value
Normal (0–15 dB)	24 (40.0)	50 (83.3)	74 (61.7)	< 0.001
Minimal (16–25 dB)	26 (43.3)	7 (11.7)	33 (27.5)	
Mild (26–40 dB)	3 (5.0)	3 (5.0)	6 (5.0)	
Moderate (41–55 dB)	7 (11.7)	0 (0.0)	7 (5.8)	
Total	**60 (100)**	**60 (100)**	**120 (100)**	

Evaluation of laterality of hearing loss showed that 68 (56.7%) right ears and 64 (53.3%) left ears exhibited hearing loss, while normal hearing was observed in 52 (43.3%) right ears and 56 (46.7%) left ears. There was no statistically significant difference in the distribution of hearing loss between the right and left ears (p=0.603), suggesting that prolonged earphone exposure affected both ears similarly without significant lateral predominance. (Table 5)

Table 5. Laterality of hearing loss among study ears

Ear	Normal n (%)	Hearing Loss n (%)	p-value
Right	52 (43.3)	68 (56.7)	0.603
Left	56 (46.7)	64 (53.3)	

Otoacoustic emission assessment demonstrated a significantly higher proportion of abnormal ("Refer") results among participants with prolonged earphone exposure. In the exposed group, 17 (28.3%) participants showed a Refer result compared with only 5 (8.3%) participants in the non-exposed group. Conversely, normal ("Pass") OAE findings were observed in 71.7% of the exposed group and 91.7% of the non-exposed group. The difference in OAE findings between the two groups was statistically significant (p=0.004), indicating a higher prevalence of outer hair cell dysfunction among individuals with prolonged earphone music exposure. (Table 6)

Table 6. Comparison of otoacoustic emission findings between study groups

OAE Result	Exposed n (%)	Non-exposed n (%)	Total n (%)	p-value
Pass	43 (71.7)	55 (91.7)	98 (81.7)	0.004
Refer	17 (28.3)	5 (8.3)	22 (18.3)	
Total	**60 (100)**	**60 (100)**	**120 (100)**	

DISCUSSION

The present study demonstrated significantly poorer auditory function among individuals with prolonged earphone use compared with non-exposed participants. The two groups were comparable with respect to age and gender, suggesting that the observed differences were primarily related to earphone exposure rather than demographic factors. Hearing thresholds were significantly elevated at all tested frequencies, with the greatest deterioration observed at 4 kHz and 6 kHz. This audiometric pattern is characteristic of early noise-induced hearing loss and reflects the greater susceptibility of the basal turn of the cochlea to prolonged acoustic stimulation. Similar high-frequency threshold shifts associated with recreational noise exposure have been described by Keppler et al., who evaluated hearing in young adults using audiometry and otoacoustic emissions, and by Gajendran et al., who reported a high prevalence of high-frequency hearing loss among medical students using personal listening devices [15,16]. These studies support the finding that prolonged exposure to amplified music through earphones can produce early cochlear damage before clinically significant hearing impairment becomes evident.

The mean pure tone audiometry threshold was significantly higher in the exposed group, and the majority of affected participants exhibited minimal or mild hearing loss, while moderate hearing loss was observed only among prolonged earphone users. These findings suggest that repeated recreational noise exposure may produce cumulative cochlear injury even in otherwise healthy young adults. The predominance of minimal hearing loss is consistent with the early stages of noise-induced hearing loss reported in previous investigations. Sulaiman et al. noted that although many young users of personal listening devices have normal hearing, repeated exposure may produce subtle auditory deficits that accumulate over time [17]. Likewise, the World Health Organization has highlighted recreational noise from personal listening devices as an emerging public health concern because prolonged exposure to unsafe listening levels can progressively impair hearing [18].

No significant difference was observed between the right and left ears, indicating bilateral and symmetrical involvement. Such symmetry is expected because both ears are generally exposed to similar sound intensities during earphone use. Bilateral high-frequency cochlear involvement has been consistently described in studies evaluating recreational noise exposure and represents the typical audiometric pattern of noise-induced hearing loss rather than localized ear pathology. Furthermore, the higher prevalence of hearing loss among prolonged earphone users in the present study is in agreement with recent evidence demonstrating that excessive use of personal listening devices increases the risk of high-frequency sensorineural hearing loss among young adults [16].

Otoacoustic emission testing identified a significantly greater proportion of abnormal responses among exposed participants, indicating impaired outer hair cell function. Since otoacoustic emissions assess cochlear outer hair cell integrity objectively, abnormal findings may precede measurable threshold elevation on conventional audiometry. Keppler et al. emphasized that otoacoustic emissions are valuable for identifying preclinical cochlear damage associated with recreational noise exposure, while the World Health Organization recommends incorporating objective hearing assessments into research and screening programs evaluating unsafe listening practices [15,18]. Together, these findings support the complementary use of pure tone audiometry and otoacoustic emissions for early detection of noise-induced cochlear dysfunction in habitual earphone users.

CONCLUSION

The present study demonstrates that prolonged exposure to earphone music is significantly associated with impaired auditory function, as evidenced by elevated pure tone audiometry thresholds, a higher prevalence of hearing loss, and increased abnormal otoacoustic emission findings compared with non-exposed individuals. High-frequency hearing thresholds were particularly affected, indicating early cochlear involvement consistent with noise-induced sensorineural hearing loss. Otoacoustic emission testing proved valuable in detecting outer hair cell dysfunction and complemented pure tone audiometry in identifying early cochlear damage. These findings highlight the importance of promoting safe listening practices, increasing awareness regarding the risks of prolonged earphone use, and incorporating periodic audiological screening among frequent earphone users to facilitate early detection and prevent progression of irreversible hearing loss.

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