

Prevalence and characteristics of tinnitus after leisure noise exposure in young adults

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Abstract

The main goal of this study was to assess the prevalence and characteristics of tinnitus among students after exposure to leisure noise. In addition, the effects of tinnitus on otoacoustic emissions (OAEs) in participants suffering from chronic tinnitus were evaluated. The study consisted of two parts. First, a questionnaire regarding leisure noise exposure and tinnitus was completed. Second, the hearing status of the subjects suffering from chronic tinnitus was evaluated and compared with a matched control group (CG). Furthermore, the psychoacoustical characteristics of their tinnitus in the chronic tinnitus group (TG) were established. The questionnaire was answered by 151 respondents. Seven persons suffering from chronic tinnitus were examined further in the second part of the study. Transient tinnitus was observed in 73.5% of the respondents after leisure noise exposure and 6.6% experienced chronic tinnitus. Transient and chronic tinnitus had similar characteristics, as established by the questionnaire. The amplitude of transient evoked otoacoustic emissions and distortion product otoacoustic emissions was reduced and the amount of efferent suppression was smaller in the TG as compared with the CG. Tinnitus induced by leisure noise is observed frequently in young adults. The characteristics of tinnitus cannot predict whether it will have a transient or rather a chronic nature. In subjects suffering from tinnitus, subclinical damage that cannot be detected by audiometry can be demonstrated by measuring OAEs. These findings underpin the importance of educating youth about the risks of noise exposure during leisure activities.

Keywords: Leisure noise exposure, prevalence, tinnitus, young adults

Introduction

It is well-known that excessive noise exposure can lead to transient, as well as chronic ear damage.^[1] Occupational noise is known as potentially harmful. Furthermore, exposure from leisure activities, especially in young adults, is a cause of concern. Smith *et al.*,^[2] reported that 18.8% of 18- to 25-year-olds had been exposed to noise from leisure activities. Therefore, young adults are at risk of ear damage, such as hearing loss (HL) or tinnitus.

The overall number of teenagers and young adults who experienced transient tinnitus after visiting discotheques, music concerts or listening to music through headphones ranges between 20% and 80%.^[3-6] Besides transient tinnitus, Widén and Erlandsson^[4] found that 8.7% of their sample

of young adults experienced chronic tinnitus. Despite the usefulness of these studies including hearing education programs, there are often differences in the prevalence of tinnitus. These differences can be due to a discrepancy in the definition of transient and chronic tinnitus used in the questionnaires. In general, transient tinnitus does usually not last longer than a few seconds to a maximum of a couple of days, while chronic tinnitus lasts from months to years.^[7] Both transient and chronic tinnitus are generally characterized as tonal^[8,9] with a high pitch.^[8,10,11]

Studies on the effects of leisure noise exposure on hearing thresholds revealed inconsistent results. Serra *et al.*,^[12] examined the effects of leisure noise exposure on hearing of young adults over a period of 4 years. A threshold shift, exceeding 30 dB HL in some subjects, was found in the 3rd year of the study and continued in the 4th year. In contrast, Lindeman *et al.*,^[13] found no deteriorated hearing thresholds. However, conventional pure-tone audiometry only detect HL as soon as a considerable amount of hair cells is damaged.^[14] This suggests that conventional audiometry is insensitive to detect subtle noise-induced cochlear changes.

Exposure to leisure noise is reported as a key factor in causing outer hair cell (OHC) damage in young people.^[5]

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Moreover, OHC dysfunction is also reported as a significant factor in the generation of tinnitus.^[15] Damage to the cochlear OHCs can be objectively documented using otoacoustic emissions (OAEs).^[16] OAEs are low-level sounds reflecting the non-linear active processes in the cochlea. Transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs) are responses following a brief stimulus or following acoustic stimulation with two pure tones presented simultaneously, respectively. One study investigated the influence of leisure noise on hair cell activity in a group of medical students by measuring the TEOAEs.^[5] They reported decreased TEOAE amplitudes and reproducibility with increased disco-visits. To the best of our knowledge, literature concerning the effects of noise-induced tinnitus on OAEs is rare. In contrast, many studies investigated the effects of tinnitus on OAEs in subjects with tinnitus caused by Meniere's disease, head injury, sudden deafness or idiopathic tinnitus. Overall, those studies reported smaller TEOAE amplitudes^[15,17-19] or DPOAE amplitudes^[15,18,20] in normal hearing subjects with tinnitus when compared to subjects without tinnitus.

The medial olivocochlear system (MOC), which has an inhibitory effect on the OHCs, is also suggested as a factor in the origin of tinnitus.^[21] Some studies reported a reduced suppression effect of the MOC system in subjects with tinnitus.^[18,22] Recently however, Geven *et al.*,^[23] found an equal amount of suppression in subjects with and without tinnitus. Furthermore, Attias *et al.*,^[24] showed increased TEOAEs in the presence of contralateral acoustic stimulation (CAS) in subjects with noise-induced tinnitus.

In light of the increasing concern about leisure noise exposure, this study assessed the effects of leisure noise in a group of young adults in Flanders. The main goal was to assess the prevalence and characteristics of transient and chronic tinnitus after exposure to leisure noise. In addition, the influence of tinnitus induced by leisure noise on hair cell activity was examined by measuring TEOAEs, DPOAEs and efferent suppression (ES) of TEOAEs in the subjects reporting chronic tinnitus.

Methods

The study consisted of two parts [Figure 1]. First, a questionnaire was distributed to assess the prevalence and characteristics of transient and chronic tinnitus. Second, the hearing status and the psychoacoustical characteristics of tinnitus were evaluated in subjects reporting chronic tinnitus.

The questionnaire was distributed online on several forums and student applications during 1 month. The responses of 151 young adults which consists of 100 females and 51 males with age range of 18-27 years (mean 23.2 years, SD 3.26 years), were further analyzed.

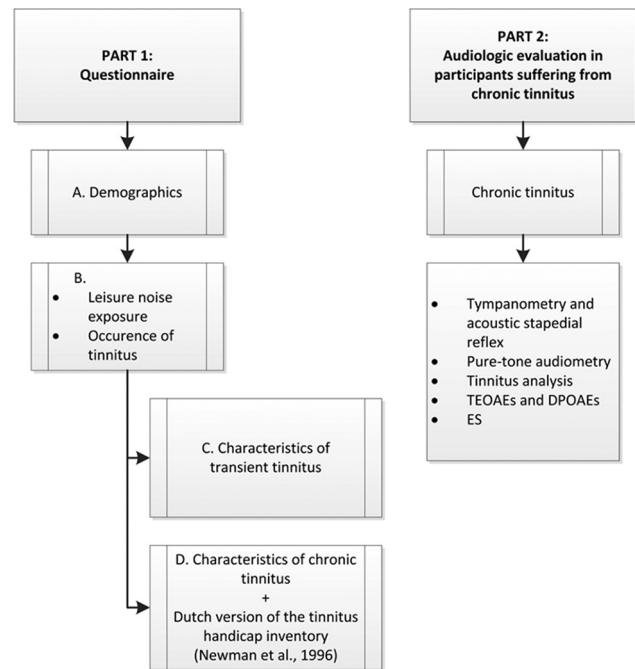


Figure 1: Schematic overview of the present study

In the second part of the study, respondents who had indicated chronic tinnitus were asked to undergo further audiologic investigations. Seven (4 females, 3 males) respondents with chronic tinnitus were agreed to participate. The hearing status was evaluated during a single session by otoscopic evaluation, admittance measures, pure-tone audiometry and OAEs. Subsequently, a tinnitus analysis was performed. A control group (CG), matching the group with chronic tinnitus (TG) by age and gender was established. All control subjects had normal hearing, defined as hearing thresholds equal to or better than 20 dB HL at octave step frequencies from 0.25 to 8 kHz and half octave frequencies 3.0 and 6.0 kHz, together with normal middle ear function.

Part 1: Questionnaire

A questionnaire was designed containing questions about leisure noise exposure and the experience of tinnitus. After a try out on 30 other subjects ranging in age from 18 to 30 years, the clarity of some items and the adequacy of some response alternatives were adjusted.

The questionnaire comprised of 44 items which consisted of four sections. The first section addressed demographic issues as well as subjective hearing status and medical history concerning ear-related disorders. The second section included questions regarding the amount of leisure noise exposure per week or month at music events, i.e. festivals, music concerts, discotheques and parties. Furthermore, the amount of time the respondent was wearing hearing protector devices during these activities was registered. Subsequently, the presence of tinnitus after exposure to leisure noise and whether the tinnitus was transient or chronic was evaluated.

Transient tinnitus was defined as tinnitus disappearing within 72 h. If transient tinnitus occurred after exposure to leisure noise, the third section regarding the characteristics of tinnitus had to be completed. In case of chronic tinnitus, respondents filled in section four of the questionnaire, which consisted of questions on the characteristics of tinnitus and a Dutch version of the tinnitus handicap inventory (THI).^[25]

To ensure that the questionnaire was completed correctly by the subjects, instructions were provided at the beginning of the questionnaire as well as at each new section. All terminology regarding leisure noise, hearing and tinnitus was explained and appropriate examples were given.

Part 2: Audiologic evaluation in subjects with chronic tinnitus

Admittance measurements

A 226 Hz tympanometry was performed with an 85 dB sound pressure level (SPL) probe tone. Ipsilateral and contralateral acoustic stapedial reflex thresholds were measured at 1.0 kHz, as well as contralateral reflex threshold using broadband noise (Tymptstar, Grason-Stadler Inc.). A type A tympanogram and normal acoustic stapedial reflex thresholds were conditions to participate in the further audiologic evaluation.

Audiometry

Pure tone audiometry was performed using the modified Hughson-Westlake method for air conduction thresholds at conventional octave frequencies from 0.25 to 8.0 kHz and half octave frequencies 3.0 and 6.0 using an interacoustics AC-40 audiometer. Pure-tone average (PTA) was calculated as the average air conduction hearing thresholds at 0.5, 1.0 and 2.0 kHz.

Subjects were categorized as having a noise-induced threshold shift (NITS) according to the definition of Niskar *et al.*,^[26] i.e. on the basis of three audiometric criteria for at least 1 ear. First, thresholds at 0.5 and 1 kHz had to be equal to or better than 15 dB HL. Second, the maximum threshold at 3, 4, or 6 kHz had to be at least 15 dB worse than the maximum threshold obtained at 0.5 or 1 kHz. Third, the threshold at 8 kHz had to be at least 10 dB better than the maximum threshold at 3, 4, or 6 kHz.

Otoacoustic emissions

TEOAEs, DPOAEs and TEOAEs with CAS were measured using the DPOAE probe (ILO 292 USB II module with ILOv6 software; Otodynamics Ltd., Hatfield, UK). The probe was calibrated before each measurement using the 1 cc calibration cavity provided by the manufacturer.

The non-linear differential stimulus paradigm was used for TEOAE measurements. Rectangular pulses of 80 μ s at a rate of 50 clicks/s were delivered at an intensity of 80 ± 2 dB

peak equivalent sound pressure level (peSPL). Registration of TEOAEs was terminated after 260 accepted sweeps with a noise rejection setting of 4 mPa. Emissions and noise amplitudes were calculated in half octave-frequency bands centered at 1.0, 1.5, 2.0, 3.0 and 4.0 kHz using ad hoc software. A probe stability of 90% or more was needed, and TEOAEs were considered present if the signal-to-noise ratio (SNR) was at least 3 dB in each half-octave frequency band.

DPOAEs were measured with primary tone level combinations of L1/L2 = 65/55 dB SPL. The f1/f2 ratio was 1.22, with f2 ranging from 0.841 to 8.0 kHz at eight points per octave. A noise artefact rejection level of 6 mPa was used and the whole frequency range was looped until the noise amplitude fell below -5 dB SPL at individual frequencies. DPOAEs were considered present if the SNR at all individual frequencies were at least 3 dB. Emission and noise amplitude were averaged for half-octave frequency bands with center frequencies 1.0, 1.5, 2.0, 3.0, 4.0, 6.0 and 8.0 kHz.

TEOAEs with CAS were measured using TEOAEs in linear mode with and without CAS at 60 dB peSPL. CAS of continuous white noise was presented at 60 dB peSPL. Clicks were presented in alternating blocks of 10 s without and with CAS stored in memory 1 and 2, respectively. A total of 260 sweeps were obtained and the noise rejection level was 4 mPa. Only TEOAEs with SNR of at least 3 dB in the condition without CAS were further analyzed. The amount of ES was calculated as the difference in TEOAE amplitude (in dB) with and without CAS in half-octave frequency bands centered around frequencies 1.0, 1.5, 2.0, 3.0 and 4.0 kHz.

Tinnitus analysis

Tinnitus was analyzed using the same equipment that was used for pure tone audiometry. In addition, a HDA 200 phone (Sennheiser, Inc., Wedemark, Germany) was used for assessment of high-frequency (>8 kHz) tinnitus. The tinnitus analysis consisted of (1) tinnitus pitch matching, (2) tinnitus loudness matching, (3) determining the minimum masking levels (MMLs) and (4) the residual inhibition (RI) following masking.

Before pitch matching, participants indicated whether their tinnitus was tonal or noise-like. Tinnitus pitch matching consisted of a two – alternative forced choice procedure and a test for octave confusion.^[27]

Loudness matching was done at the frequency determined by pitch matching. First, the hearing threshold at this frequency was obtained according to the modified Hughson-Westlake method. Second, the sound or noise intensity was increased in 1 dB steps until the subject reported that the stimulus was as loud as the tinnitus. The intensity of the loudness match was expressed in dB sensation level (SL).

The MML, i.e. the lowest level at which a white noise can mask the tinnitus, was determined. First the subjects' hearing threshold for the white noise was measured. Subsequently, the noise level was raised in 1 dB increments until the subject reported that the tinnitus had become inaudible. The corresponding sound level was defined as the MML and was recorded in dB SL.

To determine the RI, white noise was presented during 1 min at an intensity 10 dB above the MML.^[27] After 1 min, the subject had to report whether the tinnitus had changed. Four classes of RI were considered: (1) Positive, tinnitus disappeared completely; (2) partial positive, tinnitus reduced; (3) rebound, tinnitus increased; (4) negative, tinnitus remained unchanged.

Data analysis

Statistical analysis was performed using SPSS version 19 (SPSS Inc. Chicago IL, USA). Descriptive parameters were established for the questionnaire outcomes. In addition, Chi-square was calculated ($P < 0.05$) to evaluate the relation between occurrence of tinnitus and the frequency and length of exposure to leisure noise. A Chi-square test was also used to evaluate whether the occurrence of tinnitus differed in subjects who always wore hearing protection as opposed to subjects who never wore hearing protection devices. If one or more cells had an expected count less than five, Fisher's exact test was used ($P < 0.05$). The results of the second part of the study were analyzed to establish descriptive parameters. Furthermore, a Mann-Whitney U test ($P < 0.05$) was used to evaluate whether the amplitude of TEOAEs and DPOAEs, and the amount of ES differed significantly between the TG and the CG.

Results

Part 1: Questionnaire

Transient tinnitus in one or both ears was reported by 111 (73.5%) respondents and persisted for less than 1 h in the majority of the cases. 10 subjects (6.6%) indicated chronic tinnitus that had been present for either less than 1 year (in 4 out of 10 cases) or for one up to 5 years (in 6 out of 10 cases).

In Figure 2, an overview of the characteristics of transient and chronic tinnitus is given. Both transient and chronic tinnitus were mostly observed bilaterally as a continuous pure tone with a high pitch. The THI documents the impact of tinnitus on daily functioning in persons with chronic tinnitus. In 4 cases (out of 10) a slight (0-16) impact was found. A mild (18-36) to moderate (38-56) impact was found in 4 (out of 10) and 2 cases (out of 10), respectively.

A majority of the respondents was frequently exposed to leisure noise. Weekly noise exposure was reported by 27.9% and 35.8% reported leisure noise on a monthly basis. 36.4%

reported an exposure of less than once a month. Further, the majority of respondents (70.9%) had spent 3 up to 6 h at a music event while 24.50% were exposed for 1 up to 3 h and 4.6% for over 6 h. No statistically significant relationship was found between the occurrence of tinnitus and the frequency of visiting music events ($P > 0.05$). Nevertheless, tinnitus was observed more often in respondents who spent more time (3 h or more) at a music event. However, this effect was not statistically significant ($P > 0.05$).

Hearing protection was always worn by 9 respondents (6.0%) and never by 89 respondents (58.9%). Tinnitus was observed by 67 individuals (75.28%) who never and by six persons (66.67%) who always wear hearing protection. The Fisher's exact test was used, leading to the conclusion that there was no statistically significant relationship between the occurrence of tinnitus and the frequency of wearing hearing protectors ($P > 0.05$).

Part 2: Audiologic evaluation in subjects with chronic tinnitus

7 (out of 10) persons with chronic tinnitus participated in further audiological investigations.

The psychoacoustic characteristics of chronic tinnitus were evaluated by means of a tinnitus analysis. Tinnitus was experienced bilaterally in 4 subjects (out of 7) and unilaterally in 3 subjects (out of 7). A mean pitch of 6.0 kHz (SD 6.01 Hz; 0.75-16 kHz) was found. The mean loudness was 7.6 dB SL (SD 6.35; 1-22 dB SL) and the mean MML was 12.7 dB HL (SD 6.75; 1-21 dB HL). RI was partially positive in 3 (out of 7) and negative in 2 (out of 7) subjects with tinnitus. A rebound effect was found in 2 subjects with tinnitus (out of 7).

All subjects with chronic tinnitus had a PTA better than 20 dB HL. However, 3 subjects (out of 7) met the NITS criteria. NITS were in all subjects unilateral at 6.0 kHz. A Mann-Whitney U-test showed a statistically significant difference in hearing threshold at 1 kHz between the tinnitus and the CG (U (26.50), $P > 0.05$). For TEOAEs and DPOAEs, it can be seen in Figures 3 and 4 that the mean amplitudes in the TG were lower, compared to the CG. Differences in TEOAE amplitude were statistically significant at 1.0 kHz (U (24.50), $P < 0.05$) and 4.0 kHz (U (11.00), $P < 0.05$). The amplitude of DPOAEs showed a statistically significant difference at 1.5 kHz (U (21.00), $P < 0.01$). Figure 5 shows that ES was less in the TG as compared to the CG. However, this was not statistically significant.

Discussion

The prevalence of transient tinnitus after exposure to leisure noise in the present study (73.5%) is in agreement with other studies on noise exposure in young adults.^[3,6,28] However,

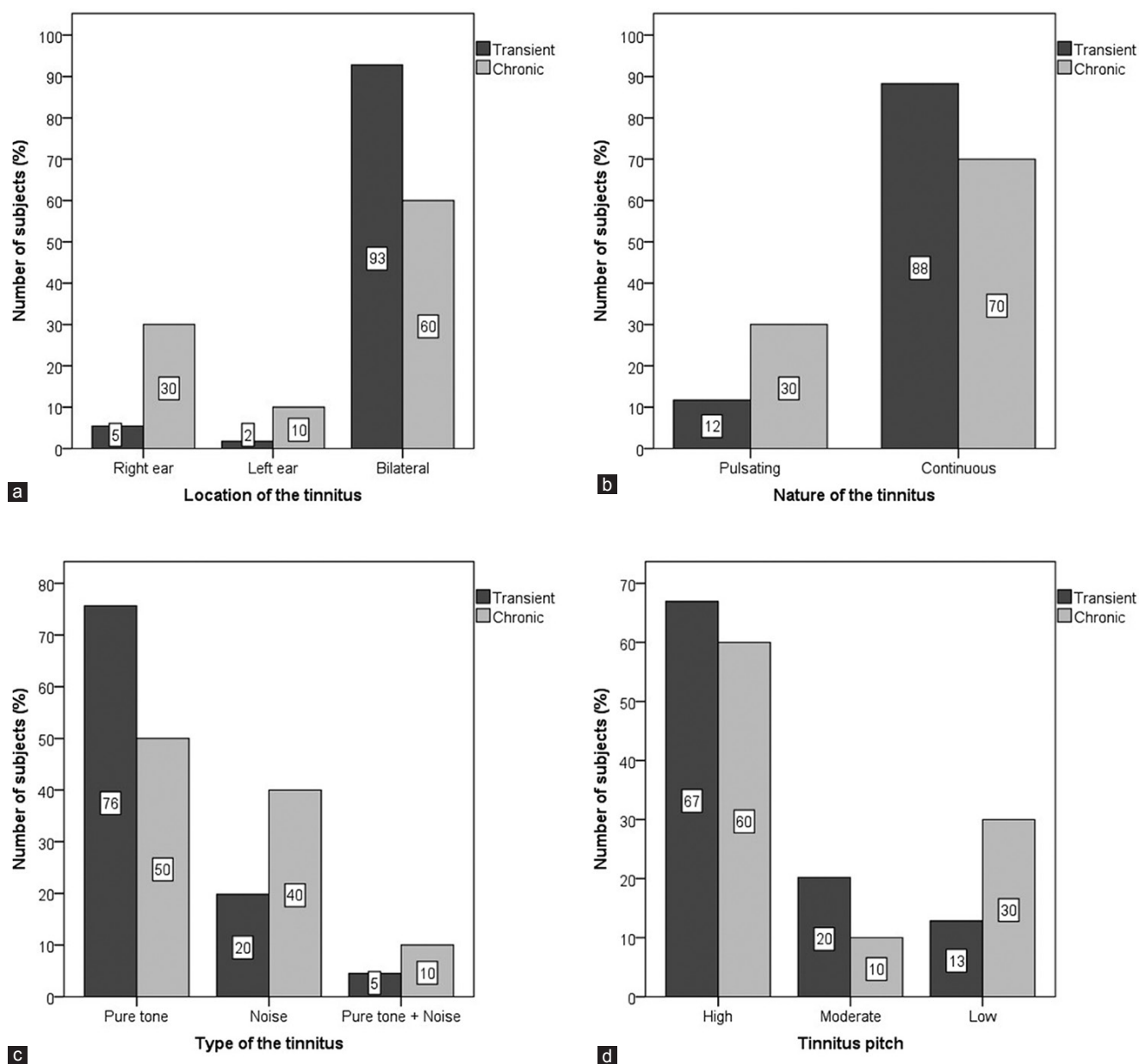


Figure 2: Overview of the characteristics of transient versus chronic tinnitus: (a) The localization of the tinnitus, (b) the nature of tinnitus, (c) the type of tinnitus and (d) the pitch of the tinnitus

one study reported a much lower prevalence of 22% which can be explained by a different definition of transient tinnitus, i.e. 24 h or longer.^[4] These authors also reported the prevalence of chronic tinnitus (8.7%), which is in agreement with the prevalence found in the present study.

Although there was no significant relation between experiencing tinnitus and the frequency of visiting music events on weekly or monthly basis, this study confirmed that many young adults expose themselves frequently to loud music during leisure activities. More respondents experience tinnitus as the length of exposure exceeded the average of 3 h. Both findings can be explained by the well-known fact that the risk of damage to hearing increases with the intensity and

exposure time.^[29] As defined by NIOSH, hazardous noise is a sound that exceeds 85 dB over a typical 8-h day^[30] and can cause temporary or permanent effects on hearing. In the study of Serra *et al.*^[12] the equivalent A-weighted sound levels in discotheques were measured and ranged from 104 dB (A) to 112 dB (A). Exposure to such high intensities implies risk of acquiring transient or chronic tinnitus every time adolescents expose themselves to loud music.

There was no statistical relation between the use of hearing protection and experiencing tinnitus. The number of subjects in this study who always wore hearing protection was very small, while the majority of subjects never wore hearing protection. The unequal distribution of these two groups

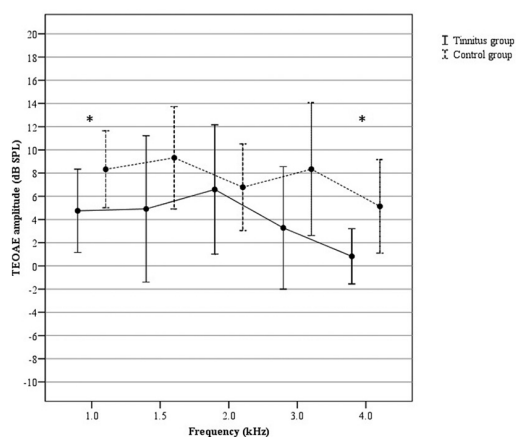


Figure 3: Transient evoked otoacoustic emissions amplitudes in dB sound pressure level for subjects with tinnitus (solid line) and the control group (dashed line): Mean \pm one standard deviation. * $P < 0.05$

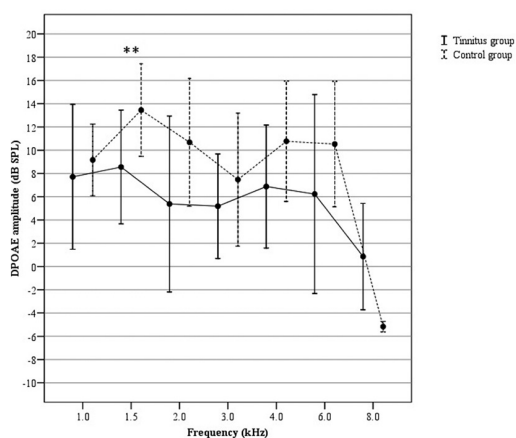


Figure 4: Distortion product otoacoustic emission amplitudes in dB sound pressure level for subjects with tinnitus (solid line) and the control group (dashed line): Mean \pm one standard deviation. ** $P < 0.01$

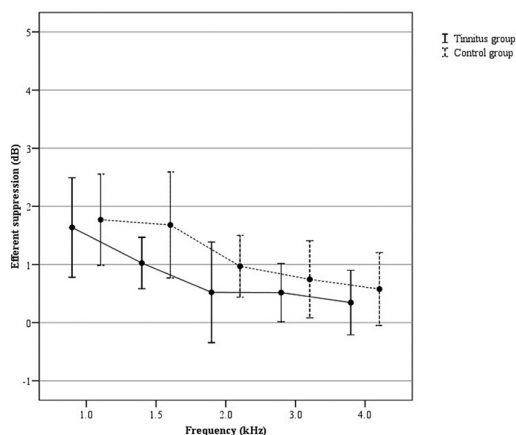


Figure 5: dB Efferent suppression for subjects with tinnitus (solid line) and the control group (dashed line). Mean \pm one standard deviation

makes it difficult to compare the risk of acquiring tinnitus. The results of the current study may nevertheless indicate that the use of hearing protection can reduce the risk of acquiring tinnitus when exposed to leisure noise since they reduce the sound intensity.

Many studies have examined the characteristics of tinnitus. The majority of those studies have focused on chronic tinnitus that was attributed to a variety of causes.^[31,32] Publications addressing the characteristics of chronic tinnitus induced by noise generally deal with tinnitus induced by occupational noise or noise in military service.^[8,11] They reported noise-induced tinnitus as being tonal, with a high pitch between 4 kHz and 8 kHz. Few studies have investigated the characteristics of temporary tinnitus induced by a short exposure to noise. Here the outcome was that tinnitus generally is experienced as a continuous tonal sound with a pitch distributed over the mid- and high frequency range.^[9,10] To the best of our knowledge, there are no publications available addressing the characteristics of transient and chronic tinnitus induced by leisure noise. In the present study, the characteristics of both transient and chronic tinnitus induced by leisure noise were documented by means of a questionnaire. In the majority of the subjects, transient and chronic tinnitus were subjectively experienced as tonal with a high pitch. The subjective experience of persons with chronic tinnitus is in agreement with the psychoacoustic measurements. This finding suggests that the characteristics of tinnitus observed after exposure to leisure noise cannot predict whether the tinnitus will be transient or chronic. Nevertheless, experiencing transient tinnitus after leisure noise exposure can be an important warning signal of early noise-induced damage to hearing.

THI indicated that for the majority of subjects with chronic tinnitus, it had a slight to moderate impact, which means that the tinnitus can be heard in a quiet environment, but can easily be masked by environmental sounds or easily be forgotten in the course of activities.^[25] Tinnitus had a lesser impact in the subjects who did not agree to participate in the further investigation. This could suggest that persons who observe a greater impact of tinnitus on daily functioning are more likely to seek help for their problem. However, the sample of subjects with chronic tinnitus was rather small in the present study and further research in a large population of young adults is needed to thoroughly document the characteristics and impact of chronic tinnitus induced by leisure noise exposure on the quality of life.

The results of the audiometric measurements showed PTAs equal or better than 20 dB HL in all subjects with chronic tinnitus. Three subjects met the NITS criteria. The amplitudes of TEOAEs and DPOAEs were reduced and the amount of ES was less in the TG as compared to the CG. It has been suggested that a decrease in OHC function could result in tinnitus before a shift in hearing threshold is seen.^[33]

However, significant differences between TG and CG were found only at 1.0 kHz and 4.0 kHz for TEOAEs and at 1.5 kHz for DPOAEs. The significant differences on the lowest of the frequencies (1.0 and 1.5 kHz) could probably be explained by the significant difference in hearing thresholds between the TG and CG at 1 kHz. Furthermore, the results might be influenced by the criteria used to determine present emissions as well as the small sample size of subjects with chronic tinnitus. Measuring OAEs in a larger sample of subjects with chronic tinnitus is needed. Nevertheless, these results suggest that TEOAEs and DPOAEs can be used as a useful tool to distinguish between normal hearing subjects with and without tinnitus induced by leisure noise. This outcome also corroborates the conclusions of Granjeiro *et al.*,^[15] namely that OHC dysfunction may be important in the generation of tinnitus.

As far as ES is concerned, the amount was less in subjects with tinnitus as compared with the control subjects. These results are in agreement with the data reported by Ceranic *et al.*^[22] and Paglialonga *et al.*^[18] However, the difference in ES between both groups in the current study was not statistically significant. Since the sample of subjects whose OAEs were obtained was very small, the results should be interpreted with caution. Nevertheless, the effect of noise-induced tinnitus on OAEs and ES and its clinical utility merits further investigation.

Conclusion

The present study showed that transient tinnitus after exposure to leisure noise occurred frequently among young adults (in 73.5%). Furthermore, chronic tinnitus was reported by some participants (in 6.6%). No predictors were found among the characteristics of tinnitus allowing to infer whether tinnitus will be transient or chronic.

In subjects with chronic tinnitus, the amplitudes of TEOAEs and DPOAEs were reduced and the amount of ES was less as compared to the CG, indicating subclinical damage and a possible role of the OHC in the generation of tinnitus induced by leisure noise. The clinical utility of OAEs and ES in subjects with tinnitus induced by leisure noise needs further research.

As an overall conclusion, it is very important to educate youth about the risks of noise exposure during leisure activities and the early symptoms of hearing damage.

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