Hearing loss in professional orchestral musicians

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INTRODUCTION

According to several studies, professional orchestral musicians are often exposed to sounds at levels exceeding the upper exposure action values from the 2003/10/EC noise directive (Royster et al. 1991; Obeling & Poulsen 1999; Laitinen et al. 2003; O'Brien et al. 2008; Toppila et al. 2011). It has been also shown that players can develop noise-induced hearing loss (NIHL) and suffer from other hearing symptoms such as tinnitus, hyperacusis, ringing in the ears, which can influence their work abilities more severely than hearing loss. However, because of insufficient audiometric evidence of hearing loss caused purely by music exposure, there is still disagreement and speculation about risk of hearing loss from music exposure alone (Axelsson & Lindgren 1981; Karlsson et al. 1983; Royster et al. 1991; Teie 1998; Obeling & Poulsen 1999; Kähäri et al. 2001; Emmerich et al. 2008; Jansen et al. 2009; Zhao et al. 2010).

The aim of this study was to assess hearing status in professional orchestral musicians and its relation with self-reported hearing ability. Another objective was to compare actual audiometric hearing threshold levels with theoretical predictions according to ISO 1999:1990.

MATERIALS AND METHODS

Study group

Participants were 85 professional musicians (38 females and 47 males), aged 24–67 years (mean ± SD: 42.9±11.5 years, median: 41.75 years) from two opera and three symphony orchestras. The study group comprised musicians playing violin (21), viola (11), cello (8), trombone (7), oboe (6), flute (6), bassoon (5), horn (4), trumpet (4), double bass (3), clarinet (3), percussion (2), tube (2), guitar (1) and piano (1).

They were recruited by advertisement and did not receive any financial compensation for their participation in the experiment. The local Ethics Committee approved the study design

Questionnaire inquiries

All musicians were interviewed according to a questionnaire developed to enable identification of occupational and non-occupational risk factors of NIHL. A special attention was paid to professional experience, i.e. the time of employment in orchestra/musical career or comparable experience, various work activities and instruments in use, time of daily and/ or weekly practice, including individual rehearsals.

In addition, musicians' hearing ability was assessed using the (modified) Amsterdam Inventory for Auditory Disability and Handicap ((m)AIADH) (Meijer et al. 2003). This inventory consists of 30 items and includes five basic disability factors dealing with a variety of everyday listening situations: (i) distinction of sounds (subscale I), (ii) auditory localization (subscale II), (iii) intelligibility in noise (subscale III), (iv) intelligibility in quiet (subscale IV), and (v) detection of sounds (subscale V). The respondents were

asked to report how often they were able to hear effectively in the mentioned situation. The four answer categories were as follows: almost never, occasionally, frequently, and almost always. Responses to each question were coded on a scale from 0 to 3; the higher the score, the smaller the perceived hearing difficulties. The total score per subject was obtained by adding the scores for 28 questions. Maximum total score of the questionnaire was 84. Additionally, the answers for each subscale were summed up (maximum score for subscale I was 24, while for the other subscale it was 15).

Hearing examinations

Conventional pure-tone audiometry (PTA) and transient–evoked otoacoustic emission (TEOAE) determinations were made in subjects under study. Before the exact examinations, otoscopy was performed in order to screen for conditions that would exclude examined subject from the study. Hearing tests were performed in quiet rooms located in concert halls and opera building where the background noise did not exceed 35 dBA.

PTA was performed using an Audio Traveller Audiometer type 222 (Interacoustics) with TDH 39 headphones. Hearing threshold levels (HTLs) for air conduction were determined using an ascending–descending technique in 5-dB steps.

A Scout Otoacoustic Emission System ver. 3.45.00 (Bio-logic System Corp.) was applied for recording and analyzing of otoacoustic emissions. TEOAE recordings of 260 averages each were collected for every subject at stimuli levels of about 80 dB, using standard clicks. The artefact rejection level was set at 20 mPa. Each response was windowed from 3.5 to 16.6 ms post stimulus and band-pass filtered from 0 to 6,000 Hz. The total TEOAE amplitude level and the TEOAE amplitude levels for frequency bands with central frequencies 1, 1.5, 2, 3 and 4 kHz were examined.

Evaluation of exposure to orchestral noise

Musicians' exposures to orchestral noise were evaluated based on data concerning sound pressure levels produced by various group of instruments. These data were collected during measurements performed with the measuring equipments placed in various instrument groups during rehearsals, concerts and performances including diverse repertoire. In general, results of 338 measurement samples (lasting in total approx. 591 hours) were collected (for details see Pawlaczyk-Luszczynska et al. 2011).

For various groups of players the weekly A-weighted noise exposure levels ($L_{EX,w}$) were calculated basing on the median values of equivalent-continuous A-weighted sound pressure levels produced by the respective instrument (e.g. violins or trumpets) and declared time of weekly practice.

Prediction of noise-induced hearing loss

The musicians' actual hearing threshold levels were compared with the theoretical predictions calculated according to ISO 1990:1990. The aforesaid standard specifies the method for determining a statistical distribution of hearing threshold levels in adult populations after given exposure to noise based on four parameters: age, gender, noise exposure level and duration of noise exposure (in years).

In order to compare predictions obtained for musicians of different gender, age, time and exposure, so-called standardized hearing threshold levels (STHLs) were determined using the following formulas (Sliwińska-Kowalska et al. 2006):

$$SHTL = 1.282 \times (HTL - PHTL_{Q50})/(PHTL_{Q10} - PHTL_{Q50}) \quad \text{for HTL} \geq PHTL_{Q50}$$

$$SHTL = 1.282 \times (HTL - PHTL_{Q50})/(PHTL_{Q90} - PHTL_{Q50}) \quad \text{for HTL} < PHTL_{Q50}$$

Where:
HTL – is the actual hearing threshold, in dB HL,
$PHTL_{Q50}$ – is the median value of predicted HTL in dB HL,
$PHTL_{Q10/Q90}$ – is the fractile Q10/ Q90 of predicted hearing threshold level, in dB HL,

These calculations were applied to the audiograms twice, i.e. the musicians' hearing was compared to the hearing of the non-noise-exposed population and noise-exposed population.

Statistical analysis

A main effects ANOVA was used to analyze the first-order (non-interactive) effects of multiple factors such as: gender, age and exposure on PTA and TEOAE results as well as the (m)AIADH scores. The study group was divided into subgroups according to gender (females and males), age (younger and older subjects) and exposure (lower- and higher-exposed to noise subjects).

Musicians were categorized as higher-exposed or lower-exposed on the basis of assigned theme values of the weekly noise exposure level. Subjects with the $L_{EX,w}$ levels above median value were classified as higher-exposed, while the others as lower-exposed. Similarly, the median value of age was used as the basis for classification subjects as younger and older ones.

The relations between results of PTA or TEOAE and musicians' self-reported hearing ability expressed in terms of the (m)AIADH scores were evaluated using Pearson's correlation coefficient. The standardized hearing threshold levels were analyzed using t-test for dependent samples.

All statistical tests were done with an assumed level of significance $p<0.05$. The STATISTICA (version 9.0) software package was employed for the statistical analysis of the data.

RESULTS

Questionnaire inquiries

Musicians under study were employed in orchestras from 1 to 44 years (mean ± SD: 19.5±11.4 years, median: 18.3 years). They were exposed from 7 to 70 hours a week (mean ± SD: 28.8±10.7 h, median: 30 h) to music at the A-weighted equivalent continuous sound pressure levels varying from 73 to 92 dB (Table 1). The weekly noise exposure levels calculated from this data ranged between 81−88 dB (mean ± SD: 84.0±2.0 dB, median: 82.8 dB) (Figure 1).

Generally, almost all subjects (97.7 %) assessed their hearing as good. However, about one quarter of them (23.8 %) noticed hearing impairment, including difficulty in speech intelligibility in noisy environment (40.9 %) and hearing whisper (18.2 %). Near-

ly every tenth musician complained of tinnitus while one third of them reported hyperacusis.

Table 1: Sound pressure levels produced by various groups of instruments (Pawlaczyk-Luszczynska et al. 2011)

Instrument/ Equivalent continuous A-weighted sound pressure level (10th/ 50th/ 90th percentile) [dB]					
Violin	81/ 84/ 87	Flute	83/ 87/ 89	Horn	85/ 88/ 92
Viola	80/ 84/ 88	Oboe	83/ 86/ 89	Trombone	84/ 87/ 90
Cello	75/ 82/ 84	Clarinet	81/ 87/ 90	Tuba	87/ 89/ 91
Double bass	74/ 83/ 84	Bassoon	83/ 86/ 90	Percussion sect.	80/ 87/ 91
Harp	78/ 82/ 85	Trumpet	84/ 89/ 91	Total	81/ 86/ 90

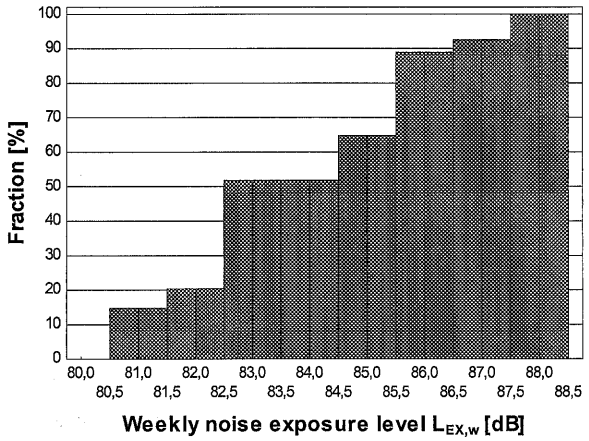

Figure 1: Cumulative distribution of the weekly noise exposure level in study group

Musicians examined using the (m)AIADH obtained mean total score of 90.9 % of maximum value, which suggests no substantial hearing difficulties in subjects under study (Table 2). Relatively low scores were frequent only in the subscale evaluating intelligibility in noise (22.2 % of subjects scored below 70 % of maximum value). The (m)AIADH scores were significantly affected by age ($p<0.05$). As expected older subjects obtained lower scores than younger ones. Neither gender nor exposure had impact on the (m)AIAHD scores ($p>0.05$).

Table 2: Musicians' self-assessment of hearing ability in the (m)AIADH scores

Score/ Mean ± SD/ 10^{th}/ 50^{th}/ 90^{th} percentile					
Total	Subscale I	Subscale II	Subscale III	Subscale IV	Subscale V
76.4±7.1* 65/ 78/ 84	23.1±1.4* 22/ 24/ 24	13.4±1.9* 10/ 14/ 15	12.4±2.2* 10/ 13/ 15	13.5±1.9* 11/ 14/ 15	14.0±1.4* 12/ 15/ 15

* Significant main effect of age ($p<0.05$)

Results of PTA and TEOAE

Audiometric hearing threshold levels determined in 85 professional orchestral musicians (165 ears) are shown in Figure 2.

A significant main effect of age on the HTLs was observed in the frequency range from 1,000 to 8,000 Hz (Figure 2b). Generally, older subjects showed higher reduction of hearing threshold level than younger ones. Similar relation was observed between males and females in the in the high frequency region from 3,000 to 8,000 Hz (Figure 2a). There was also a significant main effect of noise exposure on the HTLs at frequencies of 1,000 and 8,000 Hz. Contrary to our expectations higher-exposed subjects ($L_{EX,w}$>82.8 dB) had lower (better) HTLs compared to lower-exposed individuals ($L_{EX,w}$≤82.8 dB) (Figure 2c). However, the latter result is not surprising since the study subjects were generally exposed to sounds at relatively low levels ($L_{EX,w}$≤88 dB).

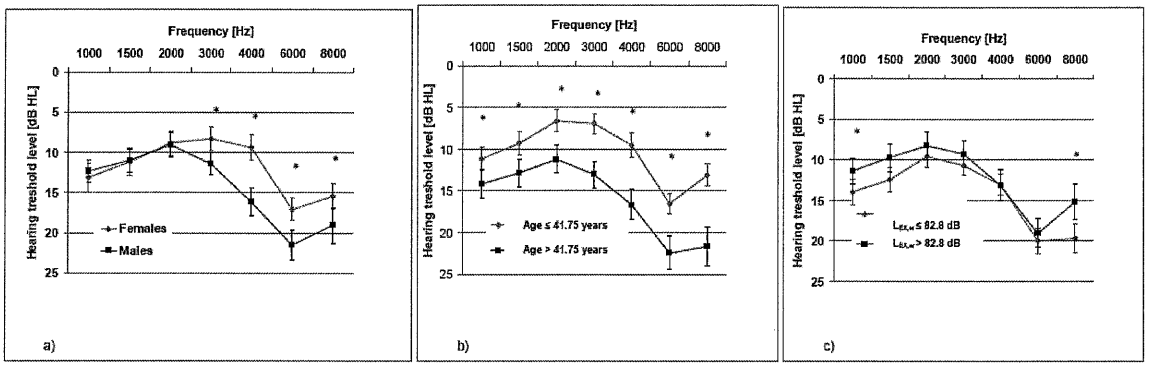

Figure 2: Audiometric hearing threshold levels (mean ± 95% CI) in various subgroups of musicians, i.e. females and males (a), younger and older subjects (b), and lower- and higher-exposed subjects (c). Significant differences between subgroups were marked (*)

Typical NIHL notches at 4,000 or 6,000 Hz of at least 15 dB depth relative to the best preceding threshold (from 1,000 Hz) were observed in 36.0 % of audiograms. Most of them (82.8 %) occurring at 6,000 Hz. The portion of total population with bilateral notching at any frequency was 17.1 %.

In the majority (95.2 %) of cases a mean value of the hearing threshold level for 500, 1,000, 2,000 and 4,000 Hz was lower than 25 dB, which corresponds to grade 0 of hearing impairment (WHO 2011). Only 4.8 % of the measured audiograms corresponded to grade 1 of hearing impairment. Moreover, all of them were found in the older musicians.

It is worth noting that according to the classification of the World Health Organization (WHO) in the case of grade 0 ("no impairment") no or very slight hearing problems can occur, and one is able to hear whispers, while in grade 1 ("slight impairment") one is able to hear and repeat words spoken in normal voice at a distance of 1 meter, but hearing aids may be needed (WHO 2011).

Summary results of TEOAE testing are shown in Figure 3. A significant main effect of gender on TEOAE amplitude, signal to noise ratio (SNR) as well reproducibility (excluding frequency band of 1 kHz) was noted (Figures 3a, 3d and 3g). Generally, females showed better results of TEOAE testing compared to males. On the other hand, age and noise exposure were found to significantly affect the reproducibility of TEOAE in the frequency range from 1 to 1.5 kHz (Figures 3e and 3f). As expected, greater reproducibility was observed in case of younger than older musicians while the opposite relation occurred between lower- and higher-exposed to noise subjects

In almost all cases (96.8 % of ears) the reproducibility of the total response of TEOAE was above 60 %. Signal to noise ratio higher than 6 dB was observed in the 69.4 % of cases.

A weak but statistically significant linear relationship was noted between PTA results and the total score of (m)AIADH as well as scores of subscales intended to evaluate intelligibility in noise (subscale III), intelligibility in quiet (subscale IV), and detection of sounds (subscale V) (Pearson's correlation coefficient r varied from -0.45 to -0.25, $p<0,05$). The linear relationships were also noted between musicians' self-assessment of hearing ability in the (m)AIADH scores and the TEOAE results ($0.22 \leq r \leq 0.45$, $p<0.05$). The highest values of correlation coefficient were noted between score of subscale III and SNR at 4 kHz as well as HTL at 6,000 Hz.

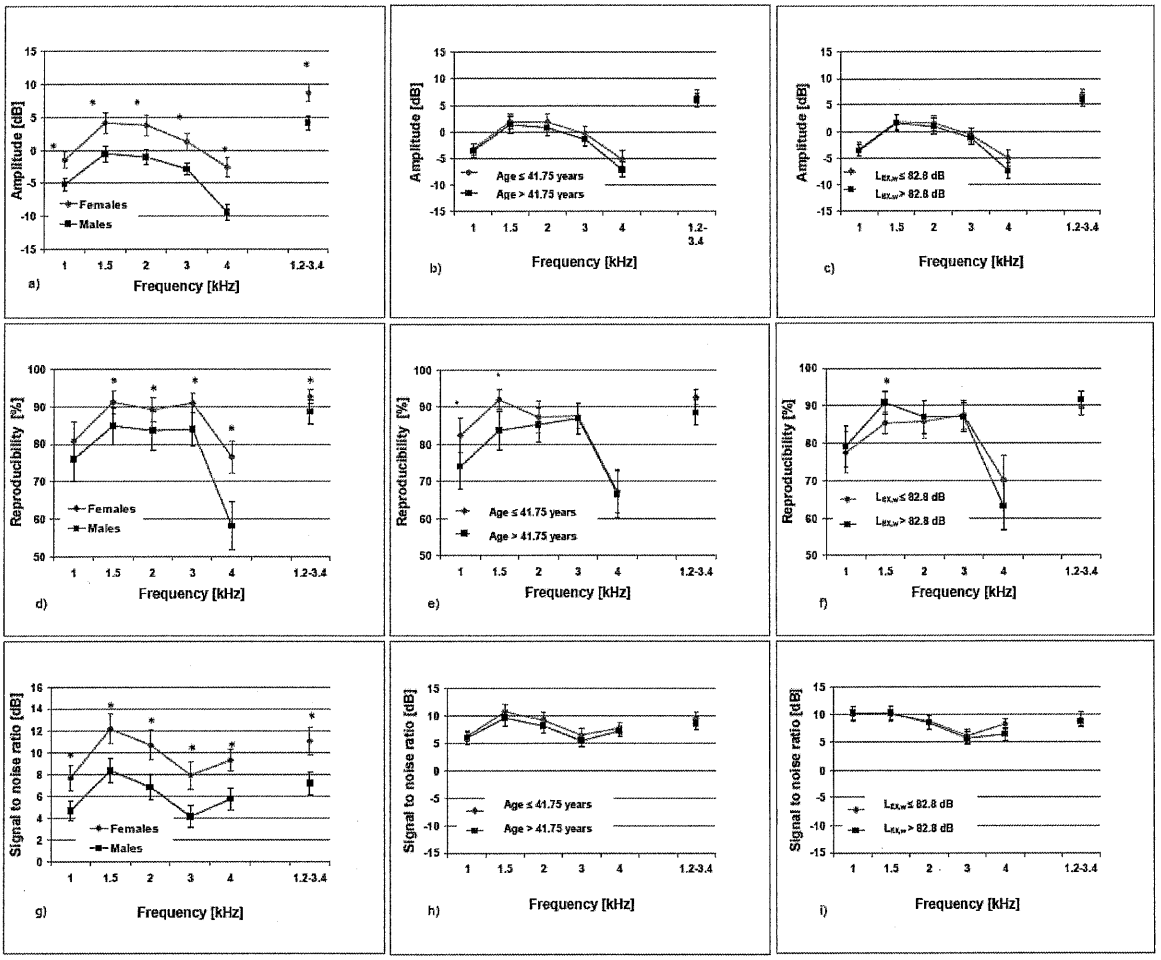

Figure 3: TEOAEs (mean ± 95% CI) in various subgroups of musicians, i.e. females and males (a, d, g), younger and older subjects (b, e, h), and lower- and higher-exposed subjects (c, f, i). Significant differences between subgroups were marked (*)

Comparison of actual and predicted hearing threshold levels

Figure 4 shows standardized hearing threshold levels in musicians under study. It is worth noting that the closer to zero value of SHTL, the better the prediction of hearing loss. On the other hand, the positive values of SHTLs indicate that actual hearing threshold levels are higher than predicted.

Comparing the musicians to non-noise-exposed population revealed that their hearing loss corresponded to the expected hearing loss at frequencies of 3,000 and 4,000 Hz ($p>0.05$). On the other hand, the actual hearing threshold levels were lower (better)

than expected for 3,000; 4,000 and 8,000 Hz ($p<0.05$), with an expected values at 2,000 and 6,000 Hz ($p>0.05$), when compared to equivalent population exposed to industrial noise. Thus, findings presented here are in line with some earlier observation that music deteriorates hearing, but less than what ISO 1999:1990 predicted (Obeling & Poulsen 1999; Toppila et al. 2011).

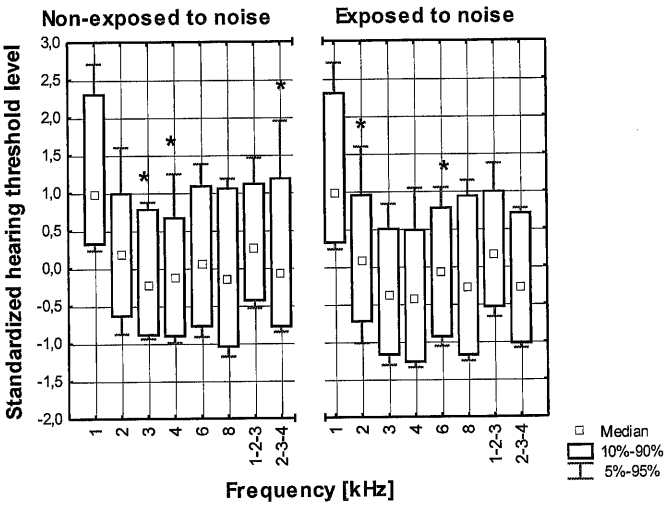

Figure 4: Comparison of the musicians' hearing loss to that of non-noise-exposed and noise-exposed populations. Standardized hearing thresholds which do not significantly differ from 0 were denoted (*)

CONCLUSIONS

- Almost all musicians had hearing threshold levels corresponding to grade 0 ("no impairment") of hearing impairment according to the WHO classification. However, high frequency notched audiograms typical for noise-induced hearing loss were found in 36 % of ears.
- Significant main effects of age and gender on hearing test results were observed. Both PTA and TEOAE showed a tendency toward better hearing in females vs. males, younger vs. older subjects. Moreover, weak but statistically significant linear relationships were noted between musicians' self-assessment of hearing ability in the (m)AIADH scores and the audiometric hearing threshold levels as well as TEOAE results.
- Measured audiometric HTLs at 3,000; 4,000 and 8,000 Hz were lower (better) than theoretical predictions according to ISO 1990:1990. Thus, music deteriorates hearing, but less than expected from exposure to orchestral noise.

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