Hearing Loss Among Military Personnel in Relation to Occupational and Leisure Noise Exposure and Usage of Personal Protective Equipment

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Abstract

Context: Hearing loss (HL) is a major health concern among military personnel due to noise from shooting, blasts, military vehicles, and noisy training environments. Nevertheless, one’s exposure can be partially reduced by using personal protective equipment (PPE). The aim of this study is to estimate the prevalence of HL among military personnel, to analyse associations between HL and self-reported occupational and leisure noise exposure, and use of PPEs.

Materials and Methods: A cross-sectional study was conducted among 150 military personnel during their routine medical examinations. First, all participants filled in a questionnaire about their exposure to noise and later the respondents went through an audiometric test. The diagnostic criteria for slight, moderate, and severe HL was HL of 25–40, 41–60, and >60 dB at 4 and 6 kHz, respectively. The associations between noise exposure and HL were studied with multinomial logistic regression analysis.

Results: The prevalence of slight to severe HL in high frequencies (4 and 6 kHz) among study participants was 62.7%. Nevertheless, the majority of it was slight, as the prevalence of severe HL was 9.3%. The prevalence of any kind of HL was highest in the Navy and the prevalence of severe HL was highest in the Central Command Units. The relative risk ratios (RRRs) for HL were higher among those who had been working for a long time in a noisy environment, working with noise-producing equipment, driving in a PASI or a Bandvagn or had been shooting with blanks at least once per week. It also appeared that military personnel who had HL, reported tinnitus more often. Respondents’ previous health problems, music-listening habits, and amount of exposure to loud noise in non-military environments were not independently associated with HL, but in several cases it increased the RRRs together with military exposure. We also found significantly more frequent HL among those never using PPEs.

Conclusion: HL loss was more prevalent among personnel who are more often exposed to military noise, especially among those who never use PPEs. The effect was enhanced by leisure time noise, but it was not independently associated to HL.

Keywords: Active service, audiometry, hearing protection, noise exposure

INTRODUCTION

Military personnel during their service are exposed to noise generated by shooting, military vehicles, and blasts, often at levels hazardous to health.[1-3] The noise exposure during service is considered by many to be the main risk factor in causing hearing loss (HL).[4,5] Consequently Lie et al. (2016)[6] concur with previous studies that sudden noise may be more deleterious to hearing than continuous noise. The prevalence of HL and tinnitus in the military population is usually higher than in the general public, often between 20% and 60%.[7-10]

The risk of HL has been assessed to be especially high among special forces,[11] where HL is more than two times higher than the armed forces overall.[8] In these units, active service members are exposed to high levels of noise from large-calibre weapons, shooting, city combat training, etc.[12] While

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Heupa et al.\textsuperscript{11} compared members of the Special Operations Battalion with Military Police administrative staff members, the analysis of audiogram results showed a hearing threshold shift of more than 25 dB at frequencies of 3, 4, and/or 6 kHz among a quarter of the Special Operations Battalion members, whereas in the control group, the hearing threshold remained unchanged.

Several studies have also listed air force pilots among the at-risk groups for hearing impairment.\textsuperscript{13-17} However, some studies such as Kuronen et al.\textsuperscript{18,19} have shown a low risk of noise-induced HL among military pilots. HL might be also a health problem in the navy among sailors of different types of warships. In a study of HL in the U.S. Navy, audiograms of active duty personnel during the period of 1979 to 2004 showed that time spent on surface warships had the greatest impact on potential HL.\textsuperscript{20}

Moreover, it has been shown that HL is significantly associated with age and service experience in all services.\textsuperscript{9,21} Higher ages often reflect longer service time and therefore longer exposure time.\textsuperscript{11} Gordon et al.\textsuperscript{17} found increasing HL risk with age from 9.4% at age 30 to 57.5% at age 50. In addition, findings indicate that men are more at risk than women which could be related to the duties that are more prevalent among them.\textsuperscript{22}

HL often remains after active military service and noise-induced HL is one of the most common health problems among veterans. According to the U.S. Department of Veterans Affairs it is the second most common disability benefit awarded to former members of the U.S. uniformed services.\textsuperscript{27} Around 2.5 million veterans receive compensation and 10% of them are for noise-induced HL.\textsuperscript{23} All of this has a high cost for society which is increasing: in 2009 disability payments for tinnitus and HL exceeded $1.2 billion.\textsuperscript{3} In 2016 this resulted in 21,382,399 disabled people worldwide who receive disability compensation for service-related auditory disabilities (tinnitus, HL, labyrinthitis).\textsuperscript{24}

Suspected noise-induced HL is partially preventable which has been shown through applying hearing conservation programmes for reducing HL in different military units. These programmes are mostly focused on noise hazard identification, noise level measurements, personalized noise dosimetry, avoidance of noise hazards, reduction of noise exposure, effective use of hearing protection, repeated audiometric testing, and educating military personnel.\textsuperscript{25-28} Increased safety requirements and more common use of personal protective equipment (PPE) have improved the hearing levels of active service members.\textsuperscript{29,30} However, the risk of noise-induced HL when using hearing protective equipment often remains since incorrect, improper, and infrequent use of PPE does not guarantee complete protection.\textsuperscript{11,17}

The aim of our study was to describe the level of HL and its pattern in the military and to evaluate the association between noise exposure and the development of HL, to ascertain whether daily exposure to different sources of noise correlates directly to HL, which is often diagnosed in active service members.

**MATERIALS AND METHOD**

**Subjects**

This study group was comprised of active service members of the defence forces (DF) who had come to regular medical examinations. Altogether 152 subjects were randomly and voluntarily recruited during these regular medical examinations, 150 of whom agreed to participate in the study (response rate of 98.7%).

**Questionnaire**

The first part of the study consisted of a questionnaire survey. We applied a questionnaire developed by Belgian scientists, who had used it in a similar cross-sectional study among the Belgian Armed Forces.\textsuperscript{1} During the current study the questionnaire was translated into national language, reviewed, and adapted in some ways to the characteristics of the national DF. The questionnaire includes questions about various sources of noise that might cause HL, e.g. working in a noisy environment, participating in shooting training, working with armoured vehicles and trucks, etc. In addition, the subjects were asked if they commonly use any PPE, and if so, what types of PPE they use. Furthermore, they were asked about exposure to noise in their daily lives, for example listening to loud music, working with noise-producing equipment, riding a motorbike, etc., all of which might also cause HL. The questionnaire was self-administrative and was filled in while waiting to be examined by an otorhinolaryngologist.

**Hearing investigations**

The second part of the study was a hearing investigation which included tone audiometry, performed by an experienced otorhinolaryngologist. First, if necessary, ear irrigation was performed. Second, hearing tests were performed, which included pure tone audiometry as well as tympanometry and measuring acoustic reflexes. The results of the examinations were evaluated and based on Collee et al.\textsuperscript{1} HL at 4 and 6 kHz was categorised into three groups: slight (25–40 dB), moderate (41–60 dB), and severe (>60 dB). In parallel the subjects’ medical history was reviewed and included in the study materials.

**Statistical analysis**

For statistical analysis of the relationship between HL and noise exposure, multinomial logistic regression analysis was applied in STATA (version 12.1; StataCorp LP, College Station, TX, USA). This statistical analysis method enables assessment of the impact of noise exposure on each degree of HL or to add different categories and factors together if necessary.
RESULTS

Among the respondents 88.7% were males and 11.3% females. Half of the respondents were 34–43 years old (50.7%) and of these 85.6% were male and 16.4% were female. The highest proportion of females was in the age groups 44–48 and 49–54. The highest proportion of females was in the navy (17.5%) and the lowest was in the air force with no female participants.

The majority of participants were serving in the Central Command Units (65.3%), followed by the Land Forces (22.7%), the Air Force (8.0%), and the Navy (4.0%). Among the respondents, 79.3% had worked in a noisy environment, and out of these, the largest proportion worked for up to 5 years (30.0%) [Table 1]. The largest group of respondents working in a noisy environment was members of the navy, but the personnel with very long exposure (> 20 years) were most prevalent among recruits from the Land Forces and the Central Command Units. Similar trends, but somewhat lower exposure levels, appeared for respondents working with noisy equipment and who had worked as shooting instructors.

Of all the respondents, 47.3% had ridden in an armoured personnel carrier (PASI) or a tracked articulated all-terrain carrier (Bandvagn) during their service and almost half of these respondents had used these vehicles for at least five years [Table 2]. In general PASI and Bandvagn are the vehicles used most often as those are part of the Land Forces’ equipment.

In Table 3 the percentages per unit of shooting blanks, small-calibre and large-calibre weapons during shooting practice at a shooting range (times per week) are presented. Of all the respondents, most had regularly shot small-calibre weapons during shooting practice at a shooting range (93.9%). The use of large-calibre weapons is more common among members of the Navy and the Land Forces.

Exposure analysis to noise from non-military sources showed that 24.8% of respondents listen often (3 hours per week) to a music player, many reporting a rather high sound level. A majority (86.2%) of respondents visited night clubs less

| Table 1: Exposure times for noisy environment and noisy equipment by service branch (% of respondents) |
| --- | --- | --- | --- | --- |
| Time spent working in a noisy environment | ≤ 5 years | 6–15 years | ≥ 16 years | Never |
| Land Force | 26.4 | 35.4 | 17.6 | 20.6 |
| Air Force | 25.0 | 25.0 | 33.3 | 16.7 |
| Navy | 50.0 | 33.3 | 16.7 | 0.0 |
| Central Command Units | 30.6 | 22.4 | 24.5 | 22.5 |
| Combined total | 30.0 | 25.9 | 23.4 | 20.7 |
| Working with noisy equipment | | | | |
| Land Force | 32.3 | 32.4 | 14.7 | 20.6 |
| Air Force | 25 | 33.3 | 16.7 | 25.0 |
| Navy | 16.7 | 33.3 | 16.7 | 33.3 |
| Central Command Units | 24.5 | 17.3 | 8.2 | 50.0 |
| Combined total | 26 | 22.7 | 10.6 | 40.7 |

| Table 2: Years spent driving in an armoured personnel carrier (PASI) or a tracked articualted all-terrain carrier (Bandvagn) during their entire service time by service branch (% of respondents) |
| --- | --- | --- | --- |
| ≤ 5 years | 6–15 years | Never |
| Land Force | 44.2 | 23.5 | 32.4 |
| Air Force | 41.6 | 0 | 58.3 |
| Navy | 33.4 | 16.7 | 50.0 |
| Central Command Units | 33.7 | 7.1 | 59.2 |
| Combined total | 36.7 | 10.6 | 52.7 |

| Table 3: Shooting small-calibre and large-calibre weapons during shooting practice at a shooting range (times per week) (% of respondents) |
| --- | --- |
| ≥ 1 | < 1 |
| Blanks | |
| Land Force | 48.3 | 51.7 |
| Air Force | 42.9 | 57.1 |
| Navy | 42.7 | 57.3 |
| Central Command Units | 44.1 | 55.9 |
| Combined total | 46.3 | 49.7 |
| Small-calibre weapons (<20 mm) | |
| Land Force | 96.9 | 3.1 |
| Air Force | 75 | 25.0 |
| Navy | 100.0 | 0.0 |
| Central Command Units | 94.4 | 5.6 |
| Combined total | 93.9 | 6.1 |
| Large-calibre weapons (≥20 mm) | |
| Land Force | 68.7 | 31.3 |
| Air Force | 60.0 | 40.0 |
| Navy | 100.0 | 0.0 |
| Central Command Units | 60.3 | 39.7 |
| Combined total | 63.7 | 36.3 |
frequently than once per month and 9.2% of respondents reported 1–2 times per month. Two-thirds (64.4%) of respondents stated that they visited rock concerts less frequently than once per year, while 27.8% visited concerts two times per month, and 7.8% visited concerts at least 3–4 times per month. Among concert attendees, 15.6% stated that they had experienced a worsening of hearing after a rock concert and 26.4% stated that they had heard ringing in their ears. Altogether 18.6% of respondents were regularly exposed to loud noises domestically (e.g. hedge trimmer/lawnmower, drill, compressor) one or more times per week, 42.1% less frequently than once a week and 39.3% were exposed rarely or never. Every seventh respondent (14.7%) drove a motorbike (most of them 20 hours per month) and 10.8% of respondents played some musical instrument (73.3% guitar, 20.0% a wind instrument, and 6.7% drums).

Among previous health disorders, 34.7% of the respondents had otitis in childhood, followed by high blood pressure (7.4%) and head traumas (4.7%). Sudden HL was reported by 2.7% of the respondents, ototoxic drugs had been used by 2.0%, and 1.3% of the respondents were diabetics. There were no respondents with drainage of the ears and/or ear surgery or early deafness in the family. Nevertheless, 28.4% said they have difficulties understanding talk in conditions with background noise and 23.8% said their hearing had deteriorated compared to three years ago.

Hearing loss and tinnitus

The prevalence of the high frequency (4 and 6 kHz) HL was 62.7%. Nevertheless, the majority of it was slight (59.5% of any kind of HL), as the prevalence of severe HL (>65 dB) was 9.3%. The prevalence of any kind of HL was highest in the navy and the prevalence of severe HL was highest in central units [Figure 1].

It appeared that 66.0% of respondents experienced noise or rustling in their ears (an indication of tinnitus), among whom 7.3% experienced it often and 48.7% sometimes. We found that the noise or rustling in ears was significantly more frequently reported among those, who had severe or moderate HL (P < 0.05). The RRRs among persons with slight to severe HL were 2.6 (95% CI 1.2–5.3) and 29.9 (95% CI 3.3–269.5) for having sometimes or often noise or rustling in ears, respectively.

The association between HL and self-reported noise exposure was studied with four different statistical models [Table 4]. In the first model, the association between HL and noise was categorized by age, since age is an important risk factor in inducing HL in itself. In the second model, the analysis was categorized by previous health problems (having otitis in childhood, sudden HL, use of ototoxic medications) that are the main risk factors for HL. In the third model listening to music (listening to a music player and visiting clubs or rock concerts) was taken into account and the fourth model included all the previous information as well as the regular exposure to domestic noise as noise from lawnmowers, hedge trimmers, drills, compressors, etc.

In Model 1, a statistically significant association (P < 0.05) was found between HL and working with noise-producing equipment [Table 5]. We could see an increase in RRRs with exposure time, being 2.57 (95% CI 1.04–6.35) and 6.50 (95% CI 1.63–25.93), when exposed for 6–15 years and more than 16 years, respectively. Moreover, personnel riding in PASIs or Bandvagns is at higher risk of HL. Riding in these vehicles for up to five years, the RRR was 2.73 (95% CI 1.22–6.05) and riding for 6 to 15 years the effect was almost doubled (RRR = 5.36, 95% CI 1.10–26.08) compared to those who had not driven these vehicles. The RRR for having HL was also significantly higher among those shooting with blanks at least once per week (RRR = 3.64, 95% CI 1.12–11.82). Being in a noisy environment, shooting small- and large-calibre weapons, and regular exposure to loud noise in a non-military environment did not have a statistically significant impact.

The results of Model 2 show the increase of RRRs for HL among those who have had an earlier health disorder compared to those who did not report this. Similar to

![Figure 1: High frequency (4 and 6 kHz) hearing loss by service branch (% of respondents).](image-url)
Model 1, HL risk was especially increased among those working with noise-producing equipment more than 16 years (RRR = 8.19, 95% CI 1.91–35.17). These people also had a higher HL risk if they had been riding in a PASI or Bandvagn, and the effect was higher among those who had ridden longer (RRR = 9.74, 95% CI 1.28–74.23 among 6–15-year riders, compared to RRR = 3.28, 95% CI 1.24–8.71 among up to 5-year riders). Being in a noisy environment, shooting with blanks, and small- and large-calibre weapons as well as regular exposure to loud noise in non-military environment did not have a statistically significant effect on the prevalence of HL. The results of Model 3 show the RRRs are even higher among those who have been working with noise-producing equipment more than 16 years (10.69, 95% CI 1.00–114.03).

The results of Model 4, adjusted to all factors, in contrast to other models, revealed the effect of being in a noisy military environment (RRR = 3.42, 95% CI 1.03–11.37). Similarly, working with noise-producing equipment for more than 16 years (RRR = 8.19, 95% CI 1.91–35.17). These people also had a higher HL risk if they had been riding in a PASI or Bandvagn, and the effect was higher among those who had ridden longer (RRR = 9.74, 95% CI 1.28–74.23 among 6–15-year riders, compared to RRR = 3.28, 95% CI 1.24–8.71 among up to 5-year riders). Being in a noisy environment, shooting with blanks, and small- and large-calibre weapons as well as regular exposure to loud noise in non-military environment did not have a statistically significant effect on the prevalence of HL. The results of Model 3 show the RRRs are even higher among those who have been working with noise-producing equipment more than 16 years (10.69, 95% CI 1.00–114.03).

### Table 4: Association between HL (from slight to severe) and noise-producing activities at work expressed as relative risk ratio (RRR)

| Activity                                      | Model 1       | Model 2       | Model 3       | Model 4       |
|-----------------------------------------------|---------------|---------------|---------------|---------------|
| Being in noisy environment                    |               |               |               |               |
| ≤5 years                                      | 1.05 (0.39–2.86) | 0.97 (0.28–3.38) | 0.21 (0.04–1.27) | 0.88 (0.23–3.41) |
| 6–15 yrs                                      | 0.97 (0.36–2.65) | 1.35 (0.39–4.72) | 0.21 (0.03–1.27) | 1.63 (0.44–6.03) |
| ≥16 yrs                                       | 2.15 (0.78–5.93) | 2.79 (0.88–8.80) | 1.10 (0.21–5.81) | 3.42 (1.03–11.37)* |
| Never                                         | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     |
| Working with noise-producing equipment        |               |               |               |               |
| ≤5 years                                      | 2.02 (0.84–4.83) | 2.47 (0.85–7.13) | 0.84 (0.19–3.71) | 2.19 (0.73–6.58) |
| 6–15 yrs                                      | 2.57 (1.04–6.35)* | 2.82 (0.89–8.95) | 1.25 (0.30–5.26) | 2.24 (0.69–7.33) |
| ≥16 yrs                                       | 6.50 (1.63–25.93)* | 8.19 (1.91–35.17)* | 10.69 (1.00–114.03)* | 8.24 (1.87–36.45)* |
| Never                                         | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     |
| Riding in PASI or Bandvagn                    |               |               |               |               |
| ≤5 years                                      | 2.73 (1.22–6.05)* | 3.28 (1.24–8.71)* | 1.58 (0.45–5.50) | 2.92 (1.08–7.92)* |
| 6–15 yrs                                      | 5.36 (1.10–26.08)* | 9.74 (1.28–74.23)* | 7.83 (0.95–64.88) | 5.22 (0.57–47.50) |
| Has not driven                                | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     |
| Shooting with blanks                          |               |               |               |               |
| At least once per week                        | 3.64 (1.12–11.82)* | 3.63 (0.85–15.42) | 5.56 (0.44–70.09) | 3.11 (0.70–13.79) |
| Never                                         | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     |
| Shooting small-calibre weapons                 |               |               |               |               |
| At least once per week                        | 3.44 (0.62–19.16) | 1.25 (0.16–9.63) | –             | 1.20 (0.15–9.53) |
| Never                                         | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     |
| Shooting large-calibre weapons                 |               |               |               |               |
| At least once per week                        | 1.32 (0.55–3.15) | 1.52 (0.49–4.69) | 1.58 (0.32–7.88) | 1.24 (0.39–3.95) |
| Never                                         | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     |
| Regular exposure to loud noise in non-military environment |               |               |               |               |
| Less than once per week                       | 1.02 (0.49–2.16) | 1.18 (0.48–2.95) | 1.61 (0.47–5.59) | –             |
| More than once per week                       | 1.18 (0.46–3.06) | 1.28 (0.40–4.13) | 1.90 (0.42–8.64) | –             |
| Never                                         | 1.00 (Ref)     | 1.00 (Ref)     | 1.00 (Ref)     | –             |

*P < 0.05; RRR, relative risk ratio; CI, confidence interval. Model 1 adjusted to age; Model 2 adjusted to previous health disorders and age; Model 3 adjusted to listening to music and age; Model 4 adjusted to previous health problems, listening to music, regular exposure to loud noise, and age. Previous health problems refer to having had an ear infection as a child, sudden hearing loss and using ototoxic medications. Listening to music refers to listening to a music player and visiting clubs or rock concerts.

### Table 5: The association between HL (from slight to severe) and previous health problems, listening to music, and being regularly exposed to loud non-military noise

| Activity                                      | RRR (95% CI) |
|-----------------------------------------------|--------------|
| Otitis in childhood                           | 0.65 (0.31–1.35) |
| Use of ototoxic drugs                         | 0.35 (0.03–4.09) |
| Occurrence of brain trauma/injury             | 2.34 (0.46–11.78) |
| Listening to music player                     | 0.76 (0.36–1.61) |
| Using a Hi-Fi device with an amplifier        | 0.51 (0.17–1.56) |
| Visiting night clubs at least once per month  | 2.60 (0.84–8.02) |
| Visiting rock concerts at least once per year | 1.44 (0.66–3.17) |
| Regular exposure to loud noise               | 1.12 (0.57–2.18) |
| Riding motorbike                              | 0.98 (0.39–2.42) |
| Participation in motorsports                 | 0.59 (0.05–6.65) |
| Playing musical instrument                    | 1.20 (0.43–3.39) |

1RRR = relative risk ratio, analysis adjusted for age.
years increased the HL risk \((\text{RRR} = 8.24, 95\% \text{ CI 1.87–36.45})\). In our analysis of riding in a PASI or Bandvagn, we could see a statistically significant impact among those riding for up to five years \((\text{RRR} = 2.92, 95\% \text{ CI 1.08–7.92})\), which is the opposite of earlier models. Shooting with blanks, and small- and large-calibre weapons as well as regular exposure to loud noise in non-military environment did not have a statistically significant effect [Table 4].

Subsequently, the independent effect of previous health disorders, listening to music and regular exposure to loud noise was tested in connection with prevalence of HL. In the analysis we could not see any statistically significant effect. Thus the non-military noise seems to have no independent effect on respondents [Table 5], but it might increase the effect of military noise [Table 4].

HL can also be related to poor use of hearing protective equipment. Even though auditory organ protective equipment was reported to be used always or almost always while shooting small-calibre weapons (94.6%) and large-calibre weapons (91.2%), there appeared to be 1.5% and 4.4% of respondents who never use it, respectively [Figure 2]. The proportion among never-users was even higher (9.1%) among those who had ridden a PASI or Bandvagn and 34.1% use hearing protective equipment in those vehicles almost never. In working with noise-producing equipment, 8.7% of respondents use it never or almost never.

In the regression analysis we could see a significant increase in RRR among those working with noise-producing equipment and those only sometimes using hearing protective equipment, \(\text{RRR} = 6.96 (95\% \text{ CI 1.05–45.97})\) (Table 8). A statistically significant association also appeared among those who never use any kind of hearing protective equipment and shoot small- or large-calibre weapons, \(\text{RRR} = 13.26 (95\% \text{ CI 1.04–169.34})\). Among the other noise sources, we could not see any statistically significant association [Table 6].

**DISCUSSION**

Exposure to noise due to various military activities has a significant impact on diagnosed high-frequency HL. Besides noise exposure, HL might be related to age, service time, earlier health problems, regular exposure to loud non-military noise, etc.\(^{[31]}\) In our analysis the general trend was that the longer the time of exposure (indicated by service time), the more it affected persons who had been diagnosed with HL. In the crudest analysis (Model 1, adjusted only for age) while working in a noisy environment, with noise inducing equipment and riding a PASI or Bandvagn, the highest RRRs appeared among those who had served more than 16 years, followed by those with 5–16 years of service time. These results seem to be consistent with other studies to prove that the longer service time in noisy conditions, the more probable noise-induced HL is.\(^{[1,9,10,14,17,20,22,32]}\)

According to Model 1 [Table 4], being in a noisy environment, shooting weapons of different calibres and being exposed to noise from other sources did not have a significant impact on HL. After adjusting for previous health problems and age, the results of Model 2 indicate that persons with HL and previous health problems were more affected by noise exposure than persons without previous health problems. Similar to the findings of Model 1, persons with HL and previous health problems were more affected by noise exposure than persons without previous health problems. The longer service time in noisy conditions, the more probable noise-induced HL is.\(^{[1,9,10,14,17,20,22,32]}\)

In our analysis we also studied exposure to shooting with blanks in relation to HL. We could see 3.64 times higher RRR...
In addition to professional noise exposure, leisure time risk of HL and use of proper PPE is vital. High noise levels (peaks above 140 dB), \[33\] it increases the once per week during field training, compared to non-

While shooting small- or large-calibre weapons

Never 8.12 (0.66–99.20) 13.26 (1.04–169.34)* 7.63 (0.43–136.59) 9.40 (1.00–88.60)

Sometimes 0.87 (0.07–10.46) 1.29 (0.10–15.86) - 0.80 (0.10–6.11)

Always 1.00 (Ref) 1.00 (Ref) 1.00 (Ref) 1.00 (Ref)

Regular exposure to loud noise in non-military environment

Never 0.62 (0.19–1.99) 0.32 (0.07–1.43) 0.15 (0.02–1.44) 0.41 (0.15–1.09)

Sometimes 0.78 (0.25–2.47) 0.54 (0.14–2.10) 0.60 (0.13–2.83) 0.66 (0.26–1.67)

Always 1.00 (Ref) 1.00 (Ref) 1.00 (Ref) 1.00 (Ref)

\[^{1}\text{Adjusted for age, } \, ^{1}P < 0.05; \text{RRR, relative risk ratio; CI, confidence interval.}\]

(95% CI 1.12–11.82) among those who shot blanks at least once per week during field training, compared to non-shooters. As shooting with blanks still creates relatively high noise levels (peaks above 140 dB), \[33\] it increases the risk of HL and use of proper PPE is vital.

In addition to professional noise exposure, leisure time exposure is part of the total noise exposure. \[34,35\] Nevertheless, our results indicate that for persons with HL and exposed to noise, listening to music regularly does not increase the risk of HL [Table 5]. However, among those who had worked for a long period of time with noise-producing equipment, listening to music player increased the RRRs for HL [Table 4].

The results of Model 4 showed that persons who had HL and previous health problems and were exposed to noise from noise-producing equipment during non-working hours were most affected by being in a noisy environment for a long period of time (more than 16 years) (RRR = 3.42) in comparison with persons without HL. They were also most affected by working with noise-producing equipment for more than 16 years (RRR = 8.24). These persons were more affected by riding in a PASI or Bandvagn if they had been riding in these vehicles for up to five years (RRR = 2.92) in comparison with persons who had been riding in them for longer. This trend differs from others because in this analysis group, most persons rode in these vehicles for up to five years, and therefore, the effect was greater. The correlations observed in Model 4 show that working as a shooting instructor, shooting with blanks and shooting weapons do not have a significant impact on persons with HL.

In our study we could see the highest prevalence of severe HL in central units, followed by the land force. The persons currently serving in central units had often served earlier in other forces and their exposure might have happened elsewhere. \[4\] Also they were older with longer exposure times which increased the risk of HL. \[1\] At the same time the total HL (from slight to severe) in central units was lower than elsewhere. This could justify the theory of exposure happening elsewhere and latter recruitment in central units. Overall the HL was highest in the navy, where a majority of the participants had at least slight HL. The average prevalence of HL in our study group was relatively high (62.7%), being similar to the higher side of the prevalence studies. \[10,36\] In the current analysis the criteria for HL were based on Collee et al., \[1\] where the HL at high frequencies (4 and 6 kHz) was applied. However, those criteria and the definition of HL vary in different studies and forces. \[36\] For instance, in the Estonian Defence Forces the HL in lower frequencies (0.5,
professional soldiers still experience disabling tinnitus and hearing protection equipment, a large proportion of could easily exceed the 8h limit value. As in Finland, despite at the same time, according to measured values, the levels Bandvagn which has not been seen as a high-risk activity. non-users was especially high while riding a PASI or never) use PPE in a noisy environment. The proportion of reported data, at least 4.8% of personnel never (or almost never) use PPE in a noisy environment. The proportion of noise exposure on surface warships by wearing hearing protection devices could reduce the number of sailors suffering HL in their naval careers, by 18%. As in our study, 83.3% of respondents from the navy had HL and regular wearing of PPE has great potential to improve this statistic among military personnel. According to the self-reported data, at least 4.8% of personnel never (or almost never) use PPE in a noisy environment. The proportion of non-users was especially high while riding a PASI or Bandvagn which has not been seen as a high-risk activity. At the same time, according to measured values, the levels could easily exceed the 8h limit value. As in Finland, despite improved hearing protection regulations and increased use of hearing protection equipment, a large proportion of professional soldiers still experience disabling tinnitus and HL. It has been shown that the prevalence of noise-induced HL could be reduced by using hearing protective equipment. Among military personnel this has been clearly indicated by studies in the Finnish Defence Forces, proving that if the use of PPE had become more common (2003–2005 vs 1984–1986), the prevalence of HL and tinnitus had decreased.[29,30] Moreover, Trost and Shaw[20] have discussed that use of PPE makes a difference: reducing noise exposure on surface warships by wearing hearing protection devices could reduce the number of sailors suffering HL in their naval careers, by 18%. In our study, 83.3% of respondents from the navy had HL and regular wearing of PPE has great potential to improve this statistic among military personnel. According to the self-reported data, at least 4.8% of personnel never (or almost never) use PPE in a noisy environment. The proportion of non-users was especially high while riding a PASI or Bandvagn which has not been seen as a high-risk activity. At the same time, according to measured values, the levels could easily exceed the 8h limit value. As in Finland, despite improved hearing protection regulations and increased use of hearing protection equipment, a large proportion of professional soldiers still experience disabling tinnitus and HL.[40]

In our study we had very high response rate (98.7%), so there is no reason to suspect non-response bias. Also the tone audiometry was conducted by two experienced otolaryngologists in the same place, which gives more confidence to the data quality. Nevertheless, as we did a cross-sectional study with only one observation, thus in the context of this article we have discussed only HL, not noise-induced HL. Moreover, we had only self-reported noise-exposure data available, which might have caused some bias in real exposure. Even though there were relatively more personnel from the Central Command Units, respondents had probably experienced most of the noise exposure earlier in their service in other forces. Another limitation of the present study was that there was a relatively low proportion of people from the air force and the navy, where the HL problems seem to be most common. Thus the very high prevalence rates among them should be taken with reservation because of the small sample size.

Conclusions

In our study we observed a relatively high proportion (62.7%) of military personnel with at least slight HL in high frequencies (4 and 6 kHz). However, around 9.3% of participants had severe HL. We could see the risk of HL increasing over a longer service time. In our analysis we found a statistically significant effect of being in a noisy environment, working with noise-producing equipment, riding in an armoured personnel carrier (PASI) or a tracked articulated all-terrain carrier (Bandvagn), and shooting with blanks on the prevalence of HL. Respondents’ previous health problems, music-listening habits and exposure to loud noise in non-military environments were not independently associated with HL, but in several cases they increased the RRRs together with military exposure.

It is important to note that noise-induced HL is partially preventable by proper use of hearing protection equipment which would require appropriate training. As in our study at least 4.8% of personnel never or almost never used PPE in noisy environments, in the context of noise-induced HL prevention we can see some potential for proper use of personal protective equipment in the military. We also saw that the HL was significantly more frequent among those never using PPEs.

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Conflicts of interest

There are no conflicts of interest.

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