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Personal audio devices and the risk of hearing loss in young adults

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Abstract

Background: Personal listening devices (PLDs) are considered one of the most popular sources of recreational noise that may result later on in hearing loss. However, most PLD users are unaware that they are putting themselves at risk of sensorineural hearing loss.

Objective: to assess and early discover subtle changes in hearing sensitivity caused by personal audio devices (PADs).

Methods: In this case control study, the participants were selected through simple random sampling with age range from 14 to 20 years. The study was conducted at the Audiology Unit, Sohag University Hospital, Sohag, Egypt between March 2018 and January 2019. The participants were divided into two groups: Group I (case group) with history of regular use of PADs and Group II (control group) who never use PADs. All participants underwent pure tone audiometry (PTA), extended high frequency (EHF) audiometry, immitencemetry and transient evoked otoacoustic emissions (TEAOE). Data were analyzed using IBM-SPSS version 23. Statistical methods used include descriptive analysis (mean, range and standard deviation), odds ratio and Pearson correlation test.

Results: The average duration of PAD use in the case group was 2 years with 68.29% of PLD use ≥4 days/ week, 63.41% of PLD use ≥ one hour daily and 39.02% preferring high volume. Tinnitus was the most common problem that occurred immediately after PAD use, followed by hearing loss. The EHF results showed a highly statistically significant difference in the threshold between the two groups at all tested frequencies (the odds ratio was 165.00 with a high degree of significance p=0.0004). The whole case group showed hearing threshold shift at all frequencies from 10 to 16 KHz at both ears. The largest hearing threshold shift occurred in the case group that used PADs for two or more years. The odds ratio for Transient Evoked Otoacoustic Emissions (TEOAE) response was 1.0649 with no statistically significant differences between case and control groups (p=0.8264). However, the mean amplitude of the overall TEOAE spectrum was lower in the case group compared with the controls. In the right ear, it was 16.85±3.02 dB in the case versus 18.92±3.14 dB in the control with the degree of the significance less than 0.01. In the left ear, it was 16.92±4.28 dB in the case versus 19.01±3.76 in the controls with the degree of the significance less than 0.05.

Conclusion: The current study suggests that the long-term use of PLDs can impair hearing function, so a screening protocol should be considered for early identification of NIHL in PLD users.

Keywords: Noise, hearing loss, personal audio devices

Abbreviations / Acronyms:
EHF: Extended high frequency; **NIHL:** Noise-induced hearing loss; **OAE:** Otoacoustic Emission; **PAD:** Personal audio device; **PLD:** Personal listening device; **PTA:** Pure tone audiometry; **SNR:** Signal-to-noise ratio; **TEOAE:** Transient Evoked Otoacoustic Emissions; **WHO:** World Health Organization

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1. Introduction

Noise-induced hearing loss (NIHL) can result from exposure to occupational noise and non-occupational or recreational noise. One of the important sources of recreational noise is Personal listening devices (PLDs) such as Walkman, cassette player, CD players, and MP3 players (1). PLD use has become one of the commonest daily habits among teenagers and young adults (2). The World Health Organization (WHO) estimates that 1.1 billion young people under 35 years could be at risk of NIHL from unsafe listening practices while using PLDs (3). The output of most PLDs often exceeds safe levels (80 dB) and with prolonged use, it can be considered a health hazard with the later development of NIHL (4, 5). Most PLD users are unaware that they are putting themselves at risk of sensorineural hearing loss (6). High-intensity sounds can cause permanent hearing loss at chronic exposures of an average 85 dB or higher (7). The cochlea contains a limited number of hair cells that, when damaged by noise exposure, they cannot regenerate, resulting in permanent hearing loss (8, 9). It has been found that extended high frequency regions of the cochlea are affected first by acoustic trauma. Both the intensity and duration of noise exposure determine the potential for damage to the hair cells of the inner ear (10). There has been much discussion among researchers regarding the hazards of recreational noise on hearing acuity during adolescence, however, no standard guideline has been presented. Thus, the rationale of our study is to generate an evidence-based protocol to assess and early discover subtle changes in hearing sensitivity after exposure to recreational noise in order to protect the hearing of PAD users.

2. Material and Methods

2.1. Participants and inclusion criteria

This case-control study was conducted on young adults, accompanied with a relative, seeking hearing assessment in the Audiology Unit, Sohag University Hospital, from March 2018 to Jan 2019. We selected 82 young adults as Group I (case group) with the following inclusion criteria: age range from 15 to 20 years, regular use of PADs in the previous 6 months, no hearing complaint, no history of hearing loss, exposure to noise, ototoxic drugs or ear operation. Group II (control group) consisted of 35 young adults with the following inclusion criteria: age from 15 to 20 years, never used PADs, no hearing complaint, no history of hearing loss, no exposure to noise, ototoxic drugs or ear operation. All participants had free otoscopic examination and tympanometry. Regarding the sample size calculation, the 15-20 years age group in Egypt amounts to 17 million, so, the accepted number of cases using PLDs in this age group was estimated to be 62. However, we selected a larger number of cases. The number of controls could be the same as cases or 40% of them so we selected 35 controls.

2.2. Questionnaire and instruments

This was conducted only for the case group. It is a self-administered questionnaire which was used to collect data from the case participants on the PAD device: (type of device, duration of device use, average time of PAD: days per week and hours per day). Participants were also asked about the preferred listening volume of PADs with 5 options 1 (Very Loud), 2 (Somewhat loud), 3 (Loud), 4 (Medium) and 5 (Low Volume). Participants were asked if they experienced any problems immediately after PAD use (tinnitus, hearing loss, earache or irritability). Pure tone audiometry was conducted on the participants in the two groups. It was carried out inside a sound treated room using an audiometer (Interacoustics AD629). The hearing of the all participants was screened at first at frequencies between 0.25 kHz and 8 kHz at 20 dB HL to ensure they had no degree of hearing loss. Extended high frequency (EHF) audiometry was carried out on all participants at frequencies between 10 and16 kHz using headphones for EHF (HDA 200). The maximum output level of the audiometer was taken as the hearing threshold if the participant failed to detect the loudest tone produced by the audiometer. Immitencemetry (Interacoustics AT235) was carried out on all participants to ensure normal middle-ear pressure prior to Otoacoustic Emission (OAE) testing. TEAOE was measured on the all participants using a diagnostic OAE analyzer (Intelligent Hearing Systems, Smart OAE) connected to a portable computer running the Smart OAE software. The participant was seated comfortably in a sound-attenuated booth with limitation of his movements. The probe (Etymotic research, ER-10D) was placed in the external ear canal of the participant with the appropriate-sized ear tip; the fitting was confirmed by the software with in-the-ear calibration. The stimulus is 75 ls clicks (rectangular pulses) with peak equivalent level of 80 dB SPL at the rate of 20 s-1. The number of averages was 1024, the filter was set at 0.5-5 kHz and the time window was 25 minutes with the first 2.5 minutes blanked out. The overall amplitude of the Transient Evoked Otoacoustic Emissions (TEOAE) spectrum and TEOAE amplitudes at four frequency bands (1, 2, 3 and 4 kHz) were determined by the software. The software's artefact rejection setting excluded the unwanted signals. The software also measured the noise floor during the recordings and calculated the corresponding signal-to-noise ratio (SNR) for the emissions. The pass response was considered if the response at a particular frequency pair or frequency band was greater than the noise floor (SNR 0 dB).

2.3. Research ethics

Written informed consent was granted by all the participants after explanation of the reasons for conducting the study. Ethical approval for conducting the study was granted by the Ethics Committee, Medical College. The work was carried out in accordance with the code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans and was approved by the Ethical Committee of the Faculty of Medicine, Sohag University, Egypt (Ref.: 23/2019). The case group was instructed to refrain from listening to their devices for 24 hours prior to the tests.

2.4. Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) software (version 23). Statistical methods used included descriptive analysis (mean, range and standard deviation) significance level in examining the hypotheses was p-value of less than 0.05.

3. Results

3.1. General findings

As regards the gender distribution, there were 50 (60.98%) males and 32 (39.02%) females. In the control group, the number of the participants was 35 with the age range from 15-20 years and the mean age was 16.82±1.21 SD. As regards the gender distribution, there were 22 (62.86%) males and 13 (37.14%) females. Smartphones, for listening to music, were the sole PAD of choice by the entire case group. As regards to the type of earphones, insert phones were being used by 63 (76.83%) and headphones were being used by 19 (23.17%). The duration and frequency of PAD usage is shown in Table 1. When we study the most important problems that occurred immediately after PAD use, tinnitus was first, followed by hearing loss, irritability and finally, earache (Table 2).

Table 1. PAD use characteristics in the case group:

Variable		Males, n (%)	Females, n (%)	Total, n (%)
Duration of PAD usage (year)	< 1	13 (26)	9 (28.13)	22 (26.83)
	1-3	21 (42)	14 (43.75)	35 (42.68)
	> 3	16 (32)	9 (28.13)	25 (30.49)
Days of PAD use/week	0-3 days	17 (34)	9 (28.13)	26 (31.71)
	≥ 4-7 days	33 (66)	23 (71.87)	56 (68.29)
Hours of PAD use/day	≤ 1 hour	17 (34)	13 (40.63)	30 (36.59)
	≥ 1 hours	33 (66)	19 (59.37)	52 (63.41)
PAD Volume preference	Very Loud	19 (38)	13 (40.63)	32 (39.02)
	Somewhat Loud	14 (28)	9 (28.13)	23 (28.05)
	Loud	12 (24)	6 (18.75)	18 (21.95)
	Medium	5 (10)	3 (9.37)	8 (9.76)
	Low	0 (0)	1 (3.12)	1 (1.22)

Table 2. Problems immediately occurs after PAD use:

Questionnaire data		Males, n (%)	Females, n (%)	Total, n (%)
Tinnitus	Very likely	22 (44)	15 (46.88)	37 (45.12)
	Quiet/Somewhat/Likely	15 (30)	10 (31.25)	25 (30.49)
	Unlikely	13 (26)	7 (21.87)	20 (24.39)
Hearing loss	Very likely	11(22)	5 (15.63)	16 (19.51)
	Quite/Somewhat/Likely	29 (58)	21 (65.63)	50 (60.98)
	Unlikely	10 (20)	6 (18.74)	16 (19.51)
Irritability	Very likely	9 (18)	5 (15.63)	14 (17.07)
	Quite/Somewhat/Likely	24 (48)	18 (56.25)	42 (51.23)
	Unlikely	17 (34)	9 (28.12)	26 (31.70)
Earache	Very likely	5 (10)	4 (12.5)	9 (10.98)
	Quite/Somewhat/Likely	23 (46)	19 (59.38)	42 (51.22)
	Unlikely	22 (44)	9 (28.12)	31 (37.80)

3.2. Pure tone audiometry and EHF audiometry

At frequencies between 0.25 kHz and 8 kHz, all participants were shown to be within normal hearing sensitivity with the mean threshold (19.44±4.41 SD for the right ear and 19.61±4.50 SD for the left ear). The odds ratio between case and control groups was 165.00 with a high degree of significance (p=0.0004). The whole case group

showed hearing threshold shift at all frequencies from 10 to 16 KHz for both ears (Table 3). The largest hearing threshold shift occurred in the case group that used PADs for two or more years. In the current study, we found that the greater hearing threshold shift occurred with the PAD group who used it for three or more years mainly in 14 and 16 KHz (Tables 4, 5)

Table 3. The mean & SD of EHF threshold for the right & left ears in both groups

Frequency (kHz)	Mean				SD				p-value
	Control group		Case group		Control group		Case group		
	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear	
10	13.25	13.33	20.97	21.01	4.86	4.90	11.02	11.08	0.0001*
12	25.42	25.62	35.52	35.49	8.94	8.92	18.27	18.30	0.0004*
14	31.22	31.17	39.35	39.41	10.45	10.50	18.02	18.08	0.0043*
16	49.11	49.19	61.78	61.81	17.52	17.48	21.25	21.31	0.0005 *

* There was a highly statistically significant difference in the threshold of EHF in the Control Right ear vs. Case Right ear & between Control left ear vs. Case left ear.

Table 4. The effect of duration of exposure on the mean & SD of EHF thresholds in the case group

Frequency (kHz)	< 3 year		> 3 years		p-value
	Mean	SD	Mean	SD	
10	20.2	11.02	23.01	12.10	0.1220
12	32	16.87	39.24	19.92	0.0130*
14	35.21	18.79	43.25	19.88	0.0086*
16	55.35	22.23	65.21	23.35	0.0063*

* There was a statistically significant difference in the threshold of EHF in the Case group with increasing year of exposure, mainly in 14 & 16 KHz.

Table 5. The correlation between different variables and EHF threshold in the case group

Variable	r	p-value
Years of exposure	0.933	0.00001*
Days of exposure	0.89	0.00001*
Hours of exposure	0.845	0.00001*
Volume of PLDs	0.957	0.00001*

* Strong positive correlation between different variables & EHF threshold.

3.3. Results of OAE

The TEOAE responses were present in all participants of the control group, while in the case group five participants (6.09%) showed no responses; three of whom had bilateral absence of response. The odds ratio for TEOAE response was 1.0649 with no statistically significant differences between case and control groups (p=0.8264). As regards the TEOAE amplitude, the mean amplitude of the overall TEOAE spectrum was lower in the case group compared with the controls. In the right ear, it was 16.85±3.02 dB in the case versus 18.92±3.14 dB in the control with the degree of the significance less than 0.01. In the left ear, it was 16.92±4.28 dB in the case versus 19.01±3.76 in the controls with the degree of the significance less than 0.05.

4. Discussion

The current study was conducted to investigate the patterns of PAD use in young adults and the risk of exposure to recreational noise, to consider the magnitude of the problem and the methods applied to early identify it. The participants selected were young adults with the age range from 15-20 years. In the case group, there was male predominance with a percentage of 60.98%. This was consistent with a study done by Saurav et al. who found that male students were more likely to listen to PADs with greater frequency than female students (11). This can be considered a very dated view in most cultures worldwide. Women are just as likely to be walking, running or riding bicycles. Our findings regarding the average duration of PAD use is in agreement with a cross sectional study done among Iranian adolescent students, which concluded that 33 of them listened to PADs for more than two hours per day (12). Similarly, another study was conducted at a medical college in India and reported that the majority of the students (77.7%) used PADs more than one hour per day (13). However, in the study done by Saurav et al., they concluded that the majority (70%) of the participants were using PADs for less than one hour per day while the rest

were using PADs for two or more hours (11). As regards the PAD volume preference, the largest percentage (39.02%) prefer very loud volume (Table 1). This is in agreement the with study done by Saurav et al. in which they found the preferred mode of listening was very loud in 20% of the case participants (11).

Regarding the most important problems that occurred immediately after PAD use, our findings are similar to a previous study done among US college students in California, which found that tinnitus and hearing loss were observed in 15.9% and 11.2% of the participants respectively (14). This can be explained by the fact that exposure to high and continuous noise can lead to ear affection first (hearing loss & tinnitus) followed by neurological complaints (irritability). In the current study, conventional pure tone audiometry (0.25 to 8 KHz) showed no abnormality among the case group at all frequencies, which is in agreement with Jian et al. who found that the hearing thresholds of the PAD subgroup were significantly higher than those of the control group in the range of 10 to 20 kHz, although they had completely normal hearing thresholds at 0.5 to 8 kHz (15). In another study, the mean hearing thresholds were found to be significantly higher at high frequencies (8-12 KHz) in PLD users compared to control group and more threshold shift was observed in the subgroup who listened for 7 h/week compared with those who listened for 2–7 h/week (16). Young adult PLD users who listened to their devices for 1 h/day had normal thresholds at conventional frequencies but showed elevated thresholds at EHFs (17). This means that the long-term exposure to loud sounds from PADs can appear in the high frequency region even if the conventional PTA appeared within the normal frequency region. Thus, EHF audiometry is more sensitive than conventional frequency audiometry in early detection of NIHL.

The duration of noise exposure is an important factor for NIHL. We found that the greater hearing threshold shift occurred with the PAD group who used it for three or more years mainly in 14 and 16 KHz. This is in agreement with the study done by Jian et al. who concluded that the hearing threshold shift occurred in a broad frequency range and had a high incidence of hearing damage in the subgroup that used PADs for 5 years (15). This revealed that the risk of hearing impairment is increased, the longer the duration of noise exposure (Table 5). The generation of evoked OAEs is attributed to the active outer hair cell (OHC) function (18). In the current study, five participants (6.09%) showed no responses in TEOAE; three of whom had bilateral absence of response. As regards the TEOAE amplitude, it was lower in PLD users than in those of the control group, which indicates an initial damage of their OHCs. In other studies, the occurrence and amplitude of TEOAEs were found to be decreased in regular young PLD users compared with non-users (19, 20). Compared with audiometry, early cochlear damage due to PLD usage may be more readily detected using OAE measurements (20, 21).

5. Strength and limitation of the study

The strengths of this study were the use of both subjective and objective methods for assessing the hazards of PLDs on the users. However, there were study limitations such as the number of participants, which requires a larger population when in order to generalize our findings. Also, there were limitations at various stages of the research including the fact that some participants failed to complete the whole test, and thus were replaced.

6. Conclusions

The long-term use of PLDs can induce NIHL. This could translate into a global hearing health problem. A standard screening protocol consisting of a questionnaire, EHF audiometry and TEOAE should be performed routinely for PLD users who use the devices for 3 years or more. Our study recommends preventive tools such as educational lectures, posters and campaigns directed at PLD users in order to educate them regarding the safe mode for listening to PLDs by decreasing the duration and intensity of use. In addition, it would be beneficial that the audiologist perform a screening protocol consisting of a questionnaire, EHF audiometry and TEOAE to early identify NIHL in PLDs users.

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Conflict of Interest:
There is no conflict of interest to be declared.

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