ORIGINAL RESEARCH ARTICLE

The Influence of Personal Listening Devices on Hearing in Egyptian University Students: A Cross-Sectional Study

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ABSTRACT

Background: Improper use of personal listening devices (PLDs) is associated with an increased risk of hearing loss. The purpose is to investigate the use of PLDs among university students and their impact on hearing.

Methodology: A study involved 310 University students, surveyed on their PLDs habits. They shared their daily PLD use, volume level, and duration of use. Participants also discussed PLD-related hearing issues and other risk factors for hearing loss. Screening used the Five-minute hearing test (FMHT) and the "Hear WHO" app. Positive cases in both tests received diagnostic pure-tone audiometry (PTA).

Results: About 70% used in-earpiece PLDs for studying, 53% used them for over 5 years. Also 83% used PLDs for over 60 mins daily, and 72% used them above volume level 6. Most (74%) were low-risk users. 10.6% tested positive for hearing loss in both screenings, with 1.6% confirmed by PTA. A shift in the 4 kHz average hearing threshold was noted. Tinnitus was reported by 49%, and ear pain by 42% of students. Higher risk PLD use predicted tinnitus, ear pain and excessive ear wax in multivariable analysis.

Conclusions: Students' high-volume PLD use is linked to auditory problems like tinnitus and ear pain. Regular hearing screenings are recommended.

Keywords: University students, Auditory problems, Hearing loss, Personal listening devices

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INTRODUCTION

Personal listening devices (PLDs) use among young adults, have significantly increased in recent years, particularly during the recent COVID-19 pandemic.[1] PLDs include mobile phones, laptops, MP3 players, and tablets connected to earpieces such as headphones, earphones, or earbuds.[2] According to the Centres for Disease Control and Prevention (CDC), the daily use of PLDs among teenagers and young adults is high enough to damage their hearing.[3] The World Health Organization (WHO) has reported that improper PLDs use puts 1.1 billion young adults at risk of hearing loss.[4] A previous study conducted in Egypt had reported that all participants who used PLDs showed hearing threshold shifts at all frequencies, with the most significant shift occurring in those who used PLDs for five or more years.[5]

Most PLDs produce high intensity sounds that exceed the safe levels set by a weighted equivalent continuous noise level (L_{Aeq}) of 85 dB over 8 hours.[6] Prolonged exposure to these high-intensity sounds can cause permanent hearing loss by damaging the cochlea's inner hair cells, leading to apoptosis and strong inflammatory reactions.[7] This type of hearing loss is called noise-induced hearing loss (NIHL). Several studies suggested that noise intensity and duration are the main determinants of hearing loss risk.[5,8,9]

Symptoms may be undetectable at the initial stage of hearing loss, with patients experiencing muffled hearing or ringing in the ears. With continuous noise exposure, the impact of hearing loss may become devastating, leading to social withdrawal and affecting mental and physical health.[10] Therefore, it is crucial to investigate patterns of PLDs use and their effects on hearing, particularly among university students. However, existing studies in Egypt are inadequate and inconclusive, making it difficult to draw firm conclusions. Thus, this research aimed to explore the patterns of PLD use and their effects on hearing among university students.

The study was conducted to investigate the use of PLDs among university students and their impact on hearing.

METHODOLOGY

Study design and population: Between January 2021 and January 2022, a cross-sectional study was carried out among students enrolled in the Faculty of Medicine and the Faculty of Science at Ain Shams University.

Sample size and techniques: The sample size was calculated using EPI Info 7 with a 95% confidence level and a 5% margin of error. It was assumed that hearing loss prevalence among PLDs users was 22%, according to a study by Thomas et al. in 2019.[11] The total number of students enrolled in both faculties in 2021 was 11,709. Therefore, a minimum required sample of 258 students was calculated. To compensate for non-response rates and incomplete questionnaires we increased the sample to 310 students, with 155 students from each college selected. Convenience sample was taken from each academic year.

Questionnaire and instruments

PLDs use and their auditory problems:

Initially, all participants completed a self-administered questionnaire asking about:

1) Demographic characteristics, which included age, gender, academic year.
2) Use of PLDs over the last six months. Students were considered PLDs users if they used a sound-producing device (e.g., mobile phone, tablet, or laptop) with earpieces. Questions covered the type of device, most used earpiece type (in-ear or closed/open-ended headphones), most common situation where students usually use their PLDs, years of PLDs use, PLDs daily use duration, and listening volume on a scale from 10 to 100.
3) Auditory problems related to PLDs use, including tinnitus, ear pain, excessive ear wax.
4) Other risk factors for hearing loss (chronic illness, ear infection, continuous noise exposure, family history of hearing loss, ear trauma /surgery and ototoxic drugs).

Screening for hearing loss: Students were screened for hearing loss by:

Five-minute hearing test (FMHT) questionnaire: The FMHT was constructed by the American Academy of Otolaryngology—Head and Neck Surgery it consisted of 15 questions, each with four possible answers: almost always (score 3), half the time (score 2), occasionally (score 1), and never (score 0), resulting in a total score between 0 and 45.[12] A cutoff value of 8 or higher was considered a possible indication of a hearing problem with 93.1% sensitivity, (95% CI: 77.2 to 99.2%) and 56.5% specificity (95% CI: 55.1 to 64.7%).[13,14]

The Hear WHO application: It was designed by the World Health Organization (WHO), has a sensitivity and specificity exceeding 85% and uses digits-in-noise technology to detect hearing problems accurately.[15] The application uses 23-digit sets and calculates a final score. A score below 50 indicates that the person's hearing may be affected and requires further investigation. All participants conducted this test in their practical classes to ensure quiet situation to avoid false results.

Audiological tests: Students who tested positive on both screening tests were referred to the Audiology Unit at Ain Shams University Hospital for diagnostic evaluation. Pure-tone audiometry (PTA) tests were conducted at 250–8000 Hz frequencies for air conduction, and the mid-octaves (3000 and 6000 Hz) were also tested when indicated. Bone conduction tests were conducted at frequencies of 500–4000 Hz. Effective masking using narrow-band noise was in-

troduced to the contralateral ear whenever indicated.[16] Hearing thresholds was performed in a double-walled, sound-treated booth. Headphones were used for hearing thresholds, and a B-71 bone vibrator was used for bone conduction thresholds. The American Speech-Language-Hearing Association (ASHA) guidelines define normal hearing as a PTA below 25 dB HL. So, participants were considered to have hearing loss if their hearing threshold (dB) exceeded 25 dB HL at any frequency in the right, left, or both ears.[16]

Statistical analysis: Statistical analysis was performed using IBM SPSS (Statistical Package for Social Science) software version 25.0. Qualitative categorical variables were presented as frequencies and percentages. Quantitative variables were presented as means with the standard deviation (SD). To facilitate comparisons years of PLDs use, average daily use duration and listening volume were converted into categories based on standard cut off points. Studies suggested that audiological changes occurring after approximately 5 years of PLDs use, so 5 years was used as cut-off value.[17,18] WHO 60/60 rule of safe listening suggests that individuals should limit their PLD usage to a maximum of 60 minutes per day and maintain the volume level at or below 60% of the device's maximum volume so 60 minutes and 60% of volume levels were used as cut-off values for daily use duration and listening volume.[6] Independent t-test was used to compare means between two groups. Multiple logistic regression was used to examine the effects of various independent variables on the presence of auditory problems. $P \leq 0.05$ was considered as the limit for statistical significance.

Risk categorization: The daily noise dose produced from PLDs was calculated based on participants' self-reported PLDs listening volumes, type of earpiece used, and daily duration of use in hours. The corresponding decibel was calculated using a specific regression equation.[19]

Earpiece type	Regression equation
Default in-ear	$0.6143\,x + 39.395$
Noise-cancelling in-ear	$0.6159\,x + 42.561$
Headphones	$0.6147\,x + 34.939$

*Where x represents reported device volume as a percentage of maximum.[19]

The decibel levels were used to calculate exposure estimates as a percentage of the daily recommended workplace exposure limit (where 100% = 8-hour 85 dB L_{Aeq}).

Time weight noise: $1\text{-}T = 8/2^{(L-85)/3}$

*L=calculated decibel from the previous equation

THEN: 2-dose = hours of use/T

The participants were classified based on their daily noise dose into three categories.[20]:

Risk status	PLD DND* criteria
Low risk	<0.5
High risk	0.5–3
Very high risk	>3

*DND: Daily noise dose

Research ethics: The study protocol was approved by the Ethical Committee at the Faculty of Medicine at Ain Shams University (Ref No: FWA000017585). Informed consent was obtained from all participants.

RESULTS

The sample included 310 students, of whom 297 (95.8%) met the definition of PLDs use. More than half of the participants 153 (51.5%) were females. The mean age of the participants was 20.8 ± 1.6 years, ranging from 18 to 25 years. Most students 257 (83%) used smart phones as PLDs and 214 (69%) used the in-earpiece with their devices. Most PLDs users 242 (78%) used it during studying. A considerable proportion of students (53%) stated that they had been using their PLDs for over 5 years. Moreover, a notable percentage of students reported extended usage, with 83% using their PLDs for more than 60 minutes per day, and 72% using them at a volume level above 6. The majority of students (74%) were classified as low-risk users in terms of PLD use. **(Table1). Table (2)** shows that ear infection and continuous noise exposure from other sources emerges as the most common risk factors, each affecting 21% of the students. Moreover, ear trauma/surgery is infrequent among students, affecting only 9% of them.

Table 1: Sociodemographic and PLDs use characteristics (N=310)

Sociodemographic characteristics	Students (%)
Device type	
Smart phone	257 (83)
Mp3 player/iPod	26 (8.3)
tablets/pc	14 (4.6)
None	13 (4.1)
In-ear	214 (69)
Earpiece type	
Closed-ended Headphones	60 (19.5)
Open-ended Headphones	23 (7.4)
None	13 (4.1)
Occasion	
Studying	242 (78)
Exercise	69 (22.3)
Transportation	57 (18.3)
Sleeping	24 (7.7)
None	13 (4.1)
Years since PLDs use	
<5 years	133 (42.9)
≥5 years	164 (53)
None	13 (4.1)
Daily use duration (minutes)	
<60 minutes	40 (12.9)
≥60 minutes	257 (83)
None	13 (4.1)
Listening Volume	
<60%	75 (24.2)
≥60%	222 (71.7)
None	13 (4.1)
Risk status	
Low	229 (74)
High/very high	68 (21.9)
None	13 (4.1)

*PLD: personal listening device

Table 2: Risk factors of hearing loss (N=310)

Risk factor	Students(%)
Ear infection	68 (21.9)
Continuous noise exposure from other sources	68 (21.9)
Chronic illness	48 (15.5)
Family history of hearing loss	43 (13.9)
Ototoxic drugs	33 (10.6)
Ear trauma/surgery	28 (9)

Table 3. Auditory problems associated with PLDs (N=297)

Auditory problem	Students (%)
Tinnitus	146 (49)
Ear pain	125 (42)
Excessive ear wax	90 (30.3)
Hearing loss by screening	33 (11)
Hearing loss by audiogram	5 (1.6)

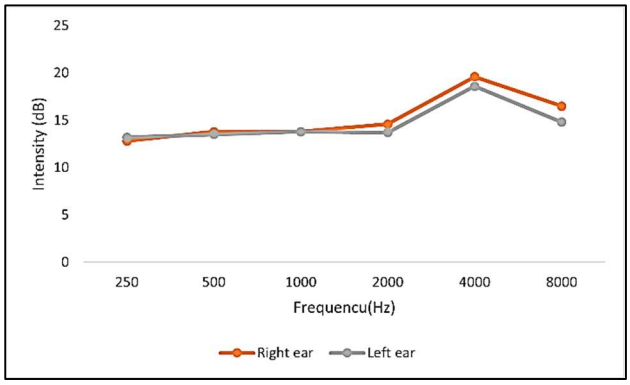

Figure 1: Average hearing threshold measured by PTA (N=33)

Table 4: Relationship between PLDs use and hearing threshold levels (N=33)

Variable	Cases	Hearing threshold level at 4kHz* (Mean ± SD)	P-value
Years since PLDs use			
<5 years	18	19.3 ± 6.1	.943+
≥5 years	15	19.5 ± 9.3	
Risk status			
Low	22	19.3 ± 8.5	.377+
High/very high	11	19.5 ± 4.5	

*Average hearing threshold from both ears was taken at 4kHz
+ Independent t t-test was used (all students conducted PTA their daily use duration exceeded 60 minutes and their listening volume was above 60% so t-test can't be conducted on those 2 variables)

Table (3) shows that self-reported tinnitus was the most common ear problem among PLDs users 146 (49%) of students reported it. Only thirty-three (11%) participants tested positive for hearing loss on both FMHT and Hear WHO screening tests. Out of 33 participants referred to undergo PTA, 5 (1.6%) tested positive (dB ≥ 25). A shift in the average hearing threshold was detected at 4 kHz in both ears while it was still within the normal range **(Figure 1). Table (4)** shows that there is no statistically significant difference observed between the duration of PLDs use or the risk status of PLDs use and the resulting hearing threshold levels. In multivariable logistic regression, the high/very risk of PLDs use was statistically significant predictor of tinnitus (OR: 2.69; 95% CI,1.46-4.65), ear pain (OR: 2.62; 95% CI,1.70-4.80), and excessive ear wax (OR 2.43; 95% CI, 1.30-4.20). **(Table 5).**

Discussion

The present study investigated the usage pattern of PLDs and their auditory effects among university students aged 18-25 years. High prevalence of unsafe listening habits is well documented among this age group.[3,4] The current study showed that the most common type of PLDs used was the smartphone with in-earpiece This finding can be explained by the convenience of smartphones which have become an integral part of our daily lives, and their ability to double as PLDs adds to their convenience. With a smartphone, users have their music, podcasts, audiobooks, and other audio content readily available in their pocket at all times. Also, the prevalence of in-earphones can be attributed to the fact that most smartphones are sold with these earpiece types, making it the default choice for PLDs among smartphone users. Similarly, other studies among university students reported same finding.[8,17]

According to the study, the majority of students (83%) used their PLDs for more than one hour, which is consistent with similar studies conducted among university students in Iran, India, and Egypt.[20,21,5] However, another study conducted by Saurav et al in India reported that most participants used PLDs for less than one-hour daily[22] citing a high level of awareness and perceived risks of PLDs use among participants. This suggests that behaviour and attitudes play a crucial role in shaping PLDs usage practices. The longer duration of PLDs use in the current study can be attributed to the fact that 78% of participants used their devices for studying and listening to online lectures. In terms of volume preference, 72% of students used their devices at a volume level above 60%, which is supported by other studies conducted in Australia, Sweden, and Egypt.[8,20,5] These studies found that young adults tend to listen to their PLDs at levels that exceed the World Health Organization's recommendations for safe listening (below 60% of the maximum volume level) [6]. This may be because young people underestimate the seriousness of noise exposure and do not consider it to be a problem.

Regarding self-reported symptoms after PLDs use, the prevalence of tinnitus in this study is concerning it was reported by half of the students. Tinnitus is a common symptom of underlying hearing damage, and it is often one of the first symptoms of hearing loss. Damage to auditory cells in the inner ear can cause the brain to try to compensate for the loss of sound by producing a ringing or humming sound, which is perceived as tinnitus.[23,24]

Table 5. Multivariable logistic regression of auditory problems with different risk factors (n=297)

	Tinnitus			EAR PAIN			Excessive ear wax		
	AOR	**(95% CI)**	**P-value**	**AOR**	**(95% CI)**	**P-value**	**AOR**	**(95% CI)**	**P-value**
Ear infection	1.68	0.94-3.10	0.078	1.43	0.81-2.52	0.213	2.1	0.91-3.78	0.24
Continuous noise exposure	0.92	0.52-1.60	0.786	1.42	0.81-2.51	0.21	0.68	0.35-1.32	0.225
Family history	0.84	0.42-1.70	0.654	1.15	0.57-2.33	0.689	1.1	0.50-2.41	0.822
Ear trauma/surgery	0.87	0.49-1.56	0.66	0.82	0.34-1.9	0.31	0.87	0.33-2.21	0.16
Ototoxic drugs	0.51	0.13-1.87	0.31	0.51	0.13-1.87	0.31	2.9	0.67-6.56	0.959
Chronic disease	1.2	0.34-3.11	0.973	1.03	0.36-3.11	0.932	0.93	0.67-1.33	0.358
Years since PLDs Use*	0.92	0.57-1.49	0.748	0.98	0.60-1.56	0.933	0.86	0.51-1.40	0.59
Risk status of PLDs use+	2.6	1.46-4.65	**0.001**	2.62	1.70-4.80	**0.001**	2.43	1.30-4.20	**0.003**

AOR: adjusted odds ratio, CI: confidence interval; *<5 years is the reference group; +Low risk is the reference group

Conversely, hearing loss can increase the perceived loudness of tinnitus, making it more bothersome for the affected individual.[25]

The findings of our study revealed a significant association between risk level of PLDs use which indicates high-volume and prolonged use of PLDs and an increased risk of tinnitus. Participants falling into the high/very high-risk category of PLDs use were 2.7 times more likely to experience tinnitus compared to those categorized as low risk. This corroborates the results of multiple previous studies that have also reported a similar relationship between high-volume and prolonged PLD use.[23,24,25] According to previous research conducted in Sohag, Egypt[5], Australia[25], and Saudi Arabia[26], the prevalence of tinnitus among young adults aged 18-25 who used PLDs ranges from approximately 45% to 75%.

The findings of our study revealed that around 42% of students reported experiencing ear pain. Participants who fell in high/very high-risk category of PLDs use were 2.6 times more likely to experience ear pain compared to those who were at low-risk category. In a previous study conducted in India on a sample of PLDs users, approximately 14% reported ear pain related to prolonged use of PLDs.[26] In another study conducted in Saudi Arabia, 23% of teenagers and adults who used PLDs reported ear pain.[27] Since most participants in the current study used in-earpieces, we would expect that friction can produce pain, especially if earpieces are tight-fitting or put pressure on the ears, can cause discomfort and potential pain in the ear cartilage or earlobes.

Excessive ear wax was detected in 30% of participants in this study, which was significantly associated with duration and volume of PLDs, participants who fell in high/very high-risk category of PLDs use were 2.4 times more likely to experience excessive ear wax compared to those who were at low-risk category. Prolonged use of earpieces in the ear canal can impact its natural self-cleaning mechanism since the constant presence of earbuds or headphones creates a physical barrier that inhibits the natural movement of the jaw and the subsequent migration of ear wax. As a result, ear wax may accumulate and become impacted in the ear canal.[28,29] However, other studies have failed to find a significant relationship between the earpiece use and excessive ear wax.[30,31]

This study showed that the prevalence of hearing loss confirmed by pure tone audiometry (PTA) was 1.6%. As compared to other studies, our study shows a lower prevalence rate as compared to previous studies in Malaysia (7.3%)[32] Egypt (16%)[33], and Nigeria (18.2%)[34]. There may be several reasons for the differences in results between studies, including differences in the demographic characteristics of the study populations, differences in analysis methods, and differences in the prevalence of risk factors for hearing loss, such as smoking, aging, or genetics. In addition, differences in testing procedures and definition of hearing loss.

It is also noted that there is high rate of false positives (85%) observed on screening compared audiogram results which can be attributed to several factors associated with the screening process. These factors include the subjective nature of the self-administered questionnaire which relies on the individual's own perception and reporting of their hearing abilities, and the potential influence of surrounding sounds on the results obtained through a mobile application.

The study found a shift in the average hearing threshold at 4 kHz in both ears while it was still within the normal range. We also found that there is no statistically significant difference observed between the years of PLDs use or the risk status of PLDs use and the resulting hearing threshold levels. This finding is supported by numerous studies conducted in Saudi Arabia, India and Canada, all used the standard frequencies of the audiogram (less than 8 kHz), all of which found no association between hearing loss and PLDs use patterns by conventional PTA.[35,19,36] In contrast, other studies that used extended high-frequency (EHF) audiograms (8–12 kHz) conducted in Saudi Arabia and United states of America found that mean hearing thresholds were significantly higher in PLDs users compared to non-users.[35,37]

LIMITATIONS

The cross-sectional design only provides a snapshot in time, making it difficult to establish causality. we cannot exclude self-report bias, where participants may not accurately report their symptoms. Further-

more, audiogram testing was limited to the standard frequency range, potentially missing hearing loss that can be detected with extended high-frequency audiometry (EHF).

Conclusion

Personal listening device (PLDs) use is highly prevalent among university students. Long daily PLDs use duration and high volume were associated with auditory problems including tinnitus, ear pain and excessive ear wax production. However, we failed to find significant relation between PLDs use and change in the hearing threshold levels. Health education campaigns can increase young people's awareness of safe listening practices and early warning signs of hearing problems.

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