Original Research

Hearing risk associated with the usage of personal listening devices among urban high school students in Malaysia

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A B S T R A C T

Objectives: To investigate listening habits and hearing risks associated with the use of personal listening devices among urban high school students in Malaysia.

Study design: Cross-sectional, descriptive study.

Methods: In total, 177 personal listening device users (13–16 years old) were interviewed to elicit their listening habits (e.g., listening duration, volume setting) and symptoms of hearing loss. Their listening levels were also determined by asking them to set their usual listening volume on an Apple iPod™ playing a pre-selected song. The iPod’s sound output was measured with an artificial ear connected to a sound level meter. Subjects also underwent pure tone audiometry to ascertain their hearing thresholds at standard frequencies (0.5–8 kHz) and extended high frequencies (9–16 kHz).

Results: The mean measured listening level and listening duration for all subjects were 72.2 dBA and 1.2 h/day, respectively. Their self-reported listening levels were highly correlated with the measured levels \((P<0.001)\). Subjects who listened at higher volumes also tend to listen for longer durations \((P=0.012)\). Male subjects listened at a significantly higher volume than female subjects \((P=0.008)\). When sound exposure levels were compared with the recommended occupational noise exposure limit, 4.5% of subjects were found to be listening at levels which require mandatory hearing protection in the occupational setting. Hearing loss \((>25 \text{ dB hearing level at one or more standard test frequencies})\) was detected in 7.3% of subjects. Subjects’ sound exposure levels from the devices were positively correlated with their hearing thresholds at two of the extended high frequencies (11.2 and 14 kHz), which could indicate an early stage of noise-induced hearing loss.

Conclusions: Although the average high school student listened at safe levels, a small percentage of listeners were exposed to harmful sound levels. Preventive measures are needed to avoid permanent hearing damage in high-risk listeners.

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Introduction

The usage of personal listening devices (PLDs) such as mp3 players and mobile phones with a music playback function has become increasingly popular worldwide, with estimated sales of 245 million units in 2012. New-generation PLDs have a long battery life, permit storage of a large number of songs, and are capable of producing high sound output levels without distortion. These features allow current PLD users to listen for longer durations and at higher volumes. The high-risk users are teenagers and young adults; prolonged exposure to loud music in these listeners could potentially damage their hearing. Compared with non-users, PLD levels for acquiring noise-induced hearing loss (NIHL), even if hearing loss becomes a must-have gadget for Malaysian teenagers. This study investigated listening habits associated with the use of PLDs in a group of urban high school students in Klang Valley, Malaysia and evaluated the impact on their hearing.

Methods

Subjects

Subjects aged 13–16 years were recruited from three schools selected at random from a list of high schools located within 20 km of the authors’ university. The appropriate sample size was calculated based on Krejcie and Morgan’s sample size determination table. Study participants responded to flyers distributed in classrooms. They had to be regular users of a PLD coupled with either a headphone or earphone for the previous six months. Participation was voluntary and students were allowed to withdraw from the study at any time.

Participants were initially subjected to a face-to-face interview to elicit demographic data and details on PLD usage (type of device used, duration of usage and average listening time per day). Subjects were also asked if they had experienced tinnitus, difficulty in hearing others or ear pain immediately after PLD usage. Those with exposure to other sources of loud noises (e.g. discotheque, concert, school band, noisy tools, home stereo) at least twice per month and prior ear problems were excluded from the study.

Estimation of listening levels

Subjects’ listening levels were estimated using two different methods: self-reported volumes and measured volumes. For self-reported volumes, subjects were asked to mark their usual listening volume on a 5.5-cm horizontal line that corresponded to 0–100% of the volume setting on their device, and the values were reported as percentage from maximum volume setting. Measured volumes were obtained by asking subjects to set the volume of an Apple iPod Nano (Apple Inc., Cupertino, CA, USA; fourth generation) while listening to the first 40 s of a preselected song (‘Just like Heaven’ by The Cure, mp3 format, 128 kbps bit rate), and measuring the actual output level of the song in decibels. This song was chosen because it was popular and the initial 40 s non-vocal component has a steady beat with minimal amplitude fluctuation (the silent lead-in period was edited out). During the test, subjects were blinded from the iPod volume setting and told to set it to their usual listening level without considering preference to the test song. The iPod Nano was coupled with an insert earphone (Sony MDR-EX51LP, Tokyo, Japan) and the test was conducted in a quiet environment with 40–50 dBA ambient noise level. The selected music level from the test earphone was measured for 40 s using an artificial ear (KEMAR ear- and cheek simulator, G.R.A.S. Sound and Vibration, 43AG, Holte, Denmark) connected to a type 1 integrating sound level meter (Norsonic, nor140, Tranby, Norway).

Calculation of hearing risk

To determine hearing risk, subjects’ measured listening levels were compared with internationally recommended occupational noise exposure safety limits for prevention of NIHL. These recommendations are expressed as time-weighted averages in A-weighted sound levels (dBA), calculated based on continuous exposure to free-field noise for 8 h/day. For comparison with occupational standards, 1/3 octave frequency band sound levels (0.025–10 kHz) measured from the artificial ear were transformed to equivalent A-weighted free field levels (L) as described in an earlier study. Following the method used by others, the 8-h equivalent continuous sound level (L) was calculated using the following formula:

\[ L_{A_{eq8h}} = L_r + 10 \log_{10}(T_f/8) \]

where \( L_r \) is the free-field corrected measured listening level (dBA), and \( T_f \) is the average daily listening duration (h/day).

Measurement of hearing thresholds

All subjects underwent autoscopic examination and tympanometry (Amplivox, Oтовave 102, Oxford, UK) to establish normal external and middle ear functions. Pure-tone audiometry was performed using a precalibrated high-frequency diagnostic audiometer (Siemens hearing instruments, SD28HF, Crawley, West Sussex, UK). Hearing thresholds were established at standard frequencies (0.5, 1.0, 2.0, 3.0, 4.0, 6.0 and 8.0 kHz) and extended high frequencies (9.0, 10.0, 11.2, 12.5, 14.0 and 16.0 kHz) for both ears using the
modified Hughson–Westlake procedure and expressed in decibels hearing level (dB HL). Following criteria used by others,
 subjects’ audiograms were analysed descriptively for incidence of hearing loss (≥25 dB HL at one or more of the standard frequencies (0.5–8.0 kHz) in either ear) and for evidence of high-frequency notches (≥10 dB threshold elevation at 3–6 kHz compared with the adjacent frequencies). Hearing tests were conducted using a portable audiometric test booth placed inside a quiet room in the schools, and sound levels inside the booth conformed to permissible levels for audiometric testing specified by the Department of Occupational Safety and Health, Malaysia. Subjects were requested to refrain from listening to their PLDs for 24 h prior to the hearing test.

**Statistical methods**

Data were analysed using Statistical Package for Social Sciences Version 17.0 (SPSS Inc., Chicago, IL, USA). Descriptive analysis (mean, range and standard deviation) was used to describe the following variables; subjects’ age, listening duration, self-reported volume setting and measured listening level. Unpaired Student’s t-test was used to compare listening levels and listening durations between male and female subjects. Pearson’s correlation test was used to analyse the association between subjects’ self-reported and measured listening levels, listening levels and listening durations, as well as subjects’ L_{Aeq8h} exposure levels and hearing thresholds at individual test frequencies. Chi-squared test was used to compare the occurrence of hearing-related symptoms for different L_{Aeq8h} exposure levels. The significance level was set at P <0.05.

**Results**

After excluding eight subjects due to ear abnormalities and prior ear problems, 177 subjects with a mean (±standard deviation) age of 15.2 ± 1.1 years were included in this study. The majority of participants reported using more than one type of PLD. The most commonly used PLDs were mobile phones (51% of subjects), followed by mp3 players (36%), laptops (17%) and CD players (1%). The average duration of PLD usage for all subjects was 2.49 ± 1.48 years.

The mean measured listening level and listening duration for all subjects were 72.2 ± 11.1 dBA and 1.2 ± 1.5 h/day, respectively. The self-reported volume settings of the subjects were significantly correlated with their measured listening levels (Pearson correlation, r = 0.716, P < 0.001). In addition, subjects who listened at higher volumes tend to listen for longer durations (Pearson correlation, r = 0.188, P = 0.012). When the self-reported and measured volume settings were compared between genders, male students were found to listen at louder volumes compared with female students (Table 1). However, the average listening durations of both groups were similar.

The calculated L_{Aeq8h} exposure levels in all subjects were normally distributed with a mean of 61.6 ± 12.9 dBA and a median of 60.5 dBA (Fig. 1). From the total number of subjects, 17.5% (13 males and 18 females) were exposed to L_{Aeq8h} levels of >75 dBA, which carries a risk of NIHL. In addition, 4.5% (three males and five females) of subjects were exposed to L_{Aeq8h} levels of ≥85 dBA, which is considered high risk, requiring mandatory hearing protection in an occupational setting.

In total, 20.9% of subjects reported having tinnitus, 21.5% had difficulty hearing others and 16.4% experienced ear pain immediately after PLD use. In order to examine the relationship between sound exposure from PLDs and these symptoms, subjects were divided into two groups based to their L_{Aeq8h} exposure levels (<75 and >75 dBA). The occurrence of these symptoms was not increased when L_{Aeq8h} exposure levels exceeded 75 dBA (Table 2).

Hearing loss was found in 13 subjects (7.3%), 12 of whom had mild hearing loss (25–40 dBA). Five of the 12 subjects had bilateral ear involvement. One subject with an L_{Aeq8h} exposure level of 62.7 dBA had moderate hearing loss (40–70 dB HL) at 6 and 8 kHz in his left ear, and at 8 kHz in his right ear. Seven subjects (3.9%) had notched audiograms (all were unilateral cases). Further statistical analysis showed no significant association between subjects’ L_{Aeq8h} exposure levels and the incidence of hearing loss, or the occurrence of notched audiograms.

When subjects’ hearing thresholds for right and left ears were pooled together at each test frequency and compared with individual L_{Aeq8h} exposure levels, there were weak but significant correlations between L_{Aeq8h} levels and hearing thresholds at 11.2 and 14 kHz (Table 3).

**Discussion**

With the increasing popularity of PLDs among teenagers, there is growing concern regarding the risk of hearing damage by improper use of these devices. Detailed population studies about the usage of current PLDs among adolescents and their possible impact on hearing, is limited. Prior studies involved small groups of PLD users and it is difficult to generalize their conclusions for other populations. The present study investigated the usage pattern of PLDs in a group of Malaysian high school students, and evaluated the potential risks of leisure ‘noise’ exposure on their hearing.

| Table 1 – Summary of data regarding usage of personal listening devices. |
|---------------------------------|-----------------|-----------------|-----------------|
|                                | Male            | Female          | P-value         |
| Subjects, n (%)                | 62 (35.0)       | 115 (65.0)      |                 |
| Listening time (h/day)         | 1.2 ± 1.3       | 1.2 ± 1.6       | 0.772           |
| Range                          | (0.1–6.0)       | (0.1–10.0)      |                 |
| Self-reported volume setting (% from maximum) | 64.3 ± 22.6 | 55.3 ± 17.7 | 0.004<sup>b</sup> |
| Range                          | (6–100)         | (13–100)        |                 |
| Measured volume level (dBA)<sup>a</sup> | 75.2 ± 10.6 | 70.6 ± 11.0 | 0.008<sup>c</sup> |
| Range                          | (56.1–94.0)     | (43.0–94.0)     |                 |

SD, standard deviation.

<sup>a</sup> A-weighted free-field equivalent sound levels.

<sup>b</sup> Statistically significant.

<sup>c</sup> Statistically significant.
Listening habits and hearing risk

Subjects’ listening habits differed from the listening patterns described in other populations in several ways. The average measured listening volume obtained in the study subjects was approximately 4 dB higher than mean listening levels in a quiet background reported by two recent studies of Canadian high school students (age 10–17 years)\(^{23}\) and a group of teenagers (age 13–17 years) in Colorado, USA,\(^{6}\) but was approximately 10 dB lower compared with teenagers (age 13–17 years) in Israel.\(^{24}\) The variations in listening levels in different populations could be due to a multitude of sociocultural factors, including the level of knowledge and attitude of users regarding the risk associated with PLD usage.\(^{6,12}\) In addition, the average listening level in the study subjects was higher compared with listening levels in a quiet environment found among older subjects in other studies.\(^{21,22}\) This finding is consistent with the notion that teenagers tend to listen to their PLDs at louder volumes compared with adults.\(^{6,12,21}\)

The average listening duration of students in this study (1.2 h/day) was also shorter compared with the average 1.5–3.0 h/day reported in other studies involving teenagers and adult listeners.\(^{3,5,6,18,19}\) At all three schools included in the present study, students were not allowed to use PLDs during school hours. Hence, the only time that the students were able to listen to their devices was outside school hours and at weekends, which explains their shorter listening durations compared with other populations.

This study found that male students were listening to their PLDs at volumes approximately 5 dB louder compared with female students. This finding agrees with other studies which showed a similar trend in high school students\(^{12,23}\) and young adults.\(^{5,19,22}\) The louder listening volumes of male subjects has been attributed to their higher risk-taking behaviour.\(^{25}\)

Based on the calculated \(L_{Aeq8h}\) levels, approximately 4.5% of the subjects were exposed to potentially damaging sound levels (\(\geq 85\) dBA), which appears to be lower than the estimated proportion of high-risk PLD users in other studies.\(^{5,17,18,24}\) As the \(L_{Aeq8h}\) levels take into account the listening time, the lower duration of listening in the subjects in the present study should reduce the overall percentage of high-risk users. In addition, it is known that listeners tend to increase their listening levels in the presence of background noise.\(^{5,19,27}\) While listening levels in the present study were measured in a quiet background, which

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>(L_{Aeq8h}) (dBA)</th>
<th>(\leq 75)</th>
<th>(&gt; 75)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tinnitus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>30 (16.9%)</td>
<td>7 (4.0%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>116 (65.5%)</td>
<td>24 (13.6%)</td>
<td></td>
</tr>
<tr>
<td>(\chi^2 = 0.064)</td>
<td>(df = 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(P = 0.800)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty hearing others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>30 (16.9%)</td>
<td>8 (4.6%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>116 (65.5%)</td>
<td>23 (13.0%)</td>
<td></td>
</tr>
<tr>
<td>(\chi^2 = 0.419)</td>
<td>(df = 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(P = 0.517)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>24 (13.6%)</td>
<td>5 (2.8%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>122 (68.9%)</td>
<td>26 (14.7%)</td>
<td></td>
</tr>
<tr>
<td>(\chi^2 = 0.002)</td>
<td>(df = 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(P = 0.966)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Although subjects’ hearing thresholds at standard frequencies were slightly higher than the expected incidence of hearing loss, occurrence of notched audiograms (at 3 kHz), 10 but the study methods were criticized for biased selection of controls. 26 However, other studies found no significant differences in hearing thresholds (up to 8 kHz) of PLD users compared with non-users. 27 Hearing thresholds of PLD users were mainly within the normal range 21 and were not correlated with listening levels and durations. 20

The present study did not find any clear signs of NIHL among the subjects, including in those exposed to unsafe sound levels. Although 7.3% of the subjects had >25 dB hearing loss at one or more standard test frequencies, this is only slightly higher than the expected incidence of hearing loss based on a similar criterion in this age group. 28 While 3.9% of subjects had audiogram notches at 3–6 kHz which is considered indicative of NIHL, 29 these notches were only found unilaterally. Furthermore, no significant relationship was found when the L_{Aeq8h} exposure levels in individual subjects were compared with the presence of hearing-related symptoms, incidence of hearing loss, occurrence of notched audiograms and hearing thresholds at any of the standard test frequencies.

NIHL due to exposure to continuous loud sound levels is typically a cumulative process, gradually worsening over time. It is estimated that hearing loss due to exposure to L_{Aeq8h} >85 dBA will be evident after at least five years of exposure. 2 As the average listening duration of the subjects was only 2.6 years, it is likely that hearing damage, if any, is still at an early stage in the majority of subjects. Early-stage hearing loss in PLD users can involve subtle cochlear outer hair cell damage 37,8 which may not be noticed in standard audiometry. Although subjects’ hearing thresholds at standard frequencies did not correlate with their L_{Aeq8h} exposure levels, positive correlation was found between exposure levels and thresholds at two of the extended high frequencies. This finding is critical as it has been suggested that the threshold deterioration at extended high frequencies (>8 kHz) is an early indicator of NIHL. 10

Recommendations

While this study indicates that the average high school student listens to their PLD at a safe level, a significant number of subjects listen at levels that carry risk of NIHL. There is a need for a larger population study to further characterize listening patterns of PLD users and identify likely listeners who are at risk. In addition, long-term impact of PLD usage on hearing should be assessed using longitudinal follow-up studies.

As NIHL is a permanent disability, preventive steps should be taken to reduce possible hearing impairment associated with excessive sound exposure from PLDs. PLD manufacturers should always include a cautionary statement regarding the risk of hearing damage related to listening at a high volume in PLD user manuals. It may also be necessary to introduce legal sound limits for PLDs, as is the case in France (maximum output of 100 dBA). Besides including optional volume limiters, it has been suggested that PLD manufacturers should include visual warning indicators for unsafe levels. 29 Finally, it is important to educate PLD users regarding hearing health and safe listening behaviour. 12,13 In line with this, the authors are presently developing an educational outreach programme to promote safe listening habits among high school students in Malaysia.
Competing interests

None declared.

REFERENCES