Australian Government
Repatriation Medical Authority

REPATRIATION MEDICAL AUTHORITY

STATEMENT OF REASONS

REGARDING THE OUTCOME OF THE INVESTIGATION INTO SIGNAL TO NOISE RATIO HEARING LOSS

PART I INTRODUCTION

1. The Repatriation Medical Authority (the Authority) has decided, pursuant to subsection 196B(6) of the Veterans' Entitlements Act 1986 (the Act), not to make Statements of Principles concerning signal to noise ratio hearing loss, following a notice of investigation gazetted on 20 October 2025.

2. After considering the sound medical-scientific evidence (SMSE) available to the Authority concerning signal to noise ratio hearing loss, the Authority formed the view that the SMSE is insufficient to enable the Authority to determine the causation of signal to noise ratio hearing loss on either the basis of the reasonable hypothesis or balance of probability standard. The SMSE is therefore insufficient to determine Statements of Principles for signal to noise ratio hearing loss.

PART II BACKGROUND TO THE INVESTIGATION

3. The Repatriation Medical Authority (the Authority) received a request for an investigation on 6 August 2025 from an applicant who is eligible under the 196E of the Act.
4. The request stated that signal to noise ratio hearing loss may be under-recognised in military personnel who experience high levels of occupational noise exposure with a view to creating a new Statement of Principles (SoP) or review an existing SoP.
5. The Authority, at its meeting on 7 October 2025, decided to issue a Notice of Investigation
6. The Notice of Investigation was signed by the Chairperson on 17 October 2025 and gazetted on 20 October 2025. Submissions were due to the Authority on 21 November 2025.

PART III SUBMISSIONS RECEIVED BY THE AUTHORITY PURSUANT TO SECTION 196F

7. Following notification of the investigation, the Authority received one submission from persons or organisations eligible to make submissions under section 196F of the Act.

8. The submission included some material that does not fall within the definition of sound medical or scientific evidence (SMSE) in accordance with section 5AB(2) of the Act.

9. The below were considered relevant SMSE with regards to signal to noise ratio loss:

    - Liberman MC, Epstein MJ, Cleveland SS, et al (2016). Toward a Differential Diagnosis of Hidden Hearing Loss in Humans. PLoS One. Sep 12;11(9):e0162726.

    - Liberman MC, Kujawa SG. (2017) Cochlear synaptopathy in acquired sensorineural hearing loss: Manifestations and mechanisms. Hear Res, 349:138-147.

    - Plack CJ, Barker D, Prendergast G. (2014). Perceptual consequences of "hidden" hearing loss. Trends Hear. Sep 9;18: 2331216514550621

10. Studies conducted in animals were largely excluded.

PART IV INFORMATION AVAILABLE TO THE REPATRIATION MEDICAL AUTHORITY

11. The following information was available to the Authority.

12. A literature search was conducted using PubMed for any relevant article concerning (("Hearing Loss/epidemiology"[Mesh] OR "Hearing Loss/etiology"[Mesh])) AND ("signal to noise ratio"[Title/Abstract]) with the search timeframe dating back to 1992. This revealed 66 articles that contained a reference to signal to noise ratio loss of which 9 were relevant. Articles were selected based on relevance, study quality, reliability and journal authority. The above search was supplemented by specific searches for various factors of interest, internet searches, manual searches of reference lists and consideration of relevant sections of textbooks, if appropriate.

13. Medical or scientific publications as set out in the bibliography attached

14. A briefing paper prepared by a Researcher of the Secretariat for presentation to the Authority

15. A discussion paper prepared by a Researcher for the October 2025 Repatriation Medical Authority meeting.

16. The material provided by the applicant with respect to their request for investigation on 5 August 2025

17. The submission received in response to the Notice of Investigation

PART V LEGISLATION TO WHICH THE AUTHORITY HAD REGARD

SMSE

Section 5AB(2) of the Act defines SMSE as follows:

*"Information about a particular kind of injury, disease or death is taken to be **sound medical-scientific evidence** if:*

(a) the information:

(i) is consistent with material relating to medical science that has been published in a medical or scientific publication and has been, in the opinion of the Repatriation Medical Authority, subjected to a peer review process; or

(ii) in accordance with generally accepted medical practice, would serve as the basis for the diagnosis and management of a medical condition; and

(b) in the case of information about how that kind of injury, disease or death may be caused - meets the applicable criteria for assessing causation currently applied in the field of epidemiology."

Relationship to Service - Section 196B(14) of the Act, states as follows:

(14) A factor causing, or contributing to, an injury, disease or death is ***related to service*** rendered by a person if:

(a) it resulted from an occurrence that happened while the person was rendering that service; or

(b) it arose out of, or was attributable to, that service; or

(c) it resulted from an accident that occurred while the person was travelling, while rendering that service but otherwise than in the course of duty, on a journey:

(i) to a place for the purpose of performing duty; or

(ii) away from a place of duty upon having ceased to perform duty; or

(d) it was contributed to in a material degree by, or was aggravated by, that service; or

(e) in the case of a factor causing, or contributing to, an injury—it resulted from an accident that would not have occurred:

(i) but for the rendering of that service by the person; or

(ii) but for changes in the person's environment consequent upon his or her having rendered that service; or

(f) in the case of a factor causing, or contributing to, a disease—it would not have occurred:

(i) but for the rendering of that service by the person; or

(ii) but for changes in the person's environment consequent upon his or her having rendered that service; or

(g) in the case of a factor causing, or contributing to, the death of a person—it was due to an accident that would not have occurred, or to a disease that would not have been contracted:

(i) but for the rendering of that service by the person; or

(ii) but for changes in the person's environment consequent upon his or her having rendered that service.

Insufficient Evidence upon Investigation - Section 196B (6) of the Act states:

(6) If, after carrying out the investigation, the Authority is of the view:

(a) that there is no sound medical-scientific evidence on which it can rely to determine a Statement of Principles under subsection (2) or (3) in respect of that kind of injury, disease or death; or

(b) that the sound medical-scientific evidence on which it can rely is insufficient to allow it to do so;

the Authority must make a declaration in writing:

(c) stating that it does not propose to make a Statement of Principles; and

(d) giving the reasons for its decision.

18. The Authority also had regard to sections 196B(2) and 196B(3) of the Act setting out its function to determine Statements of Principles on the basis of Reasonable Hypothesis and/or Balance of Probabilities.

PART VI SUMMARY OF THE SMSE

19. Review paper on the possible mechanism of signal to noise ratio loss.

Liberman and Kujawa (2017)[1] in their review stated animal studies are suggesting the most vulnerable elements of the inner ear to be the synaptic connections between hair cells and sensory neurons and that subtotal cochlear synaptopathy, and the primary neural degeneration that follows, does not elevate hearing thresholds (not detected on pure tone audiometry, in humans). The authors of this American publication also acknowledge that reports of spontaneous re-innervation can be seen (Puel et al, 1995 and Pujol and Puel1999), or that some immediate loss may be reversible (Lui et al 2012), further research is required to clarify the mechanisms leading to a signal to noise ratio loss.

20. Cohort study suggesting noise damage in young adulthood is a possible contributing factor to cochlear synaptopathy.

Liberman et al (2016)2 conducted a cohort study and tested the hypothesis that cochlear synaptopathy is widespread among young adults with normal audiometric thresholds, especially those exposed to loud noise on a regular basis, for example young people attending live music concerts. They report that high frequency audiometry may provide an early warning of ear abuse and propose an avenue for early intervention. The study also stated that noise damage in early adulthood likely accelerates the age-related further loss of hair cells and cochlear neurons and that further clinical trials of regenerative therapies will require objective measures of cochlear synaptopathy to identify candidates and to track treatment efficacy.

21. Review paper proposes ageing as an aetiology of auditory nerve fibre loss

Plack et al (2014)[3] states in their abstract that there is “no direct link made between noise exposure, cochlear neuropathy, and perceptual difficulties”. Animal experiments also reveal that the ageing process itself, in the absence of significant noise exposure, is associated with loss of auditory nerve fibres”. They also reference that signal to noise ratio loss is potentially a major health issue and that investigations are ongoing to identify the cause. The study referenced research conducted in both animal and human subjects.

22. Systematic Review regarding detection and surveillance of noise-induced hearing loss.

Makaruse et al (2025)[4] conducted a systematic review, published in Britain, proposing two important questions. Firstly, for which audiometric test frequencies or pure tone averages are hearing threshold levels (HTLs) most susceptible to early

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[1] Liberman MC, Kujawa SG. (2017) Cochlear synaptopathy in acquired sensorineural hearing loss: Manifestations and mechanisms. Hear Res, 349:138-147.

[2] Liberman MC, Epstein MJ, Cleveland SS, et al (2016). Toward a Differential Diagnosis of Hidden Hearing Loss in Humans. PLoS One. Sep 12;11(9):e0162726.

[3] Plack CJ, Barker D, Prendergast G. (2014). Perceptual consequences of "hidden" hearing loss. Trends Hear. Sep 9;18: 2331216514550621.

[4] Makaruse N, Maslin MRD, Shai Campbell Z. Early identification of potential occupational noise-induced hearing loss: a systematic review. Int J Audiol. 2025 May;64(5):419-428.

occupational noise induced hearing loss before significant damage (occurs). Secondly, they hoped to identify which early flag metric best detects early hearing shifts due to noise for occupational noise induced hearing loss (NIHL) surveillance. The study concluded that further research was required to refine current metrics and suggested exploring extended high frequencies as a tool for monitoring to prevent noise induced hearing loss.

23. Longitudinal cohort study revealing decline in the ability to recognise speech in noise declines with age, beginning age 50 years, and that smoking increases the decline.

Goderie et al (2020)[5] conducted a longitudinal cohort study on hearing where they investigated the trends of longitudinal change in speech recognition in noise. The study concluded that speech recognition in noise declined significantly over a 10-year follow-up period in adults aged 18-70 years compared to baseline. The study revealed that the increased rate of decline in the ability to recognise speech in noise starts at the age of 50 years and that smoking increases the decline. The study did not specifically address the aetiology for the hearing decline.

24. Case-control study regarding otic trauma and evaluating the best method for early detection of hearing deficits – not specifically related to the aetiology of SNRHL

Buchler et al (2012)[6] conducted a prospective case control study evaluating the relative value of pure tone audiometry (PTA), extended high-frequency audiometry (EFA) and transiently evoked otoacoustic emissions (OAE), and distortion products when monitoring acute acoustic trauma (AAT) in Switzerland. The study enrolled 71 active-duty soldiers with normal hearing. 41 soldiers suffered assault-rifle-induced acute acoustic traumas with hearing loss and tinnitus (remaining 30 soldiers acted as the control group). The study concluded that while PTA and EFA are both necessary to identify the full extent of the temporary threshold shifts following acoustic trauma, pure tone audiometry remains the most important measurement to monitor acute acoustic trauma. This study did not provide insight into signal to noise ratio loss specifically.

25. Case-control study regarding otic trauma and evaluating the best method for early detection of hearing deficits – not specifically related to the aetiology of SNRHL.

Balatsouras et al (2005) [7] conducted a case control study examining extended high frequency hearing (EHF) loss in young soldiers with acoustic trauma in Greece. The study enrolled 39 soldiers who had been hospitalised for hearing loss and tinnitus following acoustic trauma caused by shooting practice during basic training. Conventional audiometry in the frequency range 0.25 – 8 kHz and EHF audiometry in the frequency range 9-20Hz were performed on admittance and on discharge. 30 healthy recruits of similar age and sex were used as controls. The authors concluded that the use of Extended high frequency audiometry added no significant additional information to conventional pure-tone audiometry. This study did not provide insight

[5] Goderie TPM, Stam M, Lissenberg-Witte BI, et al (2020). 10-Year Follow-Up Results of The Netherlands Longitudinal Study on Hearing: Trends of Longitudinal Change in Speech Recognition in Noise. Ear Hear. May/Jun;41(3):491-499.

[6] Büchler M, Kompis M, Hotz MA. (2012) Extended frequency range hearing thresholds and otoacoustic emissions in acute acoustic trauma. Otol Neurotol. Oct;33(8):1315-22.

[7] Balatsouras DG, Homsioglou E, Danielidis V. (2005) Extended high-frequency audiometry in patients with acoustic trauma. Clin Otolaryngol. Jun;30(3):249-54.

into signal to noise ratio loss specifically.

26. Uncontrolled cross-sectional study, age and noise are factors that may lead to SNRHL

Bramhall et al (2025)[8] conducted an uncontrolled cross-sectional study to determine the listening effort during a speech perception in noise task (measured using pupillometry), and physiological indicators of cochlear deafferentation (ABR, EFR and MEMR – see key below), in a sample of military veterans in America.

Key
ABR = auditory brain response wave 1 amplitude
EFR = envelope following response magnitude
MEMR = wideband middle ear muscle reflex magnitude
NCRAR = National Centre for Rehabilitative Auditory Research Case Control
EFR = envelope following response

The veterans were expected to have high degrees of deafferentation due to their history of military noise exposure. The veterans had clinically normal hearing based on pure tone audiometry, no otologic or neurologic past history (including concussion) but did report other auditory complaints. The study enrolled 48 military veterans (63% male), aged 28-48 years, who reported frequent or constant tinnitus and/or speech perception difficulty. Participants were recruited from previous studies conducted at the NCRAR(see key above), via email and by contacting veterans with normal audiograms who were previously seen in the Portland VA audiology clinic. If both ears qualified, then one ear was chosen at random to be used over the three testing days of the study. If only one ear qualified, then this ear was used for the entire study. All participants were also screened to rule out any visual factors that would interfere with the pupillometry results and all participants were native English speakers or had learnt English by 5 years of age.

This paper also referenced several animal studies where cochlear deafferentation resulting in temporal processing and signal to noise detection deficits and the authors hypothesise that the same process would be expected in humans. As direct measurement of cochlear deafferentation is not possible in living humans they set out to study several non-invasive auditory physiological measures that are sensitive to deafferentation in animal models. Postmortem temporal bone studies have demonstrated cochlear synaptopathy in humans with age and noise exposure as risk factors in papers by the same author (Bramhall et al 2021, 2021, 2022). To date human studies into these physiological markers of cochlear synaptopathy have produced mixed findings and there is a lack of consensus regarding the impact of deafferentation on speech in noise. Suggested reasons for the missed findings included using different physiological and speech in noise measures, differences in population characteristics, differences in cognitive abilities amongst subjects and the possibility of a non-linear relationship between EFR (see key above) magnitude and the performance of the Words in noise (WIN) test. The authors hypothesise that if this non-linear relationship holds true in future studies, that an association will only be demonstrated in those at high risk of cochlear synaptopathy due to age or occupational exposure.

The study found that only one of the four physiological variables was statistically significant. There was a clear association between auditory brain response wave 1 amplitude (ABR) and pupil dilation rate. The results suggest that cochlear deafferentation may result in increased listening effort during speech perception in

[8] Bramhall NF, Buran BN, McMillan GP. (2025) Associations between physiological indicators of cochlear deafferentation and listening effort in military Veterans with normal audiograms. Hear Res, 461:109263.

noise even if performance of the task is not negatively impacted. The data also suggests the relationship between cochlear deafferentation and listening effort may be non-linear and increased listening effort may only occur after a particular threshold level of deafferentation has been reached and that further research will be necessary to confirm the non-linearity of the relationship.

The strengths of this study include that the subjects were military veterans expected to have high degrees of deafferentation due to their history of military noise exposure, the use of several tests assessing physiological variables, however the ability of these tests to detect changes is not yet clear, and the study attempted to adjust for tinnitus. The weaknesses of the study include that only 1 of 4 physiological variables returned a statistically significant result, and the results may have been confounded by PTSD, depression or anti-depressant use, or age (as veterans ages ranged from 24-48 years old).

27. Cross-sectional study of noise induced hearing loss, including SNRHL, DPOAEs) showed only one significantly decreased value at a frequency of 4Hz in the right ears of the ground staff group, EFH more sensitive in detecting lasting NIHL.

Kuo et al (2021)[9] conducted a cross-sectional study of noise-induced hearing loss in military staff (pilots and ground staff) in Taiwan. The study enrolled 40 pilots, 40 ground staff and 136 age-matched controls (mean age 30 years, 91% male). With regards to signal to noise ratio loss, the distortion-product otoacoustic emission (DPOAEs) showed only one significantly decreased value at a frequency of 4Hz in the right ears of the ground staff group (and not pilots or controls). The data indicated that measuring DPOAE's is more helpful in evaluating the instantaneous cochlear insult produced by noise exposure and that extended high frequency audiograms (EHF) are more sensitive in detecting potentially lasting NIHL.

PART VII MATERIAL FINDINGS OF FACT AND REASONS FOR DECISION

28. The Authority considered a range of SMSE examining the relationship between noise exposure and signal to noise ratio hearing loss. While several studies identified potential associations, the evidence was inconsistent and further research is required to confirm the association.

29. Therefore, the current SMSE does not yet provide sufficient clarity or consistency to support a causal relationship between loud noise and a signal to noise ratio hearing loss.

Conclusion

30. The evidence to date for an association between loud noise and a signal to noise ratio loss has produced inconsistent results. The last decade of research has not produced consistent findings with regards to the aetiology or an improved means for early detection and prevention of noise induced hearing loss, including signal to noise ratio hearing loss.

[9] Kuo CY, Hung CL, Chen HC, (2021) The Immediate and Long-Term Impact of Military Aircraft Noise on Hearing: A Cross-Sectional Comparison of Fighter Pilots and Ground Staff. Int J Environ Res Public Health, 18(6):2982.

31. The Authority concluded that the SMSE available to it at this time is insufficient to justify the making of Statements of Principles concerning “Signal to Noise Ratio Hearing Loss”.

PART VIII DECISION

32. At its meeting on 7 April 2026, the Authority decided not to make Statement of Principles in respect of Signal to Noise Ratio Hearing Loss under subsection 196B(6) of the Act as the Authority concluded, for the reasons set out above, there was insufficient SMSE.

Professor Terence Campbell AM
Chairperson
Repatriation Medical Authority

16 April 2026

PART IX BIBLIOGRAPHY

Balatsouras DG, Homsioglou E, Danielidis V. (2005) Extended high-frequency audiometry in patients with acoustic trauma. Clin Otolaryngol. Jun;30(3):249-54.

Bramhall NF, Buran BN, McMillan GP. (2025) Associations between physiological indicators of cochlear deafferentation and listening effort in military Veterans with normal audiograms. Hear Res, 461:109263.

Büchler M, Kompis M, Hotz MA. (2012) Extended frequency range hearing thresholds and otoacoustic emissions in acute acoustic trauma. Otol Neurotol. Oct;33(8):1315-22.

Goderie TPM, Stam M, Lissenberg-Witte BI, et al (2020). 10-Year Follow-Up Results of The Netherlands Longitudinal Study on Hearing: Trends of Longitudinal Change in Speech Recognition in Noise. Ear Hear. May/Jun;41(3):491-499.

Kuo CY, Hung CL, Chen HC, (2021) The Immediate and Long-Term Impact of Military Aircraft Noise on Hearing: A Cross-Sectional Comparison of Fighter Pilots and Ground Staff. Int J Environ Res Public Health, 18(6):2982.

Liberman MC, Epstein MJ, Cleveland SS, et al (2016). Toward a Differential Diagnosis of Hidden Hearing Loss in Humans. PLoS One. Sep 12;11(9):e0162726.

Liberman MC, Kujawa SG. (2017) Cochlear synaptopathy in acquired sensorineural hearing loss: Manifestations and mechanisms. Hear Res, 349:138-147.

Makaruse N, Maslin MRD, Shai Campbell Z. Early identification of potential occupational noise-induced hearing loss: a systematic review. Int J Audiol. 2025 May;64(5):419-428.

Plack CJ, Barker D, Prendergast G. (2014). Perceptual consequences of "hidden" hearing loss. Trends Hear. Sep 9;18: 2331216514550621.