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Auditory monitoring by means of evaluation of the cochlea in soldiers of the Brazilian Army exposed to impulse noise

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Abstract

Introduction: Exposure to continuous or impulse noise may lead to High Sound Pressure Induced Hearing Loss (HSPIHL) or to acoustic trauma in soldiers. Auditory evaluation by means of evoked otoacoustic emissions (EOAE) has been demonstrating its importance in the detection of subtle changes in cochlear function still unidentified in threshold tone audiometry in subjects exposed to noise. **Objective:** Studying Distortion product otoacoustic emissions (DPOAEs) before and after exposure to impulse noise in soldiers of the Brazilian Army. **Material and Method:** This is an analytical, observational, longitudinal and prospective study. Auditory evaluation was performed by means of DPOAEs in 60 soldiers before and after exposure to impulse noise, of whom 30 were reevaluated immediately after exposure and 30 were reevaluated 24 hours after exposure. **Results:** The statistical analysis revealed that both groups reevaluated after exposure to impulse noise showed a decrease in amplitudes in comparison with the tests before exposure. As for the signal/noise ratio, there was a significant difference at the frequencies of 6 and 8KHz and there was a significant association between a tinnitus complaint and the group reevaluated immediately after exposure to noise. **Conclusion:** The DPOAE test proved sensitive to detect subtle shifts after exposure to impulse noise, both with regard to the amplitude criterion and with regard to the signal/noise ratio even 24 hours after exposure. This demonstrated the applicability of the DPOAE test in monitoring the hearing of soldiers exposed to impulse noise.

Keywords: hearing loss, military personnel, occupational noise.

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INTRODUCTION

Among the several elements of occupational risk, exposure to noise is one of the agents which produces the most harmful effect on the auditory health of individuals exposed, as it may trigger hearing alterations with varying degrees, as well as non-auditory problems which will reflect on their social, family and workplace behavior[1].

Firearm explosion noise is one of the main causes of High Sound Pressure Induced Hearing Loss (HSPIHL) in the United States and an ever increasing number of people have been affected by acoustic trauma or gradual Sensorineural Hearing Loss (SNHL) secondary to excessive firearm noise[2].

Shooting and other activities related to a military career may be linked to exposure to high levels of noise, which may produce alterations in the auditory system. Among the factors which contribute to soldiers' neglect of their hearing safety in shooting activities, the following stand out: lack of information as to the real risk of exposure to shooting noise; lack of orientation, surveillance and training for the use of individual protection equipment (IPE) and the fact that unless the levels of exposure to noise are so high that they become physically uncomfortable or produce temporary hearing threshold shifts (TTS), the short-term effects of exposure to noise will not be easily noticed[3].

Soldiers, unlike industry professionals do not have a definite cycle of exposure, and may be occupationally exposed both to firearm impulse noise as well as in the artillery or even to other kinds of noise. So, noise is a constant problem in the Armed Forces, as long as it is an inherent risk agent in the military service, firearm impulse noise being one of the most damaging to hearing. As the consequences of that exposure are manifold and reach large proportions, the contingent and the sums involved are high, besides affecting the administrative, judicial and financial spheres[4].

Technological progress has made it possible to assess the cochlear function objectively by means of an evaluation of the Evoked Otoacoustic Emissions (EOAE). This is a quick, objective and non-invasive method which may detect early cochlear alterations, first and foremost in subjects exposed to noise, unidentified by tone audiometry[5].

The paucity of studies in South America about the hearing of soldiers exposed to impulse noise and considering the applicability and the preventive character in hearing monitoring by means of the EOAE test, stimulated the conduction of the present study, with the purpose of studying distortion product otoacoustic emissions (DPOAE) before and after the exposure to impulse noise and the presence of tinnitus in soldiers of the Brazilian Army.

MATERIAL AND METHOD

The application of the questionnaire and the test by means of the DPOAE was performed at the Battalion of the Presidential Guard, in Brasilia, at the Federal District.

It consists of an analytical, observational, longitudinal, prospective study.

The study group was composed of 60 male soldiers, aged between 18 and 19 without previous exposure to occupational noise. In order to participate in this project, the soldier should have normal cochlear function.

After shooting practice with 7.62mm caliber FAL Rifles, they were all allocated into two groups. Group 1 (G1) with 30 soldiers was reassessed immediately after exposure to the impulse noise whereas group 2 (G2), also composed of 30 individuals, was reassessed 24 hours after exposure.

Each soldier shot 25 times using hearing protection devices. In order to capture the DPOAEs, use was made of the equipment Eclipse from Interacoustics, which automatically monitored the level of noise, the linearity of the stimulus during the test and the appropriate position of the probe.

The DPOAEs were assessed through the simultaneous presentation of two different pure tones (f1 and f2), expressed by the ratio of 1.22. The answers were recorded at f2, but they are equivalent to 2f1-f2. The intensity parameters L1=65 dBNPS and L2=55 dBNPS were used, the cochlear conditions at the frequencies of 2, 3, 4, 6 and 8KHz having been checked. The analyses of the DPOAE were based on frequency.

The occurrence of an answer of DPOAE at a frequency was considered when the amplitude > or = -10dBNPS and a signal/noise ratio (S/N) > or = to 7dBNPS were observed at that frequency.

The analyses were performed using the SPSS 13® (*Statistical Package for the Social Sciences*, Chicago, IL) for Windows® and SigmaStat 3.11® for Windows®.

A mixed design analysis of variance model was used with the factors Group (G1: Right after or G2: 24h later; independent measurement), Time (Before and After, repeated measurement) and Frequency (2, 3, 4, 6 and 8 kHz; repeated measurement). Sphericity was not assumed and the Greenhouse-Geisser method was used for the correction of the degrees of freedom. However, the original degrees of freedom have been reported. The multiple comparison procedure used the Bonferroni correction method.

The proportion of normal results (present response) in each frequency range before the shooting practice (100%) was compared with the proportion of normal results at the same frequency range after the practice using a proportion z-test (Yates' correction). The chi-square test (Fisher's exact test) was used to test the possible association between the Group and the Occurrence of responses, and between altered results and the moment of evaluation after-practice (immediately afterwards or 24h later).

The results are presented as average ± standard deviation. The level of statistical significance was established as 5% ($p<0.05$). All the tests were two-tailed.

RESULTS

As for the amplitudes, the mixed-design ANOVA did not find any statistically significant differences between the averages recorded in each group ($F_{1, 118}=1.499$, $p=0.223$). The Time factor exerted a significant effect ($F_{1, 118}=42.749$, $p<0.001$). The averages recorded Before were higher than the ones recorded After the exposure to the noise, without taking into account the Group or the Frequency. Similarly, the Frequency factor showed a significant effect ($F_{4, 472}=222.130$, $p<0.001$).

Post hoc analyses showed that the average amplitudes of all the frequencies assessed are different from each other (2>4>3>6>8KHz; Figure 1). This effect does not depend on the group assessed and on the time, being a characteristic feature of each frequency which could be observed due to the sufficiently large size of the sample.

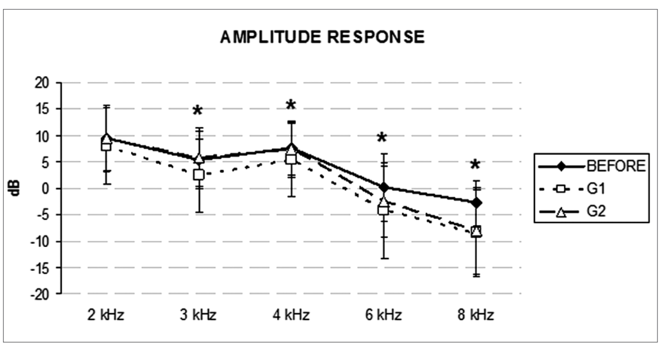

Figure 1. Mean ± standard deviation of the amplitudes of each group at each frequency. *: before>after, within each evaluated frequency.

The Group × Time interactions ($F_{1, 118}=6.057$, $p=0.05$) also exerted a significant effect. *Post hoc* analyses demonstrated that even though it had an effect in both groups, the effect of the Time factor was more intense in G1 ($F_{1, 59}=41.321$, $p<0.001$; average difference (ad=3.407 dB) in comparison with G2 ($F_{1, 59}=8.148$, $p=0.006$; ad=1.543 dB) (Note the consistently higher averages in G2 in Figure 1). In conclusion, after the exposure, both groups showed a decrease of the response amplitude, but in the group assessed right afterwards the decrease was higher.

There was also a significant effect of the interaction Time × Frequency (F4, 472=15.254, $p<0.001$). The *post hoc* analyses found that the effect of the Time factor (Before>After) was not the same at all frequencies (Figure 1). Paired t-tests found differences between the averages before and after the exposure at the frequencies of 3 (ad=1.217; $p=0.036$), 4 (ad=1.242; $p=0.029$), 6 (ad=3.542; $p<0.001$) and 8 KHz (ad=5.533; $p<0.001$). There was no difference in the average amplitudes at the frequency of 2 KHz (ad=0.842; $p=0.084$). The Group × Frequency ($F_{4, 472}=0.755$, $p=0.524$) and Group × Time and Frequency interactions ($F_{4, 472}=1.308$, $p=0.272$) did not exert a significant effect on the average response amplitudes. We can conclude that the decrease in the response amplitude was not the same for each frequency. Nevertheless, it was different among the groups.

As for the signal/noise ratio, the mixed-design ANOVA demonstrated that there was no statistically significant effect of the factor Group on the average differences in the S/N ratio ($F_{1, 117}=3.209$, $p=0.076$).

There was a significant effect of the Time factor ($F_{1, 117}=14.854$, $p<0.001$). The S/N ratio was higher before the shooting practice (ad=1.178 dB; Figure 2).

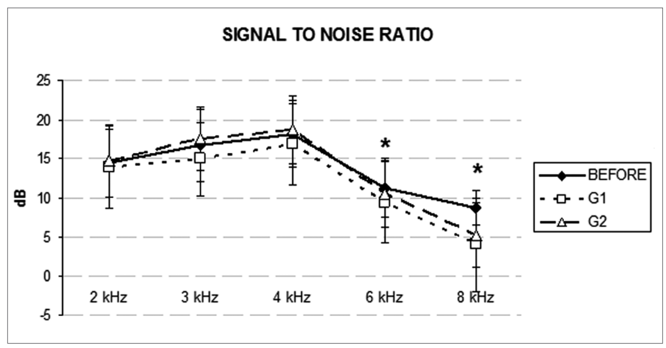

Figure 2. Mean ± standard deviation of the S / N ratio of each group at each frequency. *: before>after, within each evaluated frequency.

The frequency factor also showed a significant effect on the S/N ratio ($F_{4, 232}=282.824$, $p<0.001$).

In the multiple comparison procedure it was observed that all the frequencies showed a different S/N ratio between each other (4>3>2>6>8 kHz; Figure 2). This effect does not depend on the Time or the Group assessed.

The Time × Frequency interaction showed a significant effect on the S/N ratio ($F_{4, 468}=16.796$, $p<0.001$). *Post hoc* analyses found that the effect of the Time factor was different for each frequency. There was a significant difference at the frequencies of 6 (ad=1.292 dB; $p=0.006$) and 8KHz (ad=4.025 dB; $p<0.001$). At the frequencies of 2 (ad=0.076 dB; $p=0.863$), 3 (ad=0.450 dB; $p=0.350$) and 4KHz (ad=0.4 dB; $p=0.394$), on the other hand, there was no significant difference between the averages before and after exposure (Figure 2).

The Group × Time ($F_{1, 117}=3{,}829$, $p=0{,}053$), Group × Frequency ($F_{4, 468}=1{,}146$, $p=0{,}333$) and Group × Time × Frequency ($F_{4, 468}=1{,}264$, $p=0{,}285$) interactions did not exert a significant effect on the S/N ratio.

As for the occurrence of responses, taking into account the signal/noise ratio, the comparison of the percentages of normal results between the ears did not find significant differences in any of the frequencies studied (z<1.344, p>0.179 in all cases). The results of the S/N ratio in the right ears showed statistically significant differences at the frequency of 8KHz. In the left ears, significant differences were found at the frequencies of 6KHz and 8KHz.

No association was detected between the Group and Occurrence variables of responses in any of the frequencies assessed in the Right Ear (Figure 3).

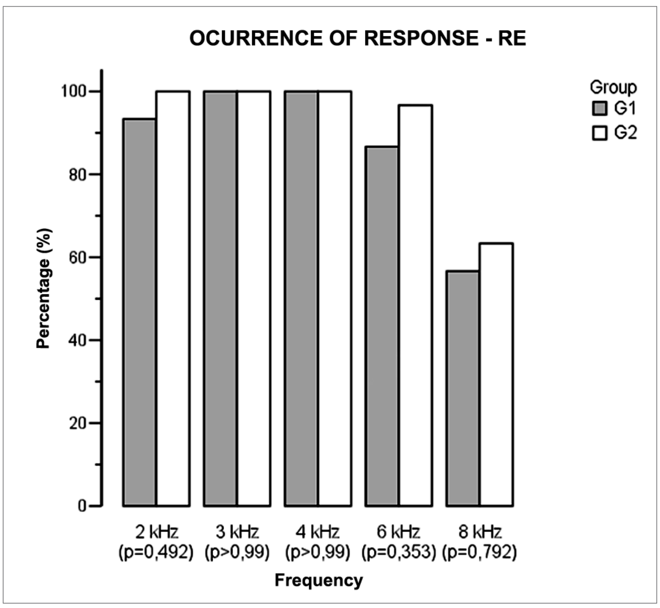

Figure 3. Percentage of occurrence of responses (S/R) in each group for each frequency measured in the right ears. The p-value refers to the association test (χ^2, Fisher's exact test) between the variables group and occurrence within each frequency.

A significant association was found in the left ear (Figure 4) between the variables when analyzed at the frequency of 6KHz. In G2, the percentage of occurrence of responses at the frequency of 6KHz was significantly smaller than in G1.

As for the presence of tinnitus, Table 1 shows the distribution of the frequencies of the variable presence of tinnitus for each kind of result in each group. There was no significant association between the presence of tinnitus and the results in either of the groups (Figure 5).

DISCUSSION

One can observe in Chart 1 that nine out of the fourteen studies were clinical studies conducted with soldiers exposed to impact noise. All were conducted in Europe or in the United States, demonstrating that studies with soldiers exposed to impact noise in Brazil are still scarce and it is a fact that soldiers are exposed both to continuous noise and to impact noise during their activities.

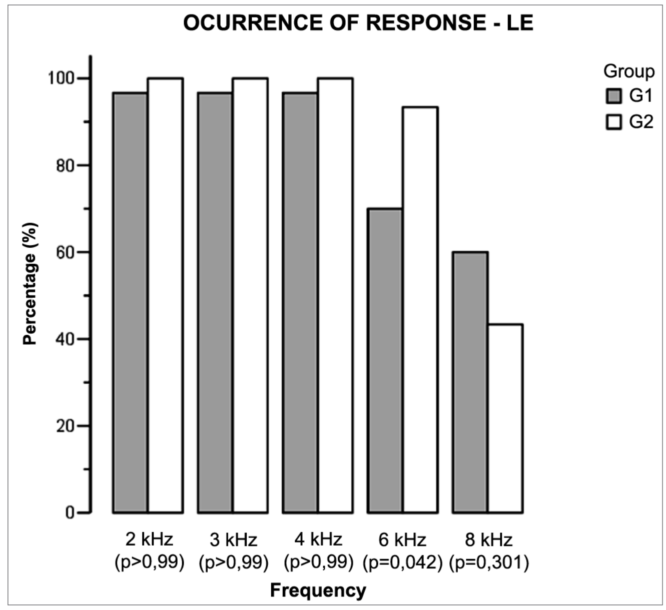

Figure 4. Percentage of occurrence of responses (S/R) in each group for each frequency measured in the left ears. The *p*-value refers to the association test (÷2, Fisher's exact test) between the variables Group and occurrence within each frequency.

Table 1. Contingency table of the variable presence of tinnitus for each category of outcome in each group.

Group	Tinnitus		χ^2
	Present	Absent	
G1			
Abnormal result	6	14	>0,99
Normal result	3	7	
G2			
Abnormal result	1	18	>0,99
Normal result	0	11	

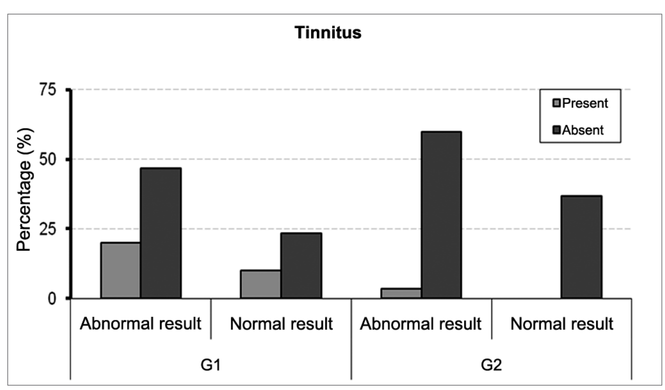

Figure 5. Percent of participants with tinnitus for each category of outcome within each group.

Chart 1. Studies conducted in the period from 2000 to 2010.

Author	Year	Country	Kind of noise	Sample	Armed Force	Evaluation method		
						TA	EOAET	DPOAE
Konopka et al.	2001	Poland	Impact	10	Army	X	X	X
Job et al.	2004	France	Impact	54	Army			X
Silva et al.	2004	Brazil	Continuous	97	Army	X		
Konopka et al.	2005	Poland	Impact	92	Army	X	X	
Duvdevany & Furst	2006	Israel	Impact	15	Army	X	X	
Konopka et al.	2006	Poland	Impact	92	Army			X
Duvdevany & Furst	2007	Israel	Impact	84	Army	X	X	
Olszewski et al.	2007	Poland	Impact	40	Army	X	X	
Bockstael et al.	2008	Belgium	Impact	55	Army		X	X
Jaruchinda et al.	2005	Thailnd	Continuous	76	Army	X		
Shupak et al.	2007	Israel	Continuous	135	Navy	X	X	X
Souza	2009	Brazil	Continuous	120	Navy	X	X	X
Marshal et al.	2009	United States	Impact	285	Navy	X	X	X
Ribeiro & Câmara	2006	Brazil	Continuous	74	Air Force	X		

Tinnitus is commonly related to exposure to noise. In 2004, Job et al. studied the presence of tinnitus and alterations of the cochlear function by means of the DPOAEs and correlated it with aspects of the emotional state, such as anxiety and tension levels in French soldiers and observed that there was a correlation of these emotional factors with the presence of tinnitus, as well as a decrease in the DPOAEs. The authors evaluated 54 soldiers with ages ranging from 20 to 22 years for two days of shooting practice, having evaluated the DPOAEs 1h before and 5 minutes after shooting[6].

It was observed that between 2000 and 2010 there was a predominance of studies with soldiers from the Army involving exposure to impulse noise (Chart 1).

A study conducted with soldiers of the American Navy by Marshal et al. in 2009 focused on the exposure to impulse noise. The authors conducted auditory evaluation by means of threshold tone audiometry, transient evoked otoacoustic emissions (TEOAE) and DPOAE in 285 soldiers before and three weeks after exposure to gun impulse noise and artillery and in 32 subjects in the control group. Changes in the threshold and significant changes in the EOAEs between 2 and 4kHz in the ears were identified in the group under study. The increase in the sensitivity of the EOAEs in comparison with the audiometric thresholds was shown in all analyses and the low level of the EOAE may indicate an increase in the risk of future auditory loss [7].

As for the auditory evaluation by means of the DPOAEs performed in the present study, the findings confirmed their importance for the detection of subtle changes in the cochlear function, mainly at the frequencies of 6 and 8KHz in soldiers exposed to impulse noise, as significant differences were observed in the values obtained both with regard to amplitudes and with regard to the signal/noise ratio and, as a result, the occurrence of the DPOAEs.

In 2006, Konopka et al. used the DPOAEs and observed a significant deterioration of the level of the DPOAEs at the frequencies of 1, 3 and 4kHz in the right ear and 2, 5 and 6kHz in the left ear, thus determining that there was a decrease in the amplitude of the DPOAE at all frequencies[8].

The present study did not detect a significant difference when comparing the right and left ears. However, after analyzing them individually, it was observed that, as far as the amplitudes are concerned, the absolute values in the right ear were slightly higher than in the left ear, regardless of the frequency analyzed.

In a previous study conducted in 2001, Konopka et al., evaluated 10 soldiers exposed to impulse noise without hearing protection devices by means of tone audiometry, EOAET and DPOAE and detected a decrease in the amplitudes in the EOAETs of 3.1dBNPS at 3KHz and 5.1dBNPS at 4KHz in the right ear and 4.3dBNPS at 1KHz and 6dBNPS at 2KHz in the left ear. In the DPOAEs, there was a decrease of 3.8dBNPS at 1 KHz and 2.9dBNPS at 3KHz in the left ear. The otoacoustic emissions proved more sensitive to cochlear monitoring than to tone audiometry. So, the decrease in the levels of the EOAETs and DPOAE in soldiers exposed to noise may be an early indication of potential hearing loss and may play a role as a screening method for soldiers exposed to noise and as a tool for monitoring early cochlear alterations[9].

Once again, differences were observed between the right and left ears, which differs from the findings of the present study, in which we found no difference between the ears tested, probably because in the present study the soldiers made use of hearing protectors.

As for the effectiveness of the use of hearing protection devices, in 2008 Bockstael et al. evaluated the effect of impact noise in the EOAEs when using a passive nonlinear hearing plug or an earmuff dependent on the active level, considering that none of the standardized techniques for measuring attenuation, real hearing threshold, installation of acoustic essay or a microphone in the real ear, was projected to test both kinds in their real conditions of use. The authors used EOAETs and DPOAE in 24 subjects. The exams were compared before and immediately after the shooting practice, and 1 hour later. Subsequently, both kinds of EOAE were evaluated in 31 subjects before and after the exposure during a five-day-long military practice. There were significant differences between the ears in most cases; the EOAEs of the right ear tended to be more robust. There were no significant alterations in the EOAEs before and after exposure, or after several days in the second experiment, suggesting that the active hearing protectors were able to prevent cochlear damage[10].

Such findings are consistent with those of the present study, since, although we have found differences at some frequencies, others were practically unaltered, which suggests that the hearing protection device used was relatively effective. Nevertheless, according to the studies described, the active hearing protection device or even the shell variety is more effective to prevent subtle changes in the otoacoustic emissions which may become permanent alterations after years of exposure to impulse noise.

Authors such as Pawlaczik-Luszczynska et al. in 2004 also used the shell hearing protection devices when comparing a threshold tone audiometry and EOAET in 28 policemen during a shooting practice and a control group (n=18) which did not make use of hearing protection devices. The authors evaluated the subjects before and between 2 and 10 minutes after the shooting practice and observed that the shell variety hearing protection devices were effective to prevent changes in the threshold in the threshold tone audiometry and that there were significant changes in the response amplitudes in the EOAETs. They observed changes at 3KHz in the tone audiometry and in the EOAETs confirming the EOAET test as being more sensitive than tone audiometry in the evaluation of temporary changes in the cochlea caused by impulse noise[11].

In the present study, it was observed that the DPOAEs showed subtle changes after the exposure to impulse noise, there having been a slight recovery in the subjects evaluated 24 hours later in comparison with those reevaluated immediately.

Several authors abroad have used the EOAETs to evaluate the differences before and after exposure to impulse noise. However, the studies which used the DPOAEs for that purpose are scarce in the literature, which justifies our difficulty in comparing the results obtained in the present study.

In 2006, Olszewski et al. used the EOAETs and did not observe significant changes in these responses after exposure to noise and as a result recommended the use of hearing protection devices since the authors considered that they were able to sufficiently attenuate the impact of firearms[12].

As for the hearing protection, it was observed that for soldiers although there are previous instruction procedures about the need for the use of the hearing protection devices during shooting activities, in practice, there is still no surveillance as to their effective use.

In the present study hearing protection devices were distributed to all soldiers who participated. However, as has been described, the hearing protector devices is partially efficient to protect completely the ears from the impulse noises. Therefore, it is suggested that active protectors with frequency selectivity be used which could make it possible to understand the commands and orientations during the activities performed, or even passive hearing protection devices such as those used by Bockstael in 2008[10].

Such data have demonstrated that it is necessary to implement a Hearing Loss Prevention Program (HLPP) for soldiers, as long as they are exposed both to impulse noise and to continuous noise in their working environment. That would also prevent the onset of auditory symptoms such as hearing loss, tinnitus and a full ear feeling, as well as prevent non-auditory symptoms resulting from hearing loss, besides contributing to social and economic aspects resulting from the treatment after the onset of the pathology.

Although tone audiometry is recommended as a procedure for auditory evaluation, the DPOAEs proved sensitive to changes occurring after exposure to impulse noise, it being possible to conduct the test in military facilities. It should be highlighted that this is a non-invasive, quick, low-cost procedure.

As for the prevention measures used in the present study, they proved partially effective, and the use of hearing protection devices which offers a higher level of attenuation of noise or even equipments with automatic frequency adjustment (active auditory protector) may be recommended.

As for the tinnitus, considering the findings of the present study, there was a significant association between the presence of tinnitus and the group evaluated. It can be observed that 3 subjects in G1 complained of tinnitus although their tests were normal after exposure, which leads us to consider the complaint irrespective of the objective observation in the test and it is suggested that such subjects be reevaluated after another exposure to impulse noise in order to investigate if the early complaint indicates an objective alteration observed in the DPOAE test or not. It can also be observed that after 24 hours, subjects practically did not have tinnitus complaints, which leads us to hypothesize that if the organism had not recovered the cochlear function completely, at least subjectively an improvement was felt to have taken place

CONCLUSION

There was a statistically significant difference in the results of the DPOAEs as to the criteria of amplitude and signal/noise ratio at the frequencies of 6KHz and 8KHz in both ears. In the soldiers exposed to impulse noise these cochlear alterations were accompanied by the tinnitus symptom mainly in the individuals reevaluated immediately after exposure.

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