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TEMPORARY HEARING THRESHOLD SHIFT MEASURED BY OTOACOUSTIC EMISSIONS IN SUBJECTS EXPOSED TO SHORT-TERM IMPULSE NOISE

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Abstract
Objectives: The aim of the study was to assess the influence of short-term impulse noise on the size and dynamics of temporary threshold shift, which precedes permanent threshold shift, i.e. noise-induced hearing loss. It was hoped to use the findings for preventive activities. **Materials and Methods:** The study included 80 healthy subjects (160 ears), aged 19–23 years, divided into two groups: group I comprised 40 recruit soldiers put to the shooting training, and group II consisted of 40 young male controls. All subjects had to show normal hearing with pure tone audiometric thresholds between 10–15 dB. Transient evoked otoacoustic emission (TOAE) measurements were performed by ILO 292 Echoport Otodynamics device 3–5 min before shooting and then 2 min, 1, 2 and 3 h, respectively after shooting. In group II the time intervals were similar. **Results:** It was found that the gunshot impulse noise from the kbk AKMS rifle caused temporary hearing threshold shift (TTS) at 1, 2, 3, 4 and 5 kHz frequencies of 1.07, 0.96, 1.41, 0.88 and 1.25 dB SPL, respectively. TTS turned out to be maximum at 4 and 5 kHz and minimum at 1 and 2 kHz. **Conclusions:** Short-term impulse noise generated by the rifle gunshots induces rather small temporary threshold shift of hearing. Anyhow, considering possibilities of different weapon noises in the military environment as well as various sources of industrial impulse noise, the usage of hearing protectors should be highly recommended.

Key words:
Impulse noise, Transient evoked otoacoustic emission, Temporary noise induced threshold shift

INTRODUCTION

It is generally agreed that impulse noise that occurs mainly in drop-forging, riveting or stamping industrial processes as well as in military forces and recreational target shooting and hunting is especially hazardous to the ear [1,2]. From the physical point of view the phenomenon is defined as an acoustic pressure disturbance of short duration less than 1 sec and high intensity with the peak sound pressure levels greater than 100 dB SPL [1,2].

Preventive methods intended at least to minimize the hearing damage are still searched. Among others, the reversible temporary threshold shift (TTS), also called an auditory

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fatigue, which precedes the development of permanent threshold shift (PTS), a synonym of noise-induced hearing loss (NIHL), is considered to be the predicting indicator of the NIHL size [1,3–5]; it is presumed that 40 dB TTS may represent some sort of critical TTS that should not be exceeded if the risk of permanent injury is to be avoided [1,3]. It is commonly accepted that otoacoustic emissions (OAEs), a modern objective tool of audiological testing, represent the functional state of outer hair cells in the cochlea [6–11], being first of all injured by noise impact [12–15]. OAEs are stable over time, do not rely on a behavioral response and are quick to obtain, therefore they have been proposed as an alternative method for monitoring cochlear damage to overcome the problems associated with pure tone audiometry [4,12–17]. Changes introduced by noise exposure that give rise to TTS have been shown to alter the amplitude or frequency composition of transient evoked otoacoustic emissions (TEOAEs) and were defined as the temporary emission shift, approximate to TTS measured audiometrically [4,5,18]. Hence, the use of TEOAEs to study temporary effects of noise exposure seems to be soundly based.

The aim of the present investigation was to assess an effect of short-term impulse noise on the magnitude and dynamics of auditory temporary changes in normally hearing individuals, using the TEOAEs recording technique.

MATERIALS AND METHODS

The study included 80 young healthy subjects (160 ears), aged 19–23 years, who had never suffered from ear diseases and/or any systemic disorders, and their hearing thresholds measured by pure tone audiometry were less than 15 dB. The subjects were divided into two study groups. Group I comprised 40 recruit soldiers put to the shooting training, aged 19–23 years (mean age, 21.4 ± 1.6 years), and group II consisted of 40 young male controls (students), aged 19–23 years (mean age, 21.2 ± 1.2 years).

After performing otolaryngological examination, pure tone audiometry and impedance audiometry (tympanometry and acoustic reflex threshold) otoacoustic emmision measurements, namely transient evoked otoacoustic emissions were carried out by ILO 292 Echoport Otodynamics device with the probe placed in the ear canal. The stimuli for TEOAEs were 80 dB SPL 80 μs click, presented at a rate of 50/s in nonlinear mode; the click intensity was automatically compensated according to the size of external auditory meatus; the responses were averaged after 260 repetitions; time of analysis was 2, 5 to 20 ms; the TEOAE level was measured in 500 Hz intervals from 500 Hz to 5000 Hz at the frequencies of 1, 2, 3, 4 and 5 kHz. Only emission of 3 dB above the noise background level was admitted to be present with 60% of repeatability. Amplitudes, frequency composition, stimuli levels, stability of the probe position and reproducibility were taken into consideration during comparative assessment of records.

In the impulse noise exposed group, TEOAEs were registered 3–5 min before and then 2 min, 1, 2 and 3 h after shooting. Each soldier was taking 5 shots (without hearing protectors) from the kbk AKMS rifle, caliber 7.62 mm, in recumbent position and after shooting he stayed in the quiet environment; the peak SPL of noise during shooting was 156 dB. In the control group, examinations were performed similary: after first testing, then 1, 2 and 3 h later.

Statistical significance was examined using two samples for the t-test.

The study was approved by the Medical Ethical Committee of the Medical University of Łódź and all subjects gave their written consent for participation in examinations (Nr RNN/92/03/KB).

RESULTS

The mean binaural amplitude values of TEOAEs 3–5 min before shooting and then 2 min, 1, 2 and 3 h after shooting in the group I vs. group II are summarized in Table 1 and Fig. 1.

The mean amplitude values of TEOAEs (across the tested frequencies) as a function of time after shooting are drawn in Fig. 2. For the frequencies of 1 and 2 kHz after 1 h and for the frequency of 3 kHz after 2 h, the mean amplitude values were similar to pre-shooting values; for the frequencies of 4 kHz and 5 kHz, the mean amplitude values have not recovered even after 3 h.

Table 1. Mean binaural* amplitude values of transient evoked otoacoustic emissions (TEOAEs) in group I vs. group II

Group I

Frequencies	Before shooting	2 min after shooting	1 h after shooting	2 h after shooting	3 h after shooting
1 kHz	-4.55	-5.62	-4.17	-4.15	-2.71
2 kHz	-7.57	-8.53	-7.88	-7.20	-4.42
3 kHz	-10.07	-11.48	-11.61	-10.48	-9.29
4 kHz	-11.26	-12.14	-13.13	-12.27	-11.11
5 kHz	-21.81	-23.06	-24.25	-23.22	-22.86

Group II

Frequencies	First measurement	1 h later	2 h later	3 h later
1 kHz	-5.83	-5.68	-5.54	-5.42
2 kHz	-8.87	-8.84	-8.89	-8.19
3 kHz	-12.91	-13.03	-12.91	-12.27
4 kHz	-17.03	-16.64	-16.84	-16.58
5 kHz	-25.30	-25.22	-24.93	-24.93

* Differences between left and right ear were not significant ($p > 0.05$)

It turned out that amplitude differences of TEOAE before and 2 min after shooting were significant ($p < 0.05$) for the frequencies of 1,2, 3 and 5 kHz.

Statistically significant differences were also observed in the mean amplitude values of TEOAE before and after shooting ($p < 0.05$) as well as in the measurements repeatability ($p < 0.05$); to the contrary, the level of TEOAE and probe stability before and 1, 2 and 3 h after shooting appeared to be not significant ($p > 0.05$), which provides evidence for the data comparability.

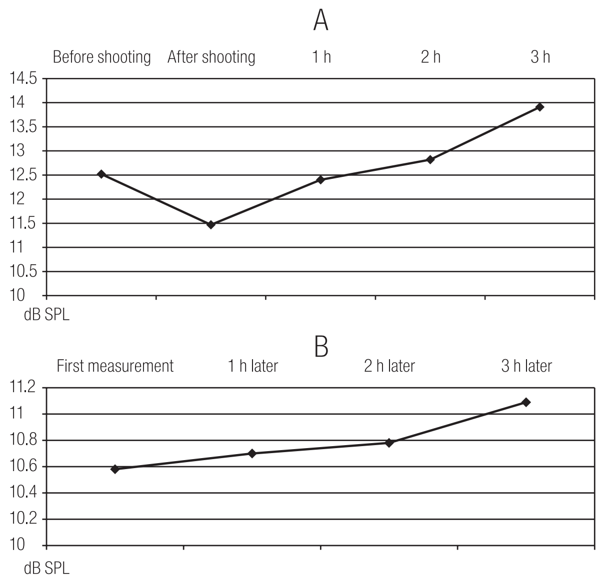

Fig. 1. Mean transient evoked otoacoustic emission (TEOAE) amplitude values in group I (A) vs. group II (B).

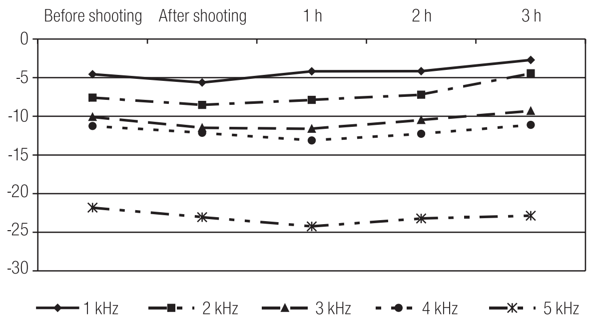

Fig. 2. Transient evoked otoacoustic emission (TEOAE) spectral distributions in group I as a function of the measurement time after shooting.

As shown in Fig. 3, no significant changes in the mean amplitude values of TEOAE (throughout all frequencies tested) as a function of the measurement time were found in group II ($p > 0.05$); the first measurement results were similar to those performed after 1, 2 and 3 h.

Table 2 shows the comparison of basic TEOAE characteristics (amplitude, reproductibility, stimuli level, probe stability) in both groups. There were no significant differences in measurements between the groups after 1 h ($p > 0.05$). Significant differences were found between the groups in mean amplitudes of TEOAE only for the frequency of 4 kHz after 2-h measurements ($p < 0.05$) as well as for the frequencies of 1, 2 and 4 kHz and stimuli level after 3-h measurements ($p < 0.05$).

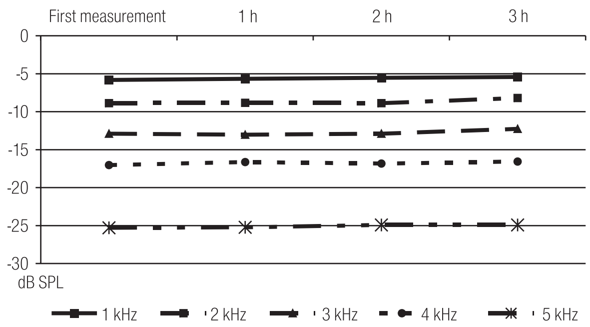

Fig. 3. Transient evoked otoacoustic emission (TEOAE) spectral distributions in group II as a function of the measurement time.

Table 2. Values of transient evoked otoacoustic emission (TEOAE) parameters in groups I and II as a function of measurement time

Parameters	After 1 h			After 2 h			After 3 h		
	Group I	Group II	Significance	Group I	Group II	Significance	Group I	Group II	Significance
Amplitude	12.40 dB SPL ±4.74	10.70 dB SPL ±4.66	p > 0.05	12.82 dB SPL ±4.44	10.78 dB SPL ±4.46	p > 0.05	13.91 dB SPL ±4.95	11.09 dB SPL ±4.43	p < 0.05
Reproducibility	81.38% ±15.03	86.73% ±8.52	p > 0.05	86,78% ±11.38	88.03% ±7.27	p > 0.05	86.31% ±11.90	87.83% ±8.40	p > 0.5
Stimuli Level	79.46 dB SPL ±2.05	78.70 dB SPL ±1.92	p > 0.05	79.36 dB SPL ±2.26	78.51 dB SPL ±1.84	p > 0.05	80.49 dB SPL ±2.04	78.95 dB SPL ±1.75	p < 0.05
Probe stability	96.38% ±2.66	95.85% ±3.13	p > 0.05	96.56% ±2.02	96.13% ±2.07	p > 0.05	95.00% ±3.35	96.21% ±1.62	p > 0.05

DISCUSSION AND CONCLUSIONS

The study was designed to investigate the influence of short-term impulse noise caused by 5 shots from the kbk AKMS rifle on the size and dynamics of temporary threshold shift.

Although TEOAEs are not *per se* measure of noise-induced TTS, but rather of temporary otoacoustic emission shift [4,13,18], there is evidence that the amount of TTS may correspond with amplitude reduction of TEOAEs. Vinck et al. [19] demonstrated that volunteers exposed for 1 h to white noise of 90 dB showed the correlation between TTS measured by pure tone audiometry and TEOAE amplitude and spectrum reduction; they found prolonged TTS recovery time for 4 kHz and the lowest TEOAE response at 5 kHz as well as the largest intensity of response at 1 kHz. Similar observations were made in other studies [5,20,21].

In our study, mean values of TTS just after shooting were: at 1 kHz – 1.07 dB SPL, at 2 kHz – 0.96 dB SPL, at 3 kHz – 1.41 dB SPL, at 4 kHz – 0.88 dB SPL, and at 5 kHz – 1.25 dB SPL; after a lapse of 1 h the TEOAE amplitudes at 1 and 2 kHz were similar to those before shooting, but at 3, 4 and 5 kHz, there was a shift of 1.54 dB SPL, 1.87 dB SPL and 2.44 dB SPL, respectively.

After another 2 h, TTS (otoacoustic emission shift) was still present at 4 kHz of 1.01 dB SPL and at 5 kHz of 1.41 dB SPL, and after 3 h, it was observed only at 5 kHz with the mean value of 1.05 dB SPL.

The TEOAE parameters in the control group had an unchanged course over time.

It may therefore be concluded that a short term exposure to impulse noise generated by the rifle gunshots of caliber 7.62 mm induces a small temporary threshold shift of hearing (otoacoustic emission shift) with maximum at high frequencies of 4 and 5 kHz and minimum at 1 and 2 kHz; if the TEOAE magnitude reduction is higher, the recovery time is prolonged.

The effect of threshold shift due to sound impact is generally attributed to various mechanisms at the middle ear, cochlear and neural levels. However, there are great individual variations in TTS, and the correlation between TTS and individual susceptibility to noise-induced hearing loss is still uncertain. Anyhow, one may assume that TEOAE reflects the functional state of the cochlea more exactly than audiometric TTS, and thus TEOAE may be regarded as a possible indicator for vulnerability of the ear. Hence, further studies on relations between TTS and TEOAE should continue.

REFERENCES

1. Sułkowski WJ. *The effects of impulse noise on hearing: general and clinical implications*. Audiol Ital 1986;3:237–46.
2. Dancer A, Buck K, Parmentier G, Hamery P. *The specific problems of noise in military life*. Scand Audiol 1998;48 Suppl:123–30.
3. Lipowczan A, Sułkowski WJ, Tengler M. *Application of TTS measurements for the evaluation of noise hazard: a field study.* Proceedings of the 4th International Congress on Noise as a Public Health Problem; 1983; Turin. Milano: Centro Ricerche e Studi Amplifon; 1983. p. 277–84.

4. Marshall L, Heller LM. *Transient-evoked otoacoustic emissions as a measure of noise-induced threshold shift.* Speech Lang Hear Res 1998;41:1319–34.
5. Liebel J, Delb W, Andes C, Koch A. *Zum diagnostischen Stellenwert der otoakustischen Emissionen (OAE) in der Erfassung eines durch Freizeitlorm verursachten TTS (Temporary threshold shift).* Arbeitsmed Sozialmed Umweltmed 1996;31:269–75.
6. Kapadia S, Lutman ME. *Are normal hearing thresholds a sufficient condition for click-evoked otoacoustic emissions?* J Acoust Soc Am 1997;101:566–76.
7. Dohlen P, Hennaux C, Chantry P, Hennebert D. *The occurrence of evoked otoacoustic emissions in a normal adult population and neonates.* Scand Audiol 1991;20:203–4.
8. Fuse T, Aoyagi M, Suzuki Y, Koike Y. *Frequency analysis of transiently evoked otoacoustic emissions in sensorineural hearing disturbances.* Acta Otolaryngol (Stockh) 1994;511:91–4.
9. Śliwińska-Kowalska M, Sułkowski WJ, Murowaniecki Z. *Evoked otoacoustic emission: Investigations in persons with normal hearing.* Otolaryng Pol 1995;49:46–56 [in Polish].
10. Ferguson MA, Smith PA, Davis AC, Lutman ME. *Transient-evoked otoacoustic emissions in a representative population sample aged 18 to 25 years.* Audiology 2000;39:125–34.
11. Vedantam R, Musiek FE. *Click-evoked otoacoustic emissions in adult subjects: standard indices and test-retest reliability.* Am J Otol 1991;12:435–42.
12. Prasher D, Sułkowski WJ. *The role of otoacoustic emissions in screening and evaluation of noise damage.* Inter J Occup Med Environ Health 1999;12:183–92.
13. Attias J, Horovitz G, El-Hatib N, Nageris B. *Detection and clinical diagnosis of noise-induced hearing loss by otoacoustic emissions.* Noise Health 2001;3:19–31.
14. Vinck BM, Van Cauwenberge PB, Leroy L, Corthals P. *Sensitivity of transient evoked and distortion product otoacoustic emissions to the direct effects of noise on the human cochlea.* Audiology 1999;38:44–52.
15. Kowalska S, Sułkowski WJ. *Measurements of click-evoked otoacoustic emission in industrial workers with noise-induced hearing loss.* Inter J Occup Med Environ Health 1997;10:441–59.
16. Kemp DT, Ryan S, Bray P. *A guide to the effective use of otoacoustic emissions.* Ear Hear 1990;11:92–105.
17. Konopka W, Grzanka A, Zalewski P. *Individual repeatability of recordings in the TEOAE time-frequency analysis.* Otolaryng Pol 2002;56:701–6 [in Polish].
18. Attias J, Bresloff I. *Noise-induced temporary otoacoustic emission shifts.* J Basic Clin Physiol Pharmacol 1996;7:221–33.
19. Vinck BM, Van Cauwenberge PB, Corthals P, De Vel E. *Multivariant analysis of otoacoustic emissions and estimation of hearing thresholds: transient evoked otoacoustic emissions.* Audiology 1998;37:315–34.
20. Prieve BA, Gorga MP, Schmidt A. *Analysis of transient-evoked otoacoustic emissions in normal hearing and hearing impaired ears.* J Acoust Soc Am 1993;93:3308–19.
21. Probst R. Coats AC, Martin GK, Lonsbury-Martin BL. *Spontaneous, click-, and toneburst-evoked otoacoustic emissions from normal ears.* Hear Res 1986;21:261–75.