Acute Acoustic Trauma in the French Armed Forces During 2007–2014

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Abstract

Context: Despite existing preventive measures, the number of acute acoustic trauma (AAT) cases reported to the French Military Epidemiological Surveillance System (MESS) remains high. Aims: The objective of this study was to describe AAT and the preventive measures already implemented. Subjects and Methods: We conducted a descriptive cross-sectional analysis of AAT using data from the MESS for the period 2007–2014. In addition, we reviewed the current prevention measures that exist in the French armed forces. Statistical Analysis Used: Comparisons between different incidence rates were made by Poisson and quasi-Poisson regression. Results: Between 2007 and 2014, 10,487 AAT cases were reported to the MESS, with a significant decrease in 2013 (P < 0.001). AAT incidence rates were the highest among those aged <25 years – 14.3 per 1000 person-years (PYs) (P < 0.001), and those in the army; with 8.1 per 1000 PYs (P < 0.001), and men had almost twice the risk of women (P < 0.001). AAT mainly occurred in training schools or at camps during exercises. The main prevention actions identified were the following: official regulations, education, making hearing protection devices (HPDs) available for all service members, and regular hearing monitoring. A working group has been set up and has proposed an informative chapter in the weapon handling instruction book, an AAT simulator, and a new HPD, the 3M® earplug, with an information brochure. Conclusions: AAT rates decreased from 2007 to 2014 in the French armed forces. Further analysis is needed to identify the underlying factors involved to improve the prevention actions proposed. The MESS and targeted surveys will assess the impact of the different prevention measures implemented.

Keywords: Acute acoustic trauma, armed forces, epidemiological surveillance, prevention

Introduction

Noise-induced hearing loss (NIHL) is the most common form of acquired hearing loss and the most frequently occurring preventable disability caused by occupational or leisure activities.[1,2] By noise, we generally mean an unpleasant, irregular, confusing, disharmonic sound.[3] The harmful impact to the inner ear caused by noise is referred to as acoustic trauma, which can be acute or chronic. Both forms are spectra of the same entity (NIHL).

Acute acoustic trauma (AAT) is defined as an injury to the inner ear caused by exposure to an impulse noise (typically equal to or greater than 140 dB, which rapidly rises to a sharp peak and then quickly fades, with a duration of 0.001–1 s).[3,4]

These intense acoustic signals can cause mechanical and metabolic damages to the delicate structures of the cochlea. Damage occurs in the organ of Corti’s basilar membrane, in particular rupture and destruction in the outer hair cells and their stereocilia, which are key elements in the mechanoelectrical transduction process of the sound signal. Stereocilia have a stiff, stacked, “organ-pipe” arrangement, which is disrupted after acoustic trauma. Over time, they merge and lose their function (cell death or apoptosis).[3,5] A short time after acoustic trauma, the cells appear to either recover or degenerate completely.[5] The clinical result is temporary impairment of hearing (temporary threshold shift) which, depending on the amount of energy or the acoustic dose, may be irreversible (permanent threshold shift). It is accompanied by continuous and intense tinnitus,
which is a major annoyance. Early hearing loss is measured using pure tone threshold audiometry.

It is very important to consider the time elapsed since the AAT. Indeed, spontaneous recovery of up to 20 dB can occur in the first 4 days. Beyond this period, the chances of recovery decrease and the prognosis is poorer. Treatment should therefore be initiated as early as possible. AAT is an emergency that requires prompt care after the occurrence of the accident.[3] There is also an individual susceptibility to otological damage and, on average, 40% of people experience permanent damage to their hearing after an AAT.[3,4,6]

Recently, otoacoustic emissions (OAE) have allowed earlier detection of cochlear dysfunction. In the first 24 h, if acoustic distortion products are absent, the risk of hearing loss is high, and they are a better predictor of persistent tinnitus.[7]

Military service members are particularly exposed to very high-level noises during training exercises and in operational situations.[8-10] The hazardous effects of impulse noises from firearms (varying from 150 to 165 dB at peak level) can interact with the continuous noises in military devices (varying from 100 to 120 dBA) to produce greater hearing loss than would be predicted by the simple additive effects of these noises.[11,12] In all cases, they are well above permissible exposure recommendations. Exposure depends on the number of shots, the type of weapon, the type of ammunition, the distance from the weapon, and proper use of hearing protection devices (HPDs).[13,14]

AAT can lead to permanent sensorial disabilities, professional reorientation, and unavailability for highly qualified staff, with costs linked to retraining for replacement personnel as well as the financial burden of disability payments to military veterans.[8,15-18] Because they constitute a public health concern for service members,[19] active epidemiological surveillance of these events has been conducted among the French armed forces since 1996.

Currently, HPDs are the primary means for avoiding AAT, with limited success as a result of technical, operational, and ergonomic constraints.[20] Thus, other preventive measures or strategies are needed to reinforce those already being implemented.

The objective of this study was to provide a baseline description of AAT cases declared in the French armed forces and then to review the preventive measures already implemented, to provide targeted recommendations for a hearing conservation program (HCP).

Subjects and Methods

In the French armed forces, around 60 health events, including AAT, are monitored through the Military Epidemiological Surveillance System (MESS). The population under military epidemiological surveillance is all active military staff, whether on duty or not, regardless of their place of employment or the origin of their medical treatment (civilian or military medical facility). The AAT case definition used was “at least one audio-vestibular symptom (tinnitus, hearing loss, dizziness or other) after an excessive sound exposure.” AAT cases were notified by means of a weekly epidemiological report (WER) with, in addition, a specific declaration form (SDF) with the patient’s sociodemographic characteristics, the circumstances of the accident, and the clinical presentation. SDFs were filled out by the medical officer and sent to the French Armed Forces Center for Epidemiology and Public Health (CESPA). In this cross-sectional study, we reviewed all AAT cases that occurred between 01/01/2007 and 12/31/2014 and these cases were notified to CESPA by a SDF. A search for duplicates (two pins on the same case) was performed based on the date of birth, the person’s unit, and the AAT onset date. Statistical analysis was performed using Excel®, EpiInfo 7.1.5®, and R version 3.1.2® software. A descriptive analysis was performed; AAT incidence rates were calculated using the data published by the Social Observatory of Defense as the denominator. Poisson and quasi-Poisson regression were used to compare incidence rates. The significance level was set at 0.05.

Results

Between 2007 and 2014, 10,487 AAT cases were reported and 10,043 SDFs were sent to CESPA. The AAT incidence rate varied between 4.0 cases per 1000 person-years (PYs) in 2011 (95% CI = 3.8–4.2) and 3.4 (3.2–3.6) in 2013 [Figure 1]. During this period, we noted a highly significant decrease in the AAT risk in 2013 [P = 0.0006, Table 1].

The principal characteristics of AAT cases and comparisons of incidence rates are presented in Tables 2 and 3. 91.2% AATs occurred in males, with an incidence rate of 4/1000 PYs.[21] The relative risk of acoustic trauma was 1.8 (95% CI = 1.7–2.0) times higher for men than for women between 2007 and 2014. The median age was 23 years (range: 17–60). Younger people (<25 years) had the highest incidence rate – 14.3 per 1000 PYs (P < 0.001), and the risk of AAT was 32 (95% CI = 22–49) times higher for the youngest service members than for the oldest. The highest AAT incidence rate was observed among soldiers serving in the army – 8.1 per 1000 PYs (P < 0.001), with a significantly higher risk RR = 8.4 (95% CI = 5.4–14.3) than the army.

### Table 1: Comparison of AAT incidence rates

| Year | RR  | 95% CI       | P-value |
|------|-----|-------------|---------|
| 2007 | 1   |             | 0.0006  |
| 2008 | 1.00| [0.92–1.08] |         |
| 2009 | 0.99| [0.92–1.07] |         |
| 2010 | 0.95| [0.88–1.02] |         |
| 2011 | 1.04| [0.97–1.13] |         |
| 2012 | 0.97| [0.89–1.04] |         |
| 2013 | 0.87| [0.80–0.94] |         |
| 2014 | 0.95| [0.88–1.03] |         |

Univariate Poisson regression (n = 10,043).
in other branches of the military. They occurred most often in continental France – 9302 out of 9626 AAT cases (96.6%), with 106 cases (1.1%) reported in overseas territories and 217 (2.3%) during operations.

With regard to the type of activity, 81.9% of AAT cases were reported by training camps or training schools during planned exercises and only 6.4% cases in an operational situation. The nature of the noise that caused the AAT in 83.5% of the cases was noise from a firearm, the FAMAS assault rifle being the most common cause of declared AAT with almost 71.2%.

Although most service members were wearing HPDs at the time of the accident (74.3%), problems were reported in 43% of the cases, as shown in Figure 2. During training exercises, the most frequently worn HPDs were nonlinear attenuation canal caps (NLAC) in 41.8% of the cases; 20% of AAT cases stated they wore no HPD.

### Table 2: Comparison of AAT incidence rates adjusted by year

|      | n   | RR  | 95% CI          | P-value |
|------|-----|-----|-----------------|---------|
| Sex  |     |     |                 |         |
| Male | 10,027 | 1 |                 | <0.0001 |
| Female |   | 1.81 | [1.66–1.97] |         |
| Age  | 10,002 | 1 |                 | <0.0001 |
| [45–60] |   | 2 | [22.00–49.01] |         |
| [17–24] |   | 2 | [5.37–14.31] |         |
| [25–34] |   | 2 | [4.11–9.31] |         |
| [35–44] |   | 2 | [2.3–3.05] |         |
| Branch | 9986 | 1 |                 | <0.0001 |
| Joint services |   | 1 | [0.66–1.85] |         |
| Army | 8.43 | [5.37–14.31] |         |
| Air  | 1.14 | [0.69–2.02] |         |
| Navy | 1.12 | [0.67–2.00] |         |
| Gendarmerie | 1.07 | [0.66–1.85] |         |

Bivariate quasi-Poisson regression.

**Figure 1:** Change in the incidence rate of acute acoustic trauma and its 95% CI declared to the French Military Epidemiological Surveillance System (2007–2014, \( n = 10,043 \))

**Figure 2:** Distribution by activity and use of hearing protection devices of AATs reported to the French MESS (2007–2014, \( n = 10,043 \))
The most significant hearing loss was in the frequency range present in 794 cases (9.2%), consisting mainly of earache. The main clinical signs were tinnitus (94.1%) and hearing loss (69.1%). These two symptoms were associated in 60.3% of the cases and were absent in 2.0%. Other clinical signs were present in 794 cases (9.2%), consisting mainly of earache. The most significant hearing loss was in the frequency range of 4000–6000 Hz for both ears, with an average loss of 20 dB in the 6000 Hz frequency. Hospitalization was required in 14.2% of the cases.

Primary prevention actions in the French armed forces included personnel selection, shooting instructions, distribution of hearing protectors, and audiometric monitoring. Secondary prevention consisted of education and audiometric supervision after an AAT. Tertiary prevention was organized with a specific prescription for HPD if there was a history of AAT, exemption from shooting, or employment restrictions.

AAT prevention is defined in regulatory texts. Moreover, a “noise and pressure” working group was established in 2013, which brought together the French Armed Forces Biomedical Research Institute (IRBA) and the General Delegation for Armaments (DGA). To reduce AAT incidence, they identified three preventive actions: (1) improve HPD performance, (2) better assess service members’ exposure to weapon noise, and (3) instruct and motivate soldiers for proper use of HPDs. Regarding the last point, they proposed the following: (a) a training module on hearing protection, taught during weapon handling instruction. It describes HPD performance and the proper way to use them, and reminds trainees to check them and that their use is mandatory. The module is currently intended for instructors and shooting directors, who are responsible for checking HPDs during all learning sessions; (b) a leaflet about the performance of the different hearing protectors; CESPA is responsible for regular updates and distribution; (c) an acoustic trauma simulator, which aims to show soldiers the communication difficulties that can result from an AAT, to motivate them to wear a HPD.

In addition to these measures, a new HPD, the 3M® earplug, is currently being implemented. These new protection devices present the characteristics of a conventional earplug when the valve is closed or a NLAC when the valve is open. In the closed mode, the average hearing level attenuation (insertion lost) is about 30–40 dB for high frequencies and 26–28 dB for low frequencies. In the open mode, attenuation is about 20–30 dB for high frequencies and 5–17 dB for low ones. They are available in three sizes for better adjustment to the ear canal.

### DISCUSSION

In our study, the large number of AAT cases reported to the French MESS was highlighted. The results of the 2002–2004 surveillance period showed an increase from 675 AAT cases in 2002 to 1135 in 2004;[23] since then, over 1000 cases have been reported each year. This could be explained by the fact that before 2003, military training in the French armed forces took place mainly at the shooting range (static exercises). But after the start of operations in Afghanistan and Ivory Coast, combat training programs (dynamic exercises) were set up, and an increase in reports of service members having the available one-size-fits-all HPD (NLAC) fall out was observed.[20] In our analysis, the incidence rate of AAT significantly decreased in 2013; however, it was not possible to clearly identify the causal factors of this decline as a result of not having all the information needed to perform the multivariable analysis.
The effect of gender is consistent with other studies and could be explained by the fact that men are more frequently exposed to noisy activities, exercises, and operations.[19,23,24] The AAT incidence rate was highest among military personnel aged 25 years or younger and then decreased with age. The same profile was found in other studies conducted in other countries, with young males most exposed to AAT during their military service or early in their military career.[13,23-25] Moreover, a high AAT incidence was found in the army, which could be the result of greater exposure to noisy weapons than in other branches; there is also evidence that infantry and guncrews (combat units) are at greater risk of NIHL.[19,26,27] Assessment of the circumstances leading to AAT revealed that over 80% of the cases reported by schools or training camps occurred during shooting drills or while trainees performed security measures with their weapon, reflecting an increased exposure of personnel during the initial training period. The same results were found in a Finnish study by Savolainen and Lehtomäki.[28] All these groups at risk—young men from the army in training camps and training schools—show a high proportion of avoidable AATs and underscore the need to reinforce health promotion and targeted educational efforts.

In contrast, AAT occurring during combat operations may be underestimated. Indeed, if the focus is on injuries by firearms, AAT may go unnoticed and will not be reported. We found that the most important source of noise was the FAMAS assault rifle, which, with its rich spectrum of high frequencies and the briefness of the sounds it emits, is very aggressive and harmful to the cochlea.[29] Like in other series, AAT presented most often as unilateral involvement and was usually accompanied by tinnitus and hearing loss.[13,30] As reported in the literature, tinnitus is almost constant and is sometimes the only symptom.[3] When tinnitus persists, it can be very disabling both psychologically (anxiety, depression) and operationally, because it may mask sound messages and cause tiredness, thereby linked to the need for greater concentration.[10]

In our study, there was a high proportion of service members who stated they were wearing a HPD at the time the AAT occurred. This could be linked to a prevarication bias, as some soldiers could have voluntarily omitted to mention that they were not wearing a HPD. It could also reflect other problems [Figure 2]. Noise attenuation by HPD would be the best preventive measure to avoid NIHL. In the armed forces, HPDs have to provide sufficient hearing protection, but without impeding hearing capabilities. It is recognized that hearing readiness is an extremely important factor of a unit’s performance in combat.[10,12] HPDs have evolved from classic passive earmuffs or earplugs (that do not allow communication) to nonlinear inserts or NLACs that allow soft sounds to flow unimpeded through a filter (enabling situation awareness), but block loud impulse noise. The drawback with NLACs, the most frequently used HPD in our series, is that they do not protect from continuous noise and are available in only one size, making it difficult to adjust them to the ear canal.[20] The need to improve compliance with HPD use and develop new materials with improved damping, reflective, and absorption characteristics has already been recognized.[31] This is why a new generation of HPD, the 3M® earplug, has both characteristics in one.

In addition, some erroneous information has been highlighted, in particular the false belief that NLACs are effective against continuous noise.[6] Therefore, education is very important, both to raise awareness about serious AAT consequences and to improve appropriate use of the different types of HPD.[32] A meta-analysis performed by El Dib et al.[33] shows that tailored or targeted education improves the mean use of HPDs compared to no intervention at all. Regarding prevention in the French armed forces, ongoing concrete actions were identified. AAT is part of the available military medical surveillance data, established in 1996 by means of a WER, and completed by a SDF since 2000. It has been demonstrated that the surveillance system plays a key role in assessing the burden of AAT.[19] The establishment of a database for monitoring NIHL had already been recommended in 1953 in the Benox Report in the US army. In that country, there is an online portal for hearing conservation data and a well-established HCP.[19,34] Other countries such as Singapore, Sweden, Canada, Finland, and Switzerland have implemented HCPs and studied their effectiveness or reinforced their regulations.[30,32,35-39] Some, like the Navy Hearing Conservation Program,[40] are dedicated to one specific branch.

With regard to the preventive measures in the French armed forces, proposals include assessment in terms of the following: (a) understanding of the training module, (b) availability of brochures combined with a poster displayed in shooting ranges or in places where weapons are distributed, (c) setting up an acoustic trauma simulator in all military schools to reach the maximum number of service members, and (d) distribution and use of new protective devices. In fact, reluctance to wear a new HPD system has been reported by Patil and Breeze. Their study pointed out that a dedicated educational program to explain their relevance is needed, and they insist that HPDs should be provided to all service personnel early in their career.[41] Another meta-analysis performed by Verbeek et al. concludes that the effectiveness of HPDs depends on training and proper use. To achieve that goal, better implementation and reinforcement of hearing loss prevention programs and better evaluation of technical interventions with long-term effects are needed.[42]

In summary, AATs are still very common in the military. Although there was a decrease in the incidence rate in 2013, further analysis is needed to identify the underlying factors involved. The population identified as being at risk is mainly young people in the army, training camps, and training schools. The human and economic repercussions for society are considerable because of permanent damage to the inner ear (tinnitus and hearing loss). These induce serious consequences at both the individual (social disadvantage) and collective level (specialized medical care, retraining, and compensation).[8,18] Therefore, analysis of surveillance data and the development of prevention measures represent the first step in the public health process.[19] There needs to be a
variety of prevention activities, and to that end, multidisciplinary work that forms part of a HCP must be implemented through the efforts of all stakeholders.

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**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Murray CJ, Atkinson C, Bhalke K, Birbeck G, Burstein R, Chou D, et al. US Burden of Disease Collaborators. The state of US health, 1990-2010: Burden of diseases, injuries, and risk factors. JAMA 2013;310:591-608.

2. National Institute of Deafness and Other Communication Disorders. Noise-induced hearing loss. Available from: http://www.nih.gov/about-nih/what-we-do/nih-almanac/national-institute-deafness-other-communication-disorders-nidcd. [Last accessed on 2016 Apr 05].

3. Nottet JB, Moulin A, Crambert A, Bonete D, Job A. Acute Auditory Trauma. EMC, Oto-rhino-laryngologie. Paris: Elsevier Masson SAS; 2010. p. 20-185- A-10.

4. Nottet JB, Crambert A, Lombard B, Boursier C, Sue B. Occupational noise-induced hearing loss. EMC, Oto-rhino-laryngologie. Paris: Elsevier Masson SAS; 2010. p. 20-185-F-10.

5. Harrison RV. The prevention of noise induced hearing loss in children. Int J Pediatr 2012;2012:473541.

6. Casanova F, Saroul N, Nottet JB. Prevention of acute audiological trauma in the army. Results of a study including 1,315 service people. Méd Armées 2011;39:63-9.

7. Nottet JB, Moulin A, Brossard N, Sue B, Job A. Otoacoustic emissions and persistent tinnitus after acute audiological trauma. Laryngoscope 2006;116:970-5.

8. Yong JS, Wang DY. Impact of noise on hearing in the military. Mil Med Res 2015;2:6.

9. Wells TS, Seelig AD, Ryan MA, Jones JM, Hooper TI, Jacobson IG, et al. Hearing loss associated with US military combat deployment. Noise Health 2015;17:34-42.

10. Guesard W, Demenieux Y, Unteremeier M, Nottet J-B., Job A. Personal protective equipment against noise in military operational environment. Part 1: Requirements and pathophysiological effects of the noise of weapons. Acoust Tech 2011;56:10-4.

11. Dancer AL, Hamery PJ. Results of human studies with linear and nonlinear earplugs: Implications for exposure limits. J Acoust Soc Am 1998;103:2878.

12. Henderson D, Hamernik RP. Impulse noise: Critical review. J Acoust Soc Am 1998;103:869-84.

13. Ylikoski ME, Ylikoski JS. Hearing loss and handicap of professional soldiers exposed to gunfire noise. Scand J Work Environ Health 1994;20:93-100.

14. Konopka W, Olszewski J, Straszynski P. Evaluation of the risk on hearing loss at soldiers. Otologyngol Pol 2006;60:249-53.

15. Taito P, Travers S, Paklepa B, Limas F, Journaux L, Morgan D. The auditory protection in the special forces. Méd Armées 2009;37:221-8.

16. Dancer A, Buck K, Hamery P, Parmentier G. Hearing protection in the military environment. Noise Health 1999;2:1-16.

17. Saunders GH, Griest SE. Hearing loss in veterans and the need for hearing loss prevention programs. Noise Health 2009;11:14-21.

18. Tufts JB, Weathersby PK, Rodriguez FA. Modeling the United States government’s economic cost of noise-induced hearing loss for a military population. Scand J Work Environ Health 2010;36:242-9.

19. Helfer TM, Canham-Chervak M, Canada S, Mitchener TA. Epidemiology of hearing impairment and noise-induced hearing injury among U.S. military personnel, 2003–2005. Am J Prev Med 2010;38:571-7.

20. Hamery P, Buck K, Zimpfer V. Personal protective equipment against noise in military operational environment. Part 2: Duality protection and communication. Acoust Tech 2011;66:15-9.

21. Directive 2003/10/EC of the European Parliament and the Council of 6 February 2003 concerning the minimum safety and health requirements related to the exposure of workers to the risks arising from physical agents (noise). Official Journal of the European Communities 42 of February 15, 2003.

22. Decree No 2006-892 of July 19, 2006 on safety and health requirements applicable to workers risk exposure due to noise and amending the Labour Code (second part: Decrees in Council of State). Official Journal of the French Republic on July 20, 2006.

23. Verret C, Matras-Vaslin V, Haus-Cheymol R, Berger F, Texier G, Mayet A, et al. Acute auditory trauma in military population, results of the 2002-2004 public health surveillance. Méd Armées 2006;34:431-5.

24. Labarrère J, Lemardeley P, Vincey P, Desjeux G, Pascal B. Acute auditory trauma in military personnel. Evaluation of 1 year epidemiological surveillance. Presse Med 2000;29:1341-4.

25. Moon IS. Noise-induced hearing loss caused by gunshot in South Korean military service. Mil Med 2007;172:421-5.

26. Collé A, Legrand C, Govaerts B, Van Der Veken P, De Boodt F, Degrave E. Occupational exposure to noise and the prevalence of hearing loss in a Belgian military population: A cross-sectional study. Noise Health 2011;13:64-70.

27. Barney R, Bohrker BK. Hearing thresholds for U.S. Marines: Comparison of aviation, combat arms, and other personnel. Aviat Space Environ Med 2006;77:53-6.

28. Savolainen S, Lehtomäki KM. Impulse noise and acute auditory trauma in Finnish conscripts. Number of shots fired and safe distances. Scand Audiol 1997;26:122-6.

29. Sue B, Asperge A. Tinnitus of acute noise-induced auditory trauma by FAMAS. Méd Armées 1988;16:207-10.

30. Muhr P, Rosenhall U. The influence of military service on auditory health and the efficacy of a Hearing Conservation Program. Noise Health 2011;13:320-7.

31. Killion MC, Monroe T, Drummarean V. Better protection from blasts without sacrificing situational awareness. Int J Audiol 2011;50 (Suppl 1):S38-45.

32. Paikkönen R, Lehtomäki K. Protection efficiency of hearing protectors against military noise from handheld weapons and vehicles. Noise Health 2005;7:11-20.

33. El Dib RP, Mathew JL, Martins RH. Interventions to promote the wearing of hearing protection. Cochrane Database Syst Rev 2012;4:CD005234.

34. McIlwain S, Gates K, Ciliax D. Heritage of army audiology and the road ahead: The Army Hearing Program. Am J Public Health 2008;98:2167-72.

35. Pellasus EO, Abel SM, Simard J, Dempsey I. Prevention of noise-induced hearing loss in the Canadian military. J Otolaryngol 1995;24:271-80.

36. Teo KJ, Chia SE, Tan TC, Ali SM. Effect of basic military training on hearing in the Singapore Armed Forces. Singapore Med J 2008;49:243-6.

37. Abel SM. Hearing loss in military aviation and other trades: Investigation of prevalence and risk factors. Aviat Space Environ Med 2005;76:1128-35.

38. Rey B, Künzli N, Probst R, Ackermann-Liebrich U. Instructor in the army and persistent tinnitus after acute auditory trauma. Laryngoscope 2011;39:63-9.

39. Savolainen S, Kuokkanen JT, Lehtomäki KM. Interventions to prevent occupational noise-induced hearing loss. Cochrane Database Syst Rev 2012;10:CD006396.