

The silent impact: the prevalence of auditory symptoms in military personnel exposed to gunshot noise

Original Article

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Abstract

Military personnel who practice shooting are often exposed to high levels of noise, thus being more predisposed to noise-induced hearing loss development. This study aims at evaluating the prevalence of auditory symptoms in the Portuguese Marine Corps. The methodology used was based on the application of a questionnaire to the military. Sociodemographic characteristics, exposure to noise, presence of auditory symptoms and otorhinolaryngological history were questioned. The results showed that, although nearly all military personnel wearing hearing protection, the prevalence of immediate and long-term symptoms of hearing loss was 43.3% and 48.3%, respectively. There was a weak positive correlation between the duration and intensity of noise and the presence of subjective hearing loss. This study suggests that it is necessary to verify these data with audiometric evaluation and it is essential to implement monitoring and prevention programs for the hearing health of marines.

Keywords: Hearing loss; Noise; Military personnel; Portuguese Marine

Introduction

Noise-induced hearing loss (NIHL) is the second most common cause of sensorineural hearing loss, affecting approximately 5% of the global population.^{1,2} Noise is defined as “any excessively loud sound with the potential to impair hearing”.¹ Depending on the intensity and duration of exposure, NIHL may be either temporary or permanent.^{1,2}

Impact noise generated by explosive mechanical events, such as gunfire, produces high-intensity acoustic wavefronts lasting for only milliseconds, followed by lower-amplitude reverberations and echoes that may persist for several seconds. The pathophysiological mechanisms underlying

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NIHL involve mechanical disruption of the cochlear structures, reduced blood flow, neuroinflammation, oxidative stress, and glutamate-mediated excitotoxicity, leading to overstimulation of postsynaptic receptors.^{2,3} Symptoms include hearing loss, tinnitus, aural fullness, hyperacusis, and otalgia.^{1,4} Pure-tone audiometry (PTA) typically reveals bilateral, symmetrical sensorineural hearing loss, characterized by preserved hearing thresholds at low and mid frequencies, a notch at 3,000–4,000 Hz, and elevated thresholds at higher frequencies.^{1,2} Otoacoustic emissions (OAE) provide additional diagnostic value, as they evaluate the outer hair cell function and may detect early abnormalities prior to obvious changes on PTA, considering that these cells are the first to be affected.^{1,2}

Military personnel who engage in firearms training are frequently exposed to gunfire noise. The use of hearing protection devices (HPDs) is essential, as they attenuate sound levels by 25–30 dB sound pressure level (SPL), thereby minimizing the risk of auditory damage.^{5,6}

NIHL affects the professional performance of this population, both in training and combat, making it critical to implement optimal prevention and monitoring strategies.

This study aimed to evaluate noise exposure, prevalence of auditory symptoms, and use of HPDs in members of the Portuguese Marine Corps who participate in firearms training.

Materials and methods

This cross-sectional study aimed to determine the prevalence of NIHL among Portuguese marines. A questionnaire (Annex 1) was developed using the Google Forms platform and sent to the commanders of various Marine Corps units. The survey was available between December 29, 2024 and January 12, 2025. All responses were anonymous.

The exclusion criteria were a history of auditory pathology, neurological disease, or use of ototoxic medication.

Data were collected using the questionnaire, which included questions on the following

items: sociodemographic variables (age and length of service), noise exposure (monthly frequency of firearms training, type of weapon, use of HPDs, training duration, and number of rounds fired), auditory symptoms (immediate or delayed hearing loss, tinnitus/aural fullness, and otalgia), and otolaryngological history (audiometric examinations and medical appointments).

The data were analyzed using Microsoft Excel® software Version 16.93.1. The prevalence of hearing impairment was determined by the proportion of individuals reporting this symptom. The relationship between the self-reported perception of hearing loss and both the intensity and duration of firearms training was analyzed using the Pearson correlation coefficient, with significance level set at 0.05.

Results

Sociodemographic characteristics:

Among the 125 marines who responded to the questionnaire, five were excluded: two had a history of auditory disease, two had a history of neurological disease, and one had undergone ototoxic therapy. All participants were men, with a mean age of 32.3 ± 8.8 years. The majority of the participants (65.6%) had more than five years of service, 28% had served between one and five years, and only 2.4% had less than one year of service (Table 1).

Regarding the firearms training frequency, 25% trained less than once a month, 36.7% trained once a month, 13.3% trained twice a month, 9.2% three times a month, and 15.8% trained at least four times a month. The primary weapons used were the 9 mm Glock pistol (82.5%) and HK G3 rifle (71.7%) (Table 1).

NIHL symptoms and HPD use

Among the 120 participants, 52 (43.3%) reported immediate hearing loss after firearms training, with no difference between the ears in most cases (46.1%) (Figure 1).

Furthermore, 68.4% and 15.8% of participants had previously experienced tinnitus/aural fullness and otalgia, respectively. These data are shown in Figures 2 and 3.

Table 1
Sociodemographic characteristics

Characteristics		n	%
Years of service	Less than 1 year	3	2,4%
	Between 1 and 5 years	35	28%
	More than 5 years	82	65,6%
Firearms training frequency	< 1 time/month	30	25%
	1 time/month	44	36,7%
	2 times/month	16	13,3%
	3 times/month	11	9,2%
	≥ 4 times/month	19	15,8%
Weapon	9 mm Glock pistol	99	82,5%
	HK G3 rifle	86	71,7%
	MP5 submachine gun	26	21,7%
	Browning M2 machine gun	16	13,3%
	Carl Gustaf M2 recoilless rifle	3	2,5%

Regarding the frequency of HPD use, 111 participants (92.5%) reported always using them, while six (5%) used them sometimes. Only three participants (2.5%) reported not using any HPD. Among the 117 marines who reported using HPDs, 85.5% used suppressors, 9.4% used earplugs, and 5.1% used a combination of both (Table 2).

Correlation of the training duration and intensity with hearing loss

The marines reported both the duration of their training sessions and the number of rounds fired (intensity) (Table 3). A weakly positive correlation was observed between the training duration and intensity and the self-reported presence of hearing loss ($r = 0.15$ and $r = 0.14$, respectively). These correlations were statistically significant, with $p\text{-value} < 0.001$.

Long-term hearing loss and monitoring

Among the participants, 58 marines (48.3%) reported long-term hearing loss. When asked about undergoing audiometric evaluations since joining their units, only 76 had been assessed, primarily in relation to participation in missions. Abnormal results were reported by 15 individuals: 13 had mild hearing loss and

two had moderate hearing loss (Table 4). Notably, there is currently no protocol for the assessment and monitoring of NIHL in the Portuguese Navy. Despite the high prevalence of self-reported NIHL symptoms (hearing loss, tinnitus, and aural fullness), only 17 marines had

Figure 1
Immediate hearing loss

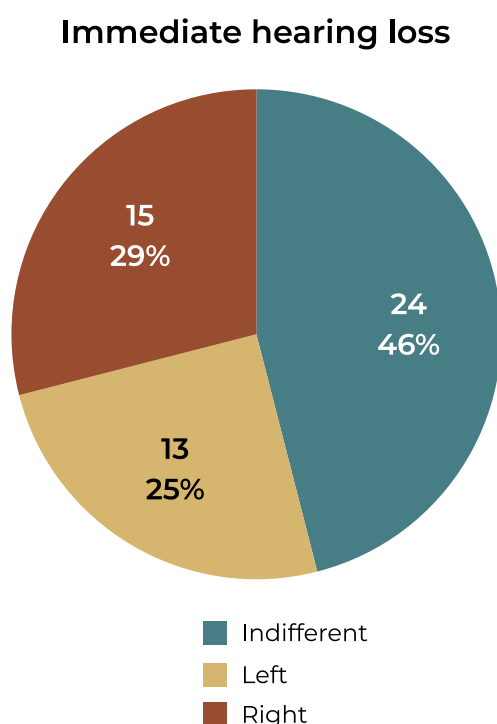


Figure 2
Tinnitus/aural fullness

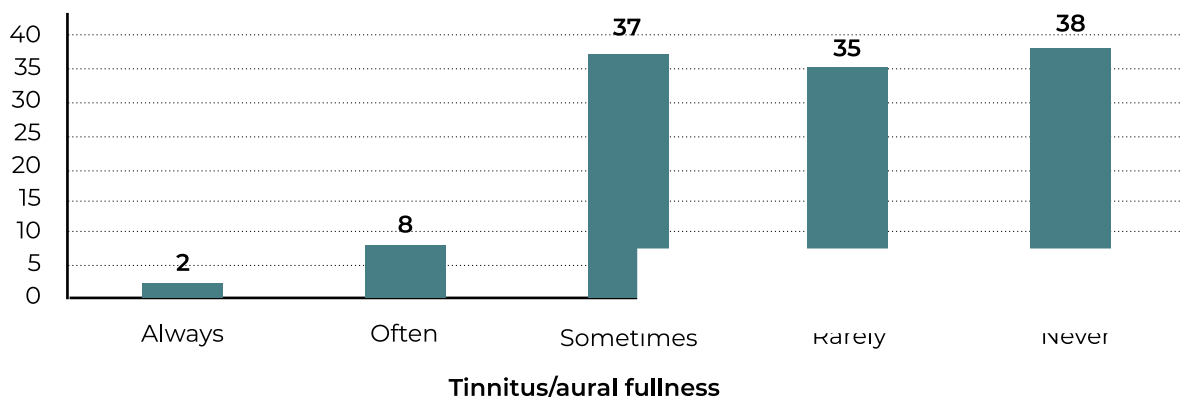


Figure 3
Otalgia

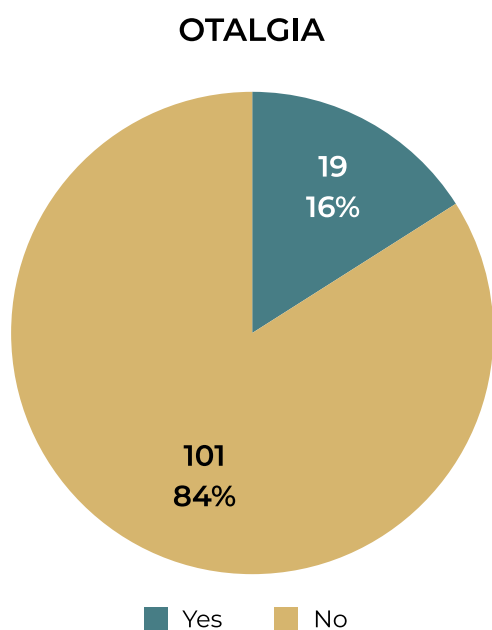


Table 2
Types of hearing protection devices (HPDs)

HPD	n	%
Suppressors	100	85,5%
Earplugs	11	9,4%
Device combination	6	5,1%

been evaluated by an otorhinolaryngologist. Finally, 104 participants (86.7%) answered YES to the last questionnaire item, “Is this a topic that concerns you?”

Discussion

The results of this study revealed that the prevalence rate was 43.3% for immediate post-training hearing loss symptoms, 48.3% for the perception of long-term hearing loss, and 68.4% for tinnitus in the analyzed sample. Although these findings were not confirmed with audiometric examinations, they align with the results of previous studies. In 2021, Alsaab e Fahad⁷ reported auditory symptoms in 58.4% of military personnel, with tinnitus as the most common symptom. Other studies conducted in Armed Forces populations have reported variable prevalence rates of NIHL, ranging from 12–68%.⁷⁻¹¹ This variability may be attributed to the differences in the study design, variations in noise exposure intensity and duration, and inconsistent use of HPDs. Our results also suggest that prolonged noise exposure (longer training duration) and higher intensity (greater number of rounds fired) are associated with an increased prevalence of hearing loss. Although the observed correlations were weak, they indicate a potential trend that requires further investigation including audiometric evaluation. According to the National Institute for Occupational Safety and Health (NIOSH), exposure to noise levels exceeding >130 dB SPL should not exceed one second.⁵ Additionally, noise levels above >120 dB SPL are known to cause immediate and permanent NIHL.² Considering that the primary weapons used in this cohort were the 9 mm Glock pistol and HK

Table 3
Characteristics of firearms training

Treinos		n	%
Number of rounds fired/session	Less than 50	82	68,3%
	Between 50 and 100	35	29,2%
	More than 100	3	2,5%
Training duration	< 1 hour	12	10%
	1 hour	36	30%
	2 hours	39	32,5%
	3 hours	13	10,8%
	4 hours	4	3,3%
	5 hours	16	13,4%

Table 4
Audiometric evaluation

Examinations			n	%
Audiometric examinations	No		44	36,7%
	Yes	Total	76	63,3%
		Normal results	47	61,9%
		Does not remember	14	18,4%
		Mild hearing loss	13	17,1%
		Moderate hearing loss	2	2,6%

G3 rifle, which produce peak sound pressure levels of 150–160 dB,^{12,13} it is evident that the daily noise level is significantly exceeded during firearms training. In this cohort, nearly all marines reported using HPDs; however, the prevalence of auditory symptoms remained high. This may be explained by the fact that HPDs typically attenuate sound by only 25–30 dB SPL, leaving noise exposure still well above the safe limits.^{5,6} Implementing measures to limit noise exposure in this professional group is challenging. Therefore, it is essential to establish an audiometric monitoring program to adopt preventive strategies, ensure auditory safety, and enable the early diagnosis of NIHL in this population. Possible interventions include: 1) mandating the use of HPDs, preferably a combination of two types; 2) conducting educational and awareness campaigns; and 3) providing otorhinolaryngological follow-up with formal audiological evaluations. The

NIOSH recommends performing a baseline PTA upon entry into the Naval School, followed by annual reevaluations covering 500, 1,000, 2,000, 3,000, 4,000, and 6,000 Hz. A threshold shift greater than > 15 dB hearing level should prompt a repeat examination to confirm hearing loss.⁵ Additionally, distortion product OAEs provide a highly sensitive method for the early detection of NIHL.¹

The main limitation of this study is the lack of audiometric confirmation of reported hearing loss, which may have led to the under- or overestimation of prevalence. Response bias is also possible, given concerns about professional implications or limited knowledge on the topic. Participation may have been higher among marines experiencing more symptoms or those more concerned about the subject. Finally, factors such as distance from the sound source and the shooting environment were not considered.

Conclusion

Military personnel engaged in firearms training are exposed to high-intensity noise that exceeds the safety limits, even when using HPDs. Consequently, NIHL remains an important occupational health concern in this population. A high prevalence of auditory symptoms was observed in this cohort, highlighting the need for further studies that incorporate audiometric assessments and implementation of systematic monitoring and prevention programs.

Conflict of Interests

The authors declare that they have no conflict of interest regarding this article.

Data Confidentiality

The authors declare that they followed the protocols of their work in publishing patient data.

Human and animal protection

The authors declare that the procedures followed are in accordance with the regulations established by the directors of the Commission for Clinical Research and Ethics and in accordance with the Declaration of Helsinki of the World Medical Association.

Privacy policy, informed consent and Ethics committee authorization

The authors declare that they have obtained signed consent from the participants and that they have local ethical approval to carry out this work.

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Scientific data availability

There are no publicly available datasets related to this work.

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ANEXO 1

Exposição a ruídos intensos - MILITARES

A alta exposição a ruídos intensos pode causar alterações auditivas permanentes incluindo hipoacusia induzida pelo ruído (surdez). Os militares estão frequentemente expostos a ruídos de disparos de armas de fogo durante os treinos. Isto pode causar diminuição da capacidade auditiva temporária ou permanente, principalmente se não forem utilizadas proteções auditivas adequadas. Este estudo, realizado no âmbito da especialidade de Otorrinolaringologia, é anónimo e visa perceber qual a prevalência da hipoacusia induzida pelo ruído nessa população.

Idade?

Há quanto tempo está na Marinha?

- ☐ Menos de 1 ano
☐ Menos de 5 anos
☐ Mais de 5 anos

Com que frequência faz treinos de disparo?

- ☐ Menos de 1 vez por mês
☐ 1 vez por mês
☐ 2 vezes por mês
☐ 3 vezes por mês
☐ 4 ou mais vezes por mês

Já notou que estava a ouvir pior imediatamente após o treino de disparo?

- ☐ Sim
☐ Não

Se respondeu Sim, qual o ouvido pior?

- ☐ Direito
☐ Esquerdo
☐ Indiferente
☐ Não senti que estava a ouvir pior

Com que frequência sente zumbido ou sensação de ouvido tapado após o treino de disparo?

- ☐ Nunca
☐ Raramente
☐ Às vezes
☐ Frequentemente
☐ Sempre

Alguma vez sentiu dor de ouvidos após o treino?

- ☐ Sim
☐ Não

Você utiliza proteção auditiva (como protetores auriculares ou abafadores) durante o treino?

- ☐ Sim
☐ Às vezes
☐ Não

Qual o tipo de proteção auditiva que usa?

Qual a intensidade do treino de disparo (número de disparos) que realiza por sessão?

- ☐ Menos de 50 disparos
☐ 50-100 disparos
☐ Mais de 100 disparos

Qual a duração dos treinos de tiro?

Qual o tipo de arma que usa no treino?

Já realizou exames de audição desde que está na marinha?

- ☐ Sim
☐ Não

Se realizou exames de audição, como eram os resultados?

- ☐ Surdez ligeira
☐ Surdez moderada
☐ Surdez grave
☐ Exame normal
☐ Não me lembro
☐ Não realizei exames de audição

Sente que sua audição tem piorado ao longo do tempo?

- ☐ Sim
☐ Não

Já consultou um otorrinolaringologista por queixas de surdez, zumbido, ouvido tapado ou outra?

- ☐ Sim
☐ Não

Apresenta algum dos seguintes antecedentes?

- ☐ Doença auditiva preexistente
☐ Utilização dos medicamentos (gentamicina, furosemida, quimioterapia ou aspirina)
☐ Doença neurológica
☐ Não tenho

Isto é um tema que o preocupa?

- ☐ Sim
☐ Não