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ORIGINAL ARTICLE

Evaluation of hearing protection used by police officers in the shooting range☆

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KEYWORDS
Noise measurement;
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Abstract
Introduction: Impact noise is characterized by acoustic energy peaks that last less than a second, at intervals of more than 1 s.
Objective: To quantify the levels of impact noise to which police officers are exposed during activities at the shooting range and to evaluate the attenuation of the hearing protector.
Methods: Measurements were performed in the shooting range of a military police department. An SV 102 audiodosimeter (Svantek) was used to measure sound pressure levels. Two microphones were used simultaneously: one external and one insertion type; the firearm used was a 0.40 Taurus® rimless pistol.
Results: The values obtained with the external microphone were 146 dBC (peak), and a maximum sound level of 129.4 dBC (fast). The results obtained with the insertion microphone were 138.7 dBC (peak), and a maximum sound level of 121.6 dBC (fast).
Conclusion: The findings showed high levels of sound pressure in the shooting range, which exceeded the maximum recommended noise (120 dBC), even when measured through the insertion microphone. Therefore, alternatives to improve the performance of hearing protection should be considered.

PALAVRAS-CHAVE
Medição de ruído;
Ruído ocupacional;
Polícia

Avaliação da proteção auditiva utilizada por policiais em estande de tiros

Resumo
Introdução: O ruído de impacto é caracterizado por apresentar picos de energia acústica de duração inferior a um segundo, em intervalos superiores a um segundo.

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Objetivo: Quantificar os níveis de ruído de impacto a que o policial militar fica exposto durante atividades de tiro com armas de fogo e analisar a atenuação do protetor auricular utilizado.
Método: As medições foram realizadas no estande de tiros de um Batalhão da Polícia Militar. Para a medição dos níveis de pressão sonora foi utilizado um audiodosímetro modelo SV 102 (Svantek). Foram utilizados dois microfones simultaneamente: um externo e outro tipo inserção, e a arma utilizada foi a pistola calibre 40, da marca Taurus®.
Resultados: Os valores obtidos no microfone externo foram de 146 dBC (pico) e ruído máximo de 129,4 dBC (fast). Os resultados obtidos no microfone de inserção foram de 138,7 dBC (pico) e ruído máximo de 121,6 dBC (fast).
Conclusão: Nossos achados evidenciaram elevados níveis de pressão sonora no estande de tiros, que ultrapassaram os limites máximos recomendados (120 dBC), mesmo em medição com microfone de inserção. Portanto, alternativas para melhorar o desempenho da proteção auditiva devem ser consideradas pela equipe de segurança da corporação.

Introduction

Exposure to noise can cause significant damage to human hearing, such as noise-induced hearing loss (NIHL). As they are exposed to noise, the military can be considered a population at risk for the development of NIHL.[1]

The military, especially during training in shooting ranges, are exposed to intense noise. Studies of the auditory profile of the military conducted in Brazil have described the presence of hearing loss in this population, which is associated with excessive exposure to impact noise.[1–3] For this reason, health professionals have expressed interest in studying the effect of impact noise on inner ear function.[4] It is important to consider that the total number of military personnel in the country including the military police[5] and the armed forces is over 700,000.[6]

Annex No. 2 of Regulatory Norm 15 (NR-15) establishes the threshold for impact noise at 130 dB (linear), measured with the response time constant for impact noise. When this time constant is not available on the meter, the NR-15 reports that the C-weighted level in fast response should be measured, and the threshold level should be 120 dB (C).[7]

According to the analysis of the laws in several countries related to limits of occupational impact noise performed by the International Institute of Noise Control Engineering, the criterion level ranges from 115 dB (A) fast, to 140 dB (C), peak. The reference indicates that C-weighted measurements are preferable to unweighted (linear) measures, as they are defined as norms, and peak levels are more appropriate to assess impulsive noises, as they cover a wider range of frequencies.[8]

The Occupational Hygiene Norm 01 (NHO-01) of FUNDACENTRO recommends that the daily exposure limit to impact noise should be determined by the number of impacts occurring during the workday, and that the level of maximum permissible peak corresponds to 140 dB (linear) or 127 dB (C).[9]

In an experimental study of cats exposed to impact noise with peak sound pressure of 135, 140, and 145 dB, the authors identified hearing loss with the greatest impairment at the frequency of 4 kHz.[10] In another study of exposure to impact noise, hearing losses diagnosed in chinchillas by electrophysiological tests were greater for frequencies of 2 and 8 kHz, compared to 500 Hz.[11]

One of the requirements for the intervention of health professionals in the prevention of hearing loss is the presence of an accurate characterization of the firearm noise. In this sense, a pioneer study found threshold values of 115.4 dB (A) for the firing of a 9 mm pistol (Beretta), and the frequency band of the noise was most prominent between 500 and 4000 kHz.[12] In another study, the maximum peaks measured at the firing range were 113.1 dB (C) for 0.40 pistol and 116.8 dB (C) for a 0.38 revolver. Additionally, the study identified through psychoacoustic analysis (Praat software) that the frequency band with the greatest energy was between 4120 and 4580 Hz, and that there was a correspondence between this frequency band and cases with hearing loss (86.7% with loss at 4 kHz).[13]

In the Federal District of Brazil, the quantification of sound levels at a firing range of the military police showed values of Lmax (maximum level) of 118 and 124 dB (A) when firing a 0.40 pistol and 0.38 revolver, respectively.[14] At measurements performed with the Brazilian Army, values of 147.3 dB (C) for a 7.62 mm-caliber light automatic rifle (LAR) were found, and the meter display showed the word ''overload'', indicating that the level of actual sound pressure was higher than that recorded by the device.[15]

To protect hearing from high sound pressure levels (>80 dB), the implementation of measures aimed to reduce the noise at its source is indicated; however, this action is not always possible; hence the use of hearing protectors is recommended.[16] When selecting the hearing protector, according to NR-9,[17] comfort, constant use, and proper hygiene must also be considered. Studies have been developed in recent years to evaluate the attenuation of hearing protectors.

Since the late 1950s, methods of measuring real-ear attenuation at threshold (REAT) have been widely used and described in the literature.[18] Another way to analyze noise in a real situation is through the microphone in real ear (MIRE) method, which have proven to be a valuable tool for the quantification of noise reduction of clamshell hearing protectors.[19]

It must be considered that the lack of user training and testing methods in the laboratory that do not portray the conditions of hearing protector use in a real-life situation lead to better attenuation performance in the laboratory, when compared to measures performed in the field.[20]

In search for a solution to hearing protection for the military during real action, researchers carried out a field experiment aiming to compare the performance for sound localization (after shooting blanks), comparing four models of hearing protectors (three ''active'' electronic types and a special insertion type for combat), and unprotected hearing (open). A total of 13 subjects were evaluated, in combat situations with ambient noise and background noise of the military vehicle (82 dBA). The study concluded that none of the tested protectors maintained the performance for sound localization equal to the open ear.[21]

Another study evaluated hearing protection in two combat situations: attack and reconnaissance missions. Army soldiers used three models of protectors (two electronic devices and a special insertion type for combat). Commanding officers of the missions assessed the performance of soldiers, and identified a slight advantage of the electronic protectors in relation to the insertion type and the unprotected ear. Nevertheless, the authors suggest further studies, as there was much variation in the responses of soldiers in relation to the preference of protector use (considering comfort *versus* hearing capacity).[22]

Recently, a comparative study was conducted between shooting a firearm with a sound suppressor (silencer) in relation to hearing protection, considering the levels of noise reduction of both. The results showed a better performance of sound suppressors in relation to hearing protection.[23]

Noise in the military environment is exceptionally intense; therefore, the attenuation provided by a single hearing protection device may not be sufficient. In experimental studies of noise attenuation as a function of frequency, the insertion type protector and individual clamshell type, when used simultaneously, showed that the combined attenuation was at least 5 dB greater than their use individually.[24] Researchers in Canada evaluated the combined hearing protection between the clamshell protector and the insertion type and achieved additional attenuation between 4 and 18 dB (SPL) in relation to individual use, depending on the tested frequency.[25]

When evaluating the attenuation of noise emitted by shooting firearms by a Special Weapons Assault Team (SWAT) in the United States, an attenuation between 25 and 35 dB SPL (peak) was documented using electronic hearing protectors alone, whereas the use of dual protection increased attenuation by 15–20 dB SPL.[26] Another study evaluated the attenuation with four distinct types of protectors, and found attenuation results ranging from 20 to 38 dB SPL (peak).[27]

The aim of the present study was to quantify the noise exposure, and to verify whether the hearing protection used by these professionals is appropriate for exposure to impact noise during activities in the firing range.

Methods

This was a prospective study of a contemporary cohort, with a cross-sectional design. Data collection was performed at the firing range of a military police battalion in the countryside of the state of São Paulo. This range is located in an open space, and the projectile bulkhead consists of tires (filled with sand). The training included the participation of 12 police officers, divided into two shooting sessions (each with six officers). The measurement of the first session was performed for the purpose of standardization of the technique and equipment adjustments. A valid collection was made during the second training session, with a total duration of 24 min.

The training sessions were standardized, with the firing line consisting of six police officers, each of them fired 25 shots, totaling 150 impacts during each session. The shots were fired simultaneously by the six policemen, as directed by the shooting instructor officer. There was no prior selection of the officers, the choice was random, and there was no interference from the researcher on the training routine.

The sound pressure level dosimeter was affixed to the vest of one of the police officers who was part of the firing line (Fig. 1). Two microphones were used simultaneously: the external was attached to the collar of the uniform, at a distance of 150 ± 50 mm from the ear; and the insertion type (MIRE) was inserted in the ear canal of the police officer, shielded by a clamshell protector with NRRsf = 24 dB (subject fit Noise Reduction Levels; Approval Certificate CA 7166).[28] The firearm used was a Taurus® 0.40 caliber pistol, which is the standard firearm used.

Before each measurement, the microphones were calibrated by an acoustic calibrator, CR: 514 model, Cirrus Research Plc. The values of the peak and Lmax were considered when analyzing the results; additionally, the frequency spectrum of the noise was analyzed (octave band).

It is important to report that the meter shows the square mean of the sound pressure variations within the specified time (1 second for the constant ''slow'' and 0.125 s for ''fast''). Thus, the Lmax represents the mean of the highest sound intensity in this time period. In the case of the peak scale, it is no longer measuring the mean squared pressure at a given time, but rather the maximum value reached by the sound pressure of each impact noise.[29]

The measurement used in the analysis of the frequency spectrum was Leq (A), which is defined as the equivalent sound pressure level and corresponds to a constant sound level, which, in the same time interval, contains the same total energy as the fluctuating sound.[14]

The procedure for evaluating the effectiveness of hearing protectors in a real-life environment was performed using the ''long method – frequency analysis.'' Information on the certificate of approval of the clamshell protector was considered; in this case, for 98% reliability of the offered protection, the values of sound levels in each frequency band were subtracted from the values of the standard deviation, multiplied by two.[18]

The equipment used was an SV 102 audiodosimeter (Svantek): ''C'' weighting circuit; fast and peak response. Considering that the equipment has two measurement channels and three independent analysis profiles, the measurement of the ''A'' weighting circuit and the slow response was complementarily programmed to support the analysis by octave band, and allow the comparison with the attenuation provided by the hearing protector manufacturer.

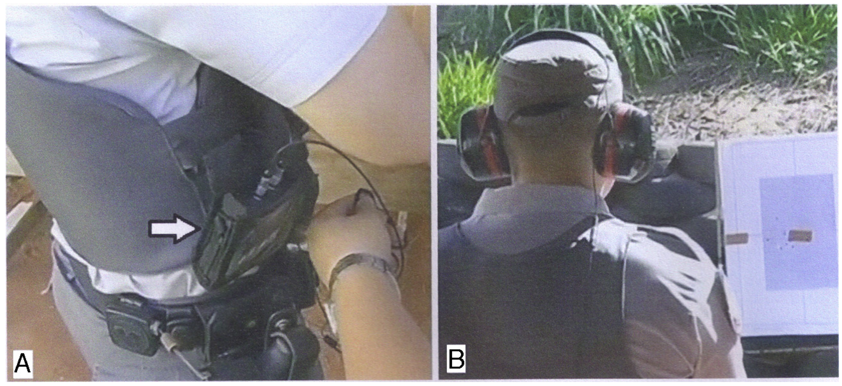

Figure 1 (A) Photograph showing audiodosimeter attached to police officer's vest (arrow); and (B) use of clamshell ear protector during training session in the shooting range.

Aiming to analyze the effectiveness of attenuation, 20 noise peaks and 20 Lmax values were randomly selected, with the descriptive analyses of these values shown in Tables 1 and 2. Data were analyzed using the Wilcoxon statistical test to compare the sound pressure levels between the microphones (external and insertion). A significance level of 5% ($p < 0.05$) was used.

Complementarily, the difference between the values indicated by the manufacturer and the actual measured attenuation values was also calculated, with analysis by ANOVA, with a significance level of 5% ($p < 0.05$).

The study was approved by the Ethics Committee in Research of a public university (Protocol No. 1385/2009), and an informed consent was signed by all participants.

Table 1 Peak measurement results in dB (C), obtained by the external and insertion microphones.

Statistical measurement	External microphone dB (C)	Insertion microphone dB (C)
Mean	144.29	130.26
Median	144.35	130.2
Standard deviation	0.90	2.62
Minimum	141.8	123.6
Maximum	146.0[a]	138.7

[a] Maximum output limit of sound pressure level measurement.

Table 2 Lmax dB (C) measurement results obtained by the external and insertion microphones.

Statistical measurement	External microphone dB (C)	Insertion microphone dB (C)
Mean	126.58	112.62
Median	126.5	112.5
Standard deviation	1.52	2.93
Minimum	123.5	108.6
Maximum	129.4	121.6

Results

The data obtained by measuring the sound pressure levels while using the two microphones (external and insertion) allowed for analyses regarding both the values of impact noise in the firing range, as well as the actual attenuation of the hearing protectors used, as shown in Table 1 (peak modality) and 2 (Lmax modality).

Table 1 shows that the evaluated hearing protector provided mean attenuation of 14.03 dB (C) in the peak modality.

Table 2 shows the measurement data of the external microphone and of the insertion type in Lmax modality. It was observed that the average attenuation of hearing protectors was 13.96 dB (C) in this modality.

Based on the results described in Tables 1 and 2, the Wilcoxon test was applied between the two analysis groups (internal and external microphone), and the result ($p < 0.001$) confirmed the rejection of the null hypothesis (H_0), i.e., there was a significant difference when comparing the results between the sound pressure levels obtained in both peak and Lmax modality.

Fig. 2 shows the values measured with the use of the external and insertion microphones, illustrating the actual attenuation of the hearing protector.

Fig. 3 demonstrates the results of the assessment of the actual attenuation provided by the hearing protector in field measurements, following the subtraction of two standard deviations.

Based on the data shown in Fig. 2, it was possible to identify the frequencies with higher sound pressure level measurements: 0.5 kHz (113.3 dBA), 1 kHz (116.3 dBA), 2 kHz (114.2 dBA), and 4 kHz (112.4 dBA). Moreover, no statistical significance was observed when analyzing the values of ''actual attenuation *versus* manufacturer attenuation − 2 SD'', using the ANOVA test ($p = 0.193$).

Subsequently, the sound pressure levels while using the hearing protector in a real-life situation were measured, which allowed comparison of the measured attenuation with that reported by the manufacturer (total value without subtracting the standard deviation), as shown in Table 3; in this case, the statistical analysis between the values was significant ($p = 0.018$).

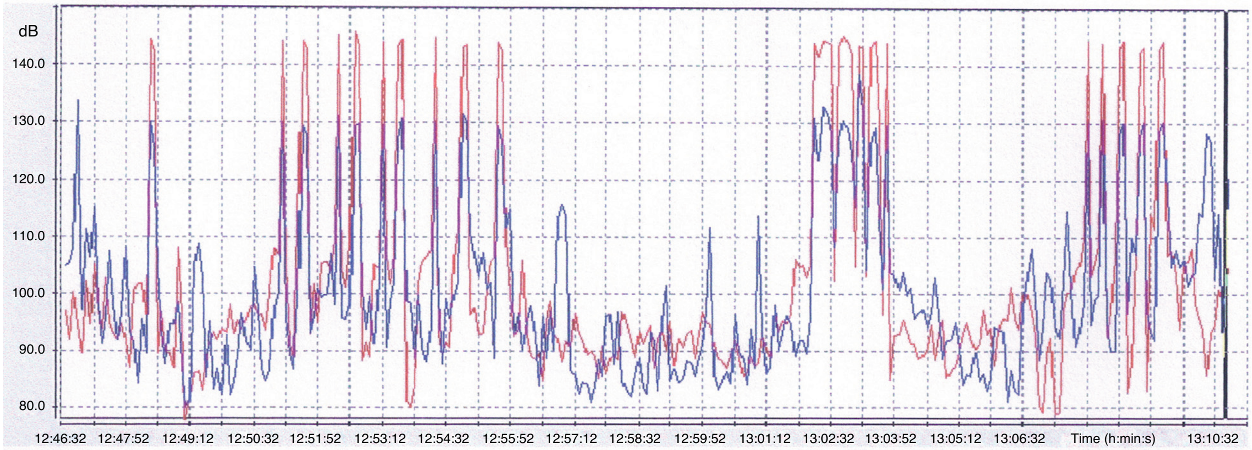

Figure 2 Sound pressure level (peak – C-weighted) measured in the shooting range as a function of time. Measurement in red with external microphone; in blue, measurement with insertion microphone (MIRE).

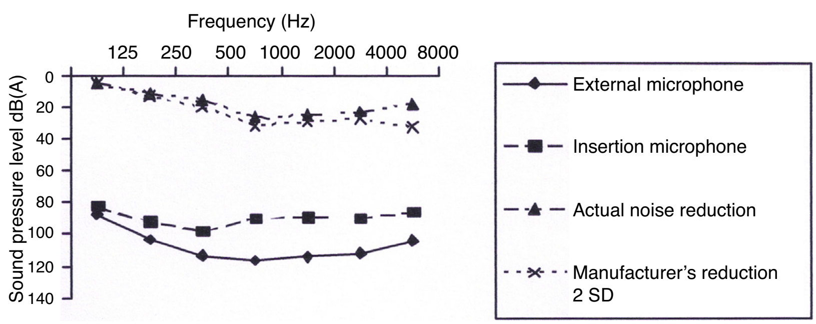

Figure 3 Values of the measurement by frequency (L EQ [equivalent level/dBA]) performed by insertion and external microphone. Values of actual noise reduction and noise reduction suggested by the manufacturer, after discounting the values of the standard deviation (SD), multiplied by two.

Discussion

Studies related to hearing health among the military are scarce in Brazil; thus, this study verified the need to increase such a research in order to allow the analysis of the acoustic environment in military police operations, as well as that of the military personnel of the armed forces (Navy, Army, and Air Force). The total number of personnel in these two branches is 700,596 professionals on active duty, of whom 412,096[5] are military police; 288,500[6] comprise the armed forces.

It is noteworthy that audiological profile studies conducted in the states of São Paulo and Paraná identified hearing loss in 27.5% and 25% of the evaluated military police personnel, respectively.[1,3]

The results of the present study demonstrated that the military police were exposed to high sound pressure levels, with maximum values of 146 dBC (peak) and 129.4 dBC (Lmax), with peak values at the limit of the equipment (overload). The above data showed severe and imminent risk of hearing loss, as they exceed the limits of national and international standards, which recommend a limit of 140 dBC (peak) and 127 dBC (fast) for impact noise.[7–9]

Other studies with the military have also identified high sound pressure levels during work activities.[1–4,13–15] It is known that the military work environment is a risk factor for hearing loss, which has motivated international studies to evaluate the attenuation of hearing protectors in the presence of impact noise[23–27]; however, no similar studies have been performed in Brazil.

Table 3 Comparison of noise reduction by frequency band: noise reduction suggested by the manufacturer *versus* attenuation measured in actual situation (ANOVA).

Frequency (Hz)	125	250	500	1000	2000	4000	8000	*p* Value
Manufacturer's reduction (dBA)	13.9	21.4	27.4	35.4	35.1	37.4	40	0.018[a]
Actual reduction (dBA)	4.5	11.2	15	26.1	24.6	22.5	17.9	

[a] Statistical significance for $p < 0.05$.

The data obtained through the insertion microphone demonstrated that the clamshell protector was effective in reducing the peak value below the criterion of 140 dB (C) (maximum was 138.7 dBC) level; however the highest value of Lmax (121.6 dBC) was above the limit established by the NR-15.[7] The data also demonstrate that although the protection used did not have the desired effect according to the NR-15,[7] it attenuated the impact noise significantly in the two evaluated modalities (peak and Lmax).

It is noteworthy that previous experimental[10,11] and military[13] studies have identified high frequencies as more susceptible to damage by impact noise, particularly at 4 kHz. Thus, it was deemed necessary to measure the frequency spectrum of the firearm noise, as this information allowed for the identification of the real attenuation value of the hearing protector. Two studies performed the acoustic analysis of the frequency spectrum; both identified that the highest levels of sound pressure are concentrated between 0.5 and 4 kHz.[12,13]

The findings of this research confirmed the analyses described above, and additional measurements per octave band form identified the actual attenuation of clamshell ear protectors, identifying that the highest levels of attenuation were found in these same frequencies (between 0.5 and 4 kHz). This finding reinforces the importance of using ear protectors during shooting activities.

Moreover, regarding the assessment of hearing protection effectiveness in the workplace, it was verified that the attenuation reported by the manufacturer was overrated, and did not match the field measurement. The lack of user training and laboratory testing methods that do not portray the use of hearing protection in real-life situations are some factors that could explain this result.[20]

The long method of assessment of hearing protectors in the workplace was effective, as two standard deviations from the attenuation value of the protector were subtracted from the measured attenuation (octave band) to obtain a reliability of 98%.[18] In this case, the values were close to those measured in a real-life situation and thus, this method can be a viable alternative for the safety/health staff of the military corps, as the calculation is made based on the values reported in the manufacturer's certificate of approval (CA).

The difference between the actual attenuation value and the suggested value could be corrected with the use of dual protection (clamshell + insertion), which guarantees at least a 5 dB increase in noise attenuation.[24] Another study identified increases from 4 to 18 dB in noise attenuation with dual protection.[25] This information is relevant, since even with the use of hearing protectors, our identified Lmax value (121.6 dBC) was above the safe level (120 dBC).[7]

Recently researchers evaluated the mean attenuation of hearing protectors used in the presence of impact noise, and found mean attenuation values between 20 and 38 dB SPL (peak),[26,27] whereas in the present study an attenuation of 14.03 dBC (peak) was identified. The data demonstrate that in addition to dual protection, it is possible to improve the performance of hearing protection with the use of next generation protectors.

Conclusion

These findings indicate that the sound pressure levels in a police shooting range showed values above those recommended by NR-15. The clamshell protectors showed statistically significantly less real attenuation than that advertised by the manufacturer, with insufficient attenuation to preserve the hearing of military police officers. Thus, the use of another brand/model of hearing protector or the possibility of joint use of two protectors (clamshell and insertion) should be considered by the military safety staff.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Heupa AB, Gonçalves CGO, Coifman H. Effects of impact noise on the hearing of military personnel. Braz J Otorhinolaryngol. 2011;77:747–53.
2. Neves BE, Mello MGS. O uso de dispositivos de proteção auditiva nos tiros de fuzil e artilharia. Cad Saúde Colet. 2007;15:97–116.
3. Guida HL, Diniz TH, Chagas PSC, Kinoshita SK. Perfil audiológico em policiais militares do estado de São Paulo. Arq Int Otorrinolaringol. 2010;14:426–32.
4. Wu CC, Young YH. Ten-year longitudinal study of the effect of impulse noise exposure from gunshot on inner ear function. Int J Audiol. 2009;48:655–60.
5. Brasil. Ministério da Justiça do Brasil. Segurança Pública, estatística [cited 01.08.12]. Available from: http://portal.mj.gov.br/data/Pages/MJCF2BAE97ITEMIDAACCEEFBA784458E99DCADBC672C3096PTBRNN.htm
6. Dias RHD. Tamanho é documento. Segurança & Defesa: a revista do profissional [cited 01.08.12]. Available from: http://www.segurancaedefesa.com/Tamanho.html
7. Brasil. Portaria GM n°. 3214. Ministério do Trabalho. Norma Regulamentadora 15, Anexo I, 6 de julho de 1978. Atividades e operações insalubres, Diário Oficial da União. Brasília; 1978 July 6.
8. International Institute of Noise Control Engineering. Upper limits of noise in the workplace, vol. 5. Noise News International; 1997. p. 206–16.
9. Fundacentro. NHO 01 – Norma de higiene ocupacional procedimento técnico – Avaliação da exposição ocupacional ao ruído [cited 31.10.11]. Available from: http://isegnet.com.br/arquivoscurso/atuais/anexo2.htm
10. Price GR, Wansack S. Hazard from an intense midrange impulse. J Acoust Soc Am. 1989;86:2185–91.
11. Roberto M, Zito F, Hamernik R, Ahroon B, Case C. Impulsive noise: PTS and anatomic correlations. Acta Otorhinolaryngol Ital. 1995;15:61–4.
12. Zannin, PHT, Celli A, Rubas A. Avaliação do ruído de impacto [cited 12.06.12]. Available from: ftp://ftp.demec.ufpr.br/disciplinas/TM124/Ru_do%20Impulsivo.pdf
13. Guida HL, Diniz TH, Kinoshita SK. Acoustic and psychoacoustic analysis of the noise produced by the police force firearms. Braz J Otorhinolaryngol. 2011;77:163–70.
14. Noronha EH, Travaglia Filho UJ, Garavelli SL. Quantificação dos níveis de ruídos num estande de tiros da PM do Distrito Federal. Humanitates. 2005;1. Available from: http://www.humanitates.ucb.br/3/ruido.htm [accessed 06.08.14].

15. Neves EB, Soalheiro M. A proteção auditiva utilizada pelo Exército Brasileiro: há efetividade? Ciênc Saúde Coletiva. 2010;15:889–98.
16. Gerges SNY. Protetores auditivos: recomendações para seleção, uso, cuidado e manutenção. Rev CIPA. 1999;236: 20.
17. Brasil. Portaria SSST n° 25. Ministério do Trabalho. Norma Regulamentadora 19, Atualizada, 29 de dezembro de 1994. Programa de prevenção a riscos ambientais. Diário Oficial da União. Brasília; 1994 December 30.
18. Gerges SNY. Ruído: fundamentos e controle. 2nd ed. Florianópolis: NR Editora; 2000.
19. Robles JME [Masters' degree dissertation] Atenuação do ruído dos protetores auditivos pelo uso da técnica MIRE. Florianópolis: Universidade Federal de Santa Catarina; 2008.
20. Berger EH. EARLog 20: the naked truth about NRRs [cited 17.06.12]. Available from: http://www.e-a-r.com/pdf/hearingcons/earlog20.pdf
21. Talcott KA, Casali JG, Keady JP, Killion MC. Azimuthal auditory localization of gunshots in a realistic field environment: effects of open-ear versus hearing protection-enhancement devices (HPEDs), military vehicle noise, and haring impairment. Int J Audiol. 2012;51 Suppl. 1:S20–30.
22. Casali JG, Ahroon WA, Lancaster JA. A field investigation of hearing protection and hearing enhancement in one device: for soldiers whose ears and lives depend upon it. Noise Health. 2009;11:69–90.
23. Branch MP. Comparison of muzzle suppression and ear-level hearing protection in firearm use. Otolaryngol Head Neck Surg. 2011;144:950–3.
24. Berger EH. EARLog13: attenuation of earplugs worn in combination with earmuffs. Am Ind Hyg Assoc J. 1984;45:B36–7.
25. Abel SM, Odell P. Sound attenuation from earmuffs and earplugs in combination: maximum benefits vs. missed information. Mil Med. 2006;77:899–904.
26. Murphy WJ, Tubbs RL. Assessment of noise exposure for indoor and outdoor firing ranges. J Occup Environ Hyg. 2007;4:688–97.
27. Murphy WJ, Flamme GA, Meinke DK, Sondergaard J, Finan DS, Lankford JE, et al. Measurement of impulse peak insertion loss for four hearing protection devices in field conditions. Int J Audiol. 2012;51 Suppl. 1:S31–42.
28. Brasil. Ministério do Trabalho e Emprego. Secretaria de Inspeção do Trabalho – SIT, Certificado de Aprovação de Equipamento de Proteção Individual [cited 17.06.12]. Available from: http://www3.mte.gov.br/sistemas/caepi/JanelaAndamentosInternet.asp?IDCA=90009252&NRCNPJ=33.181.926/0001-80&NRProcesso=46000.027118/2008-41&IDSituacao=11&NRRegistroCA=7166&IDEquipamento=3
29. Fernandes JC. Acústica e Ruído [cited 27.06.12]. Available from: http://wwwp.feb.unesp.br/jcandido/acustica/apostila.htm