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## EXPOSURE TO EXCESSIVE SOUNDS DURING ORCHESTRA REHEARSALS AND TEMPORARY HEARING CHANGES IN HEARING AMONG MUSICIANS

EKSPOZYCJA NA ZA GŁOŚNE DŹWIĘKI PODCZAS PRÓB ORKIESTROWYCH I CZASOWE ZMIANY SŁUCHU MUZYKÓW

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### ABSTRACT

**Background:** It has been shown that musicians are at risk of noise-induced hearing loss. The aim of the study has been to evaluate the temporary changes of hearing in the case of orchestral musicians after group rehearsals. **Material and Methods:** The study group comprised 18 orchestral musicians, aged 30–58 years old (mean: 40 years old) having 12–40 years (mean: 22 years) of professional experience. The temporary changes in hearing after group rehearsals were determined using transient-evoked otoacoustic emissions (TEOAEs). Noise exposures during group rehearsals were also evaluated. **Results:** Musicians' hearing threshold levels were higher (worse) than expected for the equivalent non-noise-exposed population. Moreover, the high frequency notched audiograms were observed in some of them. After rehearsals, during which musicians were exposed to orchestral noise at A-weighted equivalent-continuous sound pressure level (normalized to 8-h working day) varied from 75.6–83.1 dB (mean: 79.4 dB). The significant post-exposure reductions of TEOAE amplitudes (approx. 0.7 dB) both for the total response and frequency bands of 2000 and 3000 Hz were noted. However, there were no significant differences between pre- and post-exposure reproducibility of TEOAE. **Conclusions:** Obtained results have confirmed that orchestral musicians are at risk of hearing loss due to their professional activities, even at exposures to orchestral noise less than the limit values for occupational noise. Med Pr 2015;66(4):479–486

**Key words:** musicians, temporary changes in hearing, transient-evoked otoacoustic emission, TEOAE

### STRESZCZENIE

**Wstęp:** Wykazano, że muzycy narażeni są na ryzyko utraty słuchu wywołanej hałasem. Celem pracy była ocena czasowych zmian słuchu u muzyków orkiestrowych po udziale w próbach zespołowych. **Materiał i metody:** Badana grupa składała się z 18 muzyków orkiestrowych w wieku 20–58 lat (średnia: 40 lat) o stażu zawodowym 12–40 lat (średnia: 22 lata). Czasowe zmiany słuchu po próbach zespołowych wyznaczono na podstawie wyników badań emisji otoakustycznych przejściowych (transient-evoked otoacoustic emissions – TEOAE). Oceniono również poziom ekspozycji na hałas podczas prób zespołowych. **Wyniki:** Próg słuchu muzyków był wyższy (gorszy) niż oczekiwany w równoważnej populacji nienarażonej na hałas. Ponadto w audiogramach części muzyków zaobserwowano „załamki” typowe dla działania hałasu wysokoczęstotliwościowego. Po próbach zespołowych, podczas których muzycy byli narażeni na hałas orkiestrowy o poziomie ekspozycji na hałas odniesiony do 8-godzinego dnia pracy (skorygowany charakterystyką częstotliwościową A) o wartościach 75,6–83,1 dB (średnia: 79,4 dB), zaobserwowano statystycznie istotne obniżenie amplitudy TEOAE (ok. 0,7 dB), zarówno w przypadku zbiorczej odpowiedzi, jak i w pasmach 2000 i 3000 Hz. Nie stwierdzono jednak istotnych różnic między wynikami powtarzalności TEOAE przed ekspozycją i po ekspozycji. **Wnioski:** Uzyskane wyniki potwierdzają, że praca muzyków orkiestrowych wiąże się z ryzykiem uszkodzenia słuchu, nawet przy ekspozycji na hałas orkiestrowy nieprzekraczającej wartości dopuszczalnych dla hałasu w miejscu pracy. Med. Pr. 2015;66(4):479–486

**Słowa kluczowe:** muzycy, czasowe zmiany słyszenia, emisja otoakustyczna przejściowa, TEOAE

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## INTRODUCTION

Potential risk of noise-induced hearing loss due to loud music exposure has been widely investigated in musicians and people exposed to it. The result of surveys is ambiguous but it is supposed that the auditory symptoms are associated with exposure to music and that advanced audiological tests may be more useful for hearing tests of persons exposed to music, especially in the early stage of hearing damage. The review of research is presented in [1].

Orchestral musicians represent a professional group exposed to excessive sounds (so-called "orchestral noise") at levels exceeding permissible values for occupational noise. In spite of significant differences between the industrial noise and sounds that musicians are exposed to, many studies have shown changes in hearing caused by music [1–3]. Deterioration of musicians' hearing applies to both permanent and temporary changes in hearing [1,4].

It is commonly known that exposure to excessive sounds (noise) may cause temporary changes in hearing. Moreover, it is believed that multiple and repeated exposure causes temporary changes leading to permanent hearing loss. Some studies have confirmed the presence of temporary threshold shift after usual musicians' activities, such as exercises, rehearsals and performances [5].

It has been suggested that otoacoustic emissions, particularly transient-evoked otoacoustic emissions (TEOAEs) are more sensitive in the assessment of auditory function than pure-tone audiometric one (PTA) and may be more useful for detecting both noise induced short-term hearing changes and early hearing loss [6].

The aim of this study has been to assess the temporary changes in hearing measured by means of the TEOAE after group rehearsals in the case of professional orchestral musicians.

## MATERIAL AND METHODS

The study on temporary hearing changes caused by exposure to excessive sounds was conducted for a philharmonic orchestra during collective rehearsals. The study group comprised only professional musicians, who voluntarily decided to participate in hearing tests.

Participants included 18 musicians of philharmonic orchestras, aged 30–58 years old (mean: 40 years old), having 12–40 years (mean: 22 years) of professional experience. All of them were volunteers who did not

report any health problems associated with hearing. The study group comprised a viola (2 persons), a flute (1 person), a harp (1 person), a violin (5 persons), an oboe (1 person) a clarinet (1 person), drums (2 persons), trombones (2 persons), a trumpet (1 person), and horns (2 persons).

All musicians filled a questionnaire developed to enable identification of occupational and non-occupational risk factors for noise-induced hearing loss (NIHL). The musicians' exposures to excessive sounds were assessed from the results of sound pressure level measurements which were performed during collective rehearsals that were preceded and followed by hearing tests. Those measurements were carried out according to the methods described in PN-N-01307 [7] and ISO 9612 [8] using Svantek analyzer type SVAN 958 (prod. Svantek, Poland) as an integrating-averaging sound level meter and Brüel and Kjær personal noise dose meters Bruel and type BK 4443.

The aforesaid sound pressure level measurements were performed in a rehearsal room during preparation for a concert aimed to present arias of Italian operas (by Giuseppe Verdi, Giacomo Puccini, Gioachino Rossini, etc.). The results of noise measurement and questionnaire were described in details elsewhere [9–11].

Musicians' hearing was assessed using both pure tone audiometry (PTA) and TEOAE before the start of rehearsals. The pure-tone audiometric tests were performed at audiometric frequencies: 1 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, and 8 kHz using a tonal audiometer Traveler Audio Audiometer type 222 (Interacoustics).

Immediately after the end of a rehearsal, i.e., after exposure to orchestral noise, the TEOAE tests were repeated. A scout otoacoustic emission system ver. 3.45.00 (Bio-logic System Corp.) was applied for recording and analyzing otoacoustic emissions. Transient-evoked otoacoustic emission recordings of 260 in average 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 3.5–16.6 ms post stimulus and band-pass filtered 0–6000 Hz. The whole TEOAE response in the frequency band 1–4 kHz and the TEOAE amplitude levels for frequency bands with central frequencies 1 kHz, 1.5 kHz, 2 kHz, 3 kHz and 4 kHz were examined. Both hearing tests were carried out in a philharmonic building, in a quiet room where the A-weighted sound pressure level of background noise did not exceed 35 dB.

Audiograms were used for the purpose of verification of musicians' self-reported hearing status. In ad-

dition, the actual audiometric hearing threshold levels determined in orchestral musicians were compared with the predicted hearing loss according to ISO 1999 [12].

Due to the large number of factors that may affect the results of TEOAE performed before and after exposure to noise orchestra, in this study, the effect of risk factors, other than exposure to noise, have not been taken into account because of a small size of the study group and the significant variation in the status hearing subjects.

Statistical analysis of temporary changes in the TEOAE amplitude levels and signal to noise ratio (at frequency bands of 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz, 4000 Hz and for total response) was made using non-parametric tests for the dependent variables, i.e., Wilcoxon matched pair and Sign tests. Cases with the TEOAE amplitude below noise level were excluded from the analysis.

The differences between post- and pre-exposure amplitudes of TEOAE were evaluated using linear regression (at different frequencies and for total response). The intercept of the linear function with post exposure TEOAE amplitude axis was interpreted as the average change in the amplitude of TEOAE caused by exposure to orchestral noise in the study group.

All statistical tests were made with an assumed level of significance  $p < 0.05$ . The STATISTICA (version 6.1) software package was employed for the purpose of the statistical analysis of the data.

The study protocol was approved by the Ethics Committee of the Nofer Institute of Occupational Medicine, Łódź, Poland (decision No. 9/2010) and all

subjects gave their written consents for participation in the examinations.

## RESULTS

According to our previous results, musicians playing various instruments are subjected to varying exposures to sounds. These exposures vary considerably over time, and strongly depend on the repertoire. In order to illustrate the levels of noise, to which the musicians are exposed while playing instruments, the Table 1 presents aggregate results of measurements of sound pressure levels at positions of musicians playing various instruments [9–11].

The details concerning the study group including A-weighted noise exposure level normalized to a 40-h nominal working week ( $L_{EX,w}$ ) with respect to a weekly time of playing instruments declared by musicians) are shown in the Table 2. The  $L_{EX,w}$  values were estimated based on the results of our previous studies [9–11] and on a weekly time of playing an instrument declared by musicians. This table also presents data on the A-weighted noise exposure level during analyzed rehearsals (between TEOAE tests) normalized to a nominal 8-h working day ( $L_{EX,8h}$ ). As it has been proven, during rehearsals the study subjects were exposed to orchestral noise at levels below the limit values for occupational noise ( $< 85$  dB).

It was found that 5 subjects had notched audiograms at high frequencies. The notched audiograms were the

**Table 1.** Sound pressure levels measured during group rehearsals in orchestral musicians [9–11]

**Tabela 1.** Poziom ciśnienia akustycznego zmierzony podczas prób grupowych muzyków orkiestrowych [9–11]

Instrument	$L_{Aeq,T}+U$ [dB]	$L_{Amax}$ (range) (zakres) [dB]	$L_{Cpeak}$ (range) (zakres) [dB]
Violin / Skrzypce	84.6+2.7	90.6–107.1	106.6–131.8
Viola / Altówka	84.7+3.0	89.9–105.9	104.4–120.8
Clarinet / Klarnet	87.6+4.5	93.8–108.1	104.7–126.6
Oboe / Obój	88.1+3.6	95.7–108.3	112.5–124.7
Flute / Flet	87.8+4.0	94.7–109.2	106.8–133.5
Trombone / Puzon	90.1+4.8	96.1–111.2	115.7–128.3
Percussion / Perkusja	87.1+4.0	86.7–112.0	105.0–135.5
Harp / Harfa	83.3+3.8	91.8–101.6	110.0–125.1

$L_{Aeq,T}$  – A-weighted equivalent continuous sound pressure level / równoważny poziom dźwięku skorygowany charakterystyką częstotliwościową A;  $L_{Amax}$  – A-weighted maximum sound pressure level / maksymalny poziom dźwięku skorygowany charakterystyką częstotliwościową A;  $L_{Cpeak}$  – C-weighted peak sound pressure level / szczytowy poziom dźwięku skorygowany charakterystyką częstotliwościową C; U – expanded uncertainty for a one-side confidence interval of 95% (with coverage factor  $k = 1.65$ ) according to ISO 9612:2009 [8] / niepewność rozszerzona przy jednostronnym 95-procentowym poziomie ufności (ze współczynnikiem rozszerzenia  $k = 1,65$ ) według ISO 9612:2009 [8].

**Table 2.** Characteristics of the study group  
**Tabela 2.** Charakterystyka badanej grupy

Variable Zmienna	Respondents Badani (N = 18)		Percentile Percentyl				
	M	SD	10	25	50	75	90
Age [years] / Wiek [w latach]	39.4	9.6	30.0	32.0	36.0	44.0	56.0
Duration of a musician's activity [years] / Okres aktywności muzycznej [w latach] <sup>1</sup>	23.7	8.1	15.0	17.0	23.0	30.0	33.0
Time of playing an instrument [h/week] / Czas gry na instrumencie [godz./tydzień]	29.3	5.2	20.0	28.0	30.0	32.0	35.0
$L_{EX,40h}$ [dB] <sup>2</sup>	84.3	2.6	81.5	82.5	84.4	86.2	87.8
Time of exposure to excessive sounds (music during rehearsals) / / Czas ekspozycji na za głośne dźwięki (na muzykę w czasie prób) [min] <sup>3</sup>	182.0	76.0	91.0	133.0	189.0	243.0	272.0
$L_{EX,8h}$ [dB] <sup>4</sup>	79.4	3.8	76.5	77.8	80.1	81.9	83.1

M – mean / średnia, SD – standard deviation / odchylenie standardowe.

<sup>1</sup> Including college period (5 years) / W tym okres studiów (5 lat).

<sup>2</sup> A-weighted noise exposure level normalized to a 40-h nominal working week (with respect to weekly time of playing instruments declared by musicians) / Poziom ekspozycji na hałas odniesiony do 40-godzinnego tygodniowego wymiaru czasu pracy (z uwzględnieniem tygodniowego czasu gry na instrumentach deklarowanego przez muzyków).

<sup>3</sup> Time between transient-evoked otoacoustic emissions (TEOAE) tests / Czas między badaniami emisji otoakustycznych przejściowych (TEOAE).

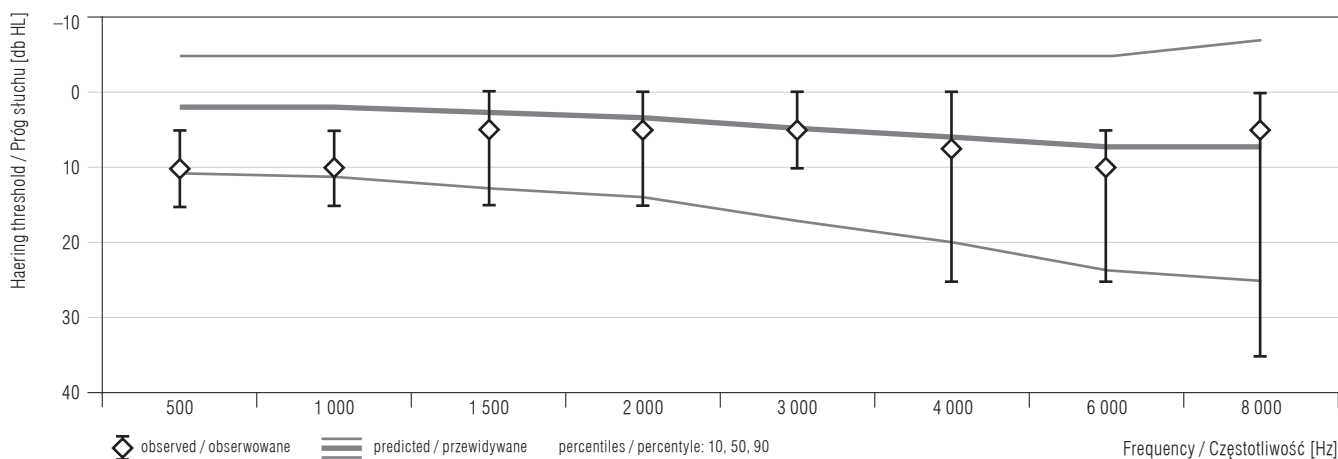
<sup>4</sup> A-weighted noise exposure level (between TEOAE tests) normalized to a nominal 8-h nominal working day / Poziom ekspozycji na hałas (między badaniami TEOAE) odniesiony do 8-godzinnego dobowego wymiaru czasu pracy.

ones, in which the differences between the maximum hearing threshold at frequencies 3 kHz, 4 kHz, 6 kHz and hearing thresholds at frequencies 2 and 8 kHz were greater than or equal to 10 dB.

Generally, the averaged audiometric hearing threshold levels of the 18 musicians (36 ears) do not exceed 15 dB HL, which indicates a good state of their hearing (Figure 1). Higher hearing threshold levels at the frequencies of 4000 Hz, 6000 Hz and 8000 Hz were only observed in the case of subjects over the age of 40 years old.

Musicians' hearing threshold levels (at 2000, 4000 and 6000 Hz) were higher than expected for age- and gender-comparable non-noise-exposed population according to ISO 1999 [12]. The observed increase in hearing thresholds below 1500 Hz was probably related to the conditions, under which hearing tests were conducted, i.e., in a quiet room (with background noise up to 35 dB(A)) in the philharmonic building instead of a sound-proof cabin.

The TEOAE results are presented in the Table 3 and Figures 2–4. As it has been proven, the TEOAE amplitude reduction was observed at all tested frequencies.



**Fig. 1.** The hearing threshold level in the study group compared to predicted hearing threshold levels according to ISO 1999 [12] in non-exposed noise population (data base A)

**Ryc. 1.** Progi słuchu w badanej grupie w porównaniu z przewidywanymi progami słuchu według ISO 1999 [12] w populacji nienarażonej na hałas (baza danych A)

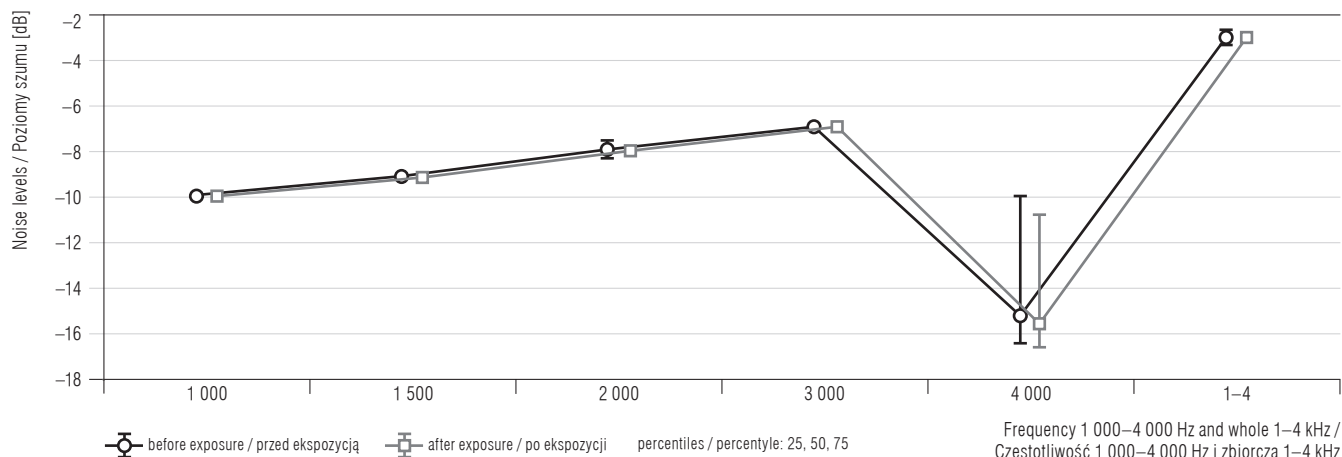
**Table 3.** Transient-evoked otoacoustic emissions (TEOAEs) in the study group\*  
**Tabela 3.** Emisje otoakustyczne przejściowe (TEOAE) w badanej grupie\*

	Frequency Częstotliwość [kHz]	M	SD	Percentile Percentyl				
				10	25	50	75	90
Pre-/post-exposure (rehearsal) of the TEOAE amplitude / Amplituda TEOAE przed ekspozycją i po ekspozycji (próbie) [dB]								
1		-3.7/-4.3	4.9/5.1	-10.0/-10.0	-8.4/-8.5	-3.2/-4.7	-1.7/-1.2	3.4/3.7
1.5		1.6/1.1	5.4/5.8	-5.9/-7.9	-2.1/-3.8	1.7/0.7	5.9/5.7	7.2/7.4
2		2.1/1.5	6.6/6.9	-5.7/-7.9	-3.1/-2.8	0.6/-0.4	6.6/5.4	12.6/13.1
3		-0.2/-0.6	6.0/6.0	-6.9/-7.0	-5.1/-6.3	-2.3/-2.6	5.0/5.5	9.9/9.6
4		-4.4/-4.5	6.4/7.0	-14.1/-15.5	-8.6/-8.3	-4.6/-5.0	2.4/3.2	4.3/4.8
whole / zbiorcza (1-4) <sup>1</sup>		6.7/6.1	5.7/6.0	-0.9/-2.8	2.3/1.5	6.7/6.2	8.9/9.2	16.2/15.1
Pre-/post-exposure (rehearsal) noise level / Poziom szumów przed ekspozycją i po ekspozycji (próbie) [dB]								
1		-9.8/-9.9	0.5/0.4	-10.0/-10.0	-10.0/-10.0	-10.0/-10.0	-10.0/-10.0	-9.3/-9.4
1.5		-8.8/-8.8	1.0/1.1	-9.2/-9.2	-9.2/-9.2	-9.2/-9.2	-9.2/-9.0	-6.7/-7.7
2		-7.5/-7.7	1.4/0.9	-8.0/-8.0	-8.0/-8.0	-8.0/-8.0	-7.8/-8.0	-6.8/-7.0
3		-6.8/-6.9	0.5/0.3	-7.0/-7.0	-7.0/-7.0	-7.0/-7.0	-6.9/-7.0	-6.2/-7.0
4		-12.9/-13.9	4.3/3.6	-16.7/-16.9	-16.4/-16.6	-15.3/-15.6	-10/-10.8	-5.6/-7.0
whole / zbiorcza (1-4) <sup>1</sup>		-2.8/-2.9	0.9/0.7	-3.2/-3.2	-3.2/-3.2	-3.2/-3.2	-3/-3.1	-1.2/-2.7
Pre-/post-exposure (rehearsal) reproducibility of TEOAE / Powtarzalność TEOAE przed ekspozycją i po ekspozycji (próbie) [%]								
1		84.8/79.7	21.3/26.4	60.9/41.9	77.1/71.4	93.6/94.0	98.4/97.0	99.2/97.8
1.5		91.6/91.3	19.3/15.5	78.3/78.0	93.9/92.6	97.1/96.9	99.2/98.5	99.7/99.6
2		93.7/90.1	8.2/19.0	84.2/48.5	92.4/93.8	97.2/96.8	98.2/98.9	99.2/99.2
3		90.8/91.3	13.6/11.2	82.4/79.4	89.9/87.1	94.6/97.0	97.4/98.4	97.7/98.6
4		72.9/74.4	24.4/27.4	28.5/21.3	70.3/61.6	78.2/85.6	90.8/92.2	93.5/96.5
whole / zbiorcza (1-4) <sup>1</sup>		94.2/93.9	9.7/8.7	90.7/77.8	92.8/94.0	96.6/97.3	98.7/98.6	99.5/99.1

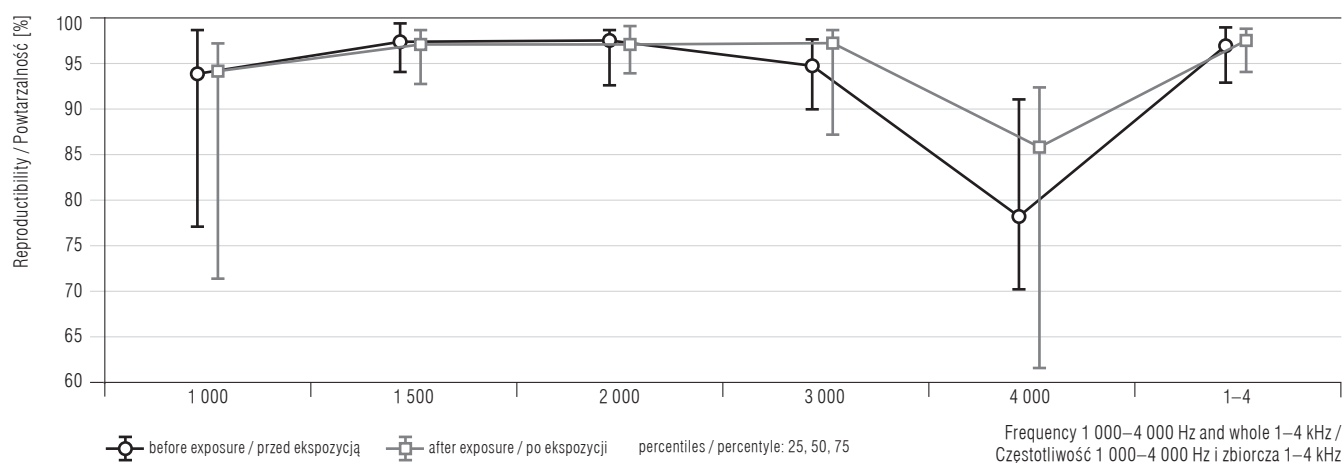
M – mean / średnia, SD – standard deviation / odchylenie standardowe.

<sup>1</sup> Whole response in the frequency band of 1–4 kHz / Odpowiedź zbiorcza w pasmach częstotliwości 1–4 kHz.

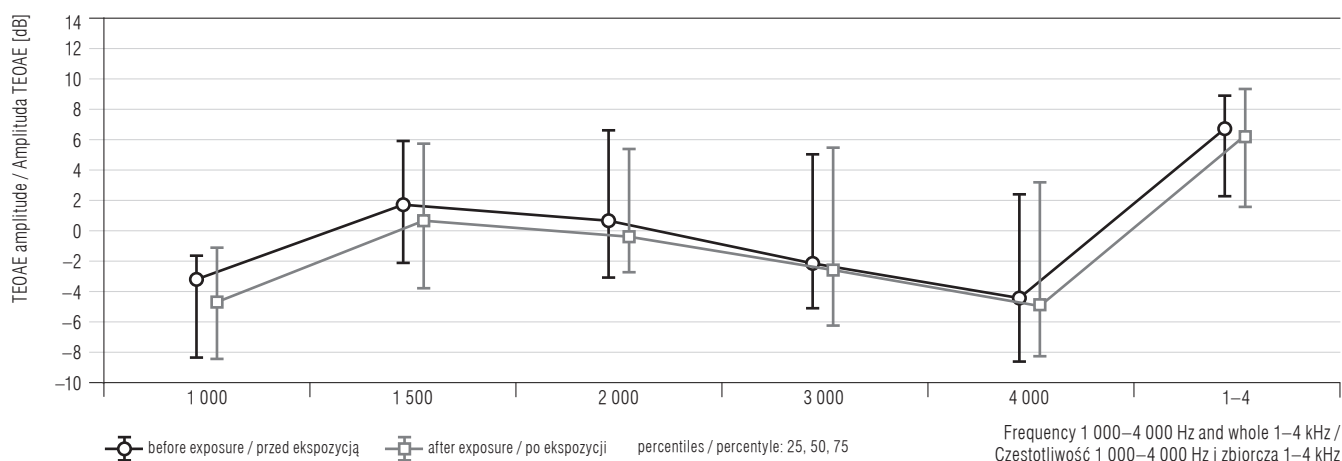
\* Only ears with the TEOAE amplitude above noise level were analyzed (27 pairs of pre- and post-exposure met that requirement) / Przeanalizowano tylko uszy z amplitudą TEOAE większą od szumów (wymóg ten spełniało 27 par wyników badań przed ekspozycją i po ekspozycji).



**Fig. 2.** Transient-evoked otoacoustic emissions (TEOAEs) tests – comparison of noise levels before and after exposure (playing instruments)  
**Ryc. 2.** Badanie emisji otoakustycznych przejściowych (TEOAE) – porównanie poziomu szumów przed ekspozycją i po ekspozycji (grze na instrumentach)



**Fig. 3.** Transient-evoked otoacoustic emissions (TEOAEs) tests – comparison of reproducibility of responses before and after exposure (playing instruments)  
**Ryc. 3.** Badanie emisji otoakustycznych przejściowych (TEOAE) – porównanie powtarzalności odpowiedzi przed ekspozycją i po ekspozycji (grze na instrumentach)



**Fig. 4.** Transient-evoked otoacoustic emissions (TEOAEs) tests – comparison of the TEOAE amplitude before and after exposure (playing instruments)  
**Ryc. 4.** Badanie emisji otoakustycznych przejściowych (TEOAE) – porównanie amplitudy TEOAE przed ekspozycją i po ekspozycji (grze na instrumentach)

**Table 4.** The post-exposure temporary changes in the transient-evoked otoacoustic emissions (TEOAEs) amplitude (at different frequencies and for total response in the frequency band 1–4 kHz) together with results of statistical tests  
**Tabela 4.** Czasowe zmiany amplitudy emisji otoakustycznych przejściowych (TEOAE) po ekspozycji (dla różnych częstotliwości i dla odpowiedzi zbiorczej w częstotliwości pasma 1–4 kHz) wraz z wynikami testów statystycznych

Frequency Częstotliwość [kHz]	Wilcoxon matched pair Test Test Wicoxona par skojarzonych									Amplitude reduction ±95% CI Redukcja amplitudy ±95% CI [dB]
	level of noise poziom szumów [dB]			reproducibility powtarzalność [%]			TEOAE amplitude amplituda TEOAE [dB]			
	T	Z	p	T	Z	p	T	Z	p	
1	12.0	0.3381	0.7353	113.0	1.5874	0.1124	76.0	1.8857	0.0593	-0.70±1.00
1.5	32.0	0.0889	0.9292	184.5	0.1081	0.9139	117.5	1.4731	0.1407	-0.60±0.60
2	14.5	1.3251	0.1851	172.0	0.0889	0.9292	91.5	2.1334	0.0329*	-0.58±0.51*
3	5.0	1.8204	0.0687	188.5	0.0120	0.9904	78.0	2.2736	0.0230*	-0.45±0.37*
4	95.0	2.0445	0.0409*	132.0	1.3694	0.1709	180.5	0.2042	0.8382	-0.01±0.99
Whole / Zbiorcza (1–4) <sup>1</sup>	16.0	1.1722	0.2411	166.5	0.2286	0.8192	72.0	2.4351	0.0149*	-0.74±0.70*

CI – confidence interval / przedział ufności, T – test statistics / statystyka testu, Z – standardized to normal distribution test statistic / statystyka testu standaryzowana do rozkładu normalnego.

<sup>1</sup> Whole response in the frequency band of 1–4 kHz / Odpowiedź zbiorcza w pasmach częstotliwości 1–4 kHz.

\* Statistically significant / Istotne statystycznie.

The post-exposure temporary changes in the TEOAE amplitude together with the results of the statistical tests are given in the Table 4. Statistically significant reduction of the TEOAE amplitude (for total response and at frequency bands of 2000 Hz and 3000 Hz) was noted after a rehearsal. The deterioration of whole amplitude in the frequency range 1–4 kHz reached 0.7 dB. The comparison of the post- and pre-exposure noise level revealed significant difference only at the frequency of 4000 Hz.

## DISCUSSION

The comparison of the post- and pre-exposure noise level of noise in the test before and after exposure showed only the differences at the frequency of 4000 Hz, which might be due to high frequency hearing losses in the study group. Statistically significant reduction in the TEOAE amplitude (for total response and at frequency bands of 2000 Hz and 3000 Hz) was observed after exposure to excessive sounds during a rehearsal. The aforesaid changes were observed after exposure to orchestral noise at relatively low sound exposure level related to a 8-h working day (~80 dB). It should be remembered that the sound pressure levels occurring during collective rehearsals of orchestras are relatively high especially in cases of wind instruments and

percussion (Table 1). In the latter case, sound pressure levels may exceed the admissible values of A-weighted maximum sound level  $L_{Amax}$  and C-weighted peak sound level  $L_{Cpeak}$  for occupational noise [13].

Earlier, the post-exposure reductions in the TEOAE amplitude were also observed in other studies concerning music exposure [6,14]. For example, Libbin [6] – in the case of college marching band members and Santos et al. [14] – in the case of disc jockeys noted temporary variations in TEOAEs in all tested frequencies. However, in those studies, sound exposure levels were higher and amounted to 85–105 dB and 93.2–109.7 dB, respectively. Also, in the case of CD players, the TEOAE reduction was observed after exposure to music corresponding to the daily noise exposure ( $L_{EX,8h}$ ) 77–83 dB [2,4]. It should be stressed that the reduction of transient otoacoustic emissions (TEOAE) was determined with high uncertainty. In the future, the size of the study groups should be increased not only in order to reduce uncertainty but also in order to analyze the effects of other risk factors than exposure to orchestral noise.

## CONCLUSIONS

Despite the unknown mechanism which causes temporary variations, it is believed that multiple and repeated exposures which cause temporary changes in hearing

may lead to permanent hearing loss. Prevalence of temporary reduction of the TEOAE response amplitude supports the statement that the professional musicians are at the risk of hearing deterioration because of their occupational activities, even in the event of exposures to orchestral noise lower than the limit values for industrial noise.

## REFERENCES

1. Zhao F, Manchaiah VKC, French D, Price SM. Music exposure and hearing disorders: An overview. *Int J Audiol.* 2010;49:54–64, <http://dx.doi.org/10.3109/14992020903202520>.
2. Jansen EJM, Helleman HW, Dreschler WA, de Laat JAPM. Noise induced hearing loss and other hearing complaints among musicians of symphony orchestras. *Int Arch Occup Environ Health.* 2009;82:153–64, <http://dx.doi.org/10.1007/s00420-008-0317-1>.
3. Keppler H, Dhoog I, Maes L, D'haenens W, Bockstael A, Philips B, et al. Short-term auditory effects of listening to an MP3 player. *Arch Otolaryngol Head Neck Surg.* 2010;136(6):538–48, <http://dx.doi.org/10.1001/archoto.2010.84>.
4. Keppler H, Dhooge I, Maes L, Bockstael A, Philips B, Swinnen F, et al. Evaluation of the olivocochlear efferent reflex strength in the susceptibility to temporary hearing deterioration after music exposure in young adults. *Noise Health.* 2014;16(69):108–15.
5. Schmuziger N, Patscheke J, Probst R. An assessment of threshold shifts in nonprofessional pop/rock musicians using conventional and extended high-frequency audiometry. *Ear Hear.* 2007;28(5):643–8, <http://dx.doi.org/10.1097/AUD.0b013e31812f7144>.
6. Libbin B. Temporary changes in auditory function among college marching band members University of Maryland. College Park; 2008 [cited 2014 Oct 19]. Available from: <http://drum.lib.umd.edu/bitstream/1903/8081/1/umi-umd-5243.pdf>.
7. PN-N-01307:1994. [Noise – Noise limit values in the workplace – Requirements for measurement]. Warszawa: Polish Committee for Standardization; 1994. Polish.
8. ISO 9612:2009. Acoustics – Determination of occupational noise exposure – Engineering method. Geneva: International Committee for Standardization; 2009.
9. Pawlaczyk-Łuszczczyńska M, Dudarewicz A, Zamojska M, Śliwińska-Kowalska M. Hearing ability in orchestral musicians. *Arch Acoust.* 2010;35(4):579–94, <http://dx.doi.org/10.2478/v10168-010-0044-y>.
10. Pawlaczyk-Łuszczczyńska M, Dudarewicz A, Zamojska M, Śliwińska-Kowalska M. Evaluation of sound exposure and risk of hearing impairment in orchestral musicians. *Int J Occup Ergon.* 2011;17(3):255–69, <http://dx.doi.org/10.1080/10803548.2011.11076892>.
11. Pawlaczyk-Łuszczczyńska M, Zamojska M, Dudarewicz A, Zaborowski K. Noise-induced hearing loss in professional orchestral musicians. *Arch Acoust.* 2013;38(2):223–34, <http://dx.doi.org/10.2478/aoa-2013-0027>.
12. ISO 1999:1990. Acoustics – Determination of occupational noise exposure and estimation of noise induced hearing impairment. Geneva: International Committee for Standardization; 1990.
13. Morais D, Benito JI, Almarazb A. Acoustic trauma in classical music players. *Acta Otorrinolaringol Esp.* 2007;58(9):401–7, [http://dx.doi.org/10.1016/S0001-6519\(07\)74956-7](http://dx.doi.org/10.1016/S0001-6519(07)74956-7).
14. Santos L, Thais C, Morata TC, Jacob LC, Albitu E, Marques JM, et al. Music exposure and audiological findings in Brazilian disc jockeys (DJs). *Int J Audiol.* 2007;46:223–31, <http://dx.doi.org/10.1080/14992020601188575>.

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