McMaster University | HEALTH FORUM

Rapid Evidence Profile

Examining the association between noise exposure and delayed hearing loss

10 May 2024

[MHF product code: REP 71]

Appendices

Appendix 1: Methodological details

We use a standard protocol for preparing rapid evidence profiles (REP) to ensure that our approach to identifying research evidence is as systematic and transparent as possible in the time we were given to prepare the profile.

Identifying research evidence

For this REP, we searched ACCESSSS, PubMed, and CINAHL for:
1) evidence syntheses
2) protocols for evidence syntheses that are underway.
3) single studies.

We searched ACCESSSS using open text terms for "hearing loss." We searched PubMed using ((noise-induced hearing loss [MESH]) OR "cochlear synaptopathy") with a filter for systematic reviews. We conducted a second PubMed search using ((noise-induced hearing loss [MESH]) OR "cochlear synaptopathy") AND (military OR Veteran)) and limited it to the last 10 years to identify single studies. We searched CINAHL using ('noise-induced hearing-loss' [major concepts] OR "cochlear synaptopathy") and limited results to systematic reviews. We conducted a second CINAHL search using ('noise-induced hearing loss [major concepts] OR "cochlear synaptopathy") AND (military OR Veteran) and limited to the last 10 years.

Each source for these documents is assigned to one team member who conducts hand searches (when a source contains a smaller number of documents) or keyword searches to identify potentially relevant documents. A final inclusion assessment is performed both by the person who did the initial screening and the lead author of the rapid evidence profile, with disagreements resolved by consensus or with the input of a third reviewer on the team. The team uses a dedicated virtual channel to discuss and iteratively refine inclusion/exclusion criteria throughout the process, which provides a running list of considerations that all members can consult during the first stages of assessment.

During this process we include published, pre-print, and grey literature. We do not exclude documents based on the language of a document. However, we are not able to extract key findings from documents that are written in languages other than Chinese, English, French, or Spanish. We provide any documents that do not have content available in these languages in an appendix containing documents excluded at the final stages of reviewing. We excluded documents that did not directly address the research questions and the relevant organizing framework.

Assessing relevance and quality of evidence

We assess the relevance of each included evidence document as being of high, moderate, or low relevance to the question.

Two reviewers independently appraised the quality of the guidelines we identified as being highly relevant using AGREE II. We used three domains in the tool (stakeholder involvement, rigour of development, and editorial independence) and classified guidelines as high quality if they were scored as 60% or higher across each of these domains.

Two reviewers independently appraise the methodological quality of evidence syntheses that are deemed to be highly relevant using the first version of the AMSTAR tool. Two reviewers independently appraise each synthesis, and disagreements are resolved by consensus with a third reviewer if needed. AMSTAR rates overall methodological quality on a scale of 0 to 11, where 11/11 represents a review of the highest quality. High-quality evidence syntheses are those with scores of eight or higher out of a possible 11, medium-quality evidence syntheses are those with scores between four and seven, and low-quality evidence syntheses are those with scores less than four. It is important to note that the AMSTAR tool was developed to assess evidence syntheses focused on clinical interventions, so not all criteria apply to those pertaining to health-system arrangements or implementation strategies. Furthermore, we apply the AMSTAR criteria to evidence syntheses addressing all types of questions, not just those addressing questions about effectiveness, and some of these evidence syntheses addressing other types of questions are syntheses of qualitative studies. While AMSTAR does not account for some of the key attributes of syntheses of qualitative studies, such as whether and how citizens and subject-matter experts were involved, researchers' competency, and how reflexivity was approached, it remains the best general-quality assessment tool of which we're aware. Where the denominator is not 11, an aspect of the tool was considered not relevant by the raters. In comparing ratings, it is therefore important to keep both parts of the score (i.e., the numerator and denominator) in mind. For example, an evidence synthesis that scores 8/8 is generally of comparable quality to another scoring 11/11; both ratings are considered 'high scores.' A high score signals that readers of the evidence synthesis can have a high level of confidence in its findings. A low score, on the other hand, does not mean that the evidence synthesis should be discarded, merely that less confidence can be placed in its findings and that it needs to be examined closely to identify its limitations. (Lewin S, Oxman AD, Lavis JN, Fretheim A. SUPPORT Tools for evidence-informed health Policymaking (STP): 8. Deciding how much confidence to place in a systematic review. *Health Research Policy and Systems* 2009; 7 (Suppl1): S8.)

Preparing the profile

Each included document is cited in the reference list at the end of the REP. For all included guidelines, evidence syntheses, and single studies (when included), we prepare a small number of bullet points that provide a summary of the key findings, which are used to summarize key messages in the text. Protocols and titles/questions have their titles hyperlinked, given that findings are not yet available.

We then draft a summary that highlights the key findings from all highly relevant documents (alongside their date of last search and methodological quality).

Appendix 2: Details about each identified evidence synthesis

<table>
<tr><th>Dimension of organizing framework</th><th>Declarative title and key findings</th><th>Relevance rating</th><th>Living status</th><th>Quality (AMSTAR)</th><th>Last year literature searched</th><th>Availability of GRADE profile</th><th>Equity considerations</th></tr>
<tr><td>Population exposed to noise
Civilian/general population
Military personnel
Type of noise exposure
Impulsive noise exposure
One-off
Repetitive exposure</td><td>The meta-analysis found a conclusive relationship between reduced auditory nerve function and age; however, only a weak association was found between noise exposure history and auditory nerve response and suggest caution when interpreting results (1)
The auditory nerve is the pathways connecting the inner ear to the central auditory system.
Results of recent studies suggest that it is more vulnerable to aging and noise exposure than when compared to other cochlear structures and has been found to disrupt the encoding of complex information such as speech, despite showing normal results on audiograms.
The only non-invasive technique for directly assessing auditory nerve function in humans is an electroencephalography (EEG) to measure wave 1 of the auditory brainstem response,
There is considerable thought that two factors, aging and noise may affect the auditory nerve.
Previous findings about the effects of noise exposure have been mixed.</td><td>High</td><td>No</td><td>2/9</td><td>2023</td><td>No</td><td>None reported</td></tr>
<tr><td>Population exposed to noise
Civilian/general population
Military personnel
Additional effects of noise exposure experienced later in life
Tinnitus</td><td>The review notes that post-traumatic arteriovenous fistulas can result in tinnitus that develops weeks or even years following a traumatic event, but the occurrence of this is quite rare (2)</td><td>Medium</td><td>No</td><td>3/9</td><td>2012</td><td>No</td><td>None reported</td></tr>
</table>

Appendix 3: Details about each identified single study

Dimension of organizing framework	Declarative title and key findings	Relevance rating	Study characteristics	Equity considerations

• Population exposed to noise
  ○ Civilian/general population
  ○ Military personnel
• Type of noise exposure
  ○ Impulsive noise exposure
    ▪ One-off
    ▪ Repetitive exposure
	The study found a not statistically significant reduction in the mean middle ear muscle reflex magnitude for young Veterans reporting high noise exposure and suggest that it may be a good indicator of cochlear synaptopathy (3)
	• The study estimated a 25% reduction in mean middle ear muscle reflex magnitude was identified, but this finding was not significant.
		High	*Publication date:* March 2022
			
			Jurisdiction studied: United States
			
			Methods used: Cross-sectional; cohort study
				• Occupation

• Population exposed to noise
  ○ Civilian/general population
  ○ Military personnel
• Type of noise exposure
  ○ Impulsive noise exposure
    ▪ One-off
    ▪ Repetitive exposure
	The study suggests that young military recruits exposed to impulse noise may present with deficits that go unnoticed in conventional audiological testing (5)
	• 27 military recruits with exposure to firearm and artillery noise were included in high-noise group, while 13 participants without reported firearm exposures were included in the low-noise group.
	• The study used a range of testing approaches including pure-tone audiometry, tympanometry, looking for the presence of distortion product otoacoustic emissions, and quantifying lifetime noise exposure.
		High	*Publication date:* October 2022
			
			Jurisdiction studied: Canada
			
			Methods used: Cross-sectional; cohort study
				• Occupation

• Population exposed to noise ○ Civilian/general population	The study identified that despite a normal audiogram, with no direct signs of cochlear damage, humans can still show a reduced amplitude of wave 1 potential and in particular demonstrates the potential for 'hidden hearing loss' that manifests as reduced neural output from the cochlea (6) • However, this hearing loss is not reported to increase over time; it may instead not be initially detected on audiograms following the noise exposure.	High	*Publication date:* 2011 *Jurisdiction studied:* None *Methods used:* Modelling study	• Modelling study

• Population exposed to noise
  ○ Military personnel
• Type of noise exposure
  ○ Impulsive noise exposure
    • One-off
    • Repetitive exposure
	The study found a reduction in peripheral auditor input that leads to compensatory gain in the central auditory system, even among individuals with normal audiograms, and may impact auditory perception (4)
	• The study noted that one explanation for auditory deficits being hidden from audiograms is partial loss of synaptic connections between the inner hair cells and their afferent nerve fibre targets, a condition called cochlear synaptopathy.
	• The review notes that this is hard to diagnose as it requires post-mortem temporal bone analysis.
		High	*Publication date:* 2020
			
			Jurisdiction studied: United States
			
			Methods used: Cross-sectional
				• Occupation

• Population exposed to noise • Additional effects of noise exposure experienced later in life ○ Tinnitus	The study suggests cochlear neural degeneration as a possible biomarker for tinnitus despite normal audiograms (7) • The study notes that tinnitus and permanent damage to the cochlear nerve can arise after a noise exposure and during aging, even when sensory cells remain intact in patients with normal audiometric sensitivity.	High	*Publication date:* 2023 *Jurisdiction studied:* United States *Methods used:* Cross-sectional	• None reported

• Population exposed to noise
  ○ Civilian/general population
  ○ Military personnel
	Noise exposure appeared to accelerate the progression of hearing loss at frequencies where hearing loss is absent or mild at the end of military service, but	High	*Publication date:* 2021	• Occupation

Dimension of organizing framework	Declarative title and key findings	Relevance rating	Study characteristics	Equity considerations
• Time elapsed since noise exposure and resulting measurement for hearing loss	has no effect on or slows the progression of hearing loss at frequencies where hearing loss exceeds approximately 50 dB (8) • The results suggest that there is delayed onset for hearing loss for veterans with no or mild hearing loss at the end of their military service, but no additional hearing loss for those who already experience significant hearing loss at the end of their service. • More longitudinal research is needed to establish whether the progression of hearing loss following the end of exposure to high-level sounds depends on the type of noise exposure (e.g., steady broadband factory noises versus impulsive sounds).		*Jurisdiction studied:* United States *Methods used:* Re-analysis of existing data from three studies (longitudinal and cross-sectional studies)	

• Population exposed to noise
  ○ Military personnel
• Type of noise exposure
  ○ Steady or continuous noise exposure
    ▪ One-off
    ▪ Repetitive exposure
• Time elapsed since noise exposure and resulting measurement for hearing loss
	When compared to baseline self-reporting on hearing loss, U.S. military members were more likely to self-report new-onset hearing loss during a follow-up survey (administered in three-year intervals) if they were combat deployed, male, of older age, and exposed to chemicals and pesticides (9)
	• Data was obtained from the Millenium Cohort Study questionnaire that collects demographic, health, and exposure data, and reported hearing loss data maintained by the Defense Occupational and Environmental Health Readiness System-Hearing Conservation.
	• 48,540 U.S. military members were surveyed, and participants who did not report hearing loss at baseline (time of entrance) survey but self-reported hearing loss during a follow-up survey (in three-year intervals) were considered as having new-onset self-reported hearing loss; 3,660 participants (7.5%) reported having new-onset hearing loss.
	• Among those deployed, new-onset hearing loss was associated with proximity to explosive devices and experiencing a combat-related head injury.
	• Members of the Army, Navy/Coast Guard, or Marines were more likely to experience hearing loss when compared to those serving in the Air Force.
		High	*Publication date:* January 2015
			
			Jurisdiction studied: United States
			
			Methods used: Cohort study
				• None identified

• Population exposed to noise
  ○ Military personnel
• Type of noise exposure
  ○ Impulsive noise exposure
    ▪ One-off
    ▪ Repetitive exposure
  ○ Steady or continuous noise exposure
    ▪ One-off
    ▪ Repetitive exposure
• Level of noise exposure
  ○ 85–110 dBA
  ○ 110–140 dBA
  ○ Over 140 dBA
	Military personnel are at risk for hearing threshold changes and decline in hearing sensitivity due to occupational noise exposure (10)
	• The focus of the study was to estimate the average annual rate of hearing threshold change during military service for individuals enrolled in the Noise Outcomes in Service members (NOISE) study after September 2001.
	• Eligible participants were individuals with continuous service and completed an audiologic assessment and questionnaires about demographics and non-military exposure.
	• Individuals are deemed noise-exposed if they were at or above 85 dB A-weighted as an eight-hour weighted time, impulse noises of more than 150 dB peak sound pressure, or ultrasonic exposure.
	• For example, the first audiogram describes zero months of military noise exposure, but one year after service, an individual may accrue three months of exposure due to basic training and 9.3 months to a military event with high noise exposure.
		Medium	*Publication date:* 2021
			
			Jurisdiction studied: United States
			
			Methods used: Longitudinal retrospective
				• None reported

Dimension of organizing framework	Declarative title and key findings	Relevance rating	Study characteristics	Equity considerations
• Time elapsed since noise exposure and resulting measurement for hearing loss	• The authors concluded that some military personnel are at risk for hearing threshold changes due to occupational noise exposure and that their hearing sensitivity is declining faster rates than people in their age group.			
• Population exposed to noise ○ Military personnel • Type of noise exposure ○ Steady or continuous noise exposure ▪ Repetitive exposure • Level of noise exposure ○ 0–85 dBA • Time elapsed since noise exposure and resulting measurement for hearing loss Sound exposure/time interval: 13.3 years	Despite working in a noisy environment with high sound exposure levels, military musicians' average hearing ability only slightly deteriorated in noise-sensitive frequencies (3, 5, and 6 kHz) over a period of 13.3 years, indicating that the long-term auditory training of musicians may lead to a delayed onset of age-related hearing loss (11) • Assuming each musician was exposed to a constant sonic load of 83 dB every working day for 13.3 years without using any ear protection devices or other protective measures, the predicted hearing losses are as follows: ± 1dB at 3 kHz, 3 dB at 4 kHz, and 2 dB at 6 kHz.	Medium	*Publication date:* 12 April 2018 *Jurisdiction studied:* Germany *Methods used:* Longitudinal study	• Occupation
• Population exposed to noise ○ Military personnel • Type of noise exposure ○ Impulsive noise exposure ▪ Repetitive exposure ○ Steady or continuous noise exposure ▪ Repetitive exposure • Time elapsed since noise exposure and resulting measurement for hearing loss • Extent of hearing loss later in life • Additional effects of noise exposure experienced later in life ○ Tinnitus	Hearing loss and tinnitus were more prevalent among personnel who experience frequent exposure to military noise; while the influence of leisure-time noise amplified this effect, it was not directly correlated with hearing loss on its own (12) • The occurrence of high-frequency hearing loss at 4 and 6 kHz was 62.7%. However, the majority of cases were classified as slight (59.5% of any kind of hearing loss), whereas severe hearing loss (>65 dB) was observed in 9.3% of cases. • 66.0% of the participants reported experiencing tinnitus, with 7.3% experiencing it often (relative risk ratio (RRR) 2.6, 95% CI 1.2–5.3) and 48.7% experiencing it sometimes (RRR 29.9, 95% CI 3.3–269.5). • Being in a noisy environment (RRR 3.42, 95% CI 1.03–11.37), working with noise-producing equipment (RRR 8.24, 95% CI 1.87−36.45), riding in an armoured personnel carrier (PASI) or a tracked articulated all-terrain carrier (Bandvagn) (RRR 2.92, 95% CI 1.08−7.92) and shooting with blanks (RRR 3.64, 95% CI 1.12−11.82) can significantly increase the risk of hearing loss, which further escalates with longer exposure time. • Participants' previous health problems, music-listening habits, and exposure to loud noise in non-military setting were not independently associated with hearing loss. However, in several cases they increased the RRR alongside with military exposure.	Medium	*Publication date:* 31 December 2020 *Jurisdiction studied:* Not reported *Methods used:* Cross-sectional observational study	• Occupation

Appendix 4: Excluded evidence documents that were based on animal studies

Document type	Hyperlinked title
Single studies	Circadian regulation of cochlear sensitivity to noise by circulating glucocorticoids
	Translating animal models to human therapeutics in noise-induced and age-related hearing loss
	Hidden hearing injury: The emerging science and military relevance of cochlear synaptopathy
	Time course of organ of Corti degeneration after noise exposure
	Disruption of ion-trafficking system in the cochlear spiral ligament prior to permanent hearing loss induced by exposure to intense noise: possible involvement of 4-hydroxy-2-nonenal as a mediator of oxidative stress
	Noise trauma induced plastic changes in brain regions outside the classical auditory pathway
	Time course of cell death due to acoustic overstimulation in the mouse medial geniculate body and primary auditory cortex
	Noise-induced hearing loss: Permanent versus temporary threshold shifts and the effects of hair cell versus neuronal degeneration

Appendix 5: Documents excluded at the final stages of reviewing

Document type	Hyperlinked title
Single studies	Hearing loss in the trenches - a hidden morbidity of World War 1
	Hearing loss in Israeli Air Force aviators: Natural history and risk factors
	Noise Outcomes in Servicemembers Epidemiology (NOISE) Study: Design, methods, and baseline results
	Hearing loss in the trenches - a hidden morbidity of World War 1
	Auditory changes following firearm noise exposure, a review
	Comparison of distortion product otoacoustic emissions and pure tone audiometry in occupational screening for auditory deficit due to noise exposure

Waddell K, Wu N, Demaio P, Bain T, Bhuiya A, Wilson MG. Rapid evidence profile #71: Examining the association between noise exposure and delayed hearing loss. Hamilton: McMaster Health Forum, 10 May 2024.

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