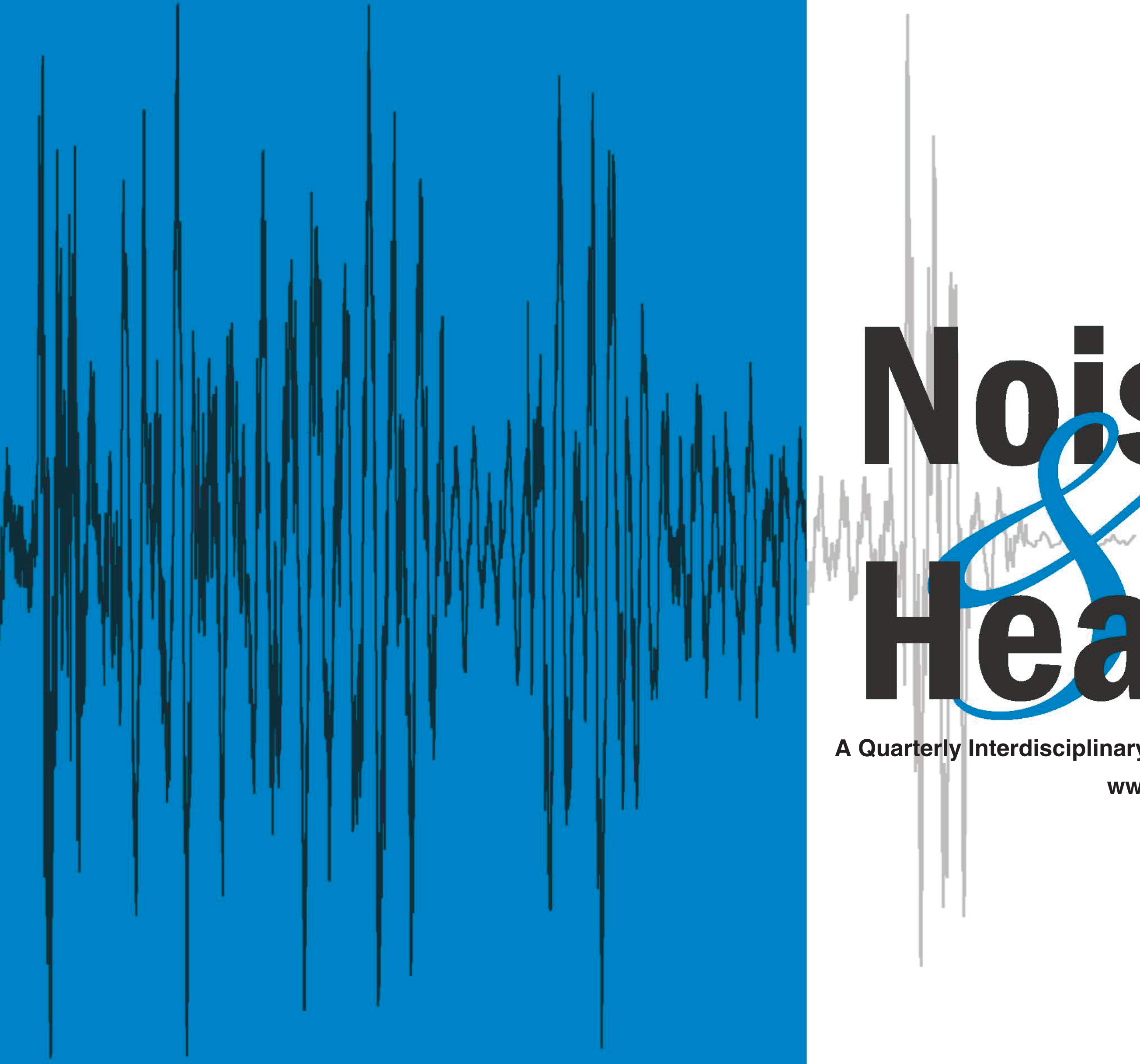
Indexed with
MEDLINE, EMBASE & SCI

ISSN 1463-1741

Impact Factor® for 2021:
1.293



Noise & Health

A Quarterly Interdisciplinary International Journal

www.noiseandhealth.org

April-June 2022 | Volume 24 | Issue 113

Medknow

Wolters Kluwer

Original Article

Evolution of Hearing in Young Adults: Effects of Leisure Noise Exposure, Attitudes, and Beliefs toward Noise, Hearing Loss, and Hearing Protection Devices

Sofie Degeest[1], Paul Corthals[1,2], Hannah Keppler[1]

[a]Department of Speech, Language and Hearing Sciences, Ghent University, Ghent, Belgium, [b]Faculty of Education, Health and Social Work, University College Ghent, Ghent, Belgium

Abstract

Context: Young people expose themselves to high levels of noise during various leisure activities and might thus be at risk of acquiring hearing-related problems due to leisure noise exposure.

Aim: The aim of this study was to compare the hearing status, amount of leisure noise exposure, and attitudes and beliefs toward noise, hearing loss, and hearing protection devices (HPDs) in university students at the moment of their enrollment in higher education and after approximately 3 years.

Settings and Design: Thirty-four female university students were tested at the moment of their enrollment in higher education and after approximately 3 years.

Method and Material: Hearing was evaluated using pure-tone audiometry and transient evoked and distortion product otoacoustic emissions. A questionnaire was used to evaluate leisure noise exposure and attitudes and beliefs toward noise, hearing loss, and HPDs.

Results: There were significant differences after the 3-year period: a deterioration in hearing at some tested frequencies, an increase in the occurrence of temporary tinnitus after leisure noise exposure, an increase in noise exposure related to visiting nightclubs and music venues, and differences in attitudes and beliefs toward noise, hearing loss and HPDs.

Conclusions: More longitudinal studies are needed to evaluate the onset and progression of hearing loss due to leisure noise exposure. In the meantime, hearing conservation programs targeting young people should be optimized.

Keywords: Attitudes, hearing, leisure noise exposure, young adults

Key Messages: There were differences in hearing status and the experience of hearing-related symptoms as well as differences in the amount of leisure noise exposure and the attitudes toward noise, hearing loss, and hearing protection after the 3-year period. Therefore, the long-term effects of noise exposure should be further investigated.

INTRODUCTION

One of the most common preventable causes of acquired hearing loss in developed countries is noise exposure.[1] Besides occupational noise exposure, there is concern regarding the increase in social noise exposure.[2] Young people expose themselves voluntarily to high levels of noise during various leisure activities, of which visiting nightclubs, discotheques, and live concerts are considered as major sources[2-7] in combination with the use of personal music players.[8] It is also known that listening or attendance habits for activities with leisure noise exposure change during different phases of life.[8,9]

Noise exposure can result in alterations in the structural elements of the organ of Corti[10] leading to a loss of hearing sensitivity and impaired speech discrimination.[11] To evaluate the effects of leisure noise exposure on hearing

Access this article online

Quick Response Code:

Website:
www.noiseandhealth.org

DOI:
10.4103/nah.nah_7_21

Address for correspondence: Sofie Degeest, MS, PhD, Ghent University Hospital, Corneel Heymanslaan 10 (poli 1 – 2nd floor), B-9000 Ghent.
E-mail: Sofie.Degeest@ugent.be

Received: 4 February 2021 **Revised:** 22 February 2021
Accepted: 16 March 2021 **Published:** 25 July 2022

For reprints contact: reprints@medknow.com

How to cite this article: Degeest S, Corthals P, Keppler H. Evolution of Hearing in Young Adults: Effects of Leisure Noise Exposure, Attitudes, and Beliefs toward Noise, Hearing Loss, and Hearing Protection Devices. Noise Health 2022;24:61-74.

thresholds, mostly cross-sectional studies were conducted.[4,12] Although an increase in the prevalence of noise-induced hearing loss due to leisure noise was reported,[13] it was recently stated that there is insufficient evidence that abnormal hearing thresholds caused by leisure noise exposure in young populations are widespread or increasing over time.[14] One possible reason for this insufficient evidence may be attributed to the use of pure-tone audiometry to detect noise-induced hearing loss, as the effectiveness of this technique to detect minimal hearing loss is debated.[15] Hence, the use of other techniques such as speech-in-noise tests,[16] a dual-task paradigm to evaluate listening effort,[17] and otoacoustic emissions (OAEs)[18] should be further explored. Nevertheless, noise-induced hearing damage can initially be recognized by the presence of hearing-related symptoms such as tinnitus and noise sensitivity.[19] In Flanders, that is, the Dutch-speaking part of Belgium, pure-tone hearing thresholds in 517 young adults aged between 18 and 30 years were within the normal range.[20] Within these subjects, however, temporary and chronic tinnitus due to leisure noise exposure in at least one ear was present in 68.5% and 6.4%, respectively. Furthermore, subjects with chronic tinnitus had significantly higher lifetime equivalent noise exposure levels in nightclubs and music venues as compared to subjects with temporary tinnitus or without tinnitus.[21]

Besides the association between hearing and leisure noise exposure in young people, investigating an individual's risk-taking behavior is also important. Widen[22] constructed a theoretical framework to explain such individual's risk-taking behavior. Within this framework, all factors from the Theory of Planned Behavior[23] and barriers to behavioral change and triggers to action from the Health Belief Model[24] are used. The model of Widen also adds a factor "risk perception," that is, an indicator of an individual's awareness of the harmfulness of leisure noise exposure.[22] Based on this theoretical framework, risk-taking behavior regarding leisure noise exposure can be evaluated in association with hearing-related symptoms. For example, previous research showed that young adults between 18 and 30 years with more problematic attitudes regarding noise exposure had significantly worse hearing as compared to those with more negative attitudes and beliefs.[25] The hearing status of young adults experiencing more barriers to preventive action, for example, during the use of hearing protector devices (HPDs), was significantly worse in comparison to those youngsters indicating to experience less barriers to preventive actions.[25] Further, significant differences in attitudes and beliefs toward noise, hearing loss, and HPDs were found between young adults with chronic tinnitus and young adults without tinnitus as well as between young adults with temporary tinnitus and without tinnitus.[21] Finally, it was also shown by previous research that the theoretical framework of Widen[22] can be used to evaluate behavioral change in young adults longitudinally, for example, after the implementation of a hearing conservation program.[26]

Knowledge from longitudinal studies would provide more insight into the age onset and progression of hearing-related problems due to leisure noise exposure, which might be important for the optimization of hearing conservation programs targeting young people. However, information regarding the progression of hearing-related problems associated with leisure noise exposure is limited as longitudinal studies pose logistical challenges,[14] for example, an adequate long-term planning and identical methodological conditions. One study found that during a 4-year period, mean hearing thresholds of high school children in Argentina increased.[5] Moreover, they found that within the subgroup of adolescents with hearing level thresholds of more than 20 dB for one or more frequencies in the third year of the study, there was a high preference or increase in preference for musical activities.[27] More recently, a significant reduction in hearing thresholds as well as in transient evoked otoacoustic emissions (TEOAEs) amplitudes was found in adolescents tested at 14 or 15 years and retested approximately 3 years later.[28] Also, among young adults with normal hearing ranging in age between 18 and 30 years, those with absent TEOAEs or distortion product otoacoustic emissions (DPOAEs) were significantly older as compared to the subgroup of subjects with present TEOAEs or DPOAEs.[20] In addition to this limited information regarding the progression of hearing-related problems, its association with an individual's risk-taking behavior is to the best of our knowledge unknown.

The aim of the current study was to compare the hearing status, the amount of leisure noise exposure, and the attitudes and beliefs toward noise, hearing loss, and HPDs in university students at the moment of their enrollment in higher education and after approximately 3 years. A questionnaire was used, and hearing status was evaluated using pure-tone audiometry, TEOAEs, and DPOAEs. These outcomes were described and compared between both test moments. In addition, the present study evaluated whether there might be a relation between changes in attitudes toward noise, hearing loss, and HPDs and the actual use of HPDs.

Subjects and Method

Study sample

The subject group consisted of students entering the Bachelor program in Speech, Language, and Hearing Sciences at Ghent University (Belgium) during the academic year 2012-2013. Students were first evaluated when they entered the first year of the Bachelor program (further denoted as test A) and were retested when they entered the final Master program during the academic year 2015-2016 (further denoted as test B). At both test moments, a questionnaire regarding hearing-related symptoms, leisure noise exposure, and attitudes and beliefs toward noise, hearing loss, and HPDs was administered. Further, hearing status was assessed during both tests by means of an otoscopic evaluation, admittance measures, pure-tone audiometry, and measurements of TEOAEs and

DPOAEs. All testing was carried out in a sound-treaded room where ambient sound pressure levels did not exceed any of the levels specified by the ISO 8253-1 guidelines.[29] Besides, a noise-free period of at least 12 hours before testing was required in order to rule out the presence of transient threshold or emission shifts.

A total of 36 students voluntarily participated in the study. Students were excluded in case of abnormalities of the external ear, abnormal middle ear function as measured by tympanometry or acoustic stapedius reflex thresholds, or when they did not complete the questionnaire correctly for more than 95% of the questions. The responses of 34 students were further analyzed, that is, a drop out of 5.6%. Hence, the final sample at test A consisted of 34 females (mean 18.1 years; standard deviation [SD] 0.29; range 18–19 years) who all participated again during test B (mean 21.0 years; SD 0.46; range 21–22 years). The average time between test A and test B was 34.62 months (SD 0.49, range 34–35 months).

The study was approved by the local Ethical Committee and was conducted in accordance with the ethical standards stipulated in the Helsinki declaration for research involving human subjects. All participants agreed with the informed consent, in which the aims of the study were described.

Questionnaire

The questionnaire, which was based on the literature regarding leisure noise exposure and the assessment of noise-induced hearing loss and tinnitus,[30-32] consisted of 44 items distributed over five sections. More details about the questionnaire are described elsewhere.[20,21]

The first and second section, respectively, included several sociodemographic variables and questions regarding subjective hearing status and medical history concerning ear-related disorders. Subjects were required to have no hearing disorders other than noise-induced hearing loss (e.g., congenital hearing loss or conductive hearing loss due to malformations of the ossicular chain).

In the third section of the questionnaire, the amount of leisure noise exposure and the amount of time the respondent wore HPDs was questioned for several leisure activities that are common among young adults, such as visiting nightclubs and playing musical instruments. Participants were asked how many times per year, month, week, or day they attended each type of activity, the duration of their average visit to each of these (in hours), the total time of exposure to each activity (in years), as well as their estimation of loudness in terms of communicative effort. Five levels of loudness were considered: (1) the level of a normal conversation, (2) the level of a loud conversation, (3) the level at which one must shout over 1 m in order to be heard (e.g., over a table), (4) the level at which one must shout over a near distance in order to be heard (e.g., someone less than an arm's length away), and (5) the level that makes communication impossible. Based on these parameters, the lifetime equivalent noise exposure ($L_{\text{Aeq,l}}$) was calculated for each activity: $L_{\text{Aeq,l}} = L_{\text{Aeq,w}} + 10*\log10(\text{Ty})$, where $L_{\text{Aeq,w}}$ reflected the weekly noise exposure and Ty the time of exposure in years.[30] More details regarding the calculation methods can be found elsewhere.[20,21] Finally, for each of the activities, participants had to indicate how often they wore HPDs. Specifically, participants were asked for each activity if they wear HPDs "always", "sometimes," or "never". Participants who indicated to wear HPDs "sometimes" or "never" were for statistical reasons categorized into the umbrella category "not wearing HPDs."

The fourth questionnaire section consisted of Dutch modified versions of the "Youth Attitude to Noise Scale" (YANS)[32,33] and "Beliefs about Hearing Protection and Hearing Loss" (BAHPHL) instrument.[31,33] The YANS evaluates a subject's attitude toward noise and consists of 19 items that are divided over four factors: (1) attitudes toward noise associated with elements of youth culture, for example, loud music at concerts or discos (factor 1: eight items), (2) attitudes toward the ability to concentrate in noisy environments (factor 2: three items), (3) attitudes toward daily noise, for example, environmental noise such as traffic (factor 3: four items), and (4) attitudes toward the intent to influence the sound environment (factor 4: four items).[32] The BAHPHL instrument evaluates the beliefs toward hearing loss and HPDs and contains 24 items that can be divided over seven factors: (1) susceptibility to hearing loss (factor 1: six items), (2) severity of consequences of hearing loss (factor 2: three items), (3) benefits of preventive action, that is, wearing HPDs (factor 3: three items), (4) barriers to preventive action (factor 4: four items), (5) behavioral intentions, that is, the will to perform a given behavior, such as wearing HPDs (factor 5: three items), (6) social norms, for example, how the environment thinks about wearing HPDs (factor 6: two items), and (7) self-efficacy, that is, the extent of one's belief to execute the behavior necessary to protect hearing (factor 7: three items).[31] Both the YANS and the BAHPHL instrument use a five-point Likert scale ranging from "totally disagree" to "totally agree". A higher score on the YANS indicates a positive attitude, where noise is seen as unproblematic. Consistent with the YANS, higher scores on the BAHPHL instrument also correspond with a more positive attitude, meaning that one does not care about the possible consequences of hearing loss and is unaware of the benefits of wearing HPDs.

The fifth and last part of the questionnaire included questions regarding the presence of tinnitus after leisure noise exposure and whether the tinnitus was temporary or chronic. Temporary tinnitus was defined as disappearing within 72 hours after the exposure to leisure noise.

Admittance measures

The tympanogram and acoustic stapedius reflex thresholds were, respectively, measured using a 226 Hz probe tone at

85 dB sound pressure level (SPL) and an ipsilateral 1.0 kHz probe tone (AA222 Audio Traveler and TDH39 headphones Interacoustics, Assens, Denmark). Type A tympanograms and normal acoustic stapedius reflex thresholds were required to be included in the study.

Audiometric evaluation

Pure-tone audiometry was performed using the modified Hughson-Westlake method for air conduction thresholds at the conventional octave frequencies from 0.25 to 8.0 kHz and half-octave frequencies 3.0 and 6.0 kHz (AA222 Audio Traveler and TDH39 headphones Interacoustics, Assens, Denmark). Specifically, the intensity level of the pure tones was decreased from the starting level of 30 dB HL in 15 dB steps until there was no response. Subsequently, the intensity level was decreased by 10 dB after each correct detection of the pure tone and increased by 5 dB for each nonresponse. The hearing threshold was determined as the lowest intensity at which the participant respond at least 50% of the time (i.e., two out of three responses). Furthermore, it was ensured that the ambient sound pressure levels did not exceed any of the levels specified by the ISO 8253-1 guidelines for measuring down to a minimum of −10 dB HL.[29]

Otoacoustic emissions

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

TEOAEs were recorded using a nonlinear differential stimulus paradigm and rectangular pulses of 80 μs at a rate of 50 clicks per second and an intensity of 80 ± 2 dB SPL. 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 was at least 3 dB per half-octave frequency band.

DPOAEs were measured with primary tone level combinations of $L_1/L_2 = 65/55$ dB SPL and a primary tone frequency ratio $f_1/f_2 = 1.22$, with f2 ranging from 0.841 to 8.0 kHz at eight points per octave. The whole frequency range was looped until the noise amplitude fell below −5 dB SPL at individual frequencies with a noise artifact rejection level of 6 mPa. DPOAEs were considered present if the signal-to-noise was at least 3 dB and 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.

For both TEOAEs and DPOAEs, amplitudes were compared with the age-corrected normative values as well as their test-retest variation.[34,35]

Statistical analysis

Statistical analysis was performed using The Statistical Product and Service Solutions (SPSS) version 21 (SPSS Inc. Chicago, IL, USA). Descriptive parameters were established for the hearing assessment as well as for the questionnaire outcomes, that is, the presence of hearing-related symptoms, YANS and BAHPHL outcomes, the average time spent per week at different leisure activities, and the resulting lifetime equivalent noise exposure per activity. Furthermore, pure-tone thresholds were compared with the 95th percentile value for gender- and age-corrected frequency-specific threshold norms according to ISO 7029.[36]

Subsequently, differences in hearing status between test A and B were evaluated. First, differences in pure-tone thresholds were evaluated using a three-way repeated measures analysis of variance (ANOVA), with ear (right versus left ear), frequency (0.25–8.0 kHz), and test moment (test A versus B) as within-subject factors. Second, differences in TEOAE and DPOAE amplitudes were evaluated. For TEOAE amplitudes, a three-way repeated measures ANOVA was used with ear (right versus left ear), frequency (half-octave frequency bands 1.0–4.0 kHz), and test moment (test A versus B) as within-subject factors. For DPOAE amplitudes, also a three-way repeated measures ANOVA was used with ear (right versus left ear), frequency (half-octave frequency bands 1.0–8.0 kHz), and test moment (test A versus B) as within-subject factors. For each repeated measures ANOVA model, the underlying assumption of sphericity was assessed by the Mauchly’s test. In case of violation of the sphericity assumption, the Greenhouse-Geisser adjustment was applied to adjust the degrees of freedom. If the main effects or interactions were found to be significant, tests of within-subjects contrasts were performed in order to compare the different levels of the within-subject factors.

In addition to the differences in hearing status, differences in hearing-related variables, leisure noise exposure, and attitudes toward noise and HPDs were evaluated between test A and B. In case of continuous variables, paired samples *t*-tests were used. To examine possible correlations between categorical variables, χ^2 tests were performed. If one or more cells had an expected count less than five, Fisher exact test was used.

Finally, the number of students showing a real change in attitudes over time was determined. Therefore, the test-retest variability and in particular the minimal detectable difference (MDD) of both the total YANS and BAHPHL scores and each of their factors was used.[37] The MDD can be defined as the difference between the scores of YANS and BAHPHL at test A and B that must exist in order to conclude that there is a real change in attitudes. If the score at test B exceeds the MDD based on the scores at test A,[37] the score at test B may be considered as a result of a real difference not due to personal variation or measurement error.[38] Hence, based on the individual scores at test A and the MDD, a score interval was determined for each student separately for both the total YANS and BAHPHL scores and each of their factors: [MDD+individual score;MDD-individual score]

If the score for an individual was higher than the upper limit of the interval, this was considered as a real change toward more positive attitudes. Likewise, if the score for an individual was lower than the lower limit of the interval, this was considered as a real change toward more negative attitudes.

For all statistical analyzes, a significance level of 0.05 was used.

RESULTS

Hearing assessment

All subjects had type A tympanograms and normal acoustic stapedius reflex thresholds at both test A and B. Regarding pure-tone audiometry, the mean pure-tone thresholds for the right and left ears of all participants obtained at test A and B are presented in Figure 1. A three-way repeated measures ANOVA was used to evaluate differences in pure-tone thresholds based on the factors "ear," "frequency," and "test moment". There was a significant main effect of frequency on pure-tone thresholds, $F(4.1, 119.7) = 33.846$; $P < 0.001$. Tests of within-subject contrasts were performed with the frequency of 4.0 kHz as reference since noise-induced hearing loss often begins at this frequency. Results revealed that pure-tone thresholds were significantly higher (i.e., poorer) at the frequencies of 0.25 kHz ($F[1,29] = 99.771$; $P < 0.001$), 0.5 kHz ($F[1,29] = 72.149$; $P < 0.001$), 1.0 kHz ($F[1,29] = 5.740$; $P = 0.023$), 6.0 kHz ($F[1,29] = 67.289$; $P < 0.001$) and 8.0 kHz ($F[1,29] = 32.948$; $P < 0.001$). At 3.0 kHz, the pure-tone threshold was significantly lower compared to 4.0 kHz, $F(1, 29) = 11.897$, $P = 0.002$. No significant difference was found with the pure-tone threshold at 2.0 kHz ($F[1,29] = 0.010$; $P > 0.05$). In addition, a significant main effect of the test moment on pure-tone thresholds was found ($F[1.0, 29.0] = 54.969$; $P < 0.001$), indicating that the pure-tone thresholds were overall higher (i.e., poorer) for test B compared to test A. No significant interactions between the factors ear, frequency, and test moment were found ($P > 0.05$).

Regarding TEOAE and DPOAE amplitudes, the mean amplitudes for the right and left ears of all participants obtained in test A and B are presented in Figures 2 and 3, respectively. Furthermore, a three-way repeated measures ANOVA was used to evaluate differences in TEOAE and DPOAE amplitudes based on the factors "ear," "frequency,"

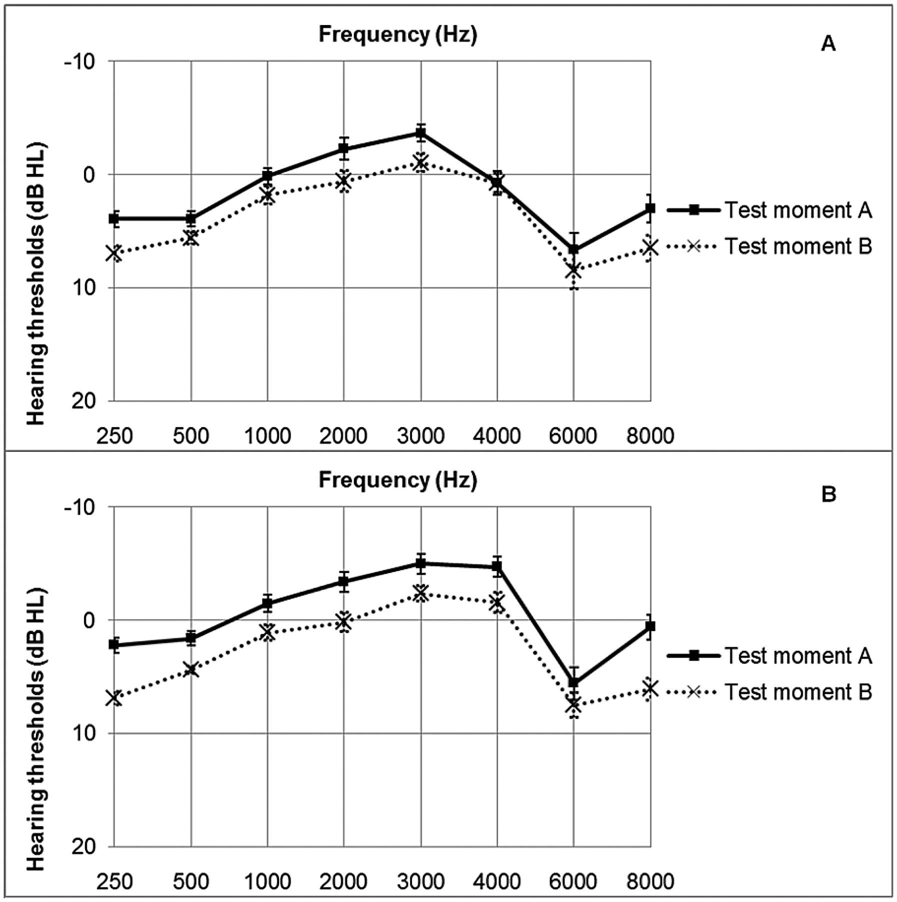


Figure 1: Comparison of pure-tone air-conduction hearing thresholds (mean ± one standard error) of right (panel A) and left ears (panel B) obtained at test A (solid line) and B (dashed line)

and “test moment”. For the TEOAE amplitudes, a significant main effect of frequency was found, $F(4.0, 72.0) = 5.678$; $P < 0.001$. Based on the tests of within-subjects contrasts with the half-octave frequency band 4.0 kHz as the reference, TEOAE amplitudes were significantly higher at half-octave frequency bands 1.5 kHz ($F[1,18] = 18.533$; $P < 0.001$) and 2.0 kHz (F [1,18] = 7.719; $P = 0.012$). There was also a significant main effect of the test moment on TEOAE amplitudes ($F[1.0, 18.0] = 10.553$; $P = 0.004$), indicating that TEOAE amplitudes were overall lower at test B compared to test A. No significant interactions between the factors ear, frequency, and test moment were found ($P > 0.05$).

Similar to the TEOAE amplitudes, a significant main effect of frequency on DPOAE amplitudes was found, $F(2.9, 49.2) = 25.744$; $P < 0.001$. Using the half-octave frequency band 4.0 kHz as the reference, tests of within-subjects contrasts revealed that DPOAE amplitudes were significantly higher at half-octave frequency bands 1.5 kHz ($F[1,17] = 32.772$; $P < 0.001$), 2.0 kHz (F[1,17] = 12.811; $P = 0.002$), and 6.0 kHz ($F[1,17] = 43.843$; $P < 0.001$). Besides, DPOAE amplitudes were significantly lower at half-octave frequency bands 3.0 kHz ($F[1,17] = 9.674$; $P = 0.006$) and 8.0 kHz ($F[1,17] = 17.554$; $P = 0.001$). No significant difference was found with the DPOAE amplitude at 1.0 kHz (F[1,17] = 0.741; $P > 0.05$). In contrast to the pure-tone thresholds and TEOAE amplitudes, the main effect of the test moment on DPOAE amplitudes was borderline nonsignificant ($F[1.0, 17.0] = 3.636$; $P = 0.074$). However, a trend toward lower DPOAE amplitudes at test B compared to test A could be observed. There was, however, a significant interaction effect between the test moment and frequency, $F(2.8, 47.3) = 4.172$; $P = 0.012$, indicating that the difference in DPOAE amplitudes between test A and B differs for the different half-octave frequency bands. Specifically, tests of within-subjects contrasts with the half-octave frequency band 4.0 kHz as reference showed that DPOAE amplitudes

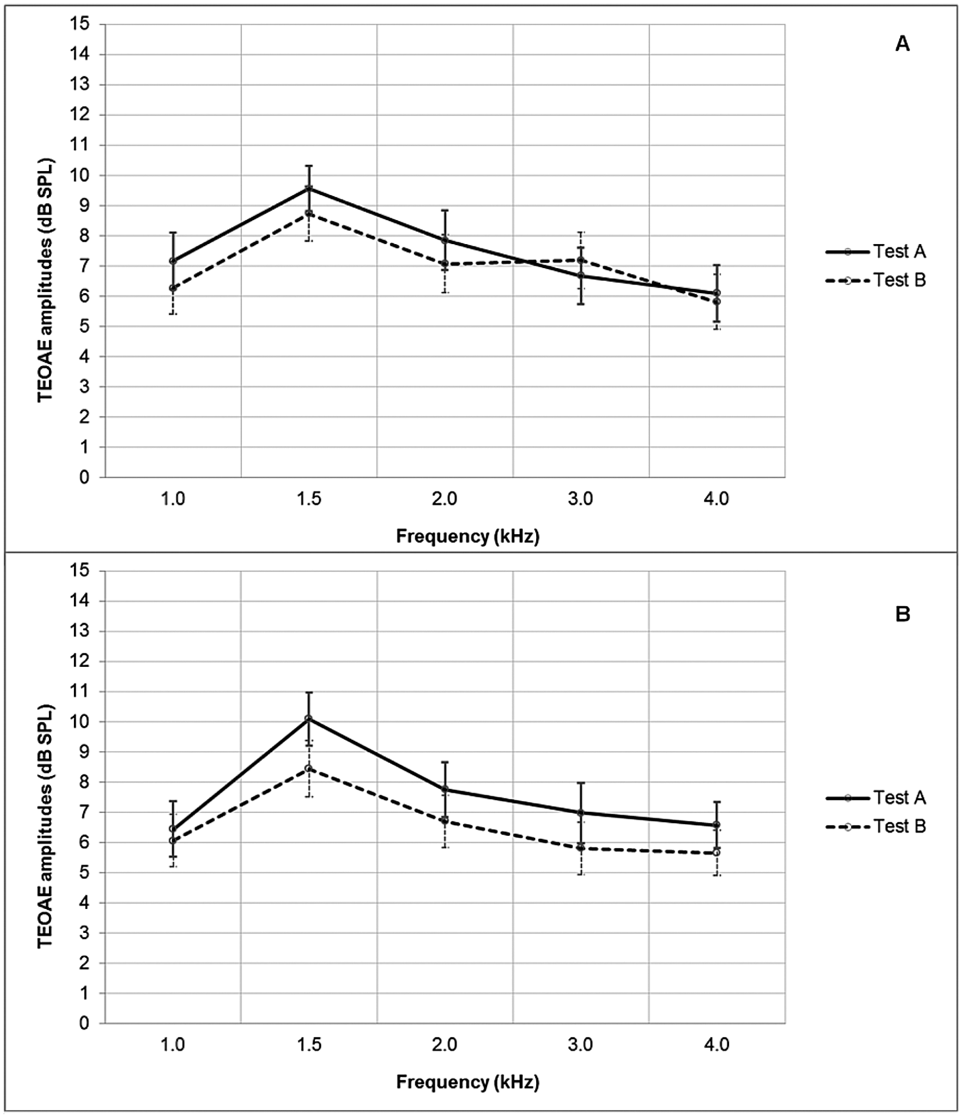


Figure 2: Comparison of present TEOAE amplitudes (mean ± one standard error) of right (panel A) and left ears (panel B) obtained from test A (solid line) and B (dashed line)

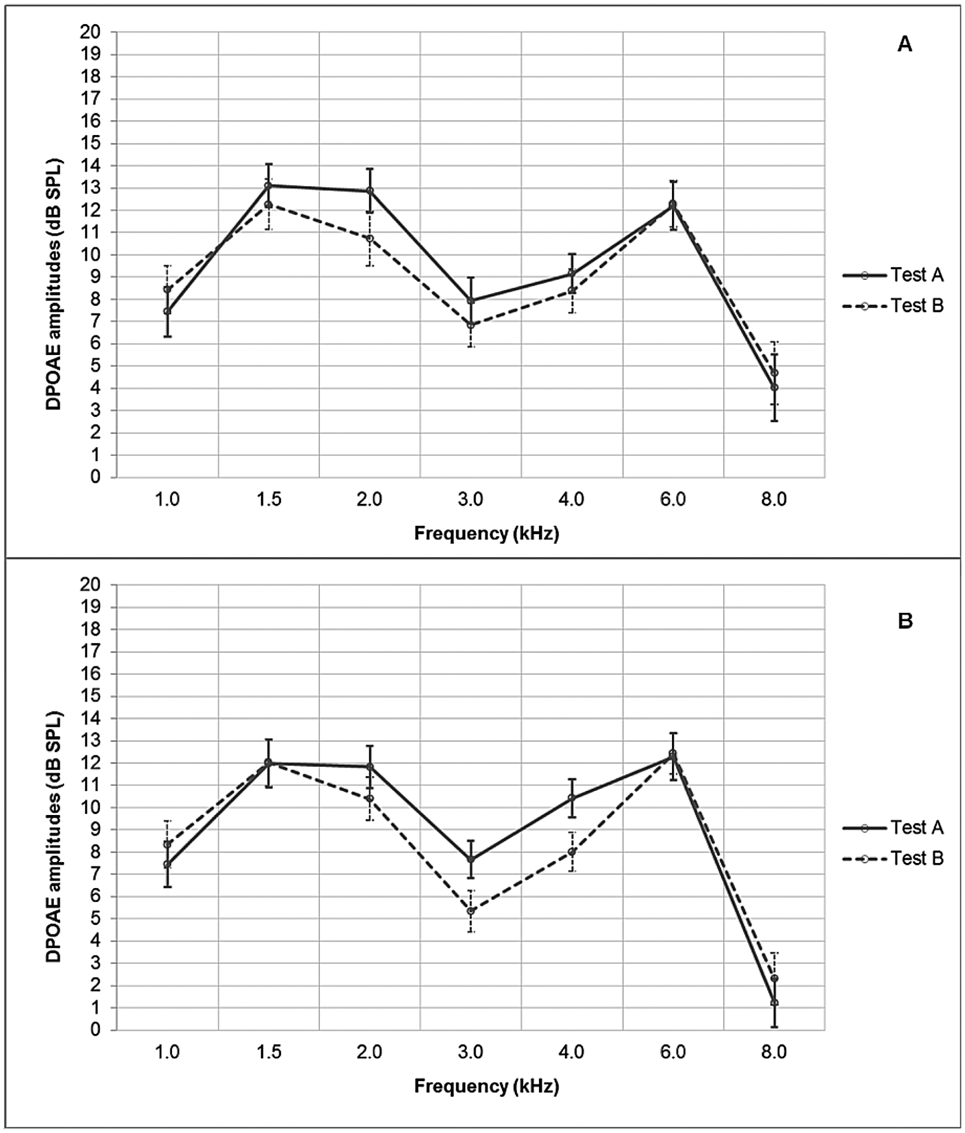


Figure 3: Comparison of present DPOAE amplitudes (mean ± one standard error) of right (panel A) and left ears (panel B) obtained from test A (solid line) and B (dashed line)

increased at test B compared to test A at half-octave frequency bands 1.0 kHz ($F[1.0, 17.0] = 5.001$; $P = 0.039$) and 8.0 kHz ($F(1.0, 17.0) = 10.609$; $P = 0.005$) Table 1.

Hearing-related symptoms

In Table 2, the percentage of self-reported hearing-related symptoms after leisure noise exposure is given for test A and B. In general, tinnitus was often reported by the subjects in this study. At test A, 73.5% of the subjects reported temporary tinnitus, while 8.8% of the subjects reported chronic tinnitus. Comparing these results with those at the test B showed no differences in the occurrence of chronic tinnitus, though the occurrence of temporary tinnitus increased with 11.8% as compared with the test A. This difference in occurrence of temporary tinnitus was statistically significant according to the Fisher exact test ($P < 0.001$). Regarding the subjective experience of hearing loss, it can be seen from Table 2 that all subjects (100%) reported to have good hearing capabilities at both test A and B. No significant differences in the occurrence of dullness were found between both tests (Fisher exact test, $P > 0.05$).

Leisure noise exposure and the use of hearing protector devices

Table 3 provides an overview of the subjects' attendance, average time spent per week, number of years, self-estimated median loudness, and $L_{\mathrm{Aeq},1}$ for the different leisure activities at test A and B.

At test A, the highest attendance was found for watching movies or plays (100.0%), attending musical concerts or festivals (100.0%), and visiting nightclubs or music venues (97.1%). Furthermore, attending musical concerts and festivals as well as visiting nightclubs and music venues were described as the loudest, where one must shout over a near distance. Out of these activities, visiting nightclubs and music venues amounted to the highest noise exposure, with an average $L_{\mathrm{Aeq,l}}$ of 76.5 dB (SD 13.92; range 43.63–97.96 dB). Regarding test B, the percentage of subjects' attendance and mean hours per week participating in each activity as well as the median loudness and the average $L_{\mathrm{Aeq,l}}$ for each activity was largely the same as at test A. Paired samples *t*-tests showed no significant differences in mean hours per week participation and $L_{\mathrm{Aeq,l}}$ between test A and B for all activities ($P > 0.05$), except for visiting nightclubs and music venues. More specifically, subjects spent significantly more hours per week visiting nightclubs and music venues (mean 5.9 hours per week; SD 4.87) at test B compared to test A (mean 3.8 hours per week; SD 3.20), $t(32) = -2.655$; $P = 0.012$. Furthermore, $L_{\mathrm{Aeq,l}}$ for nightclubs and music venues was significantly higher at test B (mean 83.6 dB; SD 10.93) compared to test A (mean 76.5 dB; SD 13.92), $t(32) = -2.787$; $P = 0.009$.

Table 3 further shows the use of HPDs at both test A and B for all activities. For test A, the participants never wear HPDs for the majority of activities. Subjects only wore HPDs at musical concerts or festivals (50%), visits of nightclubs and music venues (18.2%), playing in a band or orchestra (11.1%), and practicing musical instruments (7.1%). Similar to test A, subjects did not report wearing HPDs in the majority of activities at test B. However, in case of attending concerts or festivals, visiting nightclubs and music venues, practicing musical instruments, and playing in a band or orchestra, the frequency of wearing HPDs was higher compared to test A. According to the Fisher exact test, the difference in wearing HPDs was statistically significant when visiting nightclubs and music venues ($P = 0.018$).

Table 1: Comparison of present TEOAEs and DPOAEs at test A and B. At all tested half-octave frequency bands (in kHz), the number and percentage of present TEOAEs and DPOAEs are given ($n = 34$)

	Frequency (kHz)	Test A		Test B	
		n	%	n	%
TEOAEs	1	32	94.12	32	94.12
	1.5	33	97.06	32	94.12
	2	33	97.06	32	94.12
	3	33	97.06	30	88.24
	4	27	79.41	28	82.35
DPOAEs	1	31	91.18	32	94.12
	1.5	33	97.06	34	100
	2	33	97.06	34	100
	3	32	94.12	33	97.06
	4	34	100	33	97.06
	6	34	100	34	100
	8	27	79.41	31	91.18

Table 2: Comparison of the self-reported hearing symptoms obtained at test A and B ($n = 34$)

	Test A		Test B	
	n	%	*n*	%
Tinnitus				
Temporary tinnitus	25	73.5	29	85.3
Chronic tinnitus	3	8.8	3	8.8
No tinnitus	6	17.6	2	5.9
Subjective hearing loss				
Good	34	100	34	100
Poor	0	0	0	0
Dullness				
Yes	18	52.9	20	58.8
No	16	47.1	14	41.2

Note: Subjective hearing loss concerns the participants' opinion of their hearing ability.

Table 3: Comparison of the subject's participation in each leisure activity at both test A and B ($n = 34$).

Activity	Attendance		Time spent				Median loudness		$L_{Aeq,l}$ in dB		Wearing HPDs	
	(%)		Hours per week		Years				mean (SD)		*n*(%)	
			mean (SD)		mean (SD)							
Test	A	B	A	B	A	B	A	B	A	B	A	B
Watching movies or plays	100	97.1	0.3 (0.26)	0.2 (0.12)	8.6 (3.95)	10.0 (4.70)	2	2	59.6 (7.41)	59.1 (8.00)	0	0
Attending musical concerts or festivals	100	91.2	0.8 (2.53)	0.3 (0.23)	2.8 (1.23)	5.0 (2.07)	4	4	67.8 (13.77)	71.4 (7.62)	50	58.1
Visiting nightclubs or music venues	97.1	100	3.8 (3.20)	5.9 (4.87)	3.0 (1.09)	5.0 (1.34)	4	4	76.5 (13.92)	83.5 (10.81)	18.2	50
Listening to PMPs through headphones	91.2	88.2	3.9 (4.12)	3.1 (4.60)	5.2 (2.70)	7.6 (3.53)	2	2	60.0 (8.41)	61.0 (10.56)	N.A.	N.A.
Listening to a home stereo or radio	82.4	73.5	7.1 (5.60)	7.1 (5.74)	9.0 (4.94)	9.3 (4.97)	1	1	62.5 (6.85)	63.8 (7.37)	0	0
Practicing a musical instrument	41.2	32.4	2.9 (3.96)	1.0 (0.96)	7.9 (2.89)	10.2 (2.75)	2	2	64.1 (13.13)	62.2 (8.26)	7.1	18.2
Attending sport events	35.3	52.9	1.9 (2.05)	1.3 (2.13)	5.8 (4.31)	5.6 (4.30)	2	2	60.0 (13.10)	58.6 (10.30)	0	0
Playing in a band or orchestra	26.5	17.6	0.8 (0.74)	0.8 (0.71)	4.1 (1.90)	6.7 (3.83)	3	3	67.9 (9.56)	67.3 (11.77)	11.1	16.7
Other noisy leisure time activities	20.6	11.8	4.8 (2.45)	2.4 (1.62)	7.6 (6.16)	9.3 (6.65)	2	2	69.0 (6.85)	64.3 (9.02)	0	0
Using noisy tools	2.9	11.8	N.A.	1.1 (1.93)	N.A.	7.0 (4.24)	N.A.	3	N.A.	67.7 (5.53)	0	0

HPDs, hearing protector devices; PMPs, personal music players; SD, standard deviation. **Note:** $L_{\mathrm{Aeq,l}}$ is the lifetime equivalent noise exposure. Loudness scale: (1) level of a normal conversation, (2) level of a loud conversation, (3) level at which one must shout over 1 m in order to be heard (e.g., over table), (4) level at which one must shout over a near distance in order to be heard (e.g., someone less than an arm's length away), and (5) level that makes communication impossible.

Attitudes toward noise, hearing loss, and hearing protector devices

Table 4 reflects for both test A and B the mean and standard deviation of the total scores on the YANS and BAHPHL instrument as well as their factors. Concerning the YANS for both test A and B, the highest average score was found for the attitudes regarding daily noise, indicating that the subjects have problematic positive attitudes toward daily noises, such as traffic noise. The lowest average score was related to the attitudes intending to influence the sound environment, indicating that the subjects tend to do something to make the environment quieter. For the factors of the BAHPHL instrument, the highest average score at both test A and B was found for the barriers to preventive action, which means that the subjects tend to experience more barriers against modifying their behavior. The lowest average score at test A was found for the severity of consequences of hearing loss, indicating that the subjects are more aware of the consequences of hearing loss. For test B, the lowest average score was found for the susceptibility to hearing loss, indicating that the subjects felt more susceptible to hearing loss at that time.

Table 4 further shows the results of a paired samples *t*-test to compare the scores on the YANS and BAHPHL instrument at test A and B. Regarding the YANS, significant lower scores were found for the factor “elements of youth culture” ($P = 0.012$), which means that the subjects became more aware of the effects of loud music, for example, at concerts or nightclubs. In contrast, the scores for the factor “daily noise” were significantly higher ($P = 0.014$), suggesting that the subjects became less aware of the effects of noise during daily activities. As for the subscales of the BAHPHL instrument, significant lower scores were found for the factors “susceptibility to hearing loss” ($P = 0.002$) and “self-efficacy” ($P = 0.001$), indicating that the subjects felt more susceptible to hearing loss over time and were more convinced about being able to execute the behavior necessary to protect their own hearing.

Finally, Table 5 shows the number of students showing a real change in attitudes over time based on their individual scores at test A and the MDD for each factor of the YANS and BAHPHL separately. In general, less than 50% of the students showed a real change in attitudes on each of the factors of both YANS and BAHPHL. In the majority of these students, the attitudes became more negative for the entire YANS score as well as the factors related to “youth culture” and “concentration in noisy environments.” Likewise, for the entire BAHPHL score as well as for the factors related to “susceptibility to hearing loss,” behavioral intentions,” “social norms,” and “self-efficacy,” the attitudes became more negative in the majority of the subjects showing a real change in attitudes over time [Table 5].

DISCUSSION

A longitudinal study of 34 female university students at the moment of their enrollment in higher education and after approximately 3 years was conducted to evaluate hearing status by means of pure-tone audiometry, TEOAEs, and DPOAEs on the one hand and leisure noise exposure and attitudes and beliefs toward noise, hearing loss, and HPDs by means of a questionnaire on the other hand.

With regard to the hearing assessment, results showed that pure-tone thresholds were within the normal range of hearing at both test A and B and that TEOAEs and DPOAEs were present in the majority of the students.[34,36] These findings are in accordance with the studies of Mostafapour *et al*.[39] and Williams *et al*.,[40] who also did not find a clinically

Table 4: Comparison of the mean scores on the entire YANS and BAHPHL as well as their factors obtained at test A and B ($n = 34$)

		Test A			Test B			Paired samples *t*-test	
		Mean	SD	Range	Mean	SD	Range	*T*	*P*
YANS	Elements of youth culture	2.4	0.45	1.63–3.50	2.1	0.48	1.38–3.25	**2.66**	**0.012**
	Concentration in noisy environments	2.6	0.89	1.00–4.33	2.5	0.74	1.33–4.00	0.247	0.806
	Daily noise	3.2	0.76	1.75–5.00	3.5	0.76	2.00–5.00	**–2.587**	**0.014**
	Intent to influence sound environment	2	0.45	1.25–5.00	1.8	0.48	1.00–2.75	1.888	0.068
	Entire YANS	2.5	0.4	1.79–3.16	2.4	0.41	1.58–3.32	1.323	0.195
BAHPHL instrument	Susceptibility to hearing loss	1.7	0.34	1.00–2.33	1.4	0.41	1.00–2.50	**3.297**	**0.002**
	Severity of the consequences of hearing loss	1.5	0.41	1.00–2.67	1.5	0.55	1.00–2.67	-0.257	0.799
	Benefits of preventive action	1.7	0.49	1.00–2.67	1.7	0.6	1.00–3.00	-0.163	0.871
	Barriers to preventive action	3.1	0.6	2.00–4.25	3	0.91	1.25–4.75	0.733	0.469
	Behavioral intentions	2.2	0.78	1.00–3.67	1.9	0.96	1.00–4.33	1.764	0.087
	Social norms	2.4	0.69	1.00–4.00	2.3	0.83	1.00–4.00	0.7	0.489
	Self-efficacy	2.8	0.74	1.67–4.33	2.3	0.65	1.00–3.33	**3.628**	**0.001**
	Entire BAHPHL	2.2	0.29	1.67–2.83	2	0.42	1.29–3.04	**3.121**	**0.004**

BAHPHL, Beliefs about Hearing Protection and Hearing Loss; SD, standard deviation; YANS, Youth Attitude to Noise Scale. Note. Higher mean values on the YANS and the BAHPHL are associated with more pro-noise attitudes. For both YANS and BAHPHL instrument, the mean, standard deviation, and range of scores are reflected as well as the *t* and *p* values from the paired samples *t*-test are given. Significant differences are indicated in bold.

Table 5: The number of subjects showing a real change in attitude over time according to YANS and BAHPHL questionnaires

		Change in attitude between test A and B	
		More negative attitude	More positive attitude
		n(%)	*n*(%)
YANS	Elements of youth culture	7 (87.5%)	1 (12.5%)
	Concentration in noisy environments	4 (66.7%)	2 (33.3%)
	Daily noise	0 (0.0%)	1 (100.0%)
	Intent to influence sound environment	1 (100.0%)	0 (0.0%)
	Entire YANS	4 (80.0%)	1 (20%)
BAHPHL	Susceptibility to hearing loss	8 (80.0%)	2 (20%)
	Severity of the consequences of hearing loss	3 (42.9%)	4 (57.1%)
	Benefits of preventive action	4 (50.0%)	4 (50.0%)
	Barriers to preventive action	8 (53.3%)	7 (46.7%)
	Behavioral intentions	7 (70.0%)	3 (30.0%)
	Social norms	6 (60.0%)	4 (40.0%)
	Self-efficacy	8 (100.0%)	0 (0.0%)
	Entire BAHPHL	11 (91.7%)	1 (8.3%)

BAHPHL, Beliefs about Hearing Protection and Hearing Loss; YANS, Youth Attitude to Noise Scale. **Note:** A real change in attitude between test A and B was determined by using the test-retest variability and in particular the minimal detectable difference (MDD) of both the total YANS and BAHPHL scores and each of their factors.

significant hearing loss in young adults. In contrast with their hearing status, the majority of the students reported to have experienced tinnitus at the first test, of which 73.5% was temporary and 8.8% was chronic tinnitus. The presence of temporary and chronic tinnitus is similar to the previous studies[8,30,41-45] but is higher as compared to the epidemiologic data in Flemish young adults ranging from 18 to 30 years.[21] However, the study of Gilles *et al*.[46] also reported a higher prevalence of chronic tinnitus in Flemish medical students. Hence, the differences in prevalence of temporary and chronic tinnitus might be explained by the studied sample in the current study, which only consisted of students.

Exposure to excessive noise levels has been reported as a risk factor for hearing damage.[7,8,47] Hence, the current study evaluated the amount of noise exposure during several leisure activities. In accordance with previous research,[4,21] it was found that visiting nightclubs or music venues contributed more to the lifetime equivalent noise exposure as compared to listening to personal music players. However, it should be emphasized that listening habits change during different phases of life,[8,9] whereby personal music players are used more frequently and at higher levels by adolescents than subjects above 19 years of age.[2,48,49] Furthermore, risk-taking behavior regarding leisure noise exposure was evaluated using the YANS and BAHPHL instrument. Regarding the factors of the YANS, comparable[21,25] and lower[32,46] mean scores were found, which might be related to variables such as gender, cultural differences, and socioeconomic status in the studied sample.[32,50,51] The mean scores on the BAHPHL instrument for the factors behavioral intentions and social norms are better as compared to previous studies.[21,25] This might be related to the inclusion of only women in this study. Specifically, previous research has demonstrated that young men are more likely to put their health at risk compared to women.[52] Hence, gender may have an effect on social norms, persons' risk perception and attitudes toward noise, and the resulting behavioral intentions.[22] In addition, better mean scores on the BAHPHL instrument may be related to the effects of preventive campaigns conducted in Flanders in the previous years[53] as well as to the specific study program of the students included in the current study, whereby the behavior of the students might have been influenced by these campaigns (e.g., the Flemish government campaign "help ze niet naar de tuut") or the courses (e.g., course in preventive audiology) provided in their study program.

The results of the hearing assessment and the outcomes on the questionnaire in students entering higher education were compared with their results after approximately 3 years. A repeated measures ANOVA was used to evaluate differences in pure-tone thresholds as well as TEOAE and DPOAE amplitudes based on three factors, that is, the ear of the participant, the test frequency, and the test moment. Regarding the factor ear, no significant main effects were found pertaining to the pure-tone thresholds as well as TEOAE and DPOAE amplitudes. In contrast, a significant main effect of frequency on pure-tone thresholds as well as TEOAE and DPOAE amplitudes was found. The highest (i.e., poorest) pure-tone thresholds were found at the frequencies of 6.0 and 8.0 kHz. Although it had been described that noise-induced hearing loss is a sensorineural hearing deficit that begins at the higher frequencies,[54,55] it is not possible to draw conclusions about the possible relation with leisure noise exposure. As stated above, pure-tone thresholds were within normal limits at all tested frequencies. Moreover, according to the gender- and age-corrected frequency-specific threshold norms,[36] pure-tone thresholds can be slightly higher at 6.0 and 8.0 kHz, even for young adults. With regard to the TEOAE and DPOAE amplitudes, higher responses were found at 1.5 and 2.0 kHz for TEOAEs and at 1.5, 2.0, and 6.0 kHz for DPOAEs. These results could be expected based on the known response characteristics of both TEOAEs and DPOAEs, whereby TEOAEs show a maximum response between 1.0 and 2.0 kHz[56] and DPOAEs show a maximum response at 1.5 and 5.5 kHz.[57]

The present study was, however, mainly interested in the evolution of the hearing status over the 3-year period. First, a significant deterioration of the overall pure-tone thresholds was found between test A and B. Based on the well-known relation between age and hearing deterioration,[36] we would not expect age-related hearing changes in this group of students. In the present study, pure-tone thresholds increased by 2 to 5 dB from test A (i.e., subjects' mean age was 18 years) to test B (i.e., subjects' mean age was 21 years). According to the gender- and age-corrected frequency-specific threshold norms,[36] the estimated change in pure-tone thresholds over a 3-year period for young adults between 18 and 21 years ranges between 0 and 1 dB, which is lower than the 3-year changes found in this study. In contrast, the changes that were found were less than 5 dB HL, which is within the scope of normal test-retest variation of pure-tone audiometry. Second, a significant main effect of the test moment on TEOAE amplitudes was found, whereby the overall TEOAE amplitudes decreased after 3 years. For DPOAEs, no significant main effect of the test moment was found, though a trend toward lower DPOAE amplitudes at test B compared to test A could be observed. These deteriorations in TEOAE and DPOAE amplitudes may be an indication of progressive hearing changes. However, the differences in TEOAE and DPOAE amplitudes between test A and B were within the scope of normal test-retest variation of TEOAEs and DPOAEs described by Keppler, *et al*.[35] According to the literature, the OAE responses can vary as a result of some nonauditory factors, such as probe placement, test parameters, and the recording instrument,[33] which limit the reliability of OAEs to detect minimal cochlear changes.[35] Finally, with regard to DPOAEs, a significant interaction was found between the test moment and the tested frequency. Specifically, DPOAE amplitudes decreased over the 3-year period, except at half-octave frequency bands 1.0 and 8.0 kHz. This result can be explained by the response characteristics of DPOAEs, whereby it is known that they can be recorded reliably in the frequency region of 1.5 to 6.0 kHz. Therefore, as also described by Keppler *et al*.,[35] the reliability of DPOAE amplitudes is lower at 1.0 and 8.0 kHz.

Although the deteriorations of pure-tone thresholds as well as TEOAE and DPOAE amplitudes are within the scope of their test-retest variation and, therefore, may be not clinically relevant, systematic negative changes in hearing status over the 3-year period could be observed in this study. In addition, there was a significant increase of 11.8% in the occurrence of temporary tinnitus during the 3-year period. The question may, therefore, arise whether changes in the amount of leisure noise exposure may have led to even minimal changes in hearing and the increase in the occurrence of temporary tinnitus. In the current sample, there was a significant increase in average time spent per week and in lifetime equivalent noise exposure for nightclubs and music venues during the 3-year period, while other activities remained stable regarding attendance, time spent per week, and lifetime equivalent noise levels. These changes in leisure noise exposure during lifetime are consistent with earlier studies,[2,9,28] in which nightclubs and music venues were mostly attended during adolescence with a decrease of the number of people older than 30 years in these leasure activities. Hence, the change in frequency of attendance in different leisure activities during the 3-year period, and therefore noise exposure levels, did not vary enough among the students in this study in order to evaluate a possible relation between leisure noise exposure and the changes in hearing. Moreover, in the literature, it is assumed that it is too soon to detect the effects of leisure noise exposure on hearing,[58] whereby it is possible that these effects will be present in the long term. This could be supported by the finding that age resulted in significant differences in hearing in a group of young adults between 18 and 30 years.[20] Longitudinal studies monitoring the changes in leisure habits from adolescence to adulthood are, therefore, needed to evaluate a possible relation with an individual's hearing status.

Based on the model of Widen,[22] changes in hearing or experiencing symptoms such as tinnitus may serve as a trigger to more anti-noise attitudes and more preventive behavior. Moreover, the study of Rawool and Colligon-Wayne[59] showed that the use of HPDs is associated with the previous experience with hearing loss and tinnitus. The present study evaluated the change in the scores for the entire YANS and BAHPHL and each of their factors between test A and B. A significant difference in the mean score was found for the factors related to "youth culture" and "daily noise" of the YANS and the factors related to "susceptibility to hearing loss" and "self-efficacy" of the BAHPHL. However, to conclude that the score at test B can be considered as a result of a real difference, the present study used the MDD of each of the factors of the YANS and BAHPHL.[37,38] In accordance with the theoretical model of Widén,[22] more negative attitudes were found in the majority of subjects showing a real change in attitudes over time for the factors of the YANS related to the "elements of youth culture" and the "ability to concentrate in noisy environments." Besides, based on the BAHPHL instrument, these subjects also indicate to be more susceptible to hearing loss and had also more negative attitudes regarding the factors related to "social norms" and "self-efficacy". Such changes might also have led to a more negative attitude toward noise (i.e., more awareness of the negative effects of noise).[22] Moreover, the model of Widen[22] stated that more awareness about the effects of noise exposure may also lead to a more consistent use of HPDs. Indeed, the present study observed a trend whereby the majority of the students showing a real change in attitudes indicated they have the intention to wear HPDs. Furthermore, the use of HPDs while attending nightclubs and music venues significantly increased during the 3-year period.

Notwithstanding, it should be mentioned that, in general, a real change in the attitudes over time was found in less than 50% of the students in this study. Moreover, the actual use of HPDs during different leisure activities also remained low. The question may, therefore, arise whether there are potential variables that cause no change in attitudes and nonuse of HPDs. Although behavioral changes might be induced by the effects of preventive campaigns conducted in Flanders in the last years[53] as well as to the study program of the students included in the current study, the present study did not evaluate the students' familiarity with preventive campaigns or information regarding the risks of noise exposure provided during their study program. Two Flemish studies found a significant decrease in several subscales of the YANS and BAHPHL after educating youth about the impact of noise on hearing, which implies a more negative attitude toward noise and more awareness of the benefits of wearing HPDs.[26,60] However, both studies measured the effect only after 6 months, and so it is possible that the changes in attitudes that were found did not persist in the long term. Hence, it is possible that for some students in this study changes in attitudes did not persist over the 3-year period. Furthermore, factors such as cost, comfort, looks, and communication while wearing HPDs may be important for the nonuse of HPDs.[61] Further longitudinal research is, therefore, needed to evaluate changes in attitudes toward noise as well as possible variables leading to the nonuse of HPDs.

The results of the current study should be considered taking into account some limitations. First, due to the small sample size and consequently large standard deviation of pure-tone thresholds, TEOAE and DPOAE amplitudes, it can be hypothesized that significant difference between test moments is hampered. Second, as also stated above, the sample of the current study contained only female university students entering the study program of Speech, Language, and Hearing Sciences, which might have influenced the results that were found. Finally, the lifetime equivalent noise exposure levels are potentially subject to errors since they are based on a retrospective estimation of leisure noise exposure in hours per week, number of years, and subjective loudness, which might be imprecise. However, the study of Beach *et al*.[62] indicated that persons can make a reasonable estimate of the loudness of activities they participated in. Nevertheless, large-scaled longitudinal studies spanning lower to higher education and eventually at the time of employment are needed. This would allow a thorough evaluation of hearing from an age where only minimal noise exposure is present to an age where habits regarding leisure noise exposure have changed. Within such studies, a group of students who are not exposed to leisure noise should also be included. Such information would be useful for existing or future hearing conservation programs. Hearing conservation programs aim to increase knowledge and awareness regarding the effects of noise exposure, thus inducing a more health-orientated behavior.[63] The effectiveness of preventive campaigns targeting young populations is equivocal[26,60,64]; therefore, there is room for improvement of hearing conservation programs. First, self-experienced symptoms such as temporary tinnitus due to leisure noise exposure as part of an individual's risk-taking behavior could be used as a warning sign or trigger for more health-orientated behavior.[22] Second, more attention to the relevant leisure noise exposures and their changing pattern during lifetime could be beneficial. Third, improving the design, looks, marketing, and packaging of earplugs could make them more attractive to young people.[61] Finally, behavioral change should not only be restricted at an individual's level, but also in society,[65] for example, by a strict compliance of the existing regulations for noise levels at indoor and outdoor music venues.

CONCLUSION

During a 3-year period, there was a slight deterioration in hearing thresholds, TEOAE and DPOAE amplitudes, as well as a significant increase in the occurrence of temporary tinnitus after leisure noise exposure. There were also significant differences in attitudes and beliefs toward noise, hearing loss and HPDs, as well as a significant increase in noise exposure related to visiting nightclubs and music venues. As such, the current study adds knowledge regarding the progression of hearing and change in leisure noise exposure and attitudes and beliefs toward noise, hearing loss, and HPDs in young adults.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Dobie RA. The burdens of age-related and occupational noise-induced hearing loss in the United States. Ear Hear 2008;29:565-77.
2. Smith PA, Davis A, Ferguson MA, Lutman ME. The prevalence and type of social noise exposure in young adults in England. Noise Health 2000;2:41-56.
3. Jokitulppo JS, Bjork EA. Estimated leisure-time noise exposure and hearing symptoms in a finnish urban adult population. Noise Health 2002;5:53-62.
4. Keppler H, Dhooge I, Vinck BM. Hearing in young adults. Part II: The effects of recreational noise exposure. Noise Health 2015;17:245-52.
5. Serra MR, Biassoni EC, Richter U, *et al.* Recreational noise exposure and its effects on the hearing of adolescents. Part I: an interdisciplinary long-term study. Int J Audiol 2005;44:65-73.
6. Williams W, Beach EF, Gilliver M. Clubbing: the cumulative effect of noise exposure from attendance at dance clubs and night clubs on whole-of-life noise exposure. Noise Health 2010;12:155-8.
7. Beach EF, Williams W, Gilliver M. Estimating young Australian adults' risk of hearing damage from selected leisure activities. Ear Hear 2013;34:75-82.

8. Meyer-Bisch C. Epidemiological evaluation of hearing damage related to strongly amplified music (personal cassette players, discotheques, rock concerts) high-definition audiometric survey on1364 subjects. Int J Audiol 1996;35:121-42.
9. Beach EF, Gilliver M, Williams W. Leisure noise exposure: participation trends, symptoms of hearing damage, and perception of risk. Int J Audiol 2013;52 Suppl 1:S20-S5.
10. Talaska AE, Schacht J. Mechanisms of noise damage to the cochlea. Audiol Med 2007;5:3-9.
11. ACOEM Evidence based statement. Noise-induced Hearing Loss. JOEM 2003; 45(6):579-581.
12. Cone BK, Wake M, Tobin S, Poulakis Z, Rickards FW. Slight-mild sensorineural hearing loss in children: audiometric, clinical, and risk factor profiles. Ear Hear 2010;31:202-12.
13. Shargorodsky J, Curhan SG, Curhan GC, Eavey RD. Change in prevalence of hearing loss in US adolescents. JAMA 2010;304:772-8.
14. Carter L, Williams W, Black D, Bundy A. The leisure-noise dilemma: hearing loss or hearsay? What does the literature tell us? Ear Hear 2014;35:491-505.
15. Schlauch RS, Carney E. The challenge of detecting minimal hearing loss in audiometric surveys. Am J Audiol 2012;21:106-19.
16. Gilles A, Schlee W, Rabau S, Wouters K, Fransen E, Van de Heyning P. Decreased speech-in-noise understanding in young adults with tinnitus. Front Neurosci 2016;10(288):1-14.
17. Degeest S, Keppler H, Corthals P. The effect of tinnitus on listening effort in normal-hearing young adults: a preliminary study. J Speech Lang Hear Res 2017;60:1036-45.
18. le Clercq CM, van Ingen G, Ruytjens L, van der Schroeff MP. Music-induced hearing loss in children, adolescents, and young adults: a systematic review and meta-analysis. Otol Neurotol 2016;37: 1208-16.
19. Daniel E. Noise and hearing loss: a review. J. Sch Health 2007;77: 225-31.
20. Degeest S, Clays E, Corthals P, Keppler H. Epidemiology and risk factors for leisure noise-induced hearing damage in Flemish young adults. Noise Health 2017;19:10-9.
21. Degeest S, Keppler H, Corthals P, Clays E. Epidemiology and risk factors for tinnitus after leisure noise exposure in Flemish young adults. Int J Audiol 2017;56:121-9.
22. Widen SE. A suggested model for decision-making regarding hearing conservation: towards a systems theory approach. Int. J. Audiol 2013;52:57-64.
23. Ajzen I. The theory of planned behavior. Organ Behav Hum Decis Processes 1991;50:179-211.
24. Rosenstock IM. The health belief model and preventive health behavior. Health Educ Monogr 1974;2:354-86.
25. Keppler H, Dhooge I, Vinck BM. Hearing in young adults. Part I: the effects of attitudes and beliefs towards noise, hearing loss and hearing protector devices. Noise Health 2015;17:237-44.
26. Keppler H, Dhooge I, Degeest S, Vinck BM. The effects of a hearing education program on recreational noise exposure, attitudes and beliefs towards noise, hearing loss and hearing protector devices in young adults. Noise Health 2015;17:253-62.
27. Biassoni EC, Serra MR, Richter U, *et al.* Recreational noise exposure and its effects on the hearing of adolescents. Part II: development of hearing disorders. Int J Audiol 2005;44:74-85.
28. Biassoni EC, Serra MR, Hinalaf M, *et al.* Hearing and loud music exposure in a group of adolescents at the ages of 14-15 and retested at 17-18. Noise Health 2014;16:331-41.
29. International Organization for Standardization. Acoustics – Audiometric test methods – Part 1: Basic pure tone air and bone conduction audiometry. ISO 8253–1 :2010.
30. Jokitulppo JS, Toivonen M, Bjork EA. Estimated leisure-time noise exposure, hearing thresholds, and hearing symptoms of Finnish conscripts. Mil Med 2006;171:112-6.
31. Svensson EB, Morata TC, Nylen P, Krieg EF, Johnson AC. Beliefs and attitudes among Swedish workers regarding the risk of hearing loss. Int J Audiol 2004;43:585-93.
32. Widen SE, Holmes AE, Erlandsson SI. Reported hearing protection use in young adults from Sweden and the USA: effects of attitude and gender. Int J Audiol 2006;45:273-80.
33. Keppler H. Optimization of the diagnosis of noise-induced hearing loss with otoacoustic emissions (doctoral dissertation). Ghent: Ghent University; 2010.
34. Keppler H, Dhooge I, Corthals P, *et al.* The effects of aging on evoked otoacoustic emissions and efferent suppression of transient evoked otoacoustic emissions. Clin Neurophysiol 2010;121:359-65.
35. Keppler H, Dhooge I, Maes L, *et al.* Transient-evoked and distortion product otoacoustic emissions: a short-term test-retest reliability study. Int J Audiol 2010;49:99-109.
36. International Organization for Standardization. Acoustics — statistical distribution of hearing thresholds as a function of age. ISO 7029; 2000.
37. Degeest S, Maes L, Leyssens L, Keppler H. Test-retest reliability of questionnaires regarding attitudes and beliefs towards noise, hearing loss and hearing protector devices in young adults. Noise Health 2017;20(93):31-36.
38. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med 1998;26:217-38.
39. Mostafapour SP, Lahargoue K, Gates GA. Noise-induced hearing loss in young adults: the role of personal listening devices and other sources of leisure noise. Laryngoscope 1998;108:1832-9.
40. Williams W, Carter L, Seeto M. Pure tone hearing thresholds and leisure noise: is there a relationship? Noise Health 2015;17:358-63.
41. Widen SE, Erlandsson SI. Self-reported tinnitus and noise sensitivity among adolescents in Sweden. Noise Health 2004;7:29-40.
42. Chung JH, Des Roches CM, Meunier J, Eavey RD. Evaluation of noise-induced hearing loss in young people using a web-based survey technique. Pediatrics 2005;115:861-7.
43. Zocoli AM, Morata TC, Marques JM, Corteletti LJ. Brazilian young adults and noise: attitudes, habits, and audiological characteristics. Int J Audiol 2009;48:692-9.
44. Mercier V, Hohmann BW. Is electronically amplified music too loud? What do young people think? Noise Health 2002;4:47-55.
45. Rosanowski F, Eysholdt U, Hoppe U. Influence of leisure-time noise on outer hair cell activity in medical students. Int Arch Occup Environ Health 2006;80:25-31.
46. Gilles A, De Ridder D, Van Hal G, Wouters K, Kleine Punte A, Van de Heyning P. Prevalence of leisure noise-induced tinnitus and the attitude toward noise in university students. Otol Neurotol 2012;33:899-906.
47. Lipscomb DM. Ear damage from exposure to rock and roll music. Arch Otolaryngol 1969;90:545-55.
48. West PD, Evans EF. Early detection of hearing damage in young listeners resulting from exposure to amplified music. Br J Audiol 1990;24:89-103.
49. Maassen M, Babisch W, Bachmann KD, *et al.* Ear damage caused by leisure noise. Noise Health 2001;4:1-16.
50. Widen SE, Erlandsson SI. The influence of socio-economic status on adolescent attitude to social noise and hearing protection. Noise Health 2004;7:59-70.
51. Widen SE, Bohlin MC, Johansson I. Gender perspectives in psychometrics related to leisure time noise exposure and use of hearing protection. Noise Health 2011;13:407-14.
52. Widén S, Bohlin M, Johansson I. Gender perspectives in psychometrics related to leisure time noise exposure and use of hearing protection. Noise Health 2011;13:407-14.
53. Bockstael A, Botteldooren D, Keppler H, Desloover T. Hearing conservation campaigns for adolescants: visibility and effects reported by university students. Proceedings of the 10th European Congress and Exposition on Noise Control Engineering (Euronoise 2015). Belgian Acoustical Association.; Acoustical Society of the Netherlands.; European Acoustics Association Maastricht, 1-3 June 2015. The Netherlands; 2015. p. 797-801.
54. Daniel E. Noise and hearing loss: a review. J Sch Health 2007;77:225-31.
55. Rabinowitz PM. Noise-induced hearing loss. Am Fam Physician 2000;61:2759-60.

56. Probst R, Lonsbury-Martin BL, Martin GK. A review of otoacoustic emissions. J Acoust Soc Am 1991;89:2027-67.
57. Gorga MP, Neely ST, Ohlrich B, Hoover B, Redner J, Peters J. From laboratory to clinic: a large scale study of distortion product otoacoustic emissions in ears with normal hearing and ears with hearing loss. Ear Hear 1997;18:440-55.
58. Morata TC. Young people: their noise and music exposures and the risk of hearing loss. Int J Audiol 2007;46:111-2.
59. Rawool VW, Colligon-Wayne LA. Auditory lifestyles and beliefs related to hearing loss among college students in the USA. Noise Health 2008;10:1-10.
60. Gilles A, Van de Heyning P. Effectiveness of a preventive campaign for noise-induced hearing damage in adolescents. Int J Pediatr Otorhinolaryngol 2014;78:604-9.
61. Bockstael A, Keppler H, Botteldooren D. Musicians earplugs: appreciation and protection. Noise Health 2015;17:198-208.
62. Beach EF, Williams W, Gilliver M. The objective-subjective assessment of noise: young adults can estimate loudness of events and lifestyle noise. Int J Audiol 2012;51:444-9.
63. Peters RJ. The role of hearing protectors in leisure noise. Noise Health 2003;5:47-55.
64. Weichbold V, Zorowka P. Effects of a hearing protection campaign on the discotheque attendance habits of high-school students. Int J Audiol 2003;42:489-93.
65. Reddy R, Welch D, Ameratunga S, Thorne P. Development of the hearing protection assessment (HPA-2) questionnaire. Occup Med (Lond) 2014;64:198-205.