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Otoacoustic Emissions before and after Listening to Music on a Personal Player

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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: The problem of the potential impact of personal music players on the auditory system remains an open question. The purpose of the present study was to investigate, by means of otoacoustic emissions (OAEs), whether listening to music on a personal player affected auditory function.





Material/Methods: A group of 20 normally hearing adults was exposed to music played on a personal player. Transient evoked OAEs (TEOAEs) and distortion product OAEs (DPOAEs), as well as pure tone audiometry (PTA) thresholds, were tested at 3 stages: before, immediately after, and the next day following 30 min of exposure to music at 86.6 dBA.

Results: We found no statistically significant changes in OAE parameters or PTA thresholds due to listening to the music.

Conclusions: These results suggest that exposure to music at levels similar to those used in our study does not disturb cochlear function in a way that can be detected by means of PTA, TEOAE, or DPOAE tests.

MeSH Keywords: **Otoacoustic Emission • Amplified Music Exposure • Noise Induced Hearing Loss • Temporary Threshold Shift**

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Background

With an increase in people's exposure to noise, the development of methods for detecting and assessing the impact of noise on the human auditory system is becoming increasingly important. There have been many studies on the effect of sound exposure on hearing. The effect of industrial [1–3], impulse [4–7], and broad-band noise [8–10] on the auditory system have already been well documented.

Recently, as portable music players (Discmans, MP3 players, and smartphones) become more common, especially among young people, the problem of the potential impact of reproduced music on the auditory system is receiving more interest. Fligor and Cox [11] studied the output levels of commercially available portable music players. The mean levels obtained from 6 typical devices at volume settings of 5–10 varied from 80 to over 115 dBA. Studies of typical exposure levels during music listening have shown that the average level is about 85 dBA [12,13], but it also reaches higher levels in 25% of listeners [14,15] and over 100 dBA in about 5% [16]. Exposure to music at levels exceeding 90 dBA has been shown to affect hearing and cause temporary pure tone audiometry (PTA) threshold shifts [17–22]. Continued exposure to amplified music with a mean level of 90 dBA can cause permanent hearing loss [19,23,24]. Even short-term exposure to strongly amplified music has been shown to induce permanent hearing loss [25]. On the other hand, some researchers have shown that long-term musical training does not affect the cochlear function, contrary to 2–4 years of noise exposure [26]. The listening habits and hearing damage due to personal listening devices were reviewed by Punch et al. [27]. From various studies it could be concluded that listening to music for about 1 h per day with levels not exceeding 90 dBA should not damage hearing.

Otoacoustic emissions (OAEs) [28] can be used as a general screening hearing test [29,30], and can even be used as an indicator of increased risk of hearing loss [31,32]. OAEs are more sensitive than pure tone audiometry to the early stages of hearing damage due to noise exposure [33,34]. Some OAE studies have investigated the effect of prolonged exposure to loud music [35] and specifically to the use of personal music players [36–38]. Bhagat and Davis [36] reported that 30-min MP3 player music exposure can cause a significant decrease in DPOAE amplitudes, even though there was no change in hearing thresholds. In other studies [37,38], however, the decrease in OAE amplitudes coincided with temporary threshold shifts when levels exceeded 90 dBA, and exposure time was 1 and 4 hours, respectively. Nevertheless, it seems to be the case that most humans are able to retain quite good hearing throughout their lives despite experiencing loud noise on a daily basis.

The purpose of the present study was to investigate whether listening to music on a personal player for 30 min and at levels

of around 85 dBA affected auditory function. Higher frequencies of up to 16 kHz for DPOAEs and for PTA were of special interest in order to look for possible changes at the basal regions of the cochlea, which are most prone to damage [39].

Material and Methods

Experiment design

The main aim of the study was to evaluate the influence of amplified music on otoacoustic emissions. In order to investigate the effect, participants were exposed to 30 min of looped audio track played on a typical portable CD player. All subjects were audiotically tested 3 times: at the beginning of the study just before exposure to the music; immediately after 30 min of exposure; and the next day. The third test performed at about 24 h after the exposure, as some studies have shown that full recovery of DPOAE levels and TEOAE parameters after noise exposure can take more than a few hours. For example, Vinck et al. [40] reported that in a group of subjects exposed to amplified disco music, TEOAE parameters and DPOAE levels had not fully recovered 8 h later. In the present study, before exposure, pure tone audiometry (PTA), impedance audiometry, transient evoked otoacoustic emissions (TEOAE), and distortion product otoacoustic emissions (DPOAE) tests were performed. Immediately after exposure to music, TEOAE, DPOAE, and PTA in the 2–8 kHz frequency range were tested. The following day, all the tests except impedance audiometry were repeated.

Subjects

The study participants were 20 normal-hearing adults (40 ears). The group consisted of 10 male and 10 female volunteers, aged 22–27 years. The mean age was 24.3 years with standard deviation of 1.53 years.

Test and participant selection criteria

Pure tone audiometry (PTA) was carried out at octave intervals from 125 to 8000 Hz, and at half-octave intervals from 1500 to 6000 Hz. Additionally, high-frequency PTA tests were performed for each subject at frequencies of 9, 10, 11.2, 12.5, 14, 16, 18, and 20 kHz. Middle ear function was evaluated using impedance audiometry, as middle ear status may significantly affect OAE properties [41]. Parameters monitored were tympanometric peak pressure, static admittance, gradient, and ear canal volume. Also, ipsilateral and contralateral acoustic reflex thresholds at 0.5, 1, 2, and 4 kHz were tested.

The selection criteria were: normal hearing thresholds and normal middle ear function. All 20 subjects included in the study had pure tone audiometry hearing thresholds for both ears below

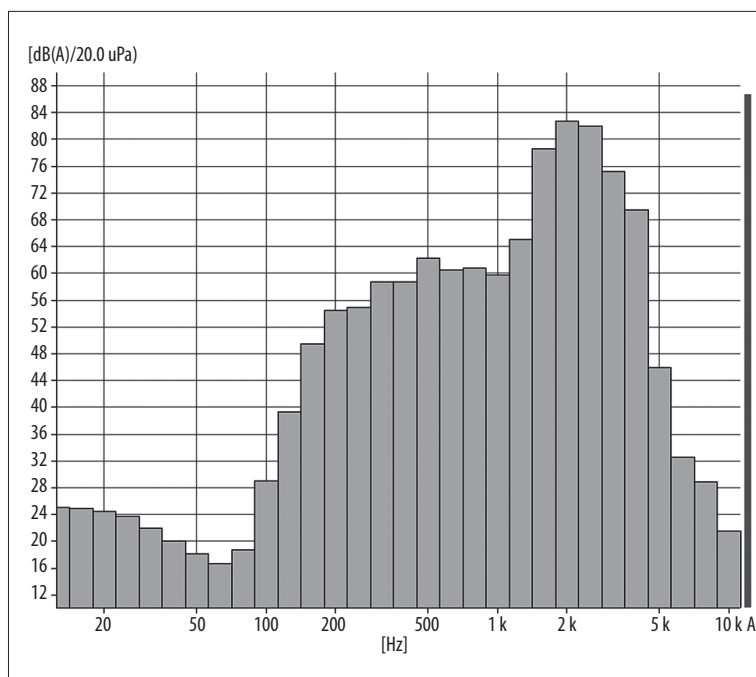


Figure 1. The power spectral density of the audio track presented to the experiment participants.

20 dB HL for typical test frequencies from 125 to 8000 Hz at octave intervals. All had type A tympanograms with correct tympanometry parameters, and ipsilateral and contralateral reflex threshold levels were within the norm. None of participants reported any excessive music or noise exposure in their daily life.

Audiometric equipment

Pure tone audiometry tests were performed using a Madsen Astera (Otometrics, Otosuite v. 3.35.02) device. TDH-39 earphones were used for 125–8000 Hz stimuli and Sennheiser HDA 200 were used for the 9–20 kHz frequency range. Impedance audiometry and acoustic reflex threshold tests were performed with a Madsen Zodiac 901. TEOAEs and DPOAEs were recorded on a HearID system (Mimosa Acoustics Inc., v. 3.3.0.0) with an ER10C probe (Etymotic Research). The HearID and Zodiac 901 systems were calibrated at the beginning of the first and third test series.

Noise exposures

The study participants were exposed to amplified music during 1 session with a total length 30 min: 48 s. The sound was a 4min: 24 s of Celtic music audio track (“Cry of the Celts” by Michael Flatley) looped 7 times and played on a Sony D-NE511 portable CD player. During the music exposure, the volume was continuously set to maximum gain. The sound level of the track was measured by means of a Brüel & Kjær system (type 3160-A-2/2) connected to a head and torso simulator (type 4128C). The total acoustic level of the track was 86.6 dBA. The power spectral density of the track is presented in Figure 1. Most of the signal energy was between 100 Hz and 5000 Hz.

Results

In order to look for the effect of amplified music on the subjects’ auditory system, 3 sets of auditory tests were analyzed: before listening to the music, immediately after 30 min of exposure, and the following day. There were no statistically significant differences in TEOAE and DPOAE results between left and right ears; therefore, all ears were studied as a single dataset.

Pure tone audiometry

During the first and third tests, PTA was performed for frequencies ranging from 125 Hz up to 16 kHz, covering almost the full range of human auditory perception. In total, 18 frequencies were tested and the results are presented in Figure 2. In the second test, performed immediately after music exposure, the number of tested frequencies was limited to 5, to shorten the time, while covering the range over which effects were likely to be observed. Tested frequencies were 2, 3, 4, 6, and 8 kHz. Mean changes in hearing thresholds for these frequencies were 0.25 (SD=3.57), –0.25 (SD=4.52), –0.63 (SD=6.01), 0.75 (SD=9.44), and 0.0 dB (SD=7.07 dB), respectively. No statistically significant changes in the PTA hearing level that could be caused by exposure to the music were observed ($p>0.05$).

Transient evoked otoacoustic emissions

TEOAEs were recorded at each of the 3 stages of the experiment. The mean global response level for each of the 3 tests was 4.53, 4.94, and 4.85 dB, with standard deviation of 3.31, 3.06,

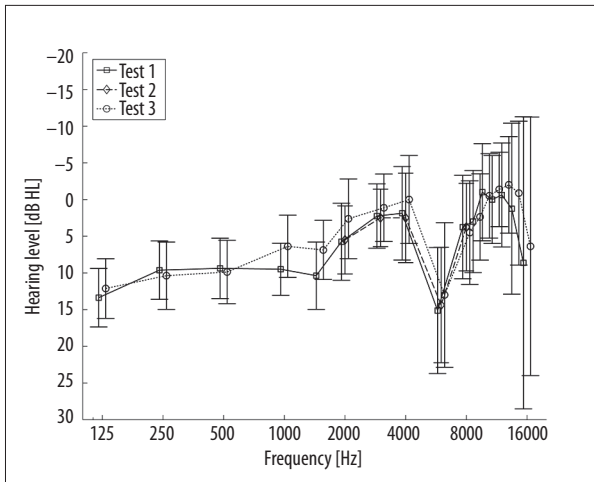


Figure 2. Pure tone audiometry thresholds obtained in a group of 20 subjects (40 ears) for 3 tests: before listening to the music (squares, solid line); immediately after 30 min of exposure (diamonds, dashed line); and the following day (circles, dotted line).

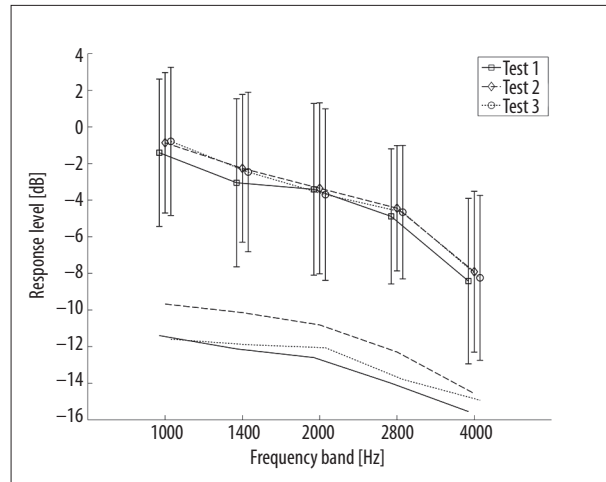


Figure 4. TEOAE response levels obtained in a group of 20 subjects (40 ears) in 3 tests: before listening to the music (squares, solid line); immediately after 30 min of exposure (diamonds, dashed line); and the following day (circles, dotted line). The 3 lines without markers at the bottom indicate the mean noise level for the 3 tests.

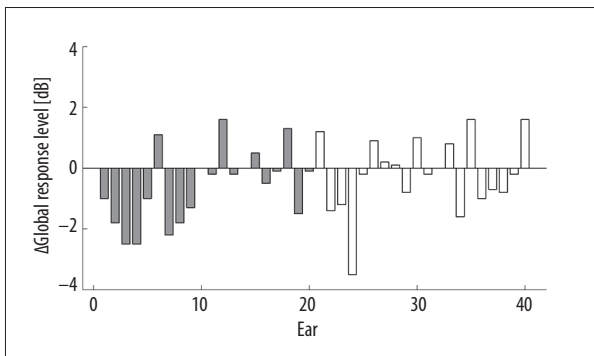


Figure 3. Changes in global response levels (after minus before) for each of the 20 subjects (40 ears): 10 males (gray bars) and 10 females (white bars) due to 30-min exposure to amplified music.

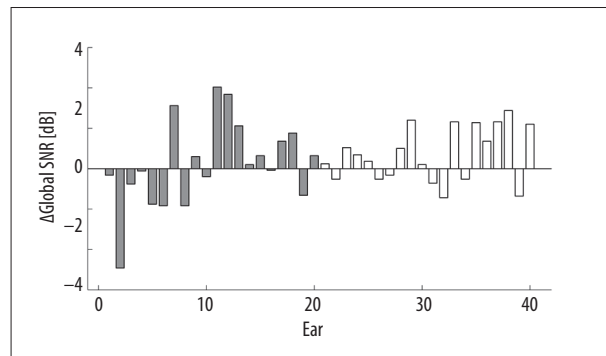


Figure 5. Changes in global SNRs for a group of 20 subjects (40 ears): 10 males (gray bars) and 10 females (white bars) due to 30-min exposure to amplified music.

and 3.32 dB, respectively. There were no statistically significant ($p > 0.05$) differences between global response levels in the tests.

Figure 3 presents individual changes in global response level due to 30 min of music exposure for both ears of each subject. The maximum change, a decrease, was around -3.5 dB (ear number 24). Nevertheless there were a number of ears in which an increase of the level was observed (ears number 6, 12, 15, 18, 21, 26, 27, 28, 30, 33, 35, and 40). Statistical analysis showed that changes in global response values between test 1 and test 2 (after exposure to music) were not significantly different than changes between test 1 and test 3.

Mean values of response level obtained for frequency bands with center frequencies at 1, 1.4, 2, 2.8, and 4 kHz are presented in Figure 4. Similar to global response level, these values

did not differ (with $p = 0.05$ significance). Also, changes in response level for each frequency band, caused by music exposure, were not significantly different from changes between the first and third test.

The mean total signal-to-noise ratios (SNRs) in the 3 tests were 9.11 (SD=4.26), 7.94 (SD=3.82), and 9.37 dB (SD=4.39 dB). Although a decrease in the mean SNR value after 30 min of exposure to music and recovery after a day can be observed, the differences between these values were not statistically significant. Individual changes in global SNR values after music exposure for each subject are presented in Figure 5. The maximum change was around -12.3 dB (ear number 2). Nevertheless, there were many ears in which an increase in SNR (not a decrease) was observed (ears 7, 9, 11, 12, 13, 14, 15, 17, 18, 20, 21, 23, 24, 25, 28, 29, 30, 33, 35, 36, 37, 38, and 40).

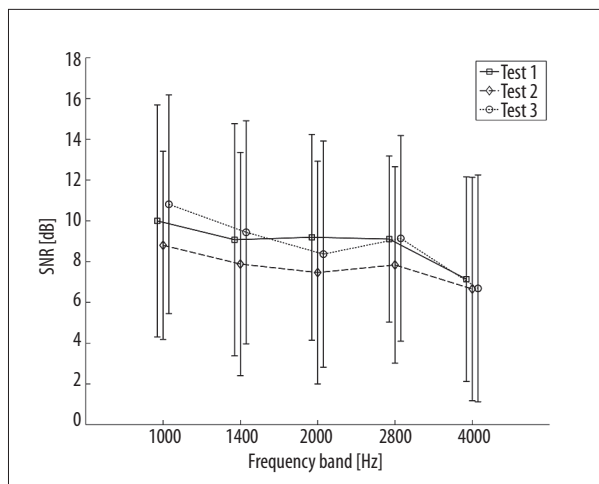


Figure 6. TEOAE signal-to-noise ratios obtained in a group of 20 subjects (40 ears) in 3 tests: before listening to music (squares, solid line); immediately after 30-min exposure (diamonds, dashed line); and the following day (circles, dotted line).

The mean SNR values for individual frequency bands are presented in Figure 6. The decrease in SNRs obtained for test 2 (immediately after music exposure) can be noted for all frequency bands. Maximum temporary SNR shift between test 1 and test 2 was 1.73 dB, observed in the 2 kHz band, and the minimum was 0.48 dB in the 4 kHz band. The mean value of the shift for all 5 frequency bands was 1.17 dB (SD=0.45 dB). Although these differences can be visually distinguished with ease, the mean values were not statistically different ($p>0.05$). Also, changes in band SNRs due to exposure to music were not significantly different from variations in the values between test 1 and test 3.

Distortion product otoacoustic emissions

The second OAE test complementing TEOAE recordings was the distortion product otoacoustic emission test, which was performed at each of 3 stages of the experiment. Figure 7 presents DPOAE levels in dB SPL for all 3 tests. A slight decrease in the levels after music exposure can be noted for some frequency bands but none of them were significant.

Discussion

The present study attempted to answer the question of whether listening to music at levels around 85 dBA and for 30 min caused any significant effects on OAEs and PTAs.

Many studies on the effect of amplified music on the auditory system characteristics already exist. Some show temporary changes in PTA thresholds caused by exposure to music, especially the frequencies 4–8 kHz, which were affected by 92–107 dBA and 110–135 dB SPL music exposure [18–22]. In

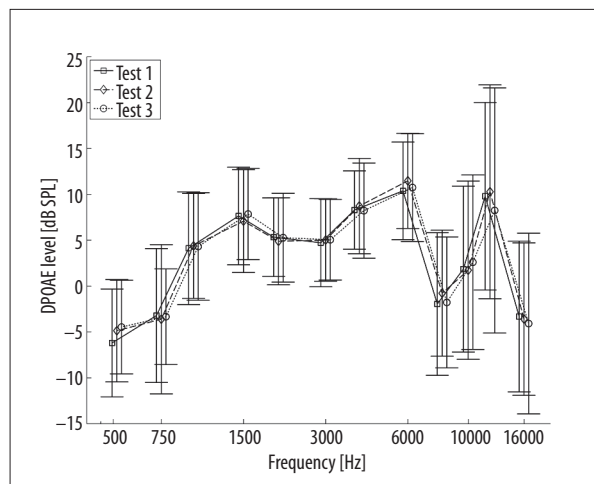


Figure 7. DPOAE levels obtained in a group of 20 subjects (40 ears) in 3 tests: before listening to the music (squares, solid line); immediately after 30-min exposure (diamonds, dashed line); and the following day (circles, dotted line).

these studies, rock and roll and pop music lasting from 10 up to 210 min were used as exposures, and temporary threshold shifts of 4–15.4 dB were obtained. The present study did not reveal any statistically significant PTA threshold shift caused by 30-min exposure for any frequency in the range of 2–8 kHz.

Some researchers have shown OAE parameters to be more sensitive to noise exposure than PTA. Vinck et al. [34,40] found significant decreases in TEOAE parameters and DPOAE levels caused by exposure to broad-band noise, although PTA thresholds did not change significantly. The same authors, in another experiment [40], showed that in a group of discotheque noise-exposed subjects, TTS in PTA recovered faster (3 h 45 min) than the TEOAE and DPOAE parameters, which did not fully recover even after 8 h. Other researchers have also reported significant changes in OAE parameters after amplified noise exposure [7,33]. The changes depend on the characteristics and level of the stimulus and length of exposure. Typically, a decrease in OAE parameters can be observed over the frequency range of 4–6 kHz [36,42].

The present study showed no statistically significant group effect on PTA, TEOAE, or DPOAE caused by amplified music exposure. Also, changes in OAE parameters between test 1 and test 2 and between test 1 and test 3 were not significantly different. These results lead to the conclusion that there is no observable effect, measured by means of typical TEOAE and DPOAE tests, on the subjects' auditory system due to the music exposure. These findings are in agreement with a recent study [43] in which no significant changes were observed in DPOAEs over the 1–6 kHz range.

These results do not mean that music and noise exposure is not harmful to hearing. The time of exposure in the present study was rather short – 30 min. Therefore, the lack of an observed

decrease in measured parameters points to the conclusion that a short listening time might have only a minimal effect on hearing.

Conclusions

Some researchers have shown that exposure to amplified music at intensities over 90 dBA had considerable impact on young people's auditory systems. However, results in the present

study indicate that 30-min exposure to 86.6 dBA amplified music did not cause measurable PTA threshold shift or significant changes in TEOAE and DPOAE parameters.

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