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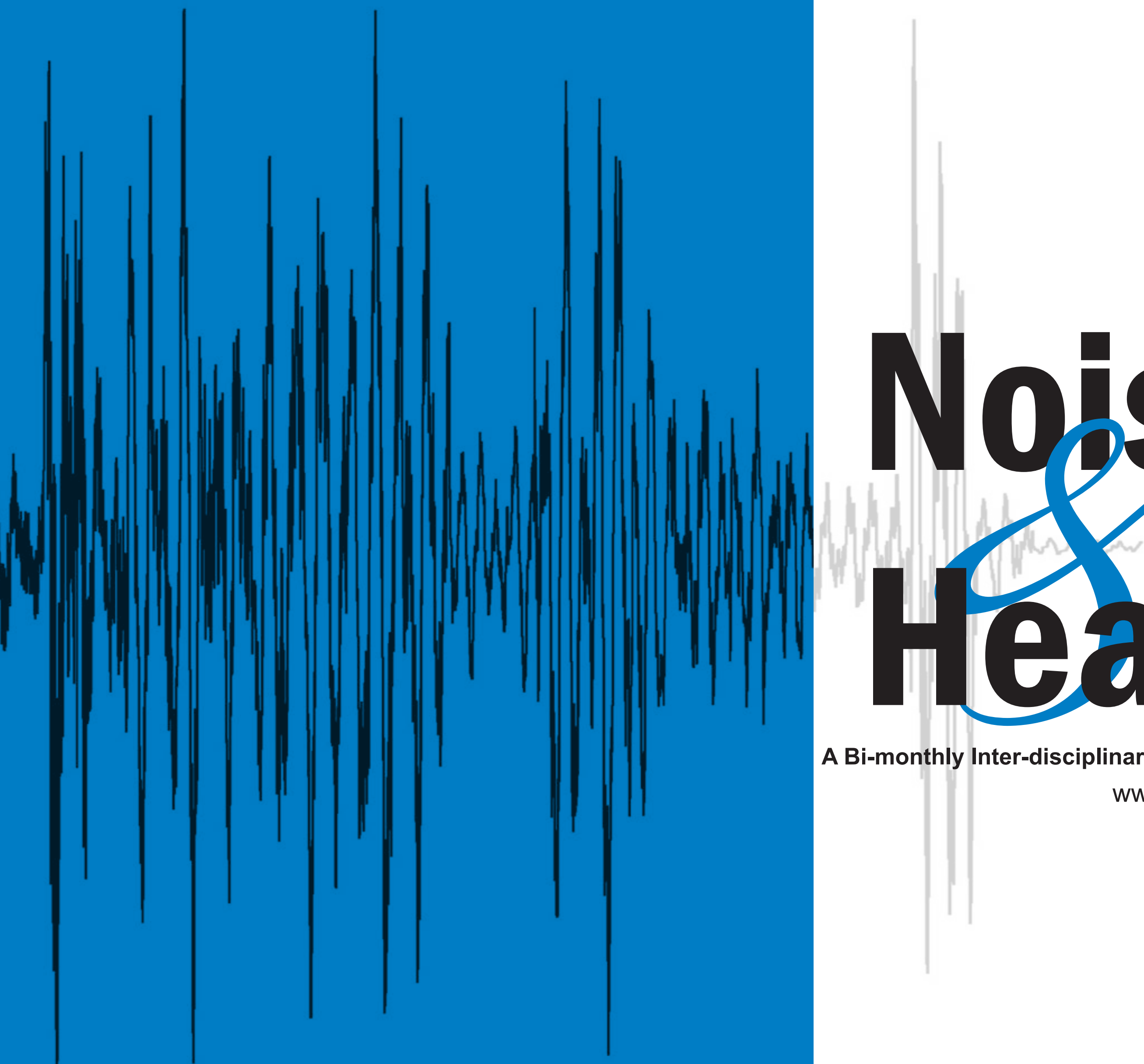

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# Epidemiology and Risk Factors for Leisure Noise-Induced Hearing Damage in Flemish Young Adults

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## Abstract

**Context:** Young people regularly expose themselves to leisure noise and are at risk for acquiring hearing damage. **Aims:** The objective of this study was to compare young adults' hearing status in relation to sociodemographic variables, leisure noise exposure and attitudes and beliefs towards noise. **Settings and Design:** A self-administered questionnaire regarding hearing, the amount of leisure noise exposure and attitudes towards noise and hearing protection as well as an audiological test battery were completed. Five hundred and seventeen subjects between 18 and 30 years were included. **Subject and Methods:** Hearing was evaluated using conventional audiometry, transient evoked and distortion product otoacoustic emissions. On the basis of their hearing status, participants were categorised into normal hearing, sub-clinical or clinical hearing loss. **Statistical Analysis Used:** Independent samples *t*-tests, chi-square tests and multiple regression models were used to evaluate the relation between groups based on hearing status, sociodemographics, leisure noise and attitudes towards noise. **Results:** Age was significantly related to hearing status. Although, the subjects in this study frequently participated in leisure activities, no significant associations between leisure noise exposure and hearing status could be detected. No relation with subjects' attitudes or the use of hearing protection devices was found. **Conclusions:** This study could not demonstrate clinically significant leisure noise-induced hearing damage, which may lead to more non-protective behaviour. However, the effects of leisure noise may become noticeable over a long-term use since age was found to be related with sub-clinical hearing loss. Longitudinal studies are needed to evaluate the long-term effects of noise exposure.

**Keywords:** Attitudes, hearing loss, leisure activities, noise, young adult

## Introduction

It is well known that exposure to excessive noise levels can induce metabolic and mechanical changes in the organ of Corti, leading to noise-induced hearing loss (NIHL).[1] Besides occupational noise exposure, there is a growing concern about the risk of noise exposure during leisure activities, especially in teenagers and young adults. Regular exposure to high noise levels at nightclubs, discotheques and live concerts[2-6] as well as exposure to high sound levels from personal music players (PMPs)[7,8] are reported among these young individuals and, therefore, might pose risks to hearing.

Several studies were conducted to determine the prevalence of leisure NIHL among teenagers and young adults. Some studies reported that NIHL is a common problem in young people as they found an increase in high frequency hearing loss.[9,10] Other studies, however, could not find such results.[11-13] The diagnosis of hearing loss should be based on pure-tone averages (PTAs) or audiogram notches in combination with a clear case history.[14,15] Hence, a possible explanation for the inconsistencies that were found may be attributed to variation in the estimation of hearing levels using pure-tone audiometry as well as to differences in the definition of normal hearing.[14] Moreover, the early stages of hearing loss may also be difficult to detect since only after a considerable amount of hair cells in the cochlea have been damaged effects are measurable with pure-tone audiometry.[16,17] Otoacoustic emissions (OAEs), which reflect the cochlear outer hair cell (OHC) function, have, therefore, been proposed as valuable tools for identifying preclinical NIHL.[18,19] OAEs

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may be particularly useful to evaluate the effect of noise on hearing as the OHCs are known to be the most vulnerable structures of the auditory organ with respect to excessive noise exposure.[20]

In addition to the differences in prevalence estimates, there is no consensus about the extent of the risk of hearing loss resulting from leisure noise exposure. Some studies point to a relation between hearing deterioration and exposure to leisure noise,[21,22] while others conclude that leisure noise has no or minimal effects on hearing as no or only slight correlations were found between hearing thresholds and leisure noise exposure.[23-28] To estimate a realistic risk of NIHL, those leisure activities that result in excessive noise exposure should be identified.[3] Although it is known that young adults participate in several leisure activities and that leisure habits may change during different phases of life,[6,8,29-31] previous research mostly focused on specific noise sources only. For example, leisure noise exposure from sources other than PMPs or from people attending nightclubs has mostly been neglected in other studies. Moreover, the risk of hearing damage also increases with noise intensity and exposure time.[32] Therefore, the participation of young people in several noisy activities as well as the corresponding accumulated lifetime noise exposure are important factors to consider.[3,33] However, information on the number of years of exposure is often missing.

The risk of hearing damage also appears to be related to a person's attitude towards noise, hearing loss and hearing protection devices (HPDs). One study by Keppler *et al.*[34] found significantly worse hearing thresholds in young adults who considered that noise was not that risky or experienced more barriers against wearing HPDs. In the current study, the theoretical framework developed by Widén[35] was used to explain young people's attitudes and behaviours towards leisure noise exposure. The model combines all the factors from the Theory of Planned Behaviour (TPB);[36] these are attitudes, subjective norms and perceived behavioural control, with the perceived benefits and barriers to modifying the behaviour and triggers to action from the Health Belief Model (HBM).[37] Attitudes are described as the tendency to respond positively or negatively towards a certain phenomenon. In addition, the intention to engage or not to engage in a particular behaviour (e.g. wearing HPDs) will be determined by subjective norms, whereas behavioural control refers to an individual's perception about the ease or difficulty of undertaking a specific behaviour. Perceived benefits and barriers with the actual behaviour can influence changing risk-taking behaviour into health-oriented behaviour. Besides, the experience of certain symptoms (e.g. hearing-related problems) can also be a trigger to behavioural change.[37] In addition to the factors of the TPB and HBM, a factor risk perception was added in the model of Widén,[35] which deals with an individual's awareness of the risks of noise exposure.

The main objective of this study was to determine the prevalence of noise-induced hearing damage in a group of Flemish young adults between 18 and 30 years as well as to explore the association with baseline sociodemographic factors, the amount of noise exposure and attitudes and beliefs towards noise, hearing loss and HPDs as outlined by the model of Widén.[35] Such information may increase knowledge about the effects of leisure noise on the hearing of young adults.

## Subject and Methods

### Study sample

This study was a cross-sectional study involving a self-administered questionnaire and a hearing assessment, consisting of an otoscopic evaluation, admittance measures, pure-tone audiometry, and measurements of transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs). A noise-free period of at least 12 h before testing was required to rule out the presence of transient threshold shifts.

A cohort of young adults between 18 and 30 years was recruited in Flanders, the northern region of Belgium. It was ensured that approximately equal samples of men and woman were recruited from the different regions in Flanders with a wide variation in age and professional status. Within a variety of settings – Flemish companies, universities and public places (e.g. sports clubs and youth associations) – individuals were invited to participate in the study by distributing an invitation letter through email, online (school) platforms or posters. Individuals, who were interested to participate in the study, contacted the researchers by e-mail.

A total of 540 young adults voluntarily participated in the study. Participants 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. Therefore, the responses of 517 young adults were further analysed, that is, a drop out of 4.3%. The final sample consisted of 307 females (mean = 22.2 years; standard deviation (SD) = 3.67; range 18–30 years) and 210 males (mean = 23.8 years; SD = 3.12; range 18–30 years). The majority of the sample (59.6%) were students, 39.5% had a permanent job and 1.4% were unemployed.

All testing was performed in a quiet room. To enable accurate testing, the ambient sound pressure levels at each frequency band between 0.25 and 8.0 kHz were measured using a 2250-B Bruël en Kjaer real time sound analyzer (Brüel and Kjær, Denmark). It was ensured that the ambient sound pressure levels did not exceed any of the levels specified by the International Organization for Standardization 8253-1 guidelines for accurate testing of normal air conduction hearing threshold levels.[38]

The study was approved by the Ethical Committee of Ghent University Hospital 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

A questionnaire was designed based on available literature regarding leisure noise exposure and the assessment of noise-induced tinnitus and NIHL.[33,39-41] After a try out on 30 subjects ranging in age from 18 to 30 years who were not included in the study, the translucency of some items and the adequacy of some response alternatives were adjusted. The final questionnaire comprised 44 items distributed over five sections.

The first section included several sociodemographic variables. Participants were asked about their age, gender and professional status (employee, unemployed or student).

The second section consisted of questions regarding subjective hearing status and medical history concerning ear-related disorders.

In the third section of the questionnaire, the amount of leisure noise exposure and the amount of time the respondent wore HPDs were recorded for several leisure activities that are common among young adults such as visiting nightclubs and playing musical instruments. In addition, the amount of occupational noise exposure was also recorded to control for as a possible confounding factor. For each activity, the weekly equivalent noise exposure ($L_{Aeq,w}$) as well as the lifetime equivalent noise exposure ($L_{Aeq,l}$) was calculated. More information regarding the calculation of the weekly and lifetime noise exposure, based on Jokitulppo *et al.*,[33] is available elsewhere.[2,42] In addition, the maximum lifetime equivalent noise exposure (maximum $L_{Aeq,l}$) was also determined for each participant.

The fourth questionnaire section consisted of a Dutch modified version of the 'Youth Attitude to Noise Scale' (YANS)[40,41] and a Dutch modified version of the 'Beliefs about Hearing Protection and Hearing Loss' (BAHPHL).[39,41] The YANS evaluates a subject's attitude towards noise and consists of 19 items that are measured using 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. The 19 items were divided over four factors representing attitudes towards noise associated with elements of youth culture (factor 1: eight items), the ability to concentrate in noisy environments (factor 2: three items), daily noises (factor 3: four items), and intent to influence the sound environment (factor 4: four items).[40] The BAHPHL instrument evaluated the attitudes towards hearing loss and HPDs and contained 24 items which can be divided over seven factors: susceptibility to hearing loss (factor 1: four items), severity of consequences of hearing loss (factor 2: three items), benefits of preventive action (factor 3: three items), barriers to preventive action (factor 4: four items), behavioural intentions (factor 5: three items), social norms (factor 6: two items), and self-efficacy (factor 7: three items).[39] Consistent with the YANS, the items were evaluated by a five-point Likert scale with higher scores corresponding to 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 and characteristics of tinnitus (e.g. localisation of the tinnitus, duration of the tinnitus, subjective experience of tinnitus pitch and loudness) after leisure noise exposure and whether the tinnitus was temporary or chronic. Temporary tinnitus was defined as disappearing within 72 h after the exposure to leisure noise. Information about the prevalence and risk factors for tinnitus is described elsewhere.[42]

## Audiometric evaluation

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 kHz (AA222 Audio Traveller and TDH39 headphones Interacoustics, Assens, Denmark). For each participant, the PTA for low- and mid-frequencies was calculated as the average of air conduction thresholds at 0.5, 1.0 and 2.0 kHz (further on denoted as $PTA_{low}$). The PTA for high frequencies (further on denoted as $PTA_{high}$) was calculated as the average of air conduction thresholds at 3.0, 4.0, 6.0 and 8.0 kHz.[15]

## Otoacoustic emissions

Both TEOAEs and DPOAEs were measured as TEOAEs test a large proportion of the cochlea simultaneously, while DPOAEs can be used to evaluate the cochlear function for higher frequency regions up to 8.0 or 10.0 kHz.[43] In this respect, both methods are an effective way to measure the OHC function and enhance the sensitivity to detect OHC damage.

TEOAEs and DPOAEs were measured using the DPOAE probe (ILO 292 universal serial bus, USB, II module with Otodynamics Ltd., Hatfield, UK, ILOv6 software). 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 µs at a rate of 50 clicks per second were delivered at an intensity of 80 ± 2 dBpeSPL. 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 centred at 1.0, 1.5, 2.0, 3.0 and 4.0 kHz using ad hoc software. Only measurements with probe stability of 90% or better were considered as valid measurements. TEOAEs were further analysed in terms of their presence/absence, whereby TEOAEs were considered present if the signal-to-noise ratio (SNR) was at least 3 dB in three or more half-octave frequency bands.

DPOAEs were measured with primary tone level combinations of L1/L2 = 65/55 dB sound pressure level (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. Emission and noise amplitude were averaged for half-octave frequency bands with centre frequencies 1.0, 1.5, 2.0, 3.0, 4.0, 6.0 and 8.0 kHz. Like TEOAEs, DPOAEs were further analysed in terms of their presence/absence, whereby DPOAEs were considered present if the SNR was at least 3 dB in five or more half-octave frequency bands.

### Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences software version 21 (SPSS Inc., Chicago, IL, USA). Descriptive parameters were established for the hearing assessment and questionnaire outcomes. Results of the hearing assessment were provided for both ears, but only one ear was selected for further statistical analysis.

On the basis of the hearing assessment data, three groups were created: (1) subjects with normal hearing; (2) subjects with sub-clinical hearing loss; and (3) subjects with clinical hearing loss. A person was considered having normal hearing if the $PTA_{low}$ and $PTA_{high}$ were, respectively, equal or better than 20 dB hearing level (HL) and 25 dB HL,[15] and if TEOAEs and DPOAEs were present. If no shifts in $PTA_{low}$ and $PTA_{high}$ were found but TEOAEs or DPOAEs were absent, a person was considered having sub-clinical hearing loss. Clinical hearing loss was considered if a shift in $PTA_{low}$ or $PTA_{high}$ was found and TEOAEs or DPOAEs were absent. For further analysis, the worst ear was selected in case of a detectable hearing loss. In case of normal hearing, one ear was chosen at random.

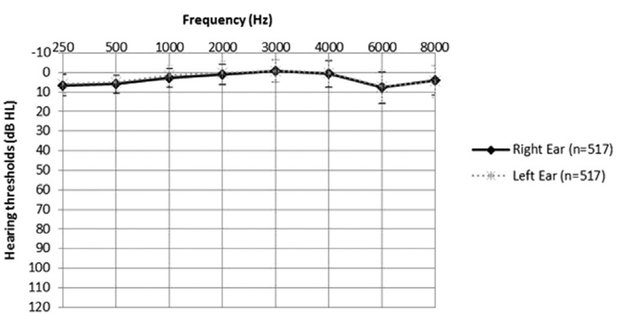


**Figure 1:** Mean ± one standard deviation of pure-tone air conduction hearing thresholds for right ears (solid line) and left ears (dashed line)

Subsequently, the distribution of all participants was illustrated with respect to baseline sociodemographic variables as well as the amount of noise exposure and attitudes and beliefs towards noise, hearing loss and HPDs. Besides, for each of these variables, chi-square tests or independent samples *t*-test were performed to evaluate their univariate relation with the groups based on hearing status. For all statistical analyses, a significance level of 0.05 was used.

Finally, binary logistic regression analysis (enter method) was used to examine the association between the groups based on hearing status and the maximum $L_{Aeq,1}$ and age (Model 1). Moreover, this association was further estimated in several models including following covariates: Model 2: gender and employment status; Model 3: use of HPDs; and Model 4: entire score on the YANS and BAHPHL instrument.

## Results

### Hearing status

Figure 1 shows the mean hearing thresholds for the right and left ears of all participants. According to an independent samples *t*-test, no significant differences were found between right and left ears for all frequencies tested ($P > 0.05$). The mean $PTA_{low}$ was 3.3 dB (SD 3.91; range −6.67 to 20.00 dB) for the right ears and 2.2 dB (SD 3.95; range −8.33 to 18.33 dB) for the left ears. In case of the $PTA_{high}$, a mean of 3.0 dB (SD 4.94; range −7.50 to 22.50 dB) was found for the right ears and 2.8 dB (SD 5.24; range −10.00 to 22.50 dB) for the left ears.

The mean TEOAE- and DPOAE-amplitudes for right ears and left ears are shown in Figure 2. When TEOAEs and DPOAEs were analysed in terms of their presence/absence, no significant differences were found between right and left ears according to chi-square tests ($P > 0.05$). TEOAEs were absent in 6.7% of the right ears and 9.0% of the left ears. DPOAEs were absent in 7.1% of the right ears and 7.0% of the left ears. Furthermore, the values for $PTA_{low}$ and $PTA_{high}$ were compared between absent and present TEOAEs and DPOAEs using independent samples *t*-tests. Values for both the $PTA_{low}$ and $PTA_{high}$ were significantly higher when TEOAEs or DPOAEs were absent ($P < 0.05$) [Table 1].

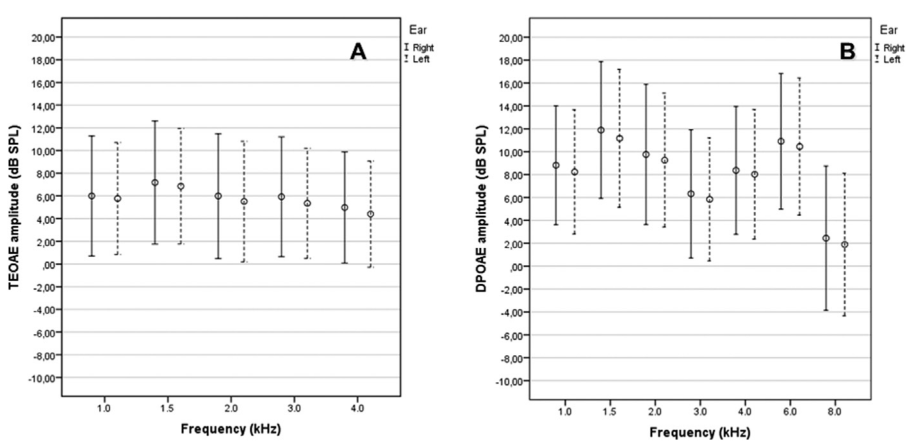


**Figure 2:** Mean ± one standard deviation TEOAE-amplitudes (a) and DPOAE-amplitudes (b) for right ears and left ears

On the basis of their hearing status determined by pure-tone audiometry and both TEOAEs and DPOAEs, 436 (84.3%) participants were classified with normal hearing, and 81 (15.7%) participants were classified with sub-clinical hearing loss. None of the participants in this study could be classified with clinical hearing loss, so that further analysis will be based on the groups with normal hearing and sub-clinical hearing loss. Table 2 shows the mean PTA-values as well as the number of present and absent TEOAEs and DPOAEs for the subjects with normal hearing and subjects with sub-clinical hearing loss.

## Univariate associations with hearing status

### *Baseline sociodemographic variables*

An overview of the baseline sociodemographic variables is presented in Table 3. Univariate analysis with the groups based on hearing status showed that subjects with sub-clinical hearing loss were significantly older (mean = 24.1 years;

**Table 1: $PTA_{low}$ and $PTA_{high}$ values for absent and present TEOAEs and DPOAEs in right ears and left ears of all participants ($n = 517$)**

| | | Absent/present | *N* | Mean | SD | Test statistic | *P* |
|---|---|---|---|---|---|---|---|
| TEOAEs | | | | | | | |
| Right ear | $PTA_{low}$ | Absent | 33 | 6.2 | 5.07 | $t$ = 4.970 | <0.001 |
| | | Present | 461 | 2.9 | 3.61 | | |
| | $PTA_{high}$ | Absent | 33 | 5.9 | 5.00 | $t$ = 3.767 | <0.001 |
| | | Present | 461 | 2.6 | 4.83 | | |
| Left ear | $PTA_{low}$ | Absent | 45 | 6.0 | 4.39 | $t$ = 7.287 | <0.001 |
| | | Present | 457 | 1.8 | 3.67 | | |
| | $PTA_{high}$ | Absent | 45 | 7.4 | 5.58 | $t$ = 6.595 | <0.001 |
| | | Present | 457 | 2.3 | 4.93 | | |
| DPOAEs | | | | | | | |
| Right ear | $PTA_{low}$ | Absent | 35 | 7.8 | 5.45 | $t$ = 7.964 | <0.001 |
| | | Present | 459 | 2.7 | 3.42 | | |
| | $PTA_{high}$ | Absent | 35 | 6.7 | 5.22 | $t$ = 4.960 | <0.001 |
| | | Present | 459 | 2.5 | 4.76 | | |
| Left ear | $PTA_{low}$ | Absent | 35 | 5.8 | 4.69 | $t$ = 5.801 | <0.001 |
| | | Present | 467 | 1.9 | 3.73 | | |
| | $PTA_{high}$ | Absent | 35 | 9.0 | 5.33 | $t$ = 7.825 | <0.001 |
| | | Present | 467 | 2.3 | 4.88 | | |

**Table 2: $PTA_{low}$ and $PTA_{high}$ values and number of absent and present TEOAEs and DPOAEs for subjects with normal hearing ($n = 436$) and subjects with subclinical hearing loss ($n = 81$)**

| | Hearing thresholds | | TEOAEs | | DPOAEs | |
|---|---|---|---|---|---|---|
| | $PTA_{low}$ | $PTA_{high}$ | Present | Absent | Present | Absent |
| | Mean ± SD | Mean ± SD | % (*n*) | % (*n*) | % (*n*) | % (*n*) |
| Normal hearing | 2.6 ± 3.45 | 3.4 ± 4.53 | 100 (436) | 0 (0) | 100 (436) | 0 (0) |
| Subclinical hearing loss | 5.8 ± 4.60 | 7.7 ± 5.50 | 29.6 (24) | 70.4 (57) | 34.6 (28) | 65.4 (53) |

**Table 3: Overview of the baseline sociodemographics variables for the total sample ($n = 517$) as well as distributed for the groups based on hearing status**

| Variable | Total sample (*n*=517) | Hearing status | |
|---|---|---|---|
| | | Normal | Subclinical hearing loss |
| Age, mean (±SD) | 22.8 (3.54) | 22.6 (3.47) | 24.1 (3.68) |
| Gender, % (*n*) | | | |
| Male | 40.6 (210) | 39.4 (172) | 46.9 (38) |
| Female | 59.4 (307) | 60.6 (264) | 53.1 (43) |
| Employment status, % (*n*) | | | |
| Employee | 39.5 (204) | 36.9 (161) | 53.1 (43) |
| Not unemployed or student | 60.5 (313) | 63.1 (275) | 46.9 (38) |

SD = 3.68) than subjects with normal hearing (mean = 22.6 years; SD = 3.47), $t\,(515) = -3.451$; $P = 0.001$. No significant association was found with gender ($\chi^2 = 1.578$; $P > 0.05$). Finally, employment status was significantly associated with hearing status ($\chi^2 = 7.467$; P = 0.006), whereby unemployed subjects or students had normal hearing (63.1%) more often compared to employed subjects, who had subclinical hearing loss more frequently (53.1%).

### *Leisure noise exposure and the use of HPDs*

In Table 4, an overview of the subjects' attendance, the average time spent per week, number of years, self-estimated median loudness and the average weekly and lifetime noise exposure for the different leisure activities is given. The highest attendance was found for watching movies or plays (95.6%), visiting nightclubs or music venues (92.5%) and attending musical concerts or festivals (85.5%). Furthermore, visiting nightclubs and music venues as well as attending musical concerts and festivals 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 weekly and lifetime equivalent noise exposure of 73.7 dBA (SD 10.54; 32.84–99.42 dBA) and 81.1 dBA (SD 10.41; 39.83–106.53 dBA), respectively. For all of the activities, the majority of the participants did not wear HPDs. The highest grades of wearing HPDs were found for attending musical concerts (26.2%), using noisy tools (24.7%) or occupational noise exposure (25.3%).

From Figure 3, it can be seen that attending nightclubs and music venues are mostly (63.4%) associated with a subject's maximum $L_{\mathrm{Aeq,l}}$, followed by musical concerts or festivals (8.9%). The maximum $L_{\mathrm{Aeq,l}}$ ranged between 60.5 and 106.5 dBA with an average of 83.4 dBA (SD = 8.70). During the activity with the maximum $L_{\mathrm{Aeq,l}}$, 18.4% of the participants wear HPDs. No significant differences in the maximum $L_{\mathrm{Aeq,l}}$ or the use of HPDs during this activity was found

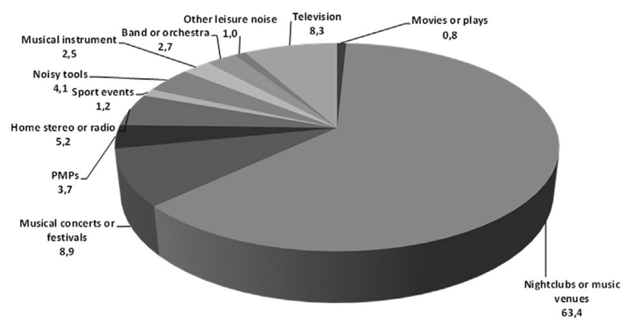


**Figure 3:** Proportions of activities to the maximum lifetime noise exposure (in %)

**Table 4: Percentage of subject's attendance, mean hours per week and mean number of years participating in each activity as well as the median loudness and mean A-weighted equivalent SPLs in dBA and the percentage of subjects wearing HPDs for each of the activities ($n = 517$)**

| Activity | Attendance (%) | Time spent | | Loudness | $L_{\mathrm{Aeq,w}}$ (dBA) | $L_{\mathrm{Aeq,l}}$ (dBA) | Wearing HPDs (%) |
|---|---|---|---|---|---|---|---|
| | | Per week | Years | | | | |
| | | Mean (SD) | Mean (SD) | | | | |
| Watching movies or plays | 95.6 | 0.4 (1.01) | 10.3 (4.50) | Loud conversation | 50.0 (8.49) | 59.6 (8.64) | 1.6 |
| Visiting nightclubs or music venues | 92.5 | 5.7 (7.41) | 6.3 (3.24) | Shout over near distance | 73.7 (10.54) | 81.1 (10.41) | 17.2 |
| Attending musical concerts or festivals | 85.5 | 0.5 (1.09) | 5.6 (3.11) | Shout over near distance | 64.4 (8.88) | 71.2 (9.33) | 26.2 |
| Listening to PMPs through headphones | 84.5 | 5.8 (8.35) | 7.1 (3.60) | Loud conversation | 58.2 (12.19) | 66.0 (12.79) | n.a. |
| Listening to a home stereo or radio | 69.4 | 10.6 (11.26) | 10.0 (6.55) | Loud conversation | 58.2 (8.82) | 67.1 (9.39) | 0 |
| Attending sport events | 49.7 | 1.5 (2.35) | 7.5 (5.02) | Shout over 1 m | 51.7 (9.73) | 59.3 (11.07) | 1.2 |
| Using noisy tools | 28.2 | 3.5 (11.12) | 5.7 (4.74) | Loud conversation | 61.7(13.67) | 67.8 (13.72) | 24.7 |
| Practicing a musical instrument | 26.7 | 3.1 (3.34) | 9.6 (4.85) | Shout over 1 m | 56.4 (11.66) | 65.2 (11.85) | 1.4 |
| Occupational noise | 15.3 | 18.5 (20.02) | 3.5 (2.86) | Shout over 1 m | 68.5 (12.41) | 72.3 (13.37) | 25.3 |
| Playing in a band or orchestra | 13.2 | 2.0 (1.81) | 6.3 (4.13) | Shout over 1 m | 65.8 (10.52) | 72.8 (11.13) | 13.2 |
| Other noisy leisure-time activities | 9.9 | 4.3 (5.19) | 5.8 (5.48) | Shout over 1 m | 66.7 (10.53) | 72.4 (12.06) | 13.7 |

*Note*: HPDs = hearing protection devices, $L_{\mathrm{Aeq,w}}$ = weekly noise exposure, $L_{\mathrm{Aeq,l}}$ = lifetime noise exposure, n.a. = not applicable, PMPs = personal music players.

according to age ($P > 0.05$). Regarding gender, a significant association with the maximum $L_{Aeq,l}$ was found, whereby men had higher maximum $L_{Aeq,l}$ (mean = 85.0 dBA; SD = 8.66) compared to women (mean = 82.1 dBA; SD = 8.47); $t$ (514) = 3.829; $P < 0.001$. No significant association was found between gender and the use of HPDs during the activity with the maximum $L_{Aeq,l}$ according to a chi-squared test ($P > 0.05$).

Regarding the groups based on hearing status, independent samples *t*-tests revealed no significant differences in $L_{Aeq,l}$ for each of the activities separately ($P > 0.05$). Likewise, no significant difference in maximum $L_{Aeq,l}$ was found for those groups ($P > 0.05$). Furthermore, chi-square tests showed no significant association between the groups based on hearing status and the use of HPDs in each of the activities, separately, as well as during the activity with the maximum $L_{Aeq,l}$ ($P > 0.05$).

### Attitudes towards noise, hearing loss and HPDs

Table 5 reflects the mean and SDs of the scores on subscales of the YANS and BAHPHL. Concerning the subscales of the YANS, the highest average score was found for the attitudes regarding daily noise, whereas the lowest average score was related to the attitudes intending to influence the sound environment. For the subscales of BAHPHL, the lowest and highest average scores were respectively found for the severity of consequences of hearing loss and the barriers to preventive action. The score on the entire YANS did not show any differences according to age, though the score was significantly lower for women (mean = 2.6; SD = 0.47) compared to men (mean = 2.9; SD = 0.47), $t$ (515) = 5.492; $P < 0.001$. The score on the entire BAHPHL did not show any significant changes with both age and gender ($P > 0.05$).

**Table 5: For the YANS and BAHPHL, the mean, standard deviation and range of scores are reflected ($n = 517$)**

| Questionnaire | Subscales | Mean | SD | Range |
|---|---|---|---|---|
| YANS | Elements of youth culture | 2.6 | 0.67 | 1.25–4.75 |
| | Concentration in noisy environments | 2.9 | 0.92 | 1.00–5.00 |
| | Daily noise | 3.5 | 0.73 | 1.50–5.00 |
| | Intent to influence sound environment | 2.2 | 0.69 | 1.00–4.50 |
| | Entire YANS | 2.7 | 0.48 | 1.36–4.37 |
| BAHPHL | Susceptibility to hearing loss | 1.8 | 0.55 | 1.00–3.83 |
| | Severity of the consequences of hearing loss | 1.6 | 0.61 | 0.99–5.00 |
| | Benefits of preventive action | 1.7 | 0.57 | 1.00–3.67 |
| | Barriers to preventive action | 3.0 | 0.81 | 1.00–5.00 |
| | Behavioural intentions | 2.6 | 1.03 | 1.00–5.00 |
| | Social norms | 2.8 | 0.87 | 1.00–5.00 |
| | Self-efficacy | 2.7 | 0.76 | 1.00–5.00 |

**Table 6: Relation of leisure time noise exposure, age and associated variables with groups based on hearing status: results of logistic regression models**

| Variable | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| | ($n$ = 517) | ($n$ = 517) | ($n$ = 517) | ($n$ = 517) |
| | OR (95% CI) | OR (95% CI) | OR (95% CI) | OR (95% CI) |
| $L_{Aeq,max}$ | 1.01 (0.98–1.04) | 1.01 (0.98–1.04) | 1.01 (0.98–1.04) | 1.01 (0.98–1.04) |
| Age | 1.12 (1.05–1.20)* | 1.10 (1.01–1.20)* | 1.13 (1.05–1.21)* | 1.12 (1.05–1.20)* |
| Gender | | | | |
| Male | | 1.00 | | |
| Female | | 0.90 (0.55–1.50) | | |
| Employment status | | | | |
| Not employed or student | | 1.00 | | |
| Employee | | 1.22 (0.64–2.31) | | |
| Wearing HPDs | | | | |
| No | | | 1.00 | |
| Yes | | | 0.79 (0.41–1.51) | |
| Attitudes total scores | | | | |
| YANS | | | | 0.77 (0.45–1.34) |
| BAHPHL | | | | 1.09 (0.60–1.99) |

*Note*: OR = odds ratio, CI = confidence interval. * indicates a significant result ($P < 0.05$).

Regarding the groups based on hearing status, no significant differences in the scores were found for the entire YANS and BAHPHL as well as each of their subscales ($P > 0.05$).

### Multivariate analysis

Finally, binary logistic regression was used to examine if the maximum $L_{\text{Aeq,l}}$ and age in combination with several covariates are associated with a person's hearing status. The maximum $L_{\text{Aeq,l}}$ was not significantly associated with hearing status in any of the multiple logistic regression models. On the other hand, each of the models showed that subjects were more likely to have sub-clinical hearing loss when they are older [Table 6]. The covariates that were included respectively in models two, three and four showed no significant association with a subject's hearing status.

## Discussion

The present study evaluated the hearing status in a group of 517 Flemish young adults between 18 and 30 years. Results showed that pure-tone thresholds were within the normal range of hearing and both TEOAEs and DPOAEs were absent in a small proportion of the tested subjects. Hence, subjects could only be categorised into a group with normal hearing and sub-clinical hearing loss. These results are consistent with the studies of Mostafapour *et al.*[24] and Williams *et al.*,[44] who did not find a significant hearing loss in young adults. Other studies, however, reported that a substantial proportion of young adults have hearing loss due to noise exposure.[9,45] As suggested by Schlauch and Carney,[14] there are several methodological differences between studies, such as the definition of a normal-hearing individual as well as the quality of the hearing measurements that are used, which may lead to inconsistent results. In this respect, the present study used a stringent set of inclusion criteria and hearing acuity was based on an average of multiple thresholds estimates as well as TEOAE and DPOAE results.[14,15]

The present study also evaluated the relation between a subject's hearing status and sociodemographic variables. Both the univariate and multivariate analysis showed that gender was not associated with hearing status. On the other hand, age was significantly associated with sub-clinical hearing loss in both the univariate and multivariate analyses. However, on the basis of well-known relation between age and hearing deterioration,[46] we would not expect clinical age-related hearing changes in such a young age group. Besides, employment status was univariately associated with hearing status, whereby sub-clinical hearing loss was more present in subjects who were employed compared to unemployed subjects or students. However, employment status was not associated with an increased risk of sub-clinical hearing loss according to the multivariate analysis. This might be explained by the fact that multivariate analyses take interdependencies between different variables into account. Employment status could be related with age, as subjects who were employed were older compared to the unemployed subjects or students in this study. The question may, therefore, rise whether the amount of noise exposure may be related to the age-related differences that were found.

Excessive exposure to noise has been repeatedly reported as a risk factor for hearing damage.[3,8,47] The present study confirmed that the majority of the young adults in this study participate in several leisure activities, with a wide variation in attendance and equivalent noise levels per activity. In accordance with previous research, nightclubs and music venues were found to have an increased risk of high noise levels.[2,3,48] Moreover, these activities yield the highest $L_{\text{Aeq,l}}$ in the majority of the subjects (63.4%). However, in accordance with previous research, no significant relations were found between hearing status and noise exposure.[26,27,44,48] A possible explanation for this result might be that the frequency of attendance in different leisure activities, and, therefore, noise exposure levels, did not show enough variation among the subjects in this age group. Indeed, no significant relation was found between age and subjects' maximum noise exposure levels. As was shown by previous research, teenagers tend to participate more in high-noise leisure activities such as attending nightclubs when they become older during the adolescence phase,[30,31] while participation in these activities seems to decrease among subjects over 30 years of age.[6,8,29] Furthermore, it might be possible that exposure to leisure noise during this period of life is too short to cause sufficient hearing loss.[4] The present study showed that the average total time young adults participated in several leisure activities is approximately 7 years [Table 3]. The effects of noise exposure may thus become noticeable over the long-term, since the effects of noise exposure on hearing are greatest during the first ten to 15 years of exposure.[49]

As a result, the consequences of excessive leisure noise exposure on hearing may not immediately be perceived by young adults or may not be experienced as serious enough.[34,50] In the present study, no significant associations were found between a subject's hearing status and the attitudes towards noise, hearing loss and HPDs. In accordance to these results, we found that the majority of the subjects did not wear HPDs during leisure activities. This reflects the model of Widén,[35] which states that subjects without hearing-related symptoms are less likely to protect their hearing. The present study also did not find a relation between hearing status and the use of HPDs. It could be expected that the subjects who never wear HPDs during noisy leisure activities have a greater risk of (sub)clinical hearing loss compared to subjects who always wear HPDs. However, as the present study did not evaluate how long someone has been wearing HPDs, it is not possible to draw conclusions about the effectivity of wearing HPDs to protect hearing.

The results of the current study should be considered taking into account some limitations. First, convenience sampling was used, which might imply that the sample is not completely representative for the whole Flemish population of young adults. Nevertheless, it was ensured that an approximately equal sample of men and woman was recruited from the different regions in Flanders with a wide variation in age and professional status. Second, the estimation of leisure noise exposure might be affected by measurement errors, that is, the self-reported time of attendance to several leisure activities might be imprecise and no actual loudness measurements were performed to calculate the A-weighted equivalent levels. However, previous research showed that subjects can make a reasonable estimate of the loudness of activities they participated in,[51] which makes it possible to detect the activities with the highest risk of excessive noise levels. Third, TEOAEs and DPOAEs were evaluated in terms of their presence/absence, which might be insufficient to reveal significant relations. Therefore, using OAE-amplitudes with clear criteria would be useful in further research concerning the effects of leisure noise exposure on hearing. Finally, this study did not detect participants with clinical hearing loss according to both tonal audiometry and OAEs. Further research including such participants is necessary to further investigate the effects of leisure noise on hearing as well as the relation with their attitudes towards noise, hearing loss and HPDs.

In conclusion, the results of the present study showed no evidence of hearing loss in a large group of Flemish young adults between 18 and 30 years. Furthermore, no consistent relations were found between a subject's actual hearing status and leisure noise exposure, which in turn could lead to more non-protective behaviour. However, the effects of leisure noise may become noticeable over the long-term as the results of this study revealed that the presence of sub-clinical hearing loss was associated with age. Longitudinal studies are needed to monitor the hearing status as well as to evaluate the long-term effects of noise exposure. Besides, preventive campaigns should further focus on self-experienced symptoms to make young adults aware of the harmful effects of excessive noise exposure.

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## Conflicts of interest

There are no conflicts of interest.

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