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

Heraldo Lorena Guida, Carla Linhares Taxini, Claudia Giglio de Oliveira Gonçalves, Vitor Engrácia Valenti

a Universidade Estadual Paulista (UNESP), Campus de Marília, São Paulo, SP, Brazil
b Universidade Tuiuti do Paraná (UTP), Curitiba, PR, Brazil

Received 11 September 2013; accepted 23 December 2013
Available online 22 August 2014

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 audiosiometer (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.

© 2014 Associação Brasileira de Otorrinolaringologia e Cirurgia Cérvico-Facial. Published by Elsevier Editora Ltda. All rights reserved.

Keywords

Noise measurement; Noise occupational; Police

PALAVRAS-CHAVE

Medicação de ruido; Ruido ocupacional; Policia

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.

Please cite this article as: Guida HL, Taxini CL, Gonçalves CG, Valenti VE. Evaluation of hearing protection used by police officers in the shooting range. Braz J Otorhinolaryngol. 2014;80:515–21.

* Corresponding author.
E-mail: hlguida@marilia.unesp.br (H.L. Guida).

http://dx.doi.org/10.1016/j.bjorl.2014.08.003
1808-8694/© 2014 Associação Brasileira de Otorrinolaringologia e Cirurgia Cérvico-Facial. Published by Elsevier Editora Ltda. All rights reserved.
**Introdução**

Exposição ao ruído pode causar danos significativos ao ouvido humano, como perda auditiva induzida por ruído (NIHL). As pessoas expostas ao ruído, especialmente militares, podem ser consideradas uma população em risco para o desenvolvimento de NIHL.1

O exército, especialmente durante o treinamento em áreas de tiroteio, é exposto a intensos níveis de ruído. Estudos de audição do exército brasileiro descreveram a presença de perda auditiva nessa população, que é associada a excessivo nível de ruído.2,3 Para este estudo, os especialistas têm expressado interesse em estudar o impacto do ruído na função auditiva.4

É importante considerar que o número total de militares na população do país inclui as forças militares e a polícia.5 O número total de militares é maior que 700.000.6

O Anexo 2 da Norma Regulatória NR-15 estabelece o limite de ruído para a atividade de tiroteio a 130 dB (linear), medindo o tempo de resposta constante para o ruído. Quando este tempo de resposta não está disponível, a NR-15 recomenda que o nível de calor linear deve ser medido. Este limite deve ser de 120 dB (C).7

De acordo com as leis em vários países, o terminal de ruído de ocupação auditiva é determinado pelo Instituto Nacional de Controle de Ruído, cujo limite de nível de ruído de 115 dB (A) é o limite de frequência, que é indicado como um referência para que os níveis de calor linear sejam preenchidos, ou parâmetros de tempo de resposta que cobrem uma gama mais ampla de frequências.8

O Norma de Higiene NR-01 (NHO-01) do FUNDA-CENTRO recomenda que a exposição diária ao ruído de intensidade seja determinado pelo número de impactos ocorrendo durante o dia de trabalho, e que o nível de ruído de máximo permitido corresponda a 140 dB (linear) ou 127 dB (C).9

Num estudo experimental de gatos expostos a ruído de tiroteio com pressão de 135, 140 e 145 dB, os autores identificaram perda auditiva com o pior desempenho no intervalo de frequência de 4 kHz.10 Em outro estudo de exposição ao ruído, a perda auditiva diagnosticada em coelhos por estudos eletrofisiológicos foram maiores para frequências de 2 e 8 kHz, comparado a 500 Hz.11

Um dos requisitos para a intervenção de profissionais de saúde em casos de perda auditiva é a presença de um modelo de armas. In this sense, a híbrida descobriram um valor de 115.4 dB (A) para tiroteio com uma espingarda (Beretta), e a frequência de ruído do fogo foi o mais provável entre 500 e 4000Hz.12 Em outro estudo, o valor máximo de ruído medido no intervalo de tiroteio foi de 113.1 dB (C) para uma espingarda de 0.40 e 116.8 dB (C) para uma revólver 0.38. Adicionalmente, a pesquisa identificou a presença de ruído embande de 14120 e 4580 Hz, bem como que houve uma relação entre o valor de frequência band e os casos de perda auditiva (86.7% com perda auditiva de 4 kHz).13

No Distrito Federal do Brasil, a quantificação de ruído a tiroteio de 118 e 124 dB (A) foi medido um ruído de 0.40 e um revólver 0.38. Uma pesquisa mostrou que a frequência de ruído de 147.3 dB (C) para uma espingarda do 7.62 mm-calibre, a frequência de tiroteio (LAR) foi medida, e o display mostrou a palavra "overload", indicando que o nível de ruído de real-ear sound pressure was higher than that recorded by the device.14

Para proteger o ouvido de alta pressão de ruído (>80 dB), a implementação de medidas para reduzir o ruído no local é indicada; entretanto, esta ação não é sempre possível; então, o uso de proteção auditiva é recomendado.15 Quando a seleção do proteção auditiva, de acordo com NR-9,16 conforto, constante, uso, e para adequação de higiene também deve ser considerado. É que foram desenvolvidos em anos anteriores para avaliar a redução de perda auditiva.

Desde os anos 1950, os métodos de medir o real-ear attenuation at threshold (REAT) têm sido amplamente utilizados e descritos na literatura.16 Outra maneira de analisar ruído em um ambiente real é através do microfone em real ear (MIRE) método, que tem provado ser um importante ferramenta para a quantificação de redução do ruído de clamshell audímetro.
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 country-side 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 NRR=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.30

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.31

The equipment used was an SV 102 audiosimeter (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.
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.

<table>
<thead>
<tr>
<th>Statistical measurement</th>
<th>External microphone (dB (C))</th>
<th>Insertion microphone (dB (C))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>144.29</td>
<td>130.26</td>
</tr>
<tr>
<td>Median</td>
<td>144.35</td>
<td>130.2</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.90</td>
<td>2.62</td>
</tr>
<tr>
<td>Minimum</td>
<td>141.8</td>
<td>123.6</td>
</tr>
<tr>
<td>Maximum</td>
<td>146.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>138.7</td>
</tr>
</tbody>
</table>

<sup>a</sup> Maximum output limit of sound pressure level measurement.

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

<table>
<thead>
<tr>
<th>Statistical measurement</th>
<th>External microphone (dB (C))</th>
<th>Insertion microphone (dB (C))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>126.58</td>
<td>112.62</td>
</tr>
<tr>
<td>Median</td>
<td>126.5</td>
<td>112.5</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.52</td>
<td>2.93</td>
</tr>
<tr>
<td>Minimum</td>
<td>123.5</td>
<td>108.6</td>
</tr>
<tr>
<td>Maximum</td>
<td>129.4</td>
<td>121.6</td>
</tr>
</tbody>
</table>

**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 (H0), 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).
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 are military police; 288,500 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.1-13,14-15 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 noise14-17; 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).

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer’s reduction (dBA)</td>
<td>13.9</td>
<td>21.4</td>
<td>27.4</td>
<td>35.4</td>
<td>35.1</td>
<td>37.4</td>
<td>40</td>
<td>0.018*</td>
</tr>
<tr>
<td>Actual reduction (dBA)</td>
<td>4.5</td>
<td>11.2</td>
<td>15</td>
<td>26.1</td>
<td>24.6</td>
<td>22.5</td>
<td>17.9</td>
<td></td>
</tr>
</tbody>
</table>

* 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. The data also demonstrate that although the protection used did not have the desired effect according to the NR-15, it attenuated the impact noise significantly in the two evaluated modalities (peak and Lmax).

It is noteworthy that previous experimental and military 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.

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.

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%. 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.

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. Another study identified increases from 4 to 18 dB in noise attenuation with dual protection. 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).

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), 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


