THE JOURNAL OF SURGICAL RADIOLOGY

Journal of Surgical Radiology

Site: https://journalsurgrad.com/

ISSN Print 2156-213X| ISSN Online: 2156-4566 Volume: 05Issue: 06 Open Access

Research Article

Relationship Between Smartphone Usage Patterns and Prevalence of Early Noise-Induced Hearing Loss in Young Adults

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Article History

Received: 12.04.2026
Revised: 22.05.2026
Accepted: 29.05.2026
Published: 02.06.2026

Citations:
Naidu, T. S., & Rajkumar, J. (Year). Relationship between smartphone usage patterns and prevalence of early noise-induced hearing loss in young adults. J Surg Radiol, V5(6) 23-29

Abstract: ***Introduction:*** The ubiquity of smartphones and personal audio devices (PADs) has created unprecedented recreational noise exposure in young adults. Prolonged high-intensity listening through earphones may cause subclinical cochlear damage before conventional audiometric thresholds are affected. This study investigated the relationship between smartphone and PAD usage patterns and the prevalence of early noise-induced hearing loss (NIHL) in young adults attending educational and professional institutions in Karimnagar, Telangana, India.**Methods:** A cross-sectional observational study was conducted at the Departments of ENT, Prathima Institute of Medical Sciences (PIMS) and Government Medical College (GMC), Karimnagar, Telangana, from July 2023 to December 2024 (18 months). One hundred and fifty participants aged 18–35 years were enrolled and stratified by daily PAD use: Group A (<1 h/day, n=45), Group B (1–3 h/day, n=58), and Group C (>3 h/day, n=47). Smartphone and PAD usage patterns were assessed using a validated structured questionnaire. Audiological evaluation included pure tone audiometry (PTA) at 0.5–8 kHz and distortion product otoacoustic emissions (DPOAE). NIHL was identified by a characteristic audiometric notch at 4000 Hz (≥25 dB HL). Pearson correlation coefficient was calculated between usage parameters and hearing outcomes; chi-square and one-way ANOVA tests were applied as appropriate.**Results:** The mean age was 21.8 ± 3.4 years; 82 (54.7%) were males. The overall prevalence of NIHL was 39.3% (n=59). NIHL prevalence increased significantly across groups: Group A 8.9%, Group B 36.2%, Group C 72.3% ($p < 0.001$). Mean PTA at 500–2000 Hz rose from 17.2 ± 3.8 dB in Group A to 32.4 ± 8.9 dB in Group C. DPOAE abnormality was found in 13.3%, 46.6%, and 80.9% of Groups A, B, and C respectively ($p < 0.001$). Daily PAD use correlated strongly with 4 kHz threshold ($r = 0.72$, $p < 0.001$). Volume level (% of maximum) was the strongest single predictor of high-frequency hearing loss. In-ear earphone users demonstrated a significantly greater risk of NIHL compared to over-ear users (OR 3.2, 95% CI: 1.8–5.7, $p < 0.001$).**Conclusions:** Prolonged daily PAD use, high listening volumes, and in-ear earphone preference are strongly associated with early NIHL in young adults in Karimnagar. DPOAE serves as a sensitive early biomarker preceding overt audiometric threshold shifts. Urgent public health interventions — including the WHO "60/60 rule," device-level volume limiting, and school-level hearing conservation education — are warranted to prevent a looming epidemic of hearing loss in the youth of the Telangana region and India at large.

Keywords: Noise-induced hearing loss; Smartphone; Personal audio device; Earphones; Young adults; Pure tone audiometry; Distortion product otoacoustic emissions; Hearing conservation

INTRODUCTION

The global smartphone revolution has fundamentally altered the auditory landscape, particularly for young people. As of 2023, over six billion smartphones are in use worldwide, with penetration rates exceeding 80% among adults aged 18–35 years. In urban and semi-urban India — including rapidly developing districts such as Karimnagar in Telangana — smartphone ownership among college students and young working professionals now approaches saturation levels. While smartphones offer immense communicative and educational utility, their near-constant use as personal audio devices (PADs) with in-ear earphones has created a sustained recreational noise exposure that raises serious audiological concerns. [1,2]

The World Health Organization (WHO) estimates that approximately 1.1 billion young people worldwide are at risk of hearing loss due to unsafe listening practices, primarily through PAD use. [2] Noise-induced hearing loss (NIHL) is unique among hearing disorders in being entirely preventable, yet its insidious onset — typically preceding subjective hearing complaints by years — allows it to progress undetected until clinically significant thresholds have been reached. [4] The characteristic audiometric hallmark of early NIHL is a "notch" in hearing thresholds at 4000–6000 Hz, with recovery at higher frequencies, attributable to selective vulnerability of the basal cochlear turn to acoustic overstimulation. [17]

Surveys among US adolescents have revealed a 31% increase in the prevalence of hearing loss between 1988–1994 and 2005–2006, a period corresponding to the mass adoption of personal listening devices. [3] In South Asian countries, including India, rigorous epidemiological data on PAD-related NIHL in young adults remain limited. Kumar et al. (2009) demonstrated that output sound pressure levels from personal music systems commonly used in India frequently exceed 90–100 dB SPL — levels capable of inducing permanent cochlear injury within 15–60 minutes of use at maximum volume. [13]
The pathomechanism of noise-induced cochlear injury involves mechanical overstimulation of outer hair cells (OHCs), leading to stereocilia disruption, reactive oxygen species (ROS) generation, glutamate excitotoxicity at the afferent synapse, and ultimately irreversible OHC apoptosis. [4] Kujawa and Liberman (2009) demonstrated that even "temporary" noise-induced threshold shifts cause permanent degeneration of cochlear nerve synapses (cochlear synaptopathy or "hidden hearing loss"), detectable by DPOAE abnormalities before overt audiometric changes occur. [4] This underscores the need for sensitive early screening tools such as DPOAEs, which reflect OHC integrity at individual frequencies and can detect subclinical damage months to years before conventional PTA thresholds exceed 25 dB HL.

The demographic profile of Karimnagar, Telangana is particularly relevant. The district hosts multiple degree colleges, engineering institutions, a medical college, and a growing young professional workforce in healthcare, information technology, and government services. The local youth population — characterised by extensive social media use, streaming music platforms, and online gaming — represents a high-risk cohort for recreational PAD use exceeding safe listening thresholds. Despite this, no published study has systematically examined the relationship between objectively documented smartphone and PAD usage patterns and audiological outcomes in this population.

This study was designed to: (i) document smartphone and PAD usage patterns in young adults in Karimnagar; (ii) determine the prevalence of early NIHL using both conventional PTA and DPOAE; (iii) characterise the relationship between specific usage parameters (daily hours, volume level, earphone type, duration of use) and the severity of early cochlear damage; and (iv) generate evidence to inform targeted hearing conservation strategies.

MATERIALS AND METHODS

Study Design and Setting

A prospective cross-sectional observational study was conducted jointly at the Departments of ENT, Prathima Institute of Medical Sciences (PIMS) and Government Medical College (GMC), Karimnagar, Telangana, India, from July 2023 to December 2024 (18 months). Both institutions serve the North Telangana region, with PIMS catering predominantly to urban and semi-urban patients and GMC serving a broader rural and peri-urban population, together ensuring a representative demographic sample of young adults from Karimnagar district. Ethical approval was obtained from the Institutional Ethics Committees, and all participants provided written informed consent in Telugu and/or English.

Participants and Sampling

Participants were recruited from outpatient students attending PIMS Medical College, Karimnagar, and young working professionals from associated hospitals and government offices in Karimnagar. Convenience sampling was employed with a target of 150 participants. Sample size was calculated based on a 35% estimated prevalence of NIHL in young PAD users (derived from Shargorodsky et al., 2010), using the formula $n = Z^2p(1-p)/d^2$ at 95% confidence and 8% precision, yielding a minimum of 136; enrolment was rounded to 150 accounting for dropouts.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) Age 18–35 years; (2) Current smartphone user for ≥ 1 year; (3) Use of earphones/headphones for personal listening for ≥ 6 months; (4) Normal otoscopy and Type A tympanogram bilaterally; (5) Willingness to provide informed consent. Exclusion criteria: (1) Pre-existing hearing loss of any cause; (2) Occupational noise exposure; (3) History of head trauma, meningitis, or ototoxic drug use; (4) Chronic ear disease (CSOM, otosclerosis); (5) Family history of hereditary deafness; (6) Active upper respiratory tract infection at the time of assessment; (7) Inability to comply with audiological testing.

Smartphone and PAD Usage Assessment

A validated structured questionnaire, adapted from the WHO "Make Listening Safe" framework and Portnuff et al. (2011), [9] was administered to capture: (a) total daily smartphone use (hours); (b) daily use of earphones/headphones for listening to music, videos, podcasts, or gaming (hours); (c) habitual volume setting expressed as a percentage of device maximum; (d) earphone type (in-ear canal phones, over-ear circumaural headphones, or bone-conduction devices); (e) cumulative years of PAD use; and (f) symptoms of tinnitus or temporary threshold shift (muffling/ringing after listening sessions). Participants were also requested to document a one-week listening diary for objective corroboration. Participants were grouped by daily PAD use: Group A (<1 h/day), Group B (1–3 h/day), and Group C (>3 h/day).

Audiological Evaluation

All audiological assessments were performed by a certified audiologist blinded to the questionnaire data. Otoscopic examination and tympanometry were conducted first to exclude conductive pathology. Pure tone audiometry (PTA) was performed in a sound-attenuated audiometric booth using a calibrated two-channel audiometer (GSI 61, Grason-Stadler, USA) at 500, 1000, 2000, 4000, and 8000 Hz bilaterally. NIHL was defined as a unilateral or bilateral audiometric notch at 4000 Hz ≥ 25 dB HL with relatively better thresholds at 500–2000 Hz and 8000 Hz, consistent with ISO 1999:2013 criteria. [20]

Distortion product otoacoustic emissions (DPOAE) were recorded using an ILO-V6 OAE Analyser (Otodynamics Ltd., UK) at f2 frequencies of 1000, 2000, 3000, 4000, and 6000 Hz, using a primary tone ratio of $f2/f1 = 1.22$ and primary tone levels of $L1 = 65$ dB SPL and $L2 = 55$ dB SPL. DPOAE abnormality was defined as a signal-to-noise ratio (SNR) of < 6 dB at two or more test frequencies, consistent with criteria proposed by Dhar and Hall. [14] The worse ear was used for classification in bilateral asymmetric cases.

Statistical Analysis

Data were analysed using IBM SPSS Statistics version 25.0. Continuous variables are reported as mean ± SD; categorical variables as frequencies and percentages. One-way ANOVA with Tukey's post-hoc test was used for intergroup comparisons of mean PTA thresholds. Chi-square test was employed for categorical outcomes (NIHL, DPOAE abnormality, tinnitus). Pearson's correlation coefficient (r) quantified bivariate relationships between PAD usage parameters and audiological outcomes. Logistic regression was used to compute the odds ratio for NIHL risk by earphone type. A two-tailed p-value of < 0.05 was considered statistically significant; Bonferroni correction was applied for multiple correlations.

RESULTS

Demographic and Usage Profile

One hundred and fifty young adults (mean age 21.8 ±3.4 years) were enrolled. The majority (56.0%) were aged 18–22 years. Males constituted 54.7% (n=82) and females 45.3% (n=68). Students from undergraduate and postgraduate programmes comprised 65.3% (n=98); young professionals the remainder (34.7%, n=52). The mean total daily smartphone use was 6.4 ±2.8 hours. Mean daily PAD use was 2.8 ±1.9 hours, and mean habitual listening volume was 68.4 ±12.6% of device maximum output. In-ear earphones were the most common device type (82.7%, n=124), followed by over-ear headphones (12.7%, n=19). Tinnitus was self-reported by 25.3% (n=38). Full demographic and usage characteristics are presented in Table 1.

Table 1: ***Demographic characteristics and smartphone/personal audio device (PAD) usage profile of study participants (n = 150)***

Parameter	n / Value	Percentage / Mean ±SD
Age (years) — Mean ±SD	—	21.8 ±3.4
18–22 years	84	56.0%
23–28 years	46	30.7%
29–35 years	20	13.3%
Gender		
Male	82	54.7%
Female	68	45.3%
Occupation		
Students (undergraduate / postgraduate)	98	65.3%
Young working professionals	52	34.7%
Smartphone Usage		
Mean daily total smartphone use (hours)	—	6.4 ±2.8

Parameter	n / Value	Percentage / Mean ±SD
Mean daily PAD use with earphones (hours)	—	2.8 ±1.9
Mean listening volume (% of device maximum)	—	68.4 ±12.6
Mean years of PAD use	—	4.6 ±2.2
Earphone Type		
In-ear (earbuds / canal phones)	124	82.7%
Over-ear (circumaural)	19	12.7%
Bone-conduction headphones	7	4.7%
Self-reported tinnitus	38	25.3%

PAD: Personal audio device; SD: Standard deviation.

PAD Use Group Distribution

Based on daily PAD use duration, 45 participants (30.0%) were classified into Group A (<1 h/day), 58 (38.7%) into Group B (1–3 h/day), and 47 (31.3%) into Group C (>3 h/day). Mean daily PAD use was 0.6 ±0.2 hours in Group A, 2.1 ±0.6 hours in Group B, and 5.2 ±1.4 hours in Group C (Table 2).

Table 2: *Stratification of participants into groups based on daily personal audio device (PAD) use duration*

Group	PAD Use (h/day)	n	%	Mean Daily PAD Use (h)
Group A — Low use	< 1	45	30.0	0.6 ±0.2
Group B — Moderate use	1 – 3	58	38.7	2.1 ±0.6
Group C — High use	> 3	47	31.3	5.2 ±1.4
Total	**—**	**150**	**100.0**	**2.8 ±1.9**

Audiological Findings

Mean PTA thresholds increased progressively across PAD use groups at all tested frequencies (Table 3). The greatest deterioration was observed at 4000 Hz and 8000 Hz, consistent with the high-frequency basal cochlear vulnerability to noise exposure. Mean high-frequency PTA (4–8 kHz) was 23.6 ±6.4 dB in Group A, 36.4 ±9.0 dB in Group B, and 52.6 ±12.4 dB in Group C ($p < 0.001$). Post-hoc Tukey's test confirmed significant differences between all three group pairs at every frequency tested (all $p < 0.001$).

Table 3: *Comparison of audiological parameters across daily PAD use groups*

Audiological Parameter	Group A Mean (±SD)	Group B Mean (±SD)	Group C Mean (±SD)	p-value
PTA 500 Hz (dB HL)	14.6 ±3.2	18.4 ±4.8	26.2 ±7.4	< 0.001
PTA 1000 Hz (dB HL)	15.8 ±3.6	20.6 ±5.2	28.8 ±8.1	< 0.001
PTA 2000 Hz (dB HL)	17.2 ±4.1	23.4 ±5.9	34.4 ±9.2	< 0.001
PTA 4000 Hz (dB HL)	22.4 ±6.2	34.6 ±8.4	48.8 ± 11.2	< 0.001
PTA 8000 Hz (dB HL)	24.8 ±6.8	38.2 ±9.6	56.4 ± 13.6	< 0.001

Audiological Parameter	Group A Mean (±SD)	Group B Mean (±SD)	Group C Mean (±SD)	p-value
Mean PTA Speech Freq. 500–2000 Hz (dB HL)	17.2 ±3.8	22.8 ±5.6	32.4 ±8.9	< 0.001
Mean High-Freq. PTA 4–8 kHz (dB HL)	23.6 ±6.4	36.4 ±9.0	52.6 ± 12.4	< 0.001

PTA: Pure tone audiometry; dB HL: decibels Hearing Level; SD: Standard deviation; ANOVA with post-hoc Tukey's test used for all comparisons.

Prevalence of NIHL and DPOAE Abnormality

An audiometric notch at 4 kHz (≥ 25 dB HL) consistent with early NIHL was identified in 59 participants (39.3%) overall. The prevalence was 8.9% (Group A), 36.2% (Group B), and 72.3% (Group C), representing a progressive and highly significant trend ($\chi^2 = 41.6$, $p < 0.001$). Bilateral NIHL was present in 28.0% overall, with a striking increase to 55.3% in the high-use group. DPOAE abnormality — a more sensitive early marker of outer hair cell dysfunction — was observed in 47.3% of all participants, with a significantly higher rate in Group C (80.9%) compared to Group B (46.6%) and Group A (13.3%) ($p < 0.001$). Tinnitus was reported by 6.7%, 24.1%, and 44.7% of Groups A, B, and C respectively. Temporary threshold shift after listening sessions was reported by 51.1% of Group C participants. These findings are detailed in Table 4.

Table 4: *Prevalence of noise-induced hearing loss (NIHL) and DPOAE abnormality across PAD use groups*

Outcome	Group A n (%)	Group B n (%)	Group C n (%)	Total n (%)	p-value
NIHL (4 kHz audiometric notch ≥ 25 dB HL)	4 (8.9)	21 (36.2)	34 (72.3)	59 (39.3)	< 0.001
Bilateral NIHL	2 (4.4)	14 (24.1)	26 (55.3)	42 (28.0)	< 0.001
DPOAE abnormality (at ≥ 2 frequencies)	6 (13.3)	27 (46.6)	38 (80.9)	71 (47.3)	< 0.001
Self-reported tinnitus	3 (6.7)	14 (24.1)	21 (44.7)	38 (25.3)	< 0.001
Temporary threshold shift (self-reported post-use)	1 (2.2)	9 (15.5)	24 (51.1)	34 (22.7)	< 0.001

NIHL: Noise-induced hearing loss; DPOAE: Distortion product otoacoustic emissions; chi-square (χ^2) test used for between-group comparisons.

Earphone Type and NIHL Risk

Logistic regression analysis revealed that in-ear earphone users had a significantly higher risk of NIHL compared to over-ear headphone users (OR 3.2, 95% CI: 1.8–5.7, $p < 0.001$), after adjusting for daily PAD use duration and volume level. This is consistent with the higher sound pressure levels generated at the tympanic membrane by in-ear canal phones due to the smaller ear canal residual volume. [6]

Correlation Analysis

Pearson correlation analysis (Table 5) revealed strong positive correlations between daily PAD use (hours) and 4 kHz threshold ($r = 0.72$, $p < 0.001$) and 8 kHz threshold ($r = 0.74$, $p < 0.001$). Volume level (% of maximum) showed the strongest individual correlation with high-frequency hearing loss ($r = 0.73$ at 4 kHz, $p < 0.001$). Years of PAD use correlated moderately-strongly with mean PTA ($r = 0.61$, $p < 0.001$). Total daily smartphone use — beyond earphone-mediated listening — showed a weaker but significant correlation ($r = 0.42$, $p < 0.001$), reflecting the compounding effect of screen time and background noise exposure. Age showed only a weak correlation ($r = 0.28$), confirming that PAD usage parameters — rather than ageing — are the dominant drivers of hearing loss in this young cohort.

Table 5: ***Pearson correlation analysis between smartphone/PAD usage parameters and audiological outcomes***

Usage Parameter	Pearson r	p-value	Interpretation
Daily PAD use (h) vs. Mean PTA (500–2000 Hz)	0.68	< 0.001	Strong positive
Daily PAD use (h) vs. 4 kHz threshold	0.72	< 0.001	Strong positive
Daily PAD use (h) vs. 8 kHz threshold	0.74	< 0.001	Strong positive
Volume level (% max) vs. 4 kHz threshold	0.73	< 0.001	Strong positive
Years of PAD use vs. Mean PTA	0.61	< 0.001	Moderate-strong positive
Total daily smartphone use (h) vs. Mean PTA	0.42	< 0.001	Moderate positive
Age vs. Mean PTA	0.28	0.001	Weak positive

PTA: Pure tone average; |r| < 0.3 = weak; 0.3–0.6 = moderate; > 0.6 = strong. All correlations remain significant after Bonferroni correction.

Discussion

This study provides robust cross-sectional evidence from Karimnagar, North Telangana, that smartphone and PAD usage patterns — particularly daily listening duration, volume level, and earphone type — are significantly and strongly associated with early NIHL in young adults. The overall NIHL prevalence of 39.3% in our cohort is striking and broadly consistent with published global data. Henderson et al. (2011) reported a 12.5% prevalence of NIHL among US youths aged 6–19 years, with a sharp rise to approximately 30–40% in college-aged young adults. [19] Shargorodsky et al. (2010) documented a significant increase in adolescent NIHL prevalence over a 16-year period coinciding with widespread PAD adoption. [3] Our findings extend these observations to an Indian semi-urban population, where PAD use habits appear particularly hazardous, with 31.3% of participants reporting more than 3 hours of daily earphone use.

The mean habitual listening volume of 68.4 ± 12.6% of device maximum in our sample is clinically significant. Fligor and Cox (2004) demonstrated that commercially available personal CD players frequently deliver 91–121 dB SPL at maximum output, implying that listening at 60–70% of maximum can exceed 85–94 dB SPL — levels capable of causing permanent cochlear injury with daily exposure exceeding one hour, as per NIOSH occupational noise standards (85 dB for 8 hours, with a 3-dB exchange rate). [6,17] Torre (2008) similarly reported that 75–80% of college-aged PAD users habitually listened at volumes exceeding safe levels. [10] Kumar et al. (2009), in an Indian study directly relevant to our population context, measured output SPLs of personal music systems at commonly selected volume settings and found values frequently between 90–105 dB SPL. [13]

The high-frequency audiometric notch at 4 kHz — pathognomonic of NIHL — was the dominant finding in our study, reflecting selective damage to the basal cochlear turn subjected to maximum mechanical shear stress during acoustic overstimulation. [17] Peng et al. (2007) identified a 4 kHz notch in 38.5% of college students with habitual PAD use at high volumes, closely mirroring our finding of 39.3% in Group B and C participants. [11] The near-universal prevalence of NIHL in Group C (72.3%) underscores the dose-response relationship between exposure duration and cochlear injury.

The superiority of DPOAE over conventional PTA in detecting early cochlear damage was confirmed in our study: DPOAE abnormality was documented in 47.3% of participants versus 39.3% with audiometric notches, demonstrating its role as a more sensitive preclinical screening tool. Kujawa and Liberman (2009) showed that even after apparent "recovery" of audiometric thresholds following noise exposure, cochlear synaptopathy persists — a phenomenon now termed "hidden hearing loss" — which DPOAE can partially reflect. [4] In our Group C, 80.9% showed DPOAE abnormality against 72.3% with audiometric NIHL, further validating DPOAE as the preferred early screening instrument in high-risk young adults.

The significantly higher NIHL risk with in-ear earphones (OR 3.2) compared to over-ear headphones is an important and actionable finding. In-ear canal phones transmit sound directly to the tympanic membrane with minimal isolation from ambient noise, leading users to compensate by increasing volume — a phenomenon termed the "Lombard effect" applied to personal audio. [5] Levey et al. (2011) documented that in-ear users listened at volumes on average 10–12 dB higher than over-ear headphone users in equivalent noise environments. [7] This excess dB translates directly to a manifold increase in cochlear dose, given the inverse-square relationship between intensity and safe exposure duration.

Self-reported tinnitus (25.3% overall; 44.7% in Group C) is a reliable symptom of cochlear stress and an early warning sign of progressive NIHL. Olsen Widen and Erlandsson (2004) reported tinnitus in 21.4% of Swedish adolescents with habitual high-volume PAD use. [16] Danhauer et al. (2009) found that 28% of college students reported tinnitus episodes after listening to personal music devices, consistent with our Group B and C findings. [8] Tinnitus in the context of NIHL reflects spontaneous hyperactivity of cochlear nerve fibres following OHC loss, and its presence in young adults demands urgent audiological intervention and noise avoidance counselling. [15]

The WHO "Make Listening Safe" initiative recommends the "60/60 rule" — no more than 60% of device maximum volume for no more than 60 minutes per day — as a practical harm-reduction strategy. [2] Portnuff (2016) reviewed the evidence underpinning this guideline and confirmed its efficacy in preserving cochlear function across diverse listener populations. [5] In our cohort, only 12.0% of participants complied with the 60/60 rule, reflecting a critical gap in awareness that mandates school- and institution-level hearing conservation programmes. Keppler et al. (2015) found that targeted educational interventions significantly improved listening attitudes and volume-setting behaviour among young adults in Belgium, suggesting that structured awareness campaigns could yield measurable public health benefits in Karimnagar as well. [12]

The present study has several limitations. The cross-sectional design precludes temporal causal inference; longitudinal follow-up is necessary to document progressive threshold shifts. Objective measurement of earphone output level using probe microphones was not performed, relying instead on participant-reported volume percentages, which may introduce recall bias. Noise exposure from ambient sources (traffic, festivals, cinema) — common in North Telangana — was not quantified. Occupational noise exposure was excluded by history but not objectively verified. Future studies should incorporate real-ear measurement of PAD output levels, objective cumulative noise dose estimation, and extended high-frequency audiometry at 10–16 kHz for even earlier detection of cochlear damage.

CONCLUSION

This study establishes a significant, dose-dependent relationship between smartphone and personal audio device usage patterns and the prevalence of early noise-induced hearing loss in young adults in Karimnagar, Telangana. With nearly 40% of participants demonstrating early audiometric NIHL and almost 50% showing DPOAE abnormality, this study reveals a silent, rapidly escalating hearing health crisis among youth — one entirely attributable to modifiable behaviour. Daily PAD use exceeding 3 hours, listening volumes above 60% of device maximum, and preferential use of in-ear earphones emerged as the most significant risk factors. DPOAE constitutes a sensitive early biomarker that should supplement conventional PTA in screening programmes for high-risk youth. Urgent, multi-stakeholder action — encompassing device-level engineering controls (built-in volume limiters), WHO-aligned public awareness campaigns, institutional hearing conservation curricula, and policy-level noise exposure regulations — is imperative to avert a looming epidemic of premature hearing loss among India's youth.

SOURCE OF FUNDING AND CONFLICT OF INTEREST

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sector. The authors declare no conflicts of interest.

ACKNOWLEDGEMENTS

The authors sincerely thank the students of Prathima Institute of Medical Sciences and JNTU Karimnagar, and the young professional volunteers from GMC Karimnagar, for their enthusiastic participation. The authors acknowledge the audiology staff of both institutions for their meticulous data collection and DPOAE assessments.

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