Impact of Usage of Personal Music Systems on Oto-Acoustic Emissions Among Medical Students

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Abstract

Background: Intact hearing is essential for medical students and physicians for communicating with patients and appreciating internal sounds with a stethoscope. With the increased use of personal music systems (PMSs), they are exposed to high sound levels and are at risk of developing hearing loss. The effect of long-term personal music system (PMS) usage on auditory sensitivity has been well established. Our study has reported the immediate and short-term effect of PMS usage on hearing especially among medical professionals. Objective: To assess the effect of short-term PMS usage on distortion product otoacoustic emissions (DPOAE) among medical professionals. Materials and Method: 34 medical students within the age range of 17–22 years who were regular users of PMS participated in the study. All participants had hearing thresholds <15 dBHL at audiometric octave frequencies. Baseline DPOAEs were measured in all participants after 18 h of non-usage of PMS. One week later DPOAEs were again measured after two hours of continuous listening to PMS. DPOAEs were measured within the frequency range of 2 to 12 kHz with a resolution of 12 points per octave. Output sound pressure level of the PMS of each participant was measured in HA-1 coupler and it was converted to free field SPL using the transformations of RECD and REUG. Results: Paired sample t test was used to investigate the main effect of short-term music listening on DPOAE amplitudes. Analysis revealed no significant main effect of music listening on DPOAE amplitudes at the octave frequencies between 2 to 4 kHz ($t_{27} = -1.02, P = 0.31$) and 4 to 8 kHz ($t_{27} = 0.24, P = 0.81$). However, there was a small but statistically significant reduction in DPOAE amplitude ($t_{27} = 2.10, P = 0.04$) in the frequency range of 9 to 12 kHz following short-term usage of PMS. The mean output sound pressure level of the PMS was 98.29. Conclusion: Short-term exposure to music affects the DPOAE amplitude at high frequencies and this serves as an early indicator for noise-induced hearing loss (NIHL). Analysis of output sound pressure level suggests that the PMSs of the participants have the capability to induce hearing loss if the individual listened to it at the maximum volume setting. Hence, the medical professionals need to be cautious while using PMS.

Keywords: Distortion product otoacoustic emissions, noise-induced hearing loss, oto-acoustic emissions, personal music system

INTRODUCTION

Intact hearing is essential for medical students and physicians for communicating with patients and appreciating internal sounds with a stethoscope. With the increased use of personal music systems (PMSs), they are exposed to high sound levels and are at risk of developing hearing loss. Along with increased usage, most adolescents played music on PMSs at the maximum volume. The majority of students listening to music at loud volumes experienced tinnitus, which is an early sign of hearing loss. However, they often fail to report about tinnitus because it was transient, which is a cause of concern among medical professionals.

Several studies have measured the sound pressure level in PMSs. Two decades ago Katz et al. warned us that stereo earphones could deliver sound pressure levels up to 120 dBA.[5] Later, it was reported that portable headphone cassette radios produced peak outputs of 90–104 dB.[6] Ising et al. measured the sound pressure level of PMS used by students and the sound levels measured as free field-corrected short time, ranging between 60 and 110 dBA.[7] Smith et al. reported that 72.6% of the participants in their study, preferred to listen to PMS at 74 dBA and 6.9% of participants preferred to listen at the level more than 90 dBA.[8] Hodgetts et al. measured the preferred sound levels for PMS. They measured the dBA weighted sound pressure...
levels of various commercially available MP3 players with different types of earphones (ear bud, over-the-ear, and over-the-ear with noise reduction circuitry). Preferred listening levels for the participants of the study ranged from 75 to 78 dBA for different types of earphones. Airo et al. measured the output sound pressure levels of PMS at a volume control setting, that is preferred by the listeners in quiet and in the presence of background noise. They reported that PMS were able to produce high sound levels, but the usual listening levels set by the users were not hazardous. However, the output sound pressure levels on average exceeded 85 dBA in the presence of noise indicating a potential risk for developing noise-induced hearing loss (NIHL) if PMS is used in a noisy setting, that is preferred by the listeners in quiet and in the presence of background noise. They reported that PMS were able to produce high sound levels, but the usual listening levels set by the users were not hazardous. However, the output sound pressure levels on average exceeded 85 dBA in the presence of noise indicating a potential risk for developing noise-induced hearing loss (NIHL) if PMS is used in a noisy situation. Fligor and Cox reported that output levels of PMS could be as high as 121 dBA indicating a possible risk for developing NIHL. These findings are further substantiated by Sulaiman et al. who found a positive correlation with the sound exposure level from PMS and the hearing thresholds at extended high frequencies.

There are growing concerns over noise exposure through PMS usage without adopting necessary caution. Loud music exposure for an extended period of time can pose a risk of permanent hearing loss, ringing in the ears, difficulties in understanding speech in noisy surroundings, memory issues, and learning problems. Meyer-Bisch reported significantly poorer pure tone hearing thresholds in individuals using PMS for more than 7 h/week. Similarly, 7.3% of the PMS users exhibited significant hearing loss at the conventional audiometric test frequency. The effects of indiscriminant use of loud music on hearing may not be evident instantly but develops over a course of time. The effects of noise on hearing are permanent, but NIHL is preventable, and so it is mandatory to adopt preventive measures. Moreover, the affected individual is unaware of the noise damage in the initial stages because the noise affects the frequencies higher than speech range initially before hearing threshold changes in the speech frequencies. Hence, it is mandatory that a person exposed to loud noise undergo audiological screening programs.

Vogel et al. opined that the dangerous decibel levels should be provided to the users of PMSs, along with the suitable usage times. The MP3 players should have an indicator of the volume output level in decibels and a signal to warn them when harmful levels are reached. Further, the manufactures of the MP3 players should be constrained by the law to install a sound limit on the MP3 players. Hence, today’s smart phones provide the safety limits. Unfortunately, sound pressure level of PMS is a product of both the PMS output and the earphones used. So PMS volume limit often does not perfectly predict the sound pressure delivered to the listener. To appreciate the music better, often individuals ignore the safety limits and/or use amplified headphones. In a recent study by Jiang et al., it was found that more than 50% of the participants exceeded the 100% daily noise dose.

The oto-acoustic emissions (OAEs) are a direct reflection of the outer hair cell function and any changes can be picked up even before they are seen in conventional pure tone audiometry. Owing to their objectivity and sensitivity, OAEs are effective in detecting the NIHL even before the changes are seen in auditory sensitivity and hence is an ideal tool to assess auditory effects of noise before or after noise exposure. LePage and Murray measured the transient evoked oto-acoustic emission (TEOAE) in 700 PMS users and reported reduced amplitude. SANTAOLALLA MONTOYA et al. compared the amplitude of TEOAE and distortion product oto-acoustic emissions (DPOAEs) in users and non-users of PMS. PMS users exhibited reduced amplitude in both types of OAEs. Music listening has a cumulative effect on the OAEs over a period of time. Regular evaluation of the OAE function can detect these subtle changes at an earlier stage, before hearing loss sets in.

Previous literature has revealed that hearing loss among physicians is common, but they may not report or notice the change. Any changes in hearing sensitivity may affect the diagnosis and in turn treatment given to patients. Hence, the study was taken up to study the effect of short-term PMS usage on DPOAE among medical professionals.

In a similar study by TRZASKOWSKI et al., it was found that there were no changes in the OAE parameters after 30 min of noise exposure (86.8 dBA). Because the participants of our study used their PMS for an average duration of 2 h, the DPOAE was measured before and 2 h after PMS usage to check the outer hair cell function.

**Materials and Methods**

**Participants**

Thirty-four medical students of the age group 17–21 of Kasturba Medical College, India who were regular users of PMS and had no gross otological or neurological deficit took part in the study. Written consent was obtained from all the subjects, and the study protocol was approved by the institutional ethical review board.

**Instruments**

The hearing sensitivity was assessed using a GSI 61 (Grason-Stadler Inc., Eden Prairie, MN, USA) two-channel diagnostic audiometer. The immittance analysis was performed using the GSI Tympstar (Grason-Stadler Inc., Eden Prairie, MN, USA) Middle Ear Analyzer, version 2. The external ear canal and the tympanic membrane were visualized using an Otoscope (Welch Allyn, Skaneateles Falls, NY, USA). A computer based DPOAE analyzer (Grason-Stadler Inc., Eden Prairie, MN, USA) (GSI AUDERA) was used to record the DPOAEs. The Affinity 440 (Interacoustics, Middelfart, Denmark) HIT module was used to measure the output sound pressure level of the PMS used by the participants.
Procedure

The participant fulfilling the inclusion criteria were assessed using DPOAEs before and after listening to their PMS. The frequency range assessed was 2–12 kHz, and the Distortion Product (DP) gram was obtained at the resolution of 12 points/octave. $F_2/F_1$ frequency ratio was 1.22 and the intensity values of the $F_1$ and $F_2$ were 65 and 55 dBSPL, respectively. DPOAE was performed on the subjects two times, once before using the PMS (minimum 18 h of nonuse) and once immediately following 2 h of use. Measurements were conducted in a soundproof room using calibrated equipment. Participants were seated comfortably in a chair and participants were instructed to relax and avoid physical movements.

Output sound pressure level of the PMS was measured in HA-1 2CC coupler using Affinity 440 HIT module. Participants were asked to play one of their frequently used sound tracks, and they were asked to adjust it to the maximum volume control setting. The earphone was coupled to the HA1 coupler using putty, and adequate sealing was ensured. Output sound pressure level was analyzed within the frequency range of 200–8000 Hz using 1/16th octave band analyzer. Root mean square amplitude values were estimated in the discrete bands with each having the bandwidth of a 1/16th octave. Output sound pressure level of PMS was estimated as the highest dBSPL among the 1/16th octave wide narrow bands (peak SPL). Further, this coupler SPL was converted to free field SPL using the transformations of the real ear to coupler field SPL using the transformations of the real ear to coupler difference and real ear unaided gain. This procedure was followed to measure the maximum capability of the PMS that the participant used.

Results

The outer hair cell function was accessed using DPOAEs among medical students in the age group of 17–21 years. DPOAE responses were analyzed in 32 frequencies which were logarithmically spaced between 2 and 12 kHz at 12 points/octave. DPOAE responses were considered to be present when DP amplitude was ≥−10 dBSPL and Sound to Noise Ratio (SNR) was ≥6 dB. Data points, which did not meet the above criteria, were excluded from the analysis. No abnormality in the OAEs was found when they were tested after 18 h of nonuse (pre-exposure). So the outer hair cell function of PMS users was found to be normal.

Grand average DP gram was obtained by averaging the DP amplitude and noise floor from all the participants. Figure 1 depicts the grand average DP gram of before and after music listening. DP amplitude at frequencies falling in one octave was averaged to get the single estimate of DP amplitude per octave. Paired sample t test was used to investigate the significant main effect of music listening on DPOAE amplitudes at each octave frequencies. Analysis revealed no significant main effect of music listening on DPOAE amplitudes at the octave frequencies between 2 and 4 kHz ($t_{67} = -1.02, P = 0.31$), 4 and 8 kHz ($t_{67} = 0.24, P = 0.81$). Mean and standard deviation DPOAE amplitude before and after music exposure are given in Table 1.

It was evident in the grand averaged DP gram that, post-exposure DP amplitudes above 9000 Hz were slightly smaller than pre-exposure DP amplitude. Hence, DP amplitudes above 9000 Hz were averaged to get a single estimate which would be referred as high frequency DP (HF-DP) in the following sections. Paired “t” test was used to investigate the difference between pre-exposure HF-DP and post-exposure HF-DP. There was a significant main effect of short-term music exposure on HF-DP ($t = 2.10, P = 0.04$). Short-term music exposure resulted in small but statistically significant reduction of HF-DP. Figure 2 depicts mean and standard deviation of HF-DP before and after music exposure.

Fine spectral analysis was performed for DP gram of both pre-exposure and post-exposure data. The fine spectral analysis was performed for the whole frequency range, that is, from 2 to 12 kHz. The ripples in the DP gram were used as a metric to quantify the fine spectrum of DP gram. Ripple was quantified by inspecting the local “minimas” and “maximas”. The ripple was said to be present when the maxima to minima difference was 20 dB. Ripple density was estimated by counting the number of ripples. Paired samples “t” test was conducted to investigate the significant main effect of music exposure on ripple density of the DP gram. The results revealed a significant main effect of music exposure on ripple density of DP gram ($t = 2.21, P = 0.05$). The mean ± standard deviation values

![Figure 1: Grand average DP gram before and after music exposure. This was obtained by averaging the DP amplitude and noise floor from all the participants.](image)

| Frequency | Pre-exposure | Post-exposure |
|-----------|--------------|---------------|
|           | Mean | Standard deviation | Mean | Standard deviation |
| 2–4 kHz   | 5.02 | 5.98           | 5.5  | 5.79           |
| 4–8 kHz   | -2.13| 4.51           | -2.25| 5.20           |

Table 1: Mean and standard deviation DPOAE amplitude, before and after music exposure.
The DPOAE amplitudes were further assessed after 2 h of continuous exposure to music. When compared to the pre-exposure data results, it was revealed that short-term music exposure did not affect the low frequency DPOAE amplitudes, that is, 2–8 kHz. But the HF-DP was reduced, and this was found to be statistically significant. So it can be concluded that short-term music exposure affects high frequencies. These findings are in consonance with the earlier reports.\textsuperscript{13,18} Sliwinska-Kowalska and Davis opined that personal music players were found to be one of the major sources of noise exposure in teenagers. They also concluded that 5–10% of young listeners of personal music devices are at a high risk of developing hearing loss after 5 or more years of exposure.\textsuperscript{11} In the current study, the DPOAE changes were observed beyond routine audiometric frequencies (2–8 kHz), which are often not incorporated in the routine hearing evaluation. Moreover with greater contribution of routine frequencies during speech communication, the effects on higher frequencies are not experienced by the listeners until lower frequencies are involved. As seen in our study, short-term exposure to music affects the high frequencies and this serves as an early indicator for NIHL. Somma et al.’s suggestions are also in line with this observation.\textsuperscript{25} These higher frequencies are essential for localization and perception of music.

Rawool indicated that in early NIHL, there is a dip in the routine audiogram in the region of 3000–6000 Hz.\textsuperscript{26} Because the damage progresses, there is progressive hearing loss on either side of this region, with usually the higher frequencies being more affected. However our observation was that the DPOAE changes were prominent at frequencies beyond routine audiometric frequencies. OAEs begin to decrease before hearing thresholds increase, and so it is possible that OAEs may help to predict future hearing loss.\textsuperscript{27,28} Attias et al. also showed that OAEs reveal subtle cochlear changes that may be overlooked in a normal audiogram.\textsuperscript{115} Hence the changes observed in the present study warrant precautionary measures to be adopted; especially, because the prevention of NIHL is the best policy to be advocated.

The effect of music exposure on hearing sensitivity is usually estimated using the traditional audiometric procedure by identifying the presence of a dip in the region of 3–6 kHz in the audiometric thresholds. However, procedures such as high frequency audiometry and OAEs are employed for measuring the effect of music exposure on hearing function. The results of the present study revealed that fine spectral details of DP gram were affected post short-term music exposure. Therefore, fine spectral details of the DP gram can be employed as a measure for estimating the effect of music exposure on hearing sensitivity. The present study was conducted to measure the immediate effect of music exposure on hearing sensitivity, which may not reflect the temporary/permanent nature of effect. Future research can be directed to quantify the recovery pattern of fine spectral details of DP gram if any. The sound pressure levels of PMSs indicate that they have the capability to induce hearing loss. Hence, from our study, we can ascertain that it is important for people in the medical profession to reduce or modify the usage of earphones. This can be brought into effect by creating awareness among them and explaining the harmful effects of excessive PMS usage and identifying the early warning signs of hearing loss such as tinnitus. They can be further counseled about the lifestyle modifications that they can incorporate. Isolator type\textsuperscript{29} and noise-canceling earphones can be used in noisy environments so that volume levels need not be increased. If not, they should restrain only to using their PMS in quiet environments. People who are exposed to frequent rock concerts should also adopt preventive measures such as using musician’s earplugs. The “80–90” rule by Portnuff,\textsuperscript{29} suggests that people can use their PMS for 90 min a day at 80% of the maximum volume to reduce hearing loss. Listening can be prolonged with lower noise levels.

The output sound pressure level could not be evaluated for all the participants. Only 22 participants consented to measure the output sound pressure level for their PMS. The mean and standard deviation of the sound pressure levels were 98.29 and 10.47 dBSPL, respectively. This result suggests that the PMS that the participants used have the capability to induce hearing loss if the individual listened to it at the maximum volume setting.

**DISCUSSION**

The present study was conducted to assess the outer hair cell function in PMS users, before and after exposure to music. The DPOAE testing was performed for this purpose, and it was found that the outer hair cell functions were normal in users of PMS after a minimum of 18 h of nonuse, indicating that the 18 h rest period was sufficient to return to base line threshold in this group, with age ranging from 17 to 21 years.

The DPOAE amplitudes were further assessed after 2 h of continuous exposure to music. When compared to the pre-exposure data results, it was revealed that short-term music exposure did not affect the low frequency DPOAE amplitudes, that is, 2–8 kHz. But the HF-DP was reduced, and this was found to be statistically significant. So it can be concluded that short-term music exposure affects high frequencies. These findings are in consonance with the earlier reports.\textsuperscript{13,18} Sliwinska-Kowalska and Davis opined that personal music players were found to be one of the major sources of noise exposure in teenagers. They also concluded that 5–10% of young listeners of personal music devices are at a high risk of developing hearing loss after 5 or more years of exposure.\textsuperscript{11} In the current study, the DPOAE changes were observed beyond routine audiometric frequencies (2–8 kHz), which are often not incorporated in the routine hearing evaluation. Moreover with greater contribution of routine frequencies during speech communication, the effects on higher frequencies are not experienced by the listeners until lower frequencies are involved. As seen in our study, short-term exposure to music affects the high frequencies and this serves as an early indicator for NIHL. Somma et al.’s suggestions are also in line with this observation.\textsuperscript{25} These higher frequencies are essential for localization and perception of music.

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volumes and volume levels can be increased with shorter durations of listening. These changes will prevent them from getting NIHL in the future, will allow them to communicate better with patients as well, and make better use of the stethoscope.

The findings need to be strengthened by including a larger sample and also by considering the level of music that the person is exposed to. The results of the study strongly indicate the need for incorporating higher frequencies during the routine hearing evaluation to pick up early signals of damage.

CONCLUSION

This study was conducted to examine the effect of using PMSs on hearing among medical students. The DPOAE was measured on two occasions, the first after 18 h of non usage of PMS and then after 2 h of continuous listening. It was observed that the DPOAEs were affected in the individuals immediately after using PMS, and this was observed at frequencies beyond 8 kHz. It is hence recommended to use PMSs with caution and also for its users to undergo hearing evaluation at regular intervals.

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Conflicts of interest

There are no conflicts of interest.

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