Headphone Listening Habits and Hearing Thresholds in Swedish Adolescents

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Abstract

Introduction: The aim of this study was to investigate self-reported hearing and portable music listening habits, measured hearing function and music exposure levels in Swedish adolescents. The study was divided into two parts. Materials and Methods: The first part included 280 adolescents, who were 17 years of age and focused on self-reported data on subjective hearing problems and listening habits regarding portable music players. From this group, 50 adolescents volunteered to participate in Part II of the study, which focused on audiological measurements and measured listening volume. Results: The results indicated that longer lifetime exposure in years and increased listening frequency were associated with poorer hearing thresholds and more self-reported hearing problems. A tendency was found for listening to louder volumes and poorer hearing thresholds. Women reported more subjective hearing problems compared with men but exhibited better hearing thresholds. In contrast, men reported more use of personal music devices, and they listen at higher volumes. Discussion: Additionally, the study shows that adolescents listening for ≥3 h at every occasion more likely had tinnitus. Those listening at ≥85 dBAeq,FF and listening every day exhibited poorer mean hearing thresholds, reported more subjective hearing problems and listened more frequently in school and while sleeping. Conclusion: Although the vast majority listened at moderate sound levels and for shorter periods of time, the study also indicates that there is a subgroup (10%) that listens between 90 and 100 dB for longer periods of time, even during sleep. This group might be at risk for developing future noise-induced hearing impairments.

Keywords: Adolescents, headphones, hearing symptoms, hearing thresholds, listening habits, portable music listening devices

INTRODUCTION

Both long and short durations of noise may affect our hearing function.[1] Young people are exposed to loud sound levels during leisure-time activities, for example, when visiting nightclubs or listening to music with headphones. It has previously been suggested that approximately 17% of the teenagers in the USA experience noise-induced hearing loss (NIHL).[2] A growing body of research indicates that excessive listening to personal music players may cause damage to the cochlea in some individuals. In addition, listening to music for long periods of time and at a high intensity are associated with several auditory symptoms, such as temporary threshold shifts, tinnitus, noise sensitivity, and distortion, which eventually may increase the risk of developing permanent hearing loss.[3-5] Sound pressure levels from personal listening devices can produce sound levels of up to 121 dBA at the highest volume control settings, and the peaks levels can be as high as 139 dB.[6] However, research focusing on the prevalence of NIHL caused by leisure-time noise exposure has reported inconsistent conclusion. Some studies report an increase in NIHL in the high frequency area,[7] whereas other studies do not confirm such results.[8] Studies in Scandinavia, Germany, the USA and China have concluded that approximately 12–15% of children, adolescents and young adults may be affected by hearing loss caused by leisure-time noise exposure.[9]

Noise exposure among adolescents in the Western world is primarily caused by behaviour based on voluntary participation in leisure-time activities that often include music exposure.[4] Adolescents and young adults are exposed to loud music, mainly from personal music players when attending school and while sleeping. This study shows that adolescents listening for ≥3 h at every occasion more likely had tinnitus. Those listening at ≥85 dBAeq,FF and listening every day exhibited poorer mean hearing thresholds, reported more subjective hearing problems and listened more frequently in school and while sleeping.

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Listening to music makes an important contribution to quality of life, and adolescent music listening varies according to places and situations, such as commuting or changes in mood.\textsuperscript{[11]} Results from a study performed in India on a sample of 70 young adults (17–24 years) revealed average listening habits of 1.5 h per day, although the individual range was between 10 min and 4 h.\textsuperscript{[12]} In addition, approximately 30\% of individuals listened to music above the safety limits (80 dBA for 8 h) prescribed by the Ministry of Environment and Forests in India. Furthermore, a positive correlation between hearing thresholds and music listening levels was identified, and a negative correlation between distortion products otoacoustic emissions (DPOAE) measures and music levels was also found. However, Keppler et al.,\textsuperscript{[13]} observed no significant differences in hearing thresholds, transient evoked otoacoustic emissions (TEOAE) amplitudes and DPOAE amplitudes between groups with intermediate or high recreational noise exposure despite the fact that one-third of the 163 participant (aged 18–30 years) exceeded the weekly equivalent noise exposure of 75 dBA for all activities. In another study on young adults, the daily mean listening time was 2 h. The results also showed that the adolescents listened for 6.5 days a week, indicating that music listening activities are quite frequent among adolescents and young adults.\textsuperscript{[11]}

Currently, a large portion of adolescents have access to portable music players either in cell-phones or MP3 players.\textsuperscript{[10]} Thus, listening to music has become very accessible given that music listening technology is incorporated in almost every cell phone, which is something that almost everybody always carries. Today’s portable music players have good sound quality and music storage capabilities. With good sound quality, music can be played at a high level without causing distortion.\textsuperscript{[14]} Given the high sound level used and frequency of use of portable music players, there are concerns about their effects on hearing function. A previous research has reported that 80\% of 13- to 18-year-old individuals listen to music using headphones for 1–3 h per day.\textsuperscript{[15]} Research has also confirmed poorer hearing thresholds for adolescents and young adults who use headphones often.\textsuperscript{[12,15,16]} Peng et al.,\textsuperscript{[16]} and Kim et al.,\textsuperscript{[15]} concluded that long-term use of headphones in adolescents is likely to impair hearing function and that the prevalence of hearing loss will likely increase with years of use.

Only a few studies have addressed the listening habits with headphones and hearing function in adolescents. Previous research has concluded that long-term use of headphones may have a negative effect on hearing and may cause hearing impairments. To accurately discuss the impact on hearing functionality, it is important to map adolescents’ portable music player listening habits and explore how much and how often they listen to them. Hearing loss, tinnitus, sound sensitivity, occlusion and distortion are undesired consequences. We urgently need more knowledge about the use of personal music devices, risk assessment and how to prevent future generations from unnecessary and costly permanent hearing damage. Thus, it is important to investigate how adolescents’ listening habits correlate with hearing function.

**Aim**

The aim of this study was to investigate self-reported hearing and portable music listening habits, measured hearing function and music exposure levels in Swedish adolescents who were 17 years of age.

**Materials and Methods**

This section will be presented in two parts.

**Part I**

Four different upper secondary schools were invited to participate in the project. The schools were located in a larger Swedish city with approximately 140,000 inhabitants, and the four schools had 843 students who were 17 years of age (mean age). Information letters about the project were sent to the principals. For further distribution, the school health care departments and teachers provided students and caregivers with a letter of consent. The inclusion criteria for the study were that the participants were aged 17 years and had a written consent from the care givers. The number of participants in this study is shown in Table 1.

**Questionnaire**

The questionnaire included 13 questions regarding the headphone listening habits with portable music players and

| Table 1: Number of participants in part I and II |
|-----------------------------------------------|
| **Part I**                                      | **Part II**                     |
| Number of questionnaires and consents received | 343                             |
| Do not use portable music, no                  | 10                              |
| Numbers of exclusions due to incorrections and missing consents | 53 |
| Questionnaires for analysis, no                | 280                             | → 50 |
| 144 boys/135 girls                            | 17 boys/33 girls                |
subjective hearing health. This questionnaire was used in a previous pilot study.\textsuperscript{[17]} The questionnaire was divided into three cluster areas. Cluster 1 contained three items that addressed history of usage (e.g., type of portable music player and headphones that were primarily used, age when starting listening, etc.). Cluster 2 included 10 items concerning contemporary using habits (e.g., questions dealing with the type of portable music player and headphones used, period of time (years), duration of time, preferred sound level, preferred type of music and types of environment, in which the person often listens to music). Cluster 3 included seven items with questions that addressed subjective hearing health tinnitus and sound sensitivity. At the end of the information letter, a question regarding voluntary participation in part II of the study was addressed.

Part II

The study was conducted in a tertiary medical system. All the students who wanted to participate in the second part with more in depth examinations were contacted via email, short message service (SMS) or mail, and an appointment was booked at an audiological research centre located at the university hospital. The participants were all given additional written information concerning the second part of the study that clarified the procedure regarding hearing and tympanometry tests and the sound level measurements to be performed on their personal music device using their preferred music and listening level. Fifty students participated in part II, as described in Table 1.

Hearing measurements

Hearing measurements were performed according to standardized methods in a soundproof booth and were conducted by an authorized audiologist according to ISO 8253-1:2010. The test procedure included otoscopy and impedance audiometry ( tympanometry and acoustic reflexes) using Grason-Stadler GSI 33 with a 226 Hz probe tone. The tympanometry was categorized as normal (A) and abnormal (B with a flat tympanogram and C with $\geq 200$ daPa, Jerger, 1970). Pure-tone audiometry (hearing thresholds (air conduction)) was performed using an Astera pure tone audiometer and TDH 39 headphones. The frequencies measured were 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz in the $-10$ to 60 dB HL range. The criteria for the normal hearing threshold were set at $-10$ to 20 dB HL for all but one or more frequencies or according to a pure-tone-average (PTA; 0.5, 1, 2 and 4 kHz) and high-frequency PTA (4, 6 and 8 kHz) $\geq 20$ dB HL. Hearing thresholds $\geq 20$ dB HL were considered abnormal. If asymmetry was observed between the hearing thresholds in the left and right ears, bone conduction was also measured.

Sound level measurements

The sound pressure levels from the portable music devices (PMDs) used by the adolescents were measured. The adolescent’s favourite music and personal, preferred listening level (PLL) were chosen by themselves. All the measurements were performed using a KEMAR head and torso simulator (KEMAR) manikin as described in an earlier study.\textsuperscript{[17]} All adolescents brought their own portable music device (PMD) and headphones, and all the measurements were made with their right headphone on KEMAR’s right ear. The adolescents were asked to choose a favourite piece and set the volume to the typical level used. Then, the right headphone was placed on KEMAR’s right ear. Thirty seconds into the song, a 60-s sampling time was initiated. $\text{Leq}^{60}$ and $\text{Max}$ and Peak levels, both linear and A-weighted in 1/3’s octave bands from 20 Hz to 20 kHz (according to IEC 1260), were sampled. Data were re-calculated (in real time) to the equivalent free- and diffuse sound field and root mean square (RMS) according to ISO-11904-2. Both free field (FF)-corrected and uncorrected data are presented. The background sound levels were recorded repeatedly during the day and did not influence the measurements in any way.

Measurement arrangements for open headphones

KEMAR was equipped with a Brüel & Kjaer 4157 coupler (IEC 60711) and a Brüel & Kjaer 4192 sound pressure microphone. The microphone was connected via a Brüel & Kjaer 2669 pre-amp to a Brüel & Kjaer 3560B front-end and to a computer with a Brüel & Kjaer computer program Pulse Labshop.

Measuring arrangement for canal phones/earbuds positioned into the external auditory meatus

This measurement arrangement was used for measuring canal phones/earbuds as these types of earphones are placed in the external auditory canal and consequently block the canal. The earbuds included several different sizes of the soft, silicon-like rings, ensuring a tight fit for the earphones; thus, different phone diameters were noted for different users. These differences suggest that the earphones tested would not necessarily fit KEMAR as well as the individual being tested. In addition, the design of KEMAR and the Brüel & Kjaer coupler 4157 create difficulties when placing the earphones sufficiently far into the external auditory canal to make the fit sufficiently tight. Thus, we used a Brüel & Kjaer DB2010 external ear stimulator attached to the previously mentioned coupler and microphone, Brüel & Kjaer 4157 and Brüel & Kjaer 4192, respectively, as their design ensures a correct fitting of earphones regardless of the diameter. The microphone was connected via a Brüel & Kjaer 2669 pre-amplifier to a Brüel & Kjaer 3560B Front-end and to a computer with Brüel & Kjaer’s Pulse Labshop program.

Statistical analysis

The data were analysed using the Statistical Package for the Social Sciences version 21.0.0.0 software (IBM SPSS Inc., Chicago, IL, United States). Descriptive statistics were used to analyse the results from the hearing thresholds and tympanometry. To analyse the variance in hearing thresholds, repeated measure analysis of variance (ANOVA) was used. The hearing thresholds were analysed in regard to gender, ear and headphone listening habits. A chi-squared test was used...
to evaluate differences regarding the prevalence hearing threshold \( \geq 20 \text{ dB HL} \) (yes/no) as well as headphone listening habits and gender differences. The Mann–Whitney \( U \) test was also used to analyse differences in listening habits. Statistical significance was defined at \( P < 0.05 \). A frequency table was used to calculate the answers for the questionnaires.

**Ethics**

The study was approved by the regional ethical board (no.: 2009/140).

**RESULTS**

**Part I: Measuring adolescent \((N = 279)\) listening habits and subjective hearing symptoms**

**Self-reported listening habits**

Almost all the participants \((n = 272/279)\) (97.1%) listened to music with a PMD. The average starting time for using a PMD was 13 years. Most of the adolescents \((n = 241, 88.6\%)\) listened every day or several times per week. The mean listening time was 2 h (range: 0.5–12 h) at every occasion. Eighty percent of the adolescents listened for 0.5–2 h at every occasion, whereas 20.0% listened for 3 h or more. The most common type of headphone used was canal phones (49.4%) and regular earbuds (37.9%). The participants mostly use their PMD during transportation, such as bus, train, boat, car, walking and biking [Figure 1]. Approximately 45% of the adolescents used their portable music player during school hours and 21% while sleeping [Figure 1].

Of all 279 adolescents, 71.0% reported no hearing problems, whereas 14.0% reported having poor hearing. Furthermore, 7–8% reported that they often or always experienced hearing problems, such as tinnitus, sound sensitivity and sound fatigue [Figure 2].

When analysing gender differences regarding listening habits, boys on average listened for significantly more hours than girls (2.4 vs. 1.6 h, respectively) at every occasion \((t = 3.260; \text{df} = 192.762; \ P < 0.001; N = 279)\) and had a slightly longer lifetime exposure than girls \((4.6/4.1 \text{ years})\), \((t = 2.126; \text{df} = 2.126; \ P < 0.05; N = 257)\).

Significantly more boys reported listening with headphones during indoor school breaks \((\chi^2 = 6.968; \text{df} = 2.126; \ P < 0.01, N = 270)\), outdoor breaks \((\chi^2 = 7.143; \text{df} = 1; \ P < 0.01, N = 270)\) and at lunchtime in school \((\chi^2 = 11.379; \text{df} = 2.126; \ P < 0.01, N = 270)\). Despite the increased sound exposure, significantly fewer boys reported some type of hearing problem (such as poor hearing, tinnitus, sound sensitivity, sound fatigue, distortion or occlusion) compared with girls \((\chi^2 = 6.223; \text{df} = 2.126; \ P < 0.01)\). Twenty-two percent of the boys \((n = 30/136)\) reported some subjective hearing problems compared with 36% of the girls \((n = 48/134)\).

**Part II: Adolescents \((n = 50)\) self-reported listening habits and hearing problems as well as measured hearing and measured preferred sound levels**

**Self-reported listening habits**

In this subsample, 46% used their PMD every day \((n = 23/50)\) and 48% used their PMD several times a week \((n = 24/50)\). The adolescents’ mean age when they started to listen to a PMD was 13.6 years (ranging from 10 to 18 years). Thus, on average, they had been listening for 4 years (ranging from 0 to 8 years). This finding was not different compared with the entire group. The mean listening time at every occasion was 1 h (median 1 h and range 0–6 h), and 86% of the adolescents listened for 0.5 to <2 h/occasion. Moreover, 14% listened for 3 h or more. The most common type of headphone used was regular loose fitted earbuds (50.0%) and occluding canal phones (46.0%). One question addressed their subjective estimation of the volume used on average. The majority reported that they used 75–100% of the maximum volume setting, but there was a large range. The most common listening situations were during transportation (bus, train, boat, car, walking, or biking), and 40% used their portable music player during school hours. Fourteen (28%) reported using their portable music player when going to and during sleep [Figure 3].

The most common type of headphone used was regular loose fitted earbuds (50.0%) and occluding ear canal phones (46.0%).

**Figure 1:** The figure shows the prevalence and different settings when 280 17-year-old students use portable music players

**Figure 2:** Percentages of self-reported hearing problems from 270, 17-year-old students
**Self-reported hearing**

Out of 50 adolescents, 30 (60%) reported having no hearing problems and 8 (16%) reported poor hearing. The results further demonstrate that 9 (18%) perceived tinnitus lasting longer than 5 min and 9 (18%) reported sound sensitivity. One conclusion is that among those who decided to participate in part II, self-reported hearing problems were more common compared with the total sample [Figure 4]. No significant difference between boys and girls regarding listening habits was observed.

**Measured hearing**

Tympanometry was performed in all 50 adolescents. All the participants had a normal bilateral middle ear function. Pure tone audiometry was performed in all participants. The mean hearing thresholds are presented for the right and left ear in Figure 5. A symmetrical hearing threshold with increased high frequency hearing thresholds (6 and 8kHz) was observed in both ears. The standard deviations were slightly larger for the right ear. Thirteen adolescents (26%) had a monaural and five adolescents (10%) had a binaural hearing threshold ≥20 dB HL at one or more frequencies. There was no significant difference between the right and left ears.

Girls exhibited significantly better hearing thresholds in the left ear compared with boys when testing over all frequencies with repeated measure ANOVA \( (F = 8.619; df = 7, 96, 17; P < 0.01; \eta^2 = 0.152) \). When testing (t-test) each frequency (3, 4, 6 and 8kHz) and the right and left ears separately, the significant difference was bilateral and was noted for all frequencies except 6kHz in the right ear [Figure 6].

Significant differences were noted for the hearing thresholds when comparing the groups who listen for 0.5–2 h \((n = 43)\) at every occasion and those who listened for 3 h or more \((n = 7)\) at every occasion. The hearing thresholds for the adolescents in the latter group exhibited poorer mean hearing thresholds in the right ear \((F = 8.253; df = 6, 96, 17; P < 0.01; \eta = 0.147)\). The maximum difference was 12 dB HL at 6kHz in the right ear.
Nine adolescents who reported tinnitus displayed slightly poorer (5 dB) but not significantly different mean hearing thresholds compared with adolescents without tinnitus for both ears. The audiograms indicated a noise-induced configuration, with a small notch configuration at 15 dB HL bilaterally at 6 kHz indicating an impact of high sound levels.

When comparing the hearing thresholds between 10 individuals choosing a higher listening volume (≥85 dB $L_{Aeq, FF}$) with 40 choosing a lower volume (<85 dB $L_{Aeq, FF}$), we observed a poorer mean hearing thresholds in both right and left ears for those choosing the higher volume. However, the differences were not statistically significant, but a tendency was observed for the left ear ($P = 0.06$). In contrast and interestingly, adolescents who had been listening with PMD’s 5 years or more showed a slight, but not significantly better hearing thresholds (3 dB at 3 kHz and 5 dB at 6 and 8 kHz on the right ear) when compared to adolescents who had been listening for <5 years.

**Measured sound levels**

The sound levels measured with KEMAR ranged between 54 and 100 dB $L_{Aeq, FF}$ (mean 76 dB $L_{Aeq, FF}$). Eighty percent of the adolescents listened with a sound level <85 dB $L_{Aeq, FF}$, 10% between 85–90 dB $L_{Aeq, FF}$, and 10% to a sound level between 90–100 dB $L_{Aeq, FF}$. The sound levels were also analysed with regards to the different headphones used. The mean sound pressure level was 75.0 dB $L_{Aeq, FF}$ for regular ear buds and 76.2 dB $L_{Aeq, FF}$ for canal phones. Figure 7 shows the highest, lowest and average measured level as well as the average measured level with the three different types of headphones used by the adolescents.

**Cross-analysis of subjective reports and measurements: PMD listening habits, subjective hearing related to exposure levels**

Table 2 presents data on the use of portable listening devices and self-reported hearing symptoms distributed on the measured sound level. There is a small group that listens to music at high sound levels and for longer periods of time. Although the sample is small, the group that listens to music at higher sound levels, >85 dB $L_{Aeq}$, also report more hearing problems (tinnitus, noise sensitivity and noise tiredness) compared with the group that listens to music at lower sound levels, <85 dB $L_{Aeq}$.

Adolescents listening at ≥85 dB $L_{Aeq, FF}$ listened for a longer period of time at every occasion, listened more frequently and used canal phones to a greater extent compared with adolescents listening <85 dB $L_{Aeq, FF}$. In addition, they reported more hearing problems, such as tinnitus, sensitivity to sounds and sound fatigue. It was also more common to listen during school hours and while sleeping. Those who listened to PMDs every day reported more hearing problems, such as subjective poor hearing and sensitivity to sounds. Furthermore, the PMDs were mainly used during transportation and school hours and when sleeping.

Adolescents who had been listening for ≥5 years used a higher volume and reported subjective poor hearing, sensitivity to sound and sound fatigue. Listening every day was more common compared with the group who listened for <5 years. However, adolescents who had been listening for
5 years did not exhibit significantly poorer hearing thresholds compared with the group listening for <5 years but reported more subjective hearing problems. This group also used their PMD in more varied settings.

**The relation between estimated and measured sound level**

When comparing their self-estimated sound level with the actual measured sound level, the results showed that several of the adolescents were not able to estimate volume in a reliable manner. For example, some estimated that they listened at 25% of the maximum sound level when the measured level was actually 81.44 dB SPL, whereas others estimated 100% of maximum sound level but listened at 73.95 dB sound pressure level (SPL). Further, there were 16 adolescents who listened between 70 and 80 dB SPL, and these participants were represented in all of the estimated volume categories (25, 50, 75 and 100% of the maximum volume setting). This finding implies that the correlation between self-estimated sound levels and measured sound levels is very poor.

**DISCUSSION**

The aim of this study was to investigate self-reported hearing and portable music listening habits, measured hearing function and music exposure levels in Swedish adolescents. The study was performed in two parts. The first part described general listening habits and self-reported hearing problems, and the second part aimed at measuring hearing function and sound level measurements among a sub-sample of 50 adolescents. There is a risk of some bias in part II given that the gender distribution did not match the original distribution in part I. Furthermore, those who did choose to participate in part II were most likely those who had a personal interest to undergo further investigation. In addition, the number of adolescents who volunteered to participate in part II was small. Hence, conclusions from the results must be drawn cautiously. The sample contained four schools located in a Swedish city with approximately 140,000 inhabitants. It is possible that differences in listening habits exist between adolescents living in larger cities and rural areas; hence, a larger sample from different parts of Sweden would have been better to make generalizations based on the results. However, comparing self-estimated listening levels with measured sound levels is a strength in this study. On the basis of our results, we can question the use of self-estimated listening levels given the lack of correlation in what the participant report and what the measurements actually show. For example, there were 16 adolescents who listened between 70 and 80 dB SPL, and they were represented in all of the estimated volume categories (25, 50, 75 and 100% of the maximum volume setting). We conclude that self-reported estimations of listening levels are not a reliable measurement.

On the basis of the results, twenty percent of 280 participants listened for 3 h or more at every occasion and 88.6% listened daily or several times a week. The most common type of headphone used included canal phones (49.4%) and regular earbuds (37.9%). The results from the measurements with different headphones revealed no significant difference between the type of headphones; however, the PLL differed with the external noise levels. The use of canal phones diminishes the perception of external sounds when using a PMD during transportation. The adolescents in this study mostly used a PMD during transportation, that is, bus, train, boat, car, walking and biking. In particular, the use of occluding headphones when bicycling implies exposure to other risks as well as hearing-related risks as the individual is not able to hear the surrounding traffic. In addition, approximately 45% of the adolescents used their portable music player during school hours, and 21% used it when sleeping. This fact increases the exposure time, also might which increase the risk for future hearing problems.

In the sample of 280 adolescents, 14.0% reported having subjective poor hearing. Furthermore, 7–8% reported often or always experience hearing problems, such as tinnitus, sound sensitivity or sound fatigue. When analysing gender differences, boys listened for more hours than girls (2.4 vs. 1.6 h, respectively) and exhibited longer lifetime exposure compared with girls. Despite increased sound exposure, significantly fewer boys reported some type of hearing problem compared with girls. This result could suggest that women are more willing to report hearing problems compared with young men. This explanation is consistent with previous results in which women report a higher degree of perceived susceptibility to noise but also perceived noise-related risks as more dangerous compared with men. A possible explanation is that it is more acceptable for women to express subjectively experienced hearing symptoms, whereas it is not as acceptable for men. Interestingly, in the present study, girls exhibited significantly better-measured hearing thresholds in the left ear compared with boys, who tend to listen more frequently and for longer and start their exposure earlier in life. It is likely that subjective hearing symptoms may serve as a trigger for more ‘careful’ and hearing preservative behaviour. Thus, women do not experience noise-induced threshold shifts to the same extent as men.

In part II, extended hearing measurements were performed in 50 adolescents. Thirteen (26%) had a monaural- and five (10%) had a binaural hearing threshold ≥20 dB HL at one or more frequencies. There was no difference between the right and left ears. The study revealed that those individuals who listened for 3 h or longer at every occasion had tinnitus or who listened to louder volumes had worse measured hearing thresholds. Most adolescents listened at a sound level <85 dB L_{Aeq, FF}. 10% listened between 85 and 90 dB L_{Aeq, FF} and 10% listened to a sound level between 90 and 100 dB L_{Aeq, FF}. The sound levels were also analysed with regards to the different headphones used. The mean sound pressure level was 75.0 dB L_{Aeq, FF} for regular loose fitted ear buds and 76.2 dB L_{Aeq, FF} for canal phones. We conclude that most individuals are not exposed to levels >85 dB. However,
there is a smaller group that listens to music at high sound levels and for longer periods of time, and they also report more hearing problems (tinnitus, noise sensitivity and auditory sound fatigue) compared with the group that listens to music at lower sound levels. In addition, adolescents listening at \( \geq 85 \text{ dB } L_{\text{Aeq}, \text{ FF}} \) more frequently used occluding canal phones compared with adolescents listening \( < 85 \text{ dB } L_{\text{Aeq}, \text{ FF}} \). We also observed a tendency for poorer hearing thresholds in the left ear for those 10 adolescents who listened at \( \geq 85 \text{ dB } L_{\text{Aeq}, \text{ FF}} \). Figure 7 reveal some small difference in hearing thresholds between those who listen at loud sound levels and those who listen at lower sound levels. However, since the sample is small, no conclusions can be drawn. If the sample was larger, we might have observed statistically significant differences given that the statistical power of the test would have increased. Hence, further research on larger samples is needed regarding behavioural patterns, sound volumes and hearing function.

Adolescents who report using their PMD for a period of time longer than 5 years reported subjective poorer hearing, sensitivity to sound and sound fatigue but did not show poorer measured hearing thresholds compared with the other group who listened for \( <5 \) years. One possible explanation for this finding might be that it is not the history of using PMD that is the main issue, but how and when it is used, that is, volume, exposure time, sound environment, etc.

The present study does not provide information about how future hearing development will proceed for these adolescents. Our knowledge is poor regarding the consequences of long-term music exposure in relation to behavioural patterns among adolescents and their transition into adulthood. Therefore, in the future, longitudinal studies on adolescents’ behavioural patterns and the development of hearing impairments should be performed.

**Conclusion**

Longer lifetime exposure in years, louder volumes and higher listening frequencies are associated with poorer hearing thresholds and self-reported hearing problems. Women tend to report subjective hearing problems to a higher extent compared with men but exhibit better measured hearing thresholds. Men report an increased use of PMDs and listen at higher volumes. Although the vast majority listened at moderate sound levels and for shorter periods of time, the study also indicates that there is a subgroup (10%) who listens between 90 and 100 dB for longer periods of time, even during sleep. This group might be at risk for developing future noise-induced hearing impairments. Hence, the importance for longitudinal studies that support preventive work for this target group is needed. Additionally, the study shows that adolescents listening \( \geq 3 \) h at every occasion reported tinnitus more often.

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**Conflicts of interest**

There are no conflicts of interest.

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