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Existing evidence on noise induced hearing loss and tinnitus in the military and other occupational groups

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Scope of the Report

This report was commissioned for the 'HearWell Collaboration' – an international collaboration with the aim of developing a comprehensive and relevant research portfolio in the areas of prevention, ultra-early detection and treatment of Noise Induced Hearing loss (NIHL) and tinnitus.

The report outlines the existing evidence for a range of issues relating to NIHL and tinnitus pertaining primarily to a military population. The report covers:

- The prevalence and incidence of NIH and tinnitus
- The detection of NIHL and tinnitus
- The impact of NIHL and tinnitus on Quality-of-Life (living with HL)
- The impact of NIHL and tinnitus on the ability to work of military personnel.
- The cost implications of NIHL and tinnitus and the cost-effectiveness of screening and prevention programmes

For each of these issues, the volume and nature of the existing secondary evidence (e.g. systematic reviews) and primary evidence was ascertained and key findings and methodological issues reported. This report aims to inform decisions about future research priorities.

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List of Abbreviations

Term	Abbreviation
Acceptable noise level	ANL
Acoustic Reflex Threshold	ART
American Academy of Otolaryngology-Head and Neck Surgery	AAO-HNS
Amsterdam Inventory for Auditory Disability and Handicap (AIADH)	AIADH
Assessing the methodological quality of systematic reviews	AMSTAR
Automated auditory brainstem response	AABR
Bone anchored hearing aids	BAHAs
Bone conduction hearing aids	BCHAs
Canadian Agency for Drugs and Technologies in Health	CADTH
Cervical vestibular evoked myogenic potentials	cVEMP
Cochrane central register of controlled trials	CENTRAL
Cochrane database of systematic reviews	CDSR
Confidence intervals	CI
Cortical evoked audiometry	CERA
Database of abstracts of reviews of effects	DARE
Decibel	dB
Distortion product otoacoustic emissions	DPOAE
Electric response audiometry using auditory steady-state response	ASSR-ERA
Evoked otoacoustic emissions	EOAE
Health and Safety Executive	HSE
Hearing Disability and Handicap Scale	HDHS
Hearing Handicap and Disability Inventory	HHDI
Hearing Handicap Inventory for Adults/Adults-Screening	HHIA/HHIA-S
Hearing Handicap Inventory for the Elderly/Elderly-Screening/Elderly-Spouse	HHIE/ HHIE-S/ HHIE-SP
Hearing Handicap Questionnaire	HHQ
Hearing in Noise Test	HINT
Health technology assessment	HTA
Hearing loss	HL
Hertz	Hz
Incremental cost-effectiveness ratio	ICER
International classification of functioning, disability and health	ICF
International classification of diseases, 9th revision, clinical modification	ICD-9 CM
International Network of Agencies for Health Technology Assessment	INHATA
Likelihood ratios	LR
Medical subject headings	MeSH
Meta-analysis	MA
Mild traumatic brain injury	MTBI
Ministry of Defence	MoD
National health and nutrition examination surveys	NHANES
Noise induced hearing loss	NIHL
Noise induced hearing threshold shift	NIHTS
Notched noise - brainstem electric response audiometry	NN-BERA
Otoacoustic emissions	OAE
Permanent threshold shift	PTS

Posttraumatic stress disorder	PTSD
Preferred reporting items for systematic reviews and meta-analysis	PRISMA
Pure tone audiometry	PTA
Quality Adjusted Life Year	QALY
Quality of Life	QoL
Royal Norwegian Navy	RNoN
Sensorineural hearing loss	SNHL
Significant threshold shifts	STS
Speech in Noise Test	SINT
Speech Recognition in Noise Test	SPRINT
Speech recognition threshold	SRT
Standard error of measurement	SEM
Steady state evoked responses	SSEP
Strengthening the reporting of observational studies in epidemiology	STROBE
Systematic review	SR
Threshold equalizing noise	TEN
Tinnitus Handicap Inventory	THI
Tinnitus Handicap Questionnaire	THQ
Tinnitus Questionnaire	TQ
Tinnitus Reaction Questionnaire	TRQ
Tinnitus Severity Index	TSI
Tinnitus Severity Questionnaire	TSQ
Transient evoked otoacoustic emissions	TEOAE
Traumatic brain injury	TBI
Uncomfortable loudness level	ULL
World Health Organisation	WHO
Whispered Voice Test	WVT
Words in Noise Test	WINT
Word Recognition Scores	WRS

1 Introduction

1.1 Background

Noise induced hearing loss (NIHL) and tinnitus are major health issues affecting the armed forces community.[1] Almost every serviceman or woman will be exposed to hazardous levels of noise from various sources such as aircraft, weapons systems and vehicles at some point in their career, putting them at risk of developing NIHL and/or tinnitus.[2, 3] NIHL can be caused by prolonged exposure to loud noise or short exposure to very high sound levels (e.g. acoustic trauma from explosion).[1] The prevalence of NIHL and tinnitus in military service personnel is greater than the general population,[1] and it is associated with considerable personal and financial cost implications.[1, 3] As hearing loss is not reversible, early detection and intervention is critical to minimise harm.[4]

1.2 Rationale for report

There is a lack of clarity around many aspects related to NIHL and tinnitus. Therefore, a review was commissioned as part of the HearWell initiative in order to reveal the extent and nature of the existing evidence on key issues pertinent to NIHL in military personnel. These issues were identified and prioritised in consultation with those representing key stakeholders (e.g. military, occupational health, otorhinolaryngology). The issues covered by this report are:

1. *The prevalence and incidence of NIH and tinnitus amongst military personnel*
2. *The detection of NIHL and tinnitus, which encompasses*:
    - reproducibility of individual tests
    - test accuracy/ level of agreement between different tests
    - incremental benefit of using more than one test
    - utility of tests in different stages of NIHL e.g. early detection
    - utility of tests in different settings
    - emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo).
3. *The impact of NIHL and tinnitus on quality-of-life (living with HL) of those with NIHL and tinnitus*
4. *The impact of NIHL and tinnitus on the ability to work of military personnel*
5. *The cost implications of NIHL and tinnitus and the cost-effectiveness of screening for, and prevention of, NIHL*

The purpose of the review was to:

- "Map" the existing evidence for each issue in terms of existing systematic reviews, or other types of evidence syntheses, such as health technology assessments or guidelines
- Appraise the quality (methodological robustness) of the existing systematic reviews and other relevant evidence and provide a brief overview of the main findings, the volume and types of

primary studies contributing to the findings, and any methodological concerns relating to the primary studies included in the review expressed by the respective review authors.

- To gauge the likely volume and nature of primary studies that would be available to populate a new systematic review where no recent review exists (i.e. assess the feasibility of a new, comprehensive systematic review).
- Identify gaps in evidence where primary studies are required.

2 Methodology

The primary focus of the review was evidence pertaining directly to a military population. Evidence identification aimed to be comprehensive and this review was undertaken using processes to minimise error and bias.

Where evidence directly relating to the military was limited, systematic reviews and other reports relating to other occupational groups or a general population were included, as this evidence may be applicable across more than one population/occupational group.

Search Strategies

To identify relevant evidence a sensitive search strategy was developed by an information specialist with input from the project team to identify systematic reviews and other relevant reports in bibliographic databases. Free text and index terms relating to NIHL and tinnitus were combined and searches were run to encompass any occupational groups. The search strategy was adapted for use in different databases which were searched from their inception to May 2016. The sources searched included MEDLINE, Embase and the Cochrane Library (CDSR, DARE and HTA); the full extensive list of sources can be found in Appendix 2. No language or study design restrictions were applied to searches. Members of HearWell were contacted to identify any relevant grey literature.

Where few or no relevant systematic reviews were available, additional searches were performed in order to gauge the volume/nature of primary studies. Search strategies were adapted for this purpose accordingly. Full details of the search strategies for reviews and primary studies are provided in Appendix 3 and Appendix 4.

Screening

All records identified from the literature search were imported into Endnote (X7.5, Thomas Reuters) and duplicate records were removed. Titles and abstracts of all records were screened for relevance to each of the target issues and full texts were obtained where necessary to facilitate this process. Screening was undertaken by a single reviewer.

Data Extraction and Quality Assessment

The type of data extracted from the identified reviews/guidelines depended on the target issue addressed. Details were extracted on the type of publication (systematic review, guideline, other), setting, population (e.g. military, other occupation), definition of hearing loss, review methods, relevant outcomes (e.g. incidence and prevalence rates, test accuracy, costs of NIHL) and any methodological limitations or concerns highlighted by the respective review authors. Assessment of the risk of bias within reviews was based on criteria derived from the AMSTAR checklist.[5]

Primary studies were not assessed for risk of bias nor formally data extracted as these studies were only to be briefly described to highlight their availability in the context of the feasibility of undertaking a new review or updating an existing review.

Data Synthesis and Presentation

Studies were grouped by the issue to which they were relevant and their details tabulated. A narrative synthesis was undertaken on each issue and a distinction made between types of evidence (review, other report or primary study) and whether the findings relate directly to a military population. Summary statements are provided in this report for each issue to aid conveyance of the key messages.

We also commented on the nature and volume of primary studies and the implications for undertaking a new systematic review in each area.

Other questions relating to NIHL and tinnitus

Whilst findings presented in this report relate only to the five priorities issues, it should be noted that the searches for secondary evidence (reviews) covered all of the issues initially identified (see Appendix 1). Search results have already been screened for relevance to these remaining issues and the reference lists are available on request. The data from these reviews can be synthesis and presented (as detailed above) if required.

3 Findings

A total of 1,983 articles were identified from the searches. Three unpublished reports (the Royal British Legion report 2014[1], Gardiner 2015[6] and Reichenbach 2014[7]) were obtained via the HearWell team. Figure 1 illustrates the study selection process.

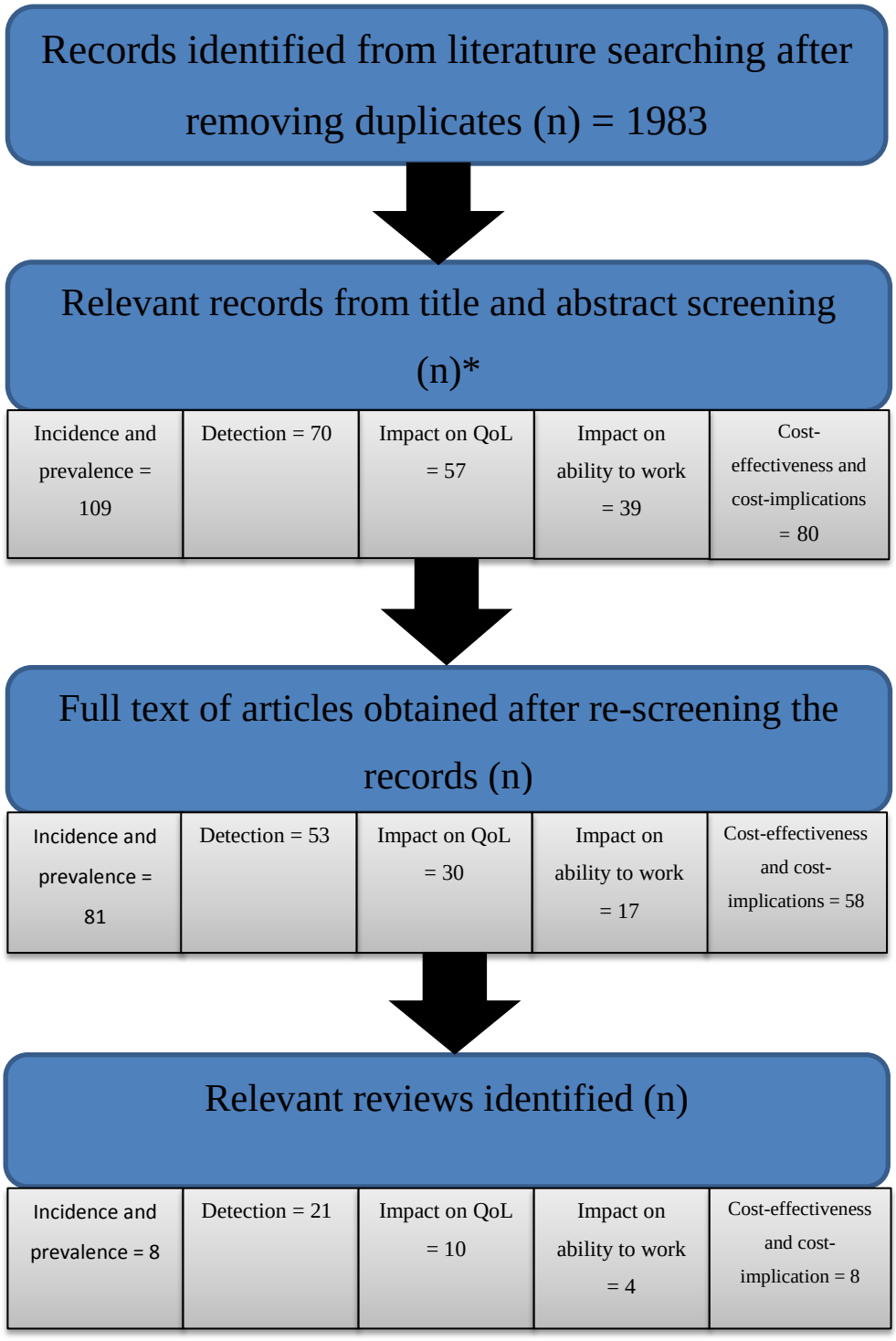

Figure 1**:** Study selection process (reviews)

*Some studies contributed to more than one section of this report

3.1 Prevalence and incidence of NIHL and tinnitus

Summary

- Four recent reviews and four additional reports informed the findings on the incidence and prevalence of NIHL and tinnitus in a military population.
- There was substantial heterogeneity between both the reviews and the primary studies included within, in terms of setting, type of military population, methods used to assess hearing loss and definition of hearing loss. This made any quantitative synthesis of data within reviews difficult, and most reviews used a mainly narrative approach to report data from primary studies.
- Where ranges or point estimates were reported, these varied widely, though there was a trend towards a greater incidence of hearing loss with blast injuries and longer length of service.
- There were some methodological concerns across the identified reviews.
- Searches to gauge the volume and nature of primary studies indicated that there is a fairly substantial pool of new evidence.
- A new review to encompass this newer evidence and to address methodological limitations of the existing reviews is warranted. Heterogeneity across the primary studies means that the review question and analyses would have to be carefully defined.

3.1.1 Existing evidence syntheses

Details of reviews relevant to the incidence and prevalence of NIHL and tinnitus are documented in Table 1 (Appendix 5). Eight reviews were identified comprising of three systematic reviews (Lie 2016[8], Theodoroff 2015[9] and Pawlaczyk-Luszczynska 2013[10]), one non-systematic review (Warner 2015[11]), two reports pertaining to the military (Royal British Legion[1] and veterans of US military service[3]), a literature review on NIHL in the armed forces (Reichenbach 2014[7], grey literature) and a document from the Ministry of Defence (MoD)[12] stating the number of armed personnel in the UK affected by poor/impaired hearing.

A protocol for a systematic review (CRD42013003398[13]) on the prevalence of hearing loss internationally (not restricted to the military) was also identified. The authors were contacted for interim findings, but no results were available and the review is currently on hold (10/11/16).

The three systematic reviews[8-10] and one non-systematic review[11] were not based specifically on UK military personnel. One review included military veterans and service members[9], one a military aviation population[11] and the remaining two[8, 10] included any occupational groups, including the military. The reviews[8-11] included mainly cross-sectional and longitudinal studies. The sample size of

the included studies ranged from 7 to 804,535 military personnel (based on the information from three reviews[8, 9, 11]). The two military reports included a report by the Royal British Legion[1] that aimed to outline information on service related hearing problems in the UK Armed forces and a budget and policy document [3] on the US military veterans. Four reviews[8-11] had undertaken extensive literature search to identify relevant studies and clearly stated the studies eligibility criteria. However, it was unclear if screening and data extraction was done in duplicate for two[8, 10, 11] and three reviews[8, 10] respectively. Information on quality assessment of included studies was reported in only one review.[8] The remaining four reviews[1, 3, 7, 12] reported insufficient information to make an assessment of their methodological quality. See Table 1 (Appendix 5) for comments on the methodology of the reviews.

Settings and populations varied both across reviews and between primary studies included in the respective reviews. Heterogeneity resulted from differences in exposed and control populations, type and length of noise exposures (e.g. continuous or impulse noise), ways of assessing hearing impairment (e.g. audiogram, clinical questionnaire) and the variable definition of NIHL (e.g. hearing loss in the frequency of 0.5 to 2 kHz, 0.5 to 4 kHz or 3 to 6 kHz). One common finding across all the reviews was that military service is associated with an increased the risk of hearing impairment. None of the reviews reported an overall summary point estimate or even a range of incidence or prevalence due to heterogeneity across the included primary studies. The main findings from included primary studies for various subgroups defined within the reviews and a wider military population are below:

- **Infantry/artillery:** Eleven studies across 3 reviews[8-10] were identified. Overall studies found "significant" (2 studies) or "higher than expected" (3 studies) hearing loss in military populations compared to control groups. Other findings were a positive correlation between hearing loss and length of noise exposure (1 study), and the occurrence of temporary hearing loss from short-term firearm exposure (5 studies). Reporting was mainly narrative, with only one study reporting a point estimate.
- **Navy:** Only one study within one review[8] was identified. This identified a greater risk of developing hearing loss for every year of service on a warship when compared to a control group with no time spent on board a ship or at a shore duty station.
- **Airforce/pilots:** Ten studies across two reviews[8, 11] were identified. Studies variously reported "better than predicted hearing" in Finnish pilots (1 study), "no significant relationship between impact of noise and hours flown" (1 study), "abnormal hearing" in a proportion of pilots (particularly fighter and helicopter pilots) (1 study), and an increase in the adjusted odds of hearing loss (increasing with years of exposure) in military aircraft maintenance workers (1 study). A further study found that otoacoustic emissions were able to predict risk of hearing impairment in pilots in the French Air Force. Five studies looked at the combined risk of solvent and noise exposure and found "abnormalities in the auditory

brainstem response" (1 study), "abnormal acoustic thresholds" (1 study) and an "adverse effect on central auditory functions" (3 studies).

- **Wider military population:** Three studies were identified within one review[9]. These variously reported on the prevalence of hearing problems (7.3%-26.6%, based on 1 study), hearing loss (0.8% -2.2% and 15.8% in two studies), threshold shifts (<0.02%-5% and 29.3% in two studies) and tinnitus (30.8% based on one study), all in US veterans and military service members from three operations in Afghanistan or Iraq (2001 to 2013).
- **Injured groups (blast exposures, traumatic brain injury or both):** Ten studies were identified within one review.[9] The prevalence of hearing problems and hearing loss ranged from 11.6% to 87% and of tinnitus from 6.1% to 75.7%. The considerable gap between the upper and lower limits of the range for prevalence of hearing loss/problems or tinnitus could be attributed to the heterogeneity of the primary studies.

For full details of all results, see Table 1 (Appendix 5).

The report from the Ministry of Defence[12] stated that as of 1 November 2013, 3,530 (2.25%) out of the 156,220 UK Armed Forces personnel had impaired hearing (grade H3), and 630 (0.4%) had poor hearing (Grade H4). The two reports on UK[1] and US[3] armed forces veterans reported that over 300,000 ex-service personnel in the UK are living with hearing loss and an estimated 3 to 4 million veterans in the US have tinnitus. Lastly the unpublished report by Reichenbach 2014[7] gave an overview of the size of NIHL in the armed forces based on 1 report[1] and 3 studies[14-16] which are summarised in Table 1 (Appendix 5).

3.1.2 Nature and likely volume of primary studies and feasibility of a new systematic review

Searches for primary studies were undertaken (July 2016) in order to identify key studies published after the cut-off search date of the most recent review, which was May 2013 (search strategy is given in Appendix 4). Twenty-four relevant studies published between 2013 and 2016 were identified. Details of the studies are presented in Table 2 (Appendix 6).

Studies were conducted in the USA (n=12), Thailand (n=2), Brazil (n=2), France (1), Greece (n=1), Norway (n=1), Sweden (n=1), Australia (n=1), Tehran (n=1), South Korea (n=1) and India (n=1). Twenty two studies were conducted exclusively in a military population and two studies were in more general adult populations but reported separate military data. Military populations across studies included war veterans, artillery officers, navy, air force and army personnel, soldiers that sustained blast and/or traumatic brain injury, personnel exposed to gunshot noise, wider service members and musicians. The main outcomes reported were NIHL, significant/permanent threshold shifts, hearing

impairment/difficulty, preclinical NIHL and tinnitus. The definition of NIHL varied across the studies.

Two additional reports of ongoing projects were identified. One is the multiphase US Department of Defence (DoD) Epidemiologic and Economic Burden of Hearing Loss (DEEBoHI) project that aims to examine rates of hearing impairment and noise-induced hearing injury, relevant noise exposures, and to determine the economic burden of these outcomes to the Department of Defence and Service Members.[17] The likely date of publication of results of the project is not known. The other is the Gulf War Era Cohort and Biorepository Project[18] that aims to find the prevalence and correlates of medical conditions affecting Gulf war era veterans. The pilot project aimed at testing the feasibility of implementing a full scale project was completed in May 2016, and results have been published in an abstract.[19]

There is a fairly substantial body of new evidence (24+ studies) that could be added to the existing review evidence. Further, there are methodological improvements that could be made if a new review were to be conducted. These would include more rigorous searches (the existing reviews were mainly limited to English language studies), comprehensive assessment of quality of the included primary studies (this is lacking in the existing reviews) and a more consistent approach to reporting of results (review summaries were often narrative or lacked reporting of any associated uncertainty, e.g. confidence intervals). However, this would not mitigate any quality issues inherent in the primary studies (such as uncertainty around the validity of methods for assessing NIHL, poor reporting of such methods and poor (reporting of) assessment of noise exposure).

The extent of the heterogeneity across all primary studies means that any overall point estimates would not be meaningful. However, a new systematic review may be able to provide some estimates within defined sub-groups with similar features (e.g. population and NIHL definition). Numbers of studies in any sub-group may be small, which may in turn result in a lack of precision around estimates. Access to grey literature (e.g. military audits) is likely to be important for a systematic review on this topic.

3.2 Detection of hearing loss and tinnitus

Summary

- The literature search identified 18 reviews (including systematic reviews, guidelines, narrative reviews) published between 1999 and 2015; reference has also been made to ongoing reviews/guidelines
- Limited evidence was found on the reproducibility and reliability of tests, the utility of various tests compared with PTA (reference standard), comparisons between behavioural and objective tests and the use of tests in different settings
- No evidence was found on the incremental benefit of using more than one test or emerging techniques for detecting "hidden" hearing loss
- Across the reviews, a wide range of tests have been evaluated, including behavioural tests, physiological tests and questionnaires; test variables also differed widely and a lack of standardisation for some tests was commented on
- Studies on tests used a range of populations (children, adults, elderly, occupational, hearing impaired, normally hearing)
- None of the reviews were specific to the detection of NIHL or tinnitus in a military population.
- Whilst most reviews included details on search strategies, many did not report comprehensively on methodological aspects, and it is thus difficult to gauge the overall methodological quality
- One of the key areas consistently underreported in reviews was quality assessment of included primary studies, and interpretation of findings in the context of quality; many of the overall review findings thus need to be interpreted with caution
- Where reviews did comment on the methodological quality of included primary studies, they noted the following: a lack of consistency for defining NIHL, lack of detail on test variables or patient characteristics, and a lack of blinding when interpreting test results
- The current evidence indicates that assessment of hearing loss and tinnitus is a complex area with limited and heterogeneous evidence, and with no consensus on which test to use (when) and the best way to use a test.
- Heterogeneity between primary studies and reviews (tests, test parameters, populations etc.) means that any formal (quantitative) synthesis of findings in future reports would be limited
- NICE guidelines on the assessment and management of NIHL are expected to be published in 2018

In planning this report it was determined that detection of hearing loss could comprise a number of sub-categories. Seven categories were considered and the identified reviews assessed for their relevance to each [see Table 3 (Appendix 7) and Table 5 (Appendix 9) for detail].

3.2.1 Existing evidence syntheses: hearing loss

3.2.1.1 Reproducibility of individual tests

Reproducibility is defined here as achieving the same test results when the test is repeated on one person on more than one occasion (intra-observer agreement), or by more than one person on one occasion (inter-observer agreement).

Quantity of evidence

Four systematic reviews examined this aspect of a test for assessment of hearing impairment/loss (Reavis 2015, Hotton 2014[20], Pirozzo 2003[21], Mahomed 2013[22]); two of these included a meta-analysis (Reavis 2015[23], Mahomed 2013[22]). Only an abstract was obtainable for Mahomed 2013.[22] A rapid response report undertaken by the Canadian Agency for Drugs and Technologies in Health (CADTH) in 2015[24] aimed to assess the effectiveness of audiograms alone to assess the ability to hear speech in noise, but did not identify any relevant studies. A record of a health technology assessment (HTA)[25] on the Hearing in Noise Test (HINT) was identified but no further details could be obtained.

Two additional reviews were initially considered: Alcaŕas 2012[26] looked at studies of clinical applications of evoked otoacoustic emissions (EOAEs) in workers exposed to noise, however the authors noted that only one of their included studies considered test-retest variability. Schonweiler 2007[27] was a review with some systematic elements, which evaluated the range of test parameters used in relation to Notched-Noise-Brainstem Electric Response Audiometry (NN-BERA); there was however no information presented on test-retest variability.

Review characteristics

Searches for relevant literature were performed in 2002 (Pirozzo 2003[21]) and 2013 (Reavis 2015[23]). A date was not stated in Hotton 2014[20], but studies up to 2012 were included. There was no information on search dates in the abstract for Mahomed 2013.[22] All four reviews considered adult populations, although children were included in some primary studies in three of the reviews (Hotton 2014[20], Pirozzo 2003[21], Mahomed 2013[22]). Both normal hearing and hearing impaired populations were included across reviews. None specifically considered a military population. The following tests were evaluated: DPOAEs, Hearing in Noise Test (HINT), Whispered Voice Test and automated and manual threshold audiometry.

Review quality

Two reviews stood out as having good methodological quality (Hotton 2014[20]; Pirozzo 2003[21]); these reviews had comprehensive search strategies, presented details on study selection, data extraction and quality assessment, and commented on the quality of the included studies. The review by Reavis 2015[23] reported limited methodological details, though it did state that study selection, data extraction and quality assessment of included studies was undertaken in duplicate; the search strategy was limited to MEDLINE and English language studies. The full text of the review by Mahomed 2013[22] was not available.

Automated and manual audiometry

Mahomed 2013[22] evaluated the test-retest reliability (within-subject comparisons) for both tests respectively, based on 29 studies (for test accuracy results see section 3.2.1.2). They found that *"test-retest reliability for automated audiometry was within typical test-retest variability for manual audiometry."* Average differences were 0.4 dB (SD 6.1, manual) and 0.3 dB (SD 6.9, automated).

Hearing in Noise Test (HINT)

Hotton 2014[20] analysed the evidence on 17 linguistic versions of HINT from 24 studies. The data suggested that the psychometric properties of the test, including applicability, validity, reliability and sensitivity of the different versions of HINT are not well established, specifically for people with hearing loss.

Whispered Voice Test

Three of the included (adult) studies in Pirozzo 2003[21] examined inter-rater agreement. Two found correlations of 0.67 and 0.88 between two different health professionals' results; one study found substantial variation in agreement between examiners, which was attributed to differences in loudness of whispering. The review by Yueh 2003[28] (described in next section 3.2.1.2 as the focus was not on test-retest variability) states that *"robust description of interobserver reliability and test-retest reliability are lacking."*

Distortion product otoacoustic emissions (DPOAE)

The meta-analysis by Reavis 2015[23] synthesised 10 DPOAE studies where test-retest variability had been estimated using the "standard error of measurement" (SEM). The aim was to obtain more precise mean SEM values which could be used to determine DPOAE level shift reference limits for different frequencies. SEM values were found to vary between 0.57 to 3.9 dB across included studies. A number of limitations and caveats are discussed for using the reference limits provided.

3.2.1.2 Test accuracy/ level of agreement between different tests

Test accuracy evaluates how well a test performs against the reference standard. Audiometry is generally considered to be the reference standard test for hearing loss despite being a behavioural test. For completeness, reviews comparing any two or more tests are included here, regardless of whether the reference standard was explicitly incorporated. Both behavioural and physiological tests are included, as well as questionnaires.

Quantity of evidence

Seven reviews were identified, with varying levels of systematic review methodology (Pirozzo 2003[21], Yueh 2003[28], Chou 2011[29], Mahomed 2013[22], Tlumak 2007[30], Schonweiler 2007[27], CADTH report[24]). A PROSPERO record[31] for an ongoing systematic review which aims to undertake a comparison of otoacoustic emissions and audiometry was also identified. A further review looking at questionnaires was identified (Souza 2015[32]), but this was a survey of the frequency of use of questionnaires and their content and did not present test accuracy findings.

Review characteristics

Search dates within the reviews were, where stated, between 2001 and 2015. All reviews included adult populations, with four reviews also including children. None focussed on a military population. Two reviews specifically addressed screening for hearing loss in adults (Yueh 2003[28], Chou 2011[29]). Tests evaluated included automated and manual audiometry, hand-held audiometric devices, the Whispered Voice Test, Hearing in Noise Test (HINT), Notched-Noise-Brainstem Electric Response Audiometry (NN-BERA), Auditory Steady-State Response Electric Response Audiometry (ASSR-ERA) and various screening questionnaires.

Review quality

The review by Pirozzo 2003[21] was assessed as having good methodological quality (see section 3.2.1.1 above). The CADTH report[24] and the review by Chou 2011[29] were also considered to be of good quality, as there were relevant details on searches strategies, study selection and quality assessment, and results were reported in the context of quality findings. Tlumak 2007[30] reported details on search strategies, selection criteria and aspects of quality. Yueh 2003[28] and Schonweiler 2007[27] did not report details beyond search strategies, and the full text of the review by Mahomed 2013[22] was not available.

Manual versus automated audiometry

Mahomed 2013[22] was primarily a review on test-retest reliability for both types of audiometry. However, they also reported that overall average differences between the two types of test were

comparable with within test differences (NB there is limited information on this review as only an abstract was available).

Whispered voice test versus audiometry

Pirozzo 2003[21] conducted a systematic review of eight studies (four in adult and four in child populations) to determine the accuracy of the Whispered Voice Test. The reference test used in the studies was audiometry. The sensitivity in the four adult studies was 90% (95% CI 82 to 95) or 100% (95% CI 95 to 100%) and the specificity ranged from 70% to 87% (95% CI 80 to 92). It was concluded that the Whispered Voice Test is a simple and accurate test for detecting hearing impairment; however, the authors also note that there was variation in test methodology across primary studies.

The CADTH review[24] found evidence relating to four different comparisons (based on one study only for each comparison):

Audiometry versus Hearing in Noise Test (HINT)

Based on one study, there was poor correlation between pure-tone audiometry and HINT scores (there were no significant differences in HINT performances between groups of participants with normal audiograms and those with slight, mild, moderate, or severe hearing loss).

Audiometry versus Words in Noise Test (WIN)

Based on one study, a linear relationship was found between the two tests, with the authors concluding that WIN provides an accurate way of measuring word recognition in background noise and is related to audiograms.

Speech Recognition in Noise Test (SPRINT) versus WIN

One study found that SPRINT and WIN were highly related.

HINT versus WIN

One study found that WIN was a more sensitive measure of speech-in-noise relative to HINT.
The authors of the CADTH review note a number of limitations in the primary studies, including: the three studies assessing WIN were conducted by the creator of the WIN; functional tests were evaluated on people stratified by a pure-tone audiogram, therefore an assumption was made that audiograms are effective at measuring speech-in-noise; and definitions of hearing loss varied across studies.

Auditory Steady-State Response Electric Response Audiometry (ASSR-ERA) versus (behavioural) audiometry

The review by Tlumak 2007[30] examined the effect of differences in test variables of ASSR-ERA on its accuracy (as compared with behavioural audiometry). A pool of 56 primary studies provided evidence for different variables. Differences in test variables affected test accuracy to a greater degree in hearing impaired or combined populations (hearing impaired and normally hearing) compared with normally hearing populations. The review goes on to define parameters within which the test might be most usefully used in different populations.

Notched-Noise-Brainstem Electric Response Audiometry (NN-BERA) versus (behavioural) audiometry

Based on the evidence from seven studies, Schonweiler 2007[27] concluded that there was good agreement between NN-BERA and audiometry, with differences in mean between pure-tone-thresholds and NN-BERA thresholds of up to 12 dB. The authors conclude that this justifies the use of NN-BERA as a "standard" method, but also state that it should not be used as the sole technique for making treatment decisions.

Reviews focussing on screening

Two reviews focused on a range of tests in the context of adult screening.

The review by Yueh 2003[28] outlined a systematic search, but reported findings on the advantages and disadvantages of various screening tests in a narrative (non-systematic) way.

Whispered Voice Test, tuning fork, Hearing Handicap Inventory for the Elderly-Screening (HHIE-S) and audioscope

The Whispered Voice and tuning fork tests suffer from poor standardisation, though "reasonable" test accuracy has been reported for the tuning fork (reference standard not stated). The Hearing Handicap Inventory for the Elderly-Screening (HHIE-S) was reported as having a sensitivity of between 0.33 and 0.80 and a specificity of between 0.67 and 0.98 based on five studies (reference test was failure to hear a 40dB tone at 1 or 2 kHz). Specificity was better overall than sensitivity and improved with higher cut-off scores on the HHIE-S. The audioscope was found to have a sensitivity of between 0.94 and 0.97 and a specificity of between 0.69 and 0.80 (based on three studies, reference test was audiometry).

The guideline by Chou 2011[29] (based on a systematic review) also evaluated a number of screening tools for identifying untreated hearing loss in adults aged 50 or older. The main findings are briefly

summarised below; the reference test for all was pure-tone audiometry or a portable audiometer. Six of the 20 included studies also compared various index tests to each other (results not reported here).

Whispered voice test (WVT), finger rub test, watch tick test

The median (range) for sensitivity and specificity of the WVT was 0.95 (0.40-1.0) and 0.82 (0.80-0.87) respectively (based on four studies). One study found an inability to hear a WVT at 6 inches or a conversation voice at 2 feet to be more useful than an inability to hear a whispered voice at 2 feet for identifying hearing loss. The diagnostic accuracy of finger rub (sensitivity {0.27 [0.19 to 0.35]}, specificity {0.98 [0.91 to 1.0]}) and watch tick test (sensitivity {0.44 [0.35–0.53], specificity {1.0 [0.95–1.0]}) at 6 inches for detecting hearing loss was calculated in one study.

Single screening question

Eight studies evaluated a single screening question about perceived hearing difficulties. For detection of hearing loss (>25 dB) based on a single screening question, the medians (range) for sensitivity and specificity of the tests were 0.67 (0.27 to 0.78) and 0.80 (0.67 to 0.89) respectively. For detection of hearing loss > 40dB, the medians (range) for sensitivity and specificity of the tests were 0.81 (0.71 to 0.93) and 0.72 (0.56 to 0.74) respectively.

HHIE-S and American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) 5-minute test

Eight studies evaluated the HHIE-S. For detection of hearing loss >25dB, the median (range) sensitivity and specificity of HHIE-S at a cut off score >8 was 0.58 (0.32 to 0.66) and 0.82 (0.76 to 0.97) respectively. Similar results were observed for detection of hearing loss > 40dB. One study evaluated the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) 5-minute test; sensitivity and specificity ranged from 0.26 to 0.90 and 0.20 to 0.97 (CI not calculable) depending on the cut-off score evaluated.

Audioscope hand-held audiometry device

Six studies that evaluated this test found variation amongst studies in frequency and tones tested with the device. For detection of hearing loss >40dB, 3 studies found the median (range) sensitivity and specificity of the device to be 0.96 (0.94 to 1.0) and 0.72 (0.42 to 0.89) respectively.

3.2.1.3 Incremental benefits of using more than one test

No relevant reviews were identified on combining tests for purposes of screening, diagnosis or management.

3.2.1.4 Utility of tests at different stages of NIHL

There were no reviews that specifically addressed the utility of one or more tests at more than one stage of NIHL, e.g. at an early or pre-symptomatic stage and once hearing loss has been established, or at different stages during the career of an individual working in an occupation with noise exposure.

There were two reviews (Yueh 2003[28]; Chou 2011[29]) discussed above (section 3.2.1.2), which focus on the screening stage only. One review (Alcaŕas 2012[26]) mentions OEA for the detection of cochlear changes and early diagnosis of NIHL, but its focus is a survey of the use of different types of OEA in clinical applications, and it does not does not provide an overview of test reliability or accuracy (the authors mention that only one of the studies they identified provided data on false-positive or false negative results). A further review (Swanepoel 2010[33]) discussed below (section 3.2.1.5) does make reference to different stages of NIHL (screening, diagnosis and intervention) but the focus is on remote and face to face telehealth applications in audiology, and findings have therefore been presented briefly under the heading below ("utility of tests in different settings").

3.2.1.5 Utility of tests in different settings

There was little information on the utility of tests in different settings. There were no reviews that focussed on a comparison of the use of (the same) tests in civilian/clinical versus military settings (e.g. in clinic versus in the field).

One review (Swanepoel 2010[33]) was identified that evaluated self-tests, remote and face to face applications of various telehealth technologies. This review had a fairly comprehensive search strategy (though limited to English language studies), but few other methodological details. Eligible studies included adults and children and use of tests for screening, diagnosis and intervention.

Five studies looked at screening of hearing loss using telehealth applications. Three of these described two self-test procedures – speech-in-noise test (n=2) and PTA screening (n=1). The remaining two studies compared face-to-face screening with remote screening of infants using automated auditory brainstem response (AABR) and OAE.

A speech-in-noise screening test, which can be used over the telephone or computer headsets was used in a large national screening program in the Netherlands in adolescents and adults. The program had high participation and the telephone based test was preferred by the elderly. The other self- test reported was internet based pure tone audiometry that screened patients by determining threshold frequencies between 500 and 8,000Hz. The study showed poor participation in the self-test but demonstrated that internet-based hearing screening tests could be performed. The review authors concluded that the triple speech-in-noise test may be a more useful self-screening test compared to

internet based tests, as the latter are confounded by a lack of control over environmental variables (such as noise level) at the remote site.

Twelve studies looked at diagnosis. Four of these used PTA (air and bone conduction) in a sound booth or sound-treated room from remote locations, and none found significant differences between the test results for remote versus face-to-face methods. One study comparing remote with face-to-face testing of HINT showed that HINT can reliably to be performed via telemedicine configuration. Three studies comparing the interpretation of face-to-face with digital images of otoscopy showed that the two procedures were in agreement with each other. A further two studies investigated the agreement between DPOAE and auditory brainstem response (ABR) test results recorded remotely and via face-to-face assessments. The results showed that remote test was as reliable as face-to-face resting. One study reported that remote intraoperative evaluation of cochlear implants and devices, and responses to electrical stimulation, was a time-saving, practical and cost-efficient option. The remaining studies evaluated the feasibility and success of remote consultation for a balance disorder and online forms for tinnitus evaluations.

3.2.1.6 **Emerging techniques for detecting "hidden" hearing loss (in vivo, in vitro)**

No relevant reviews were identified.

3.2.1.7 **Other**

Six reviews and one guideline that did not fall into the categories above are briefly described below:

Ali 2015[34]: This review aimed to find out if it was reasonable to use 1 and 8 kHz anchor points in the medico-legal diagnosis and estimation of NIHL. As this was a medico legal review, it was difficult to assess its methodological quality based on the criteria used for other reviews. The authors searched for evidence to validate or dispute the four assumptions on which the use of these anchor points is based. They found evidence contradicting all four of the assumptions. Therefore, they questioned the validity of the use of 1 and 8 kHz anchor points and concluded that this approach may be unsafe in the medico-legal diagnosis and estimation of NIHL.

Dobie 2014[35]: This was a systematic review that aimed to review the literature regarding noise-induced permanent threshold shifts and to determine if the observed data agreed with the predictions of two different exchange rates (3 and 5dB). The methodological quality of the review was not assessed as the full text could not be obtained. Based on evidence from nine studies the review concluded that a 3dB exchange rate overestimates the risk of NIHL for intermittent or fluctuating

noise, whereas a 5dB rate appears to be more accurate but also overestimates the risk, particularly for exposures above 100 dBA.

Gardiner 2015[6]: This is an unpublished narrative review produced for the HearWell Programme at the University of Birmingham. It aimed to identify and analyse studies investigating different techniques for diagnosing and quantifying noise-induced hearing loss. It encompasses some systematic review elements, but is not a fully comprehensive systematic review. The review concentrated on nine behavioural (psychoacoustic) or physiological tests. The number of studies (n) identified for the various techniques are as follows:

- Psychoacoustic tests: speech-in-noise test (SINT, n=6), high frequency audiometry (n=3), Békésy sweep audiometry (n=3).
- Physiological tests: Otoacoustic emissions (n=1), electrical response audiometry (audiometry brainstem responses [ABR, n=8] and cortical evoked audiometry [CERA, n=1]), steady state evoked responses (SSEP, n=2), cervical vestibular evoked myogenic potentials (cVEMP, n=2) and acoustic reflexes (n=2).

A narrative synthesis of the various studies identified for each technique was provided. The review showed a trend that the more face validity a test has (e.g. SINT) the less objective and repeatable the results are and vice versa (e.g. electrical response audiometry is very objective and reliable but far removed from a test of real-life hearing). The main quality concerns of the included studies highlighted by the authors were that for most studies patient inclusion and exclusion criteria were not reported robustly, and that it was unclear if blinded investigators were used to interpret study results.

Granberg 2014[36]: the review aimed to identify outcome measures used in research on adults with hearing loss as part of the development process of the International Classification of Functioning, Disability and Health core sets for hearing loss project. An outcome measure was defined as "*any measure reported in the methods or results sections if it provided information necessary to address the study aims of an included article*". The review was considered to be of good methodological quality. The review identified 386 outcome measures, which were classified under 10 categories. Despite the large number of outcome measures identified, the prevalence of specific measurements was not established. This was due to extremely low occurrence of the identified measures.

Pawlaczyk-Luszczynska 2013[10]: This review provided a narrative synthesis of studies on NIHL carried out in central, eastern and south-eastern Europe and newly independent states in the period from 1970 to 2012. The review had only few SR elements to it and selection of publications on NIHL was subjective. The main topics of the included primary studies were on assessment of noise hazards, prevalence of hearing impairment and relationship between degree of hearing impairment and noise

exposure. Reporting of findings was narrative only and suggested (based on 4 studies) that OAEs were useful for monitoring and diagnosing hearing loss, including early hearing damage.

Olsen 1999[37]: This was a meta-analysis which aimed to evaluate the Acoustic Reflex Threshold (ART) as a tool for predicting the uncomfortable loudness level (ULL). The review is not recent and methodological quality of the paper was poor. The range of mean ULLs assessed across studies of normally hearing subjects was 81-125 dB HL (median: 95 dB HL), while it was in the range of 78-116 dB HL (median: 87 dB HL) among the hearing impaired subjects. The median differences between ART and ULL were 5dB for both normal and hearing impaired subjects. The author argued that in spite of the close relationship of mean values, prediction of ULL based on ART measurement would be inaccurate because of high inter-subject variability.

A NICE[38] scoping document for a guideline in progress on assessment and management of hearing loss in adults was also found. The guidelines are expected to be published in 2018. In a response to stakeholder comments it was noted that: "*The military will be covered by this guideline but veterans will not be a group for special consideration. There is no other planned input from the military aside from via the standard channels available to registered stakeholders.*"[39] Tinnitus (without NIHL) will not be considered in the guidelines.

3.2.2 Existing evidence syntheses: tinnitus

The literature search identified a systematic review (Kamalski 2010[40]) and a clinical practice guideline (Tunkel 2014[41]) on tinnitus.

The guideline by Tunkel 2014[41] aimed to provide evidence based recommendations for clinicians managing patients with tinnitus. The topics and issues considered in the guideline include assessment, intervention/management and education of patients with tinnitus. There were details of a comprehensive search strategy and grading of evidence according to recognised guidelines.

For detection of tinnitus the guideline recommends a history and physical examination, prompt audiological examination and strongly recommends against use of imaging technologies. A comprehensive audiological examination consists of the use of PTA to obtain air and bone conduction thresholds, speech recognition threshold (SRT), and word recognition scores (WRS). No other tests for detection of tinnitus were mentioned in the guideline. Recommendations were based in some cases on scant evidence. Future research recommendations include the assessment of the validity and responsiveness of various instruments.

Kamalski 2010[40] aimed to identify disease-specific health related QoL instruments in the context of treatment evaluation in tinnitus patients, and look at the evidence for their psychometric properties. The review had details of a search strategy, study selection and data extraction, but no details of quality assessment of included studies. They found 17 studies and identified six different health-related QoL instruments (Tinnitus Handicap Inventory {THI}, Tinnitus Questionnaire {TQ}, Tinnitus Reaction Questionnaire {TRQ}, Tinnitus Severity Index {TSI}, Tinnitus Handicap Questionnaire {THQ} and Tinnitus Severity Questionnaire {TSQ}) used to measure treatment outcome in tinnitus trials. They found a high level of reproducibility for all six instruments, but no evidence on the responsiveness, i.e. the ability to detect clinically important changes over time.

3.2.3 Nature and likely volume of primary studies and feasibility of a new systematic review

A search was undertaken in MEDLINE to gauge the type and volume of relevant primary studies over the last five years (2012 to October 2016). The search was restricted to a military population, but was otherwise sensitive, as there were no restrictions by type of test/detection method, study design or language (see Appendix 4 for details). It is likely that most studies in a military population with a focus on hearing loss of any kind would have been captured.

Two hundred articles were screened for potential relevance to testing/detection of hearing loss, based mainly on title and, in some cases, abstract. Fourteen potentially relevant studies were identified [7% of total, see Table 4 (Appendix 8) for references].

Studies were heterogeneous in terms of population (e.g. veterans, general military population, post-blast exposure) and tests (e.g. PTA, otoacoustic emissions, speech-in-noise, other word recognition tests, questionnaires, self-reports, home PTA (via a PC), telephone screening). One study referred to detection of early hearing loss after a shooting exercise (Rezaee 2012).

The use of additional databases (at minimum Embase) and other sources, and a lack of restriction by year would increase the number of citations to screen. The MEDLINE search with no time restrictions yielded 1050 hits, and the yield from Embase is generally higher (up to twice the number). Similarly, broadening the searches to include other occupations would increase the yield.

Attempting to identify all relevant studies would likely necessitate reading all abstracts (and in some cases full articles) during screening, as the main aim of study may not be to evaluate or compare test(s), but may still contain information on tests used.

The heterogeneity outlined above, and additional heterogeneity in the form of timing of tests, extent of noise exposure, test variables, setting of tests, thresholds for defining NIHL, summary statistics

reported etc. would make it difficult to compare across studies. Evidence for very specific scenarios may be sparse. Interpretation of findings is further likely to be hampered by not being able to directly compare behavioural and objective tests and the fact that the reference standard is behavioural.

3.3 Impact of NIHL and tinnitus on Quality of Life (QoL)

Summary

- Nine reviews/reports examined different aspects of QoL in both military and non-military populations; primary evidence to populate the reviews was limited
- Limited evidence suggested an adverse effect on QoL and a greater proportion of psychiatric illness in those with NIHL and/or tinnitus compared with normally hearing individuals, however this was not consistent
- Limited evidence suggested that hearing rehabilitation can have a positive effect on QoL
- The relationship between psychiatric illness, other impairments and NIHL/tinnitus is poorly understood
- Searches to gauge the volume of more recent primary studies suggested that there is a paucity of primary studies investigating the impact of NIHL and tinnitus on QoL in a military population

3.3.1 Existing evidence syntheses

Nine systematic or other types of review were identified [main findings are shown in Table 6 (Appendix 10)]. Evidence including a military population was in the form of: two systematic reviews (Theodoroff 2015[9], Stevelink 2016[42]), a non-systematic review (Alamgir 2016[43]) and a report by the Royal British Legion that outlined information on service related hearing problems in the UK Armed Forces.[1] For a non-military population, four systematic reviews (Kitterick 2015[44], Miller 2015[45], Jacobson 2001[46] and Turner 2007[47]) and a clinical practice guideline on tinnitus (Tunkel 2014[41]) were identified. The reviews used various outcome measures including depression, anxiety, suicide and post-traumatic stress disorder (PTSD) to assess the impact of NIHL and tinnitus on QoL.

Review quality

Two reviews (Alamgir 2016[43] and Jacobson 2001[46]) reported insufficient information to make an assessment of their methodological quality. The methodological quality of the remaining five reviews was considered to be mostly good, with most having undertaken extensive literature searches to identify relevant studies, clearly stated the studies' eligibility criteria, and performed screening of identified citations and extracted data in duplicate. However, only two reviews (Stevelink 2016[42] and Kitterick 2015[44]) provided information on the quality assessment of included studies.

Military Population

The review by Alamgir 2016[43] found 6 studies investigating the relationship between QoL and hearing loss in veteran military populations (mainly US). Hearing loss was found to be associated with lower QoL in terms of both physical and mental health (2 studies). One study with a mixed

population (ages 20-101 and not all with military service background) found that hearing loss significantly affected some mental health ratings in younger people, but not in older people. Use of hearing aids and auditory rehabilitation positively influenced the QoL of veterans with hearing loss (2 studies), but had no effect in one.

Theodoroff 2015[9] found that none of the studies included in their review evaluated the effects of tinnitus or hearing loss on QoL among US veterans and military personnel despite this being one of the key review questions. This is likely to be due to the fact that study inclusion was limited to personnel who had served in specific US operations in order to restrict the review to a well-defined population.

Stevelink 2016[42] reviewed mental health disorders in ex-military personnel with physical impairments including hearing loss. Two studies that reported specifically on hearing impairment found that 34% of US soldiers with a hearing impairment had PTSD, and that 30% of US veterans with hearing impairment were depressed compared to 6.5% US veterans without hearing loss. A further study, with a mixed population (including hearing impairment) found that military personnel with hearing loss showed no difference to those without hearing loss in terms of depression.

The report from the Royal British Legion 2014[1] was the only report that analysed the experiences of service personnel and veterans in the UK Armed Forces with hearing loss and tinnitus. Over 1,100 responses were collected from a survey of veterans and service personnel with hearing problems. The main themes that emerged from the survey were social isolation, sleep deprivation and being unable to function in a social situation. Around 43% reported a "significant effect" on their QoL from NIHL/tinnitus, over a third reported a lack of sleep, and 1 in 5 reported not being able to attend work related meetings. Almost a quarter said that noises (from tinnitus) "severely" worry, annoy or upset them when they are at their worst. Around 40% said the noises "moderately" affected them, and 24% reported being "slightly" affected. 10% said hearing loss had a significant effect on relationships with friends and family which frequently caused misunderstandings. Limitations of the survey included missing data (non-responses to some questions), a lack of verification of service history and issues around representativeness of responders.

Non-military population

The five reviews in a non-military population covered two main areas, the effect of hearing loss on suicide, and effect of hearing devices on quality of life of those with NIHL.

Effect of hearing devices on health related QoL of adults with hearing loss

Kitterick 2015[44] investigated the impact of hearing-assistive devices on health-related QoL of adults with single-sided deafness, measured using generic and disease specific instruments. The findings showed that hearing devices had small to medium impact on health-related QoL, but only a few studies have measured the impact of devices using generic instruments. Miller 2015[45] looked at the impact of cochlear implantation on cognitive function in older adults (over 65 years) and found no relevant studies.

Hearing loss, tinnitus and suicide

Jacobson 2001[46] found no evidence to suggest a causal relationship between tinnitus and suicide (based on 3 studies). The evidence did suggest that patients who attempted suicide had pre-existing psychiatric conditions, the most common being clinical depression. A limitation of the included studies was a lack of detail on the psychiatric conditions. Turner 2007[47] reviewed suicide in deaf or hearing impaired populations and identified 13 studies, including two from the UK. There was little evidence to suggest that deafness is a risk factor for suicide and some studies reported no difference between hearing and non-hearing populations. However, they reported higher levels of depression and a greater perceived risk of suicide among deaf individuals.

The clinical practice guideline by Tunkel 2014[41] focused on tinnitus that is "bothersome and persistent" (lasting 6 months or longer) and often associated with a negative effect on the patient's QoL. According to the guideline, the QoL of patients with tinnitus can vary widely, with most patients not severely affected but with some experiencing anxiety, depression, insomnia and problems with work and family life. Suicide has been reported in tinnitus patients who have coexisting psychiatric illness; however the relationship between tinnitus and psychiatric illness is not well understood.

3.3.2 Nature and likely volume of primary studies and feasibility of a new systematic review

A literature search was undertaken in MEDLINE (2011 to November 2016) to gauge the type and volume of primary studies on the impact of NIHL and tinnitus on QoL. The searches were restricted to a military population (search strategy is given in Appendix 4). There were no restrictions on study design or language. It is likely that most studies on the impact of NIHL and tinnitus on QoL in a military population would have been captured.

The search identified 23 citations, but despite including broad search terms relating to a military population, no studies specific to this population were found. One relevant study in a general population was identified.[48] This aimed to investigate the impact of hearing impairment on the quality of life among adults with Medicare Supplement Insurance.

The number of citations to screen would increase by using additional databases and other sources and by not restricting it to a certain time period. A MEDLINE search with no date restrictions yielded 50 hits. There seems to be paucity in primary studies investigating impact of NIHL and tinnitus on QoL in a military population. Broadening the search to include other occupational groups may yield more citations. A MEDLINE search limited to 2011-2016 but not restricted to military population resulted in 834 hits. However, these may be less relevant to a military population.

3.4 Impact of NIHL and tinnitus on the ability to work of military personnel

Summary

- Limited evidence in the form of two reviews and a report by the Royal British Legion was identified
- There was heterogeneity between the reviews and the primary studies included within them, in terms of setting (country), population and outcomes assessed
- Limited evidence suggests that tinnitus and /or hearing impairment increases the risk of sickness absence
- Only the Royal British Legion report provided data pertaining to the military and found that hearing loss is a reason for medical discharge or downgrading; there is uncertainty associated with the estimates given in the report
- Searches to gauge the volume of (recent) primary studies suggests that data is sparse; more useful information may be found in grey literature (e.g. unpublished military audits/reports)

3.4.1 Existing evidence syntheses

Two relevant systematic reviews were identified: one included military and other occupational groups (Friberg 2012[49]); and one included a general population without any specific military data (Hjalte 2012[50]). An additional Royal British Legion report on the UK Armed Forces[1] was identified. The three reviews had undertaken extensive literature search to identify relevant studies, clearly stated the study eligibility criteria, and performed screening of identified citations in duplicate. However, it was unclear if data extraction was done in duplicate for two reviews [49, 50] and none provided information on formal quality assessment of included studies. Limitations noted by the review authors for primary studies include variation in how hearing loss was diagnosed and the fact that it was self-reported in some studies.

Although only a limited amount of evidence was identified, there was still some heterogeneity in terms of the setting (e.g. UK, US, Sweden), population (e.g. military, other occupational group, general population) and outcome assessed (impact on ability to work was assessed, for example, in terms of sick leave, absence from work, medical discharge from duty, career downgrade and productivity loss). The key findings on the impact of NIHL and tinnitus on the ability to work of military and other occupational groups are presented below [see Table 7 (Appendix 11) for further details].

Sick leave / absence from work

The review by Friberg 2012[49] identified no studies with a military population, but included five studies on other occupational groups. These found that tinnitus and /or hearing impairment increased the risk of sickness absence. Odd ratios for increased risk of sickness absences (using different measures/cut-offs for sick leave) in people with impaired hearing compared to those with normal hearing were given in two studies and ranged from 1.52 (CI, not reported) to 4.6 (CI 1.3 to 16.5).

Medical Discharge / downgrading in career on medical grounds/ ill health related retirement

The Royal British Legion report on the UK Armed Forces[1] stated that NIHL was the main cause for medical discharge from the Army for 62 individuals during 2007-2012 (denominators or comparisons with other occupational groups not stated). Findings from the online survey of service and ex-service personnel of the UK Armed Forces undertaken as part of the report stated that: a) Less than 3% of respondents (n= 26) had been medically discharged from the Armed Forces due to hearing loss, b) 12% (n=105) had been medically downgraded and c) 8% (n=70) had been categorised as 'P7' in their occupational health assessment due to their hearing problems. 'P7' means medically fit for duty with major employment limitations.

The review by Friberg 2012[49] found that ill health related retirement among firefighters in the UK was 16% due to ear and mastoid diagnoses in 1998 and 4% due to hearing loss in 2007 (based on two studies).

Productivity loss

One review (Hjalte 2012[50]) included information on occupational groups (based on three studies) and gave estimates of various direct and indirect costs related to medical care and costs from lost or reduced work productivity. Productivity loss was estimated using various costing approaches, but related generally to the costs associated with people being less able or unable to work. The data all relate to the USA and Australia and have therefore not been reproduced here. There was no evidence for a military population.

3.4.2 Nature and likely volume of primary studies and feasibility of a new systematic review

Searches were undertaken in MEDLINE (2011 to November 2016) to gauge the type and volume of primary studies on the impact of NIHL and tinnitus on the ability to work of military personnel. The searches were restricted to a military population and a combination of search terms for 'ability to work' was used (see Appendix 4 for full search strategy). There were no restrictions on study design or language. The search identified 36 citations. No relevant study on the impact of NIHL and tinnitus on the ability to work of military personnel was identified.

There seems to be paucity of primary studies investigating the impact of NIHL and tinnitus on ability to work of military personnel. A MEDLINE search with no date restrictions increased the citations to 101 hits. The number of citations to screen would increase by using additional databases and other sources and by including other occupational groups. A MEDLINE search limited to 2011-2016 but not restricted to a military population resulted in 2119 hits. However, these will necessarily be less relevant to a military population and the heterogeneity across studies would likely make it difficult to compare and synthesise the results from relevant primary studies. Access to grey literature (military audits and reports) is likely to be more important for a systematic review on this topic.

3.5 Cost implications of NIHL and tinnitus and the cost-effectiveness of screening for, and prevention of, NIHL

Summary:

- Seven reviews/reports included aspects of cost implications of hearing loss/disorders in military or non-military populations
- These include few primary studies, and there is thus only limited evidence available, particularly for a military population
- Substantial heterogeneity was present both across reviews and primary studies included in the reviews, in terms of setting, population, type of hearing loss and outcome measures related to cost
- The identified evidence did suggest that NIHL could have a substantial impact on both direct and indirect costs
- No review on the cost-effectiveness of screening and prevention of NIHL in a military population was identified
- Searches to gauge the volume of more recent primary studies suggested that there is a paucity of primary studies investigating the impact of NIHL and tinnitus on QoL in a military population
- The NICE guideline under development (expected 2018) will include economic evidence related to assessment and management of hearing loss

3.5.1 Existing evidence syntheses

Seven relevant reviews on the cost implications of hearing loss/ disorders were identified [see Table 8 (Appendix 12)]. Five included military populations: a systematic review (Friberg 2012[49]) and a narrative review (Alamgir 2016[51]); a report by the Royal British Legion[1] and a US Department of Veterans Affairs policy document[3]; and a clinical guideline on tinnitus (Tunkel 2014[41]).

Two reviews related to other populations: a systematic review including the general population (Hjalte 2012[50]); and a document with information on former mine workers from the UK Department of Energy & Climate Change.[52] The NICE guideline[38] on assessment and management of hearing loss in adults currently under development (expected 2018) will also include economic evidence (NB tinnitus without hearing loss is excluded from the guideline).

The reviews generally reported insufficient information to make a comprehensive assessment of their methodological quality. For example, although they clearly stated the eligibility criteria for included studies, information on data extraction and quality assessment of included studies was missing. No reviews on the cost-effectiveness of screening and prevention of hearing loss or disorders were

identified for either a military or a non-military population. The main cost effectiveness evidence identified was not relevant to this report as it was on cochlear implants and hearing aids in a non-military population.

NIHL could have a direct (e.g. cost of hearing aids, health care personnel) and/or indirect (e.g. sickness leave, disability compensation) impact on resources. Most of the reviews and reports assessed indirect cost implications of hearing loss, and only one report[1] and one systematic review[50] reported direct costs as an outcome in addition to indirect costs. Reviews, reports and the primary studies included in the reviews varied in terms of the setting (e.g. UK, US, Sweden), population (e.g. military, other occupational group, general population), outcome assessed (e.g. costs of hearing aids, sickness absences, disability compensation), definition of hearing loss, and measurement of hearing loss (e.g. self-reported or audiometry). This heterogeneity made it difficult to compare results across the identified reviews and other relevant evidence. The key results for both direct and indirect cost implications of hearing loss/ disorders in military and non-military populations are presented below:

Direct costs: costs of hearing aids

The Royal British Legion report[1] found that, based on a survey conducted as part of the report, around a third of respondents of the ex-Service community had been issued with one or two hearing aids, 67% had their aids issued by the NHS, 12% cent paid for themselves, and 11 % were MoD-funded. Limitations of the survey described in the report mean that these estimates need to be interpreted cautiously. No information on how these estimates compare to the general population were provided. One systematic review (Hjalte 2012[50]) provided cost estimates for hearing aid diagnosis and fitting based on three Swedish studies in a general population. Any estimates of direct costs regarding current/ex-military personal in any setting/country are thus lacking.

Indirect costs: disability compensation

The Royal British Legion report stated that in the UK, there were 2,460 claims for deafness and hearing loss under the Armed Forces Compensation Scheme (AFCS) between April 2005 and September 2013, with only 12% (n=295) being successful.[1] The US Department of Veterans Affairs policy document[3] and a clinical guideline on tinnitus (Tunkel 2014[41]) reported that the cost of service-connected disability payments for tinnitus in US military veterans was $1.28 billion in 2011 and is projected to rise to $2.75 billion by 2016. Cost estimates for a UK military population were not identified. The information in the other review (Friberg 2012[49]) and the document by the Department of Energy and Climate Change, UK[52] is of limited relevance to this section (disability pensions in the general Polish population[49]; and claims for NIHL of former UK mineworkers).

Total (lifetime) costs for hearing loss

No evidence was identified for a military or other occupational population. One review (Hjalte 2012[50]) reported the total financial cost of hearing loss in Australia (based on one study) and the total lifetime costs of profound hearing loss in the US (based on one study).

Other cost related information

The review by Alamgir 2016[51] has proposed a framework and statistical model for future economic analysis of hearing impairment and NIHL in active duty US military service members. It identified seven relevant costs items associated with hearing impairment and NIH injury and several data sources on which to base quantification of the major cost items. It also developed a hearing pathway diagram that represents the flow of active duty service members through experiences related to hearing conservation and hearing loss and derived a model from this pathway to represent the cumulative economic effects of these experiences.

A UK primary study (Davis 2007[53], identified during screening for reviews) found the average cost of a UK screening programme to be £13 per person screened or about £100 if treatment costs were included.

3.5.2 Nature and likely volume of primary studies and feasibility of a new systematic review

Two separate searches were undertaken in MEDLINE (2012 to October 2016) to gauge the type and volume of primary studies on cost implications of NIHL, and on cost-effectiveness of screening and prevention of NIHL. The searches were restricted to a military population and MeSH and index terms relevant to 'costs' and 'screening' were used (search strategy is given in Appendix 4). There were no restrictions on study design or language. It is likely that most studies on costs of NIHL in a military setting would have been captured.

The search yielded only 23 records. After screening these, only one relevant study on the cost impact of NIHL was identified. This study by Copper 2014[17] links to a wider project (the ongoing multiphase US Department of Defence (DoD) Epidemiologic and Economic Burden of Hearing Loss (DEEBoHI) project), part of which is also addressed in the review by Alamgir 2016[51] mentioned above.

No relevant studies on the cost-effectiveness of screening and prevention of NIHL in a military population were found.

The number of citations to screen would increase by using additional databases and other sources and by not restricting it to a certain time period. A MEDLINE search with no date restrictions yielded 92

hits when search terms for ‘cost’ and ‘military population’ were used. This still results in a small number of citations; broadening the search to include other occupational groups may yield more citations but these may be less relevant to a military population.

Evidence for cost-effectiveness of screening and prevention of NIHL is likely to be limited even when other occupational groups are included. Moreover, the heterogeneity outlined above would likely make it difficult to compare across the few relevant studies identified from the search.

4 Conclusion

This scoping exercise was undertaken to identify the existing evidence relating to a number of issues within the field of NIHL. This was not a comprehensive systematic review and as such there is no formal synthesis of findings, and no recommendations have been made. Whilst there is clearly evidence that a range of tests can demonstrate an increased risk of NIHL and tinnitus in a military population, and that there is an impact from this in terms of cost, quality-of-life and ability to work, specific (quantitative) findings are limited and extremely variable depending on the context of each study/review.

The report has highlighted the extensive heterogeneity that exists in this field, evident both across and within reviews or other evidence syntheses. The main areas of heterogeneity relate to the specific aims of the research, definition of NIHL, tests used and test parameters, populations, settings, type, level and length of noise exposure and outcome measures and metrics used to report findings. Quantitative summaries are thus rarely undertaken in reviews, and where numerical values are given they often span wide ranges.

Gaps in the (review) evidence exist in particular relating to: reproducibility and reliability of different tests; the incremental benefit of using more than one test; the relationship between behavioural and physiological tests; emerging techniques for detecting “hidden” hearing loss; implications for the ability to work and quality of life of military personnel; and costs associated with NIHL. There is also a paucity of data on UK military populations, though evidence from other military populations may to some extent be transferable.

Whilst many reviews demonstrate methodological robustness in some areas, most did not undertake a rigorous assessment of the study quality of included primary studies. This is a key component of any systematic review as it has implications of interpretation of findings, and is something that could be addressed in any future systematic reviews. It is possible that unpublished (grey) literature such as audits and surveys undertaken by the military may have a role in any future systematic reviews and mechanisms of accessing such potentially relevant data would need to be explored.

The study quality of primary studies was not formally assessed in this report, however a key concern highlighted by authors of the respective reviews was a lack of assessment or reporting on the level of noise exposure. Other concerns within primary studies are the variable definitions of NIHL, a lack of reporting on how tests were undertaken, how multiple testing was accounted for and on blinding to test results. The lack of adequate validation of tests before their applied use in clinical practice, and the lack of an objective reference test remain a concern. Whilst any new systematic review could not

mitigate flaws within primary studies, it could make these explicit and set any findings in context of these. Further, more narrowly focussed systematic review questions would help to limit heterogeneity.

This report serves to consider the available review level evidence and to inform decisions about within which areas new systematic reviews are required or feasible. Whilst most areas would benefit from an up-to-date and methodologically rigorous systematic review, this would be limited by the paucity of available primary studies, particularly for ability to work, QoL and cost implications. There are a relatively large number of recent primary studies reporting incidence and prevalence that could populate a new systematic review, however heterogeneity between studies, particularly around the definition of NIHL and population, and a lack of clear reporting around noise exposure and test methodology would mean that any findings are likely to be associated with uncertainty and be limited for particular populations/settings. Detection of NIHL in different populations and settings is the largest and most complex area. Methodological issues when undertaking a new systematic review would relate to: a lack of available primary studies for some tests/test comparisons/combinations of test; a lack of reporting of all relevant information in primary studies needed to assess their methodological robustness; the lack of evidence on reproducibility/reliability of tests which are subsequently used in test comparisons; the lack of an objective reference standard; and substantial heterogeneity across primary studies. A well designed and conducted primary study may be more useful in this context.

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5 Appendices

Appendix 1: Research questions of interest

Questions	***Considerations***
What is the size and nature of NIHL?	
Prevalence and incidence of hearing loss (NIHL, tinnitus, conductive/sensorineural, sudden HL) amongst military personnel	*Different services, operations, pre-post deployment. Need to consider definition for use in military for hearing impairment and classification of hearing loss compared with Health and Safety Executive (HSE) and compensation schemes.*
Risk/prognostic factors associated with susceptibility to NIHL and tinnitus, including accuracy of measurement of risk factors	*May include chronic diseases such as diabetes, certain types of medication, family history, genetic markers, age/sex and noise exposure history; also early signs of NIHL detected by neurophysiological tests in symptomless individuals; prognostic models including several risk factors would be of particular interest; noise exposure needs to be considered in context of use/compliance with protective equipment.*
Noise exposure levels associated with military operations	*Aim being to develop exposure profiles as well identification of high risk groups and data gaps.*
What is the optimal hearing protection?	
The use and effectiveness of hearing protection (HP) in military services.	*In field operations HP is the main method for noise reduction but little known on its correct use and field effectiveness and reasons for non-use e.g. communication requirements; important to look at compliance and barriers/facilitators for use of equipment*
Otoprotective drugs	*This may include experimental (in vitro/in vivo) studies as well as studies in humans.*
Detection of NIHL	
How can damage to hearing be detected earlier?	*It is unlikely that well-conducted PTA could be "replaced" by another test as a gold standard; however there may be tests that can be used to identify early markers of NIHL, or be used in field settings as a first screen; these tests may therefore complement PTA at different stages of the testing pathway-there would need to be a demonstrable benefit over and above using only PTA (NB this could be in terms of ease of use or cost, not necessarily test accuracy; comparisons of test accuracy are in any case difficult to establish when comparing tests that measure different aspects of hearing loss)*
How can damage to hearing be quantified more consistently and rapidly?	
Sub-questions	
What is the relationship between PTA and OAE when used to identify early case of NIHL – reproducibility, reliability	
Evidence from field studies (occupational screening assessment) on the benefits of alternative technique (e.g. OAE, speech-in-noise tests) to PTA ('gold standard') for the early detection of NIHL – review of field comparison studies.	
Does OAE (or other tests) provide additional information to PTA as an occupational screening tool	

Questions	***Considerations***
or in evaluating the extent of hearing damage?	
Utility of OEA in workplace settings	
Reliability and acceptability of other field methods for improving (self-)reporting/ referral of hearing problems to occupational health / line managers, .e.g. questionnaires, self-administered tests in field, computer based technologies	
Relationship between behavioural and physiological tests	
Emerging techniques for detecting "hidden" hearing loss (likely at be at experimental stage-in vitro or in vivo)	
How can hearing be assessed more functionally in relation to role?	
How can an accurate staging be determined for NIHL prior to damage? (Is baseline audiometry adequate for this purpose?	
Impact/treatment of established hearing loss?	
Impact of NIHL, Tinnitus on Quality-of-Life (living with HL)	*To include impact of earlier detection of NIHL on QoL*
Effect of noise exposure on performance and communication (speech perception) of military personnel	
Impact of hearing impairment on work ability on military personnel.	*Employability, return to work, grade change, workplace adjustments*
Reviews of qualitative research	
Reviews of qualitative research on barriers/facilitators for self-reporting and referral (hearing loss/ problems) to occupational health and participation in health screening programmes.	
Cost implications of NIHL	
Reviews of cost implications of NIHL, cost-effectiveness of screening, prevention etc.	*Ideally need to be able to show that identifying NIHL at an earlier stage will result in savings to NHS further down the line*

Appendix 2: List of sources for literature search

Bibliographic Databases
ARIF Reviews Database http://www.birmingham.ac.uk/research/activity/mds/projects/HaPS/PHEB/ARIF/databases/index.aspx
CINAHL (EBSCO) 9 May 2016 https://www.ebscohost.com/nursing/products/cinahl-databases/cinahl-complete
Cochrane Library (Wiley) 2016 (CDSR issue 5 of 12 2016; DARE issue 2 of 4 2016; HTA 2 of 4 2016) http://www.cochranelibrary.com/
Embase <1974 to 2016 May 16
Ovid MEDLINE(R) <1946 to May Week 1 2016
Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations <May 17, 2016
PROSPERO (register of systematic reviews protocols) https://www.crd.york.ac.uk/PROSPERO/
PubMed https://www.ncbi.nlm.nih.gov/pubmed/
Sources for Health Technology Assessments and Guidance Reports
Agency for Healthcare Research and Quality http://www.innovations.ahrq.gov/browse.aspx
Alberta Heritage Foundation. Institute of Health Economics. Health Technology Assessment Unit http://www.ihe.ca/research/health-technology-assessment/htareports
All Wales Medicines Strategy Group http://www.awmsg.org/
Canadian Agency for Drugs and Technologies in Health http://www.cadth.ca/
Horizon Scanning Research and Intelligence Centre http://www.hsc.nihr.ac.uk/
McGill Medicine. Technology Assessment Unit of MUHC (McGill University Health Centre) http://www.mcgill.ca/tau/
Monash reports – Centre for Clinical Effectiveness, Monash University http://www.med.monash.edu.au/sphpm/divisions/mchri/cce.html
National Guidelines ClearingHouse (International) http://www.guideline.gov/
NHS Clinical Knowledge Service (CKS) http://cks.nice.org.uk/
NHS Evidence https://www.evidence.nhs.uk/
NICE guidance https://www.nice.org.uk/guidance?unlid=
NIHR Technology Assessment Programme http://www.nets.nihr.ac.uk/programmes
SIGN (Scottish Intercollegiate Guidelines Network) http://www.sign.ac.uk/
Welsh Government Health and Social Care http://wales.gov.uk/topics/health/?lang=en

Government and Military Sources
2015 Military Health System Research Symposium (MHSRS) https://tracktbi.ucsf.edu/events/2015-military-health-system-research-symposium-mhsrs
GOV.UK www.gov.uk
Military Health System and Defence Health Agency Health.mil http://www.health.mil/Military-Health-Topics/Conditions-and-Treatments/Physical-Disability/Hearing-Loss
US Department of Veterans Affairs. VA Technology Assessment Program VATAP. http://www.va.gov/health/topics/

Appendix 3: Search strategy – reviews

Database: Ovid MEDLINE(R) <1946 to May Week 1 2016

1 exp Hearing Loss
2 Hearing Disorders
3 NIHL.ti,ab.
4 noise induced hearing loss.ti,ab
5 hearing.ti,ab.
6 (auditory adj2 (disease$ or disorder$)).ti,ab.
7 deaf$.ti,ab. or deafness
8 tinnitus.ti,ab.
9 Tinnitus
10 (hearing adj1 loss)
11 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
12 limit 11 to "reviews (maximizes specificity)"

Similar search terms were used for other bibliographic database (see appendix 2)

Appendix 4: Search strategies – primary studies

1) Incidence and prevalence of NIHL and tinnitus

Ovid MEDLINE(R) <1946 to July Week 2 2016>

1 exp Hearing Loss
2 Hearing Disorders
3 NIHL.ti,ab.
4 hearing.ti,ab.
5 (auditory adj2 (disease$ or disorder$)).ti,ab.
6 deaf$.ti,ab. or deafness
7 tinnitus.ti,ab.
8 Tinnitus
9 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10 incidence/ or prevalence
11 incidence.mp. or prevalence.ti,ab. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
12 incidence.mp. or prevalence.ti. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
13 Epidemiology
14 ep.fs.
15 or/10-14
16 cohort$.ti,ab.
17 cross-sectional.ti,ab.
18 or/16-17
19 15 or 18
20 9 and 19
21 Military Personnel
22 (military or soldier$ or navy or naval or seaman or officer$ or pilot$ or airforce or airman or airmen or troop$ or serviceman or servicemen or veteran$).ti,ab.
23 Military Medicine
24 armed service$.ti,ab.
25 armed force$.ti,ab.
26 or/21-25
27 20 and 26
28 limit 27 to yr="2013 - 2016"

Similar search terms were used for other databases (CINAHL, CENTRAL, Embase and Medline in process)

2) Detection of NIHL and tinnitus

Ovid MEDLINE(R) <1946 to July Week 4 2016>

1 noise induced hearing loss.mp. or exp Hearing Loss, Noise-Induced/ (7048)
2 NIHL.mp.
3 exp Hearing Loss/ or exp Hearing Tests/ or exp Hearing Disorders/ or exp Hearing Loss, Sensorineural/
4 hearing loss.mp.
5 1 or 2 or 3 or 4
6 (earl$ adj2 detect$).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
7 5 and 6

8 military.mp. or exp Military Personnel
9 exp Military Personnel/ or army.mp.
10 airforce.mp.
11 soldier$.mp.
12 servicemen.mp.
13 veteran$.mp. or exp Veterans/
14 8 or 9 or 10 or 11 or 12 or 13
15 7 and 14 (10)

3) Impact of NIHL and tinnitus on quality of life

Ovid MEDLINE(R) <1946 to November Week 3 2016>

16 exp Hearing Loss
17 Hearing Disorders
18 NIHL.ti,ab.
19 noise induced hearing loss.ti,ab.
20 hearing.ti,ab.
21 auditory adj2 (disease$ or disorder$)).ti,ab.
22 deaf$.ti,ab. or deafness
23 tinnitus.ti,ab.
24 Tinnitus/
25 (hearing adj1 loss).ti,ab.
26 or/1-10
27 (military or defence or army or navy or airforce or soldier$ or servicem?n or servicewom?n or infantry or artillery or veteran$).ti,ab.
28 military medicine/
29 military personnel/
30 exp naval medicine/
31 Veterans Disability Claims/
32 Veterans/
33 or/12-17
34 11 and 18
35 "Value of Life"
36 Quality-Adjusted Life Years
37 quality adjusted life.ti,ab.
38 health status indicators
39 health utili$.tw.
40 quality of wellbeing.tw.
41 quality of well being.tw.
42 cost utility study.tw.
43 cost utility studies.tw.
44 quality of life
45 life style
46 health status
47 health status indicators
48 or/20-32
49 19 and 33
50 limit 34 to yr="2011 - 2016"
51 11 and 33
52 limit 36 to yr=”2011-2016” (834)

4) Impact of NIHL and tinnitus on the ability to work of military personnel

Ovid MEDLINE(R) <1946 to November Week 3 2016>

1 exp Hearing Loss
2 Hearing Disorders
3 NIHL.ti,ab.
4 noise induced hearing loss.ti,ab.
5 hearing.ti,ab.
6 (auditory adj2 (disease$ or disorder$)).ti,ab.
7 deaf$.ti,ab. or deafness
8 tinnitus.ti,ab.
9 Tinnitus/
10 (hearing adj1 loss).ti,ab.
11 or/1-10
12 (military or defence or army or navy or airforce or soldier$ or servicem?n or servicewom?n or infantry or artillery or veteran$).ti,ab.
13 military medicine
14 military personnel
15 exp naval medicine
16 Veterans Disability Claims
17 Veterans
18 or/12-17
19 11 and 18
20 ((ability or fitness or fit) adj3 work).ti,ab.
21 Work Capacity Evaluation
22 (capacity adj3 work).ti,ab.
23 (illness or sickness).mp. or absence.ti,ab. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
24 (absence adj3 (sickness or illness)).ti,ab
25 sick leave.ti,ab.
26 Sick Leave
27 Retirement
28 (early adj2 retirement).ti,ab.
29 absenteeism/ or efficiency/ or presenteeism
30 absentee$.ti,ab.
31 (career adj2 (progress$ or impact or path$ or choice$)).ti,ab.
32 or/20-31
33 11 and 32
34 18 and 33
35 limit 34 to yr="2011 - 2016"
36 limit 33 to yr="2011 - 2016"

5) Cost implications of NIHL and cost-effectiveness of screening, prevention of NIHL

Ovid MEDLINE(R) <1946 to October Week 2 2016>

a) Cost implication

1 exp Hearing Loss
2 Hearing Disorders
3 NIHL.ti,ab.
4 noise induced hearing loss.ti,ab.
5 hearing.ti,ab.
6 (auditory adj2 (disease$ or disorder$)).ti,ab.
7 deaf$.ti,ab. or deafness

8 tinnitus.ti,ab.
9 Tinnitus
10 (hearing adj1 loss).ti,ab. (32625)
11 or/1-10
12 (military or defence or army or navy or airforce or soldier$ or servicem?n or servicewom?n or infantry or artillery or veteran$).ti,ab.
13 military medicine
14 military personnel
15 exp naval medicine
16 Veterans Disability Claims
17 Veterans
18 or/12-17
19 11 and 18
20 economics
21 exp "costs and cost analysis"
22 cost of illness
23 exp health care costs
24 economic value of life
25 exp economics medical
26 exp economics hospital
27 exp "fees and charges"/ (286)
28 (cost or costs or costed or costly or costing).tw.
29 (economic$ or pharmaeconomic$ or price$ or pricing).tw.
30 or/20-29 (632828)
31 19 and 30
32 "Compensation and Redress"
33 (compensation or compensate or claim$ or pension$ or lawsuit$ or litigation$ or litigate or damages).mp. or redress.ti,ab. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
34 exp Pensions/
35 exp Jurisprudence
36 or/32-35
37 19 and 36
38 31 or 37
39 limit 38 to yr="2012 - 2016"

b) Cost effectiveness of screening and prevention

1 exp Hearing Loss
2 Hearing Disorders
3 NIHL.ti,ab.
4 noise induced hearing loss.ti,ab.
5 hearing.ti,ab.
6 (auditory adj2 (disease$ or disorder$)).ti,ab.
7 deaf$.ti,ab. or deafness
8 tinnitus.ti,ab.
9 Tinnitus
10 (hearing adj1 loss).ti,ab.
11 or/1-10
12 (military or defence or army or navy or airforce or soldier$ or servicem?n or servicewom?n or infantry or artillery or veteran$).ti,ab.
13 military medicine
14 military personnel
15 exp naval medicine

16 Veterans Disability Claims
17 Veterans/ (12516)
18 or/12-17 (123073)
19 11 and 18 (1080)
20 screen$.ti,ab. (509988)
21 (early adj3 detect$).ti,ab. (60426)
22 early diagnosis/ (20402)
23 or/20-22 (573038)
24 19 and 23 (86)
25 limit 24 to yr="2012 - 2016" (9)

Appendix 5: Table 1 - Prevalence and incidence of NIHL and tinnitus

Author, year Search cut-off date	Type of publication	Setting/ population Type of Studies included	Definition of hearing loss/tinnitus	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
MILITARY with or without other occupation (Review)						
Lie A *et al*. 2016[8] May 2013	Systematic review with narrative synthesis of evidence on the development of NIHL in working life.	Any occupational group exposed to occupational noise alone or in combination with other factors; **separate findings for military presented** (no restrictions on type) Cross-sectional and longitudinal studies on noise and hearing.	Variable-as defined in individual studies. Studies looked at hearing loss at the following frequency ranges: 0.5 to 2kHz, 0.5 to 4 kHz and 3 to 6kHz. Averages calculated for both ears, and data also presented for better/worse ear.	**96 studies in total were included for various occupations. 11 studies on NIHL in a military population were included.** <u>Infantry/artillery (6 studies)</u> **Christiansson and Wintzell 1999:** *"Significant hearing loss found in infantry officers (n=204) exposed to impulse noise from various weapons."* **Segal *et al* 1988:** *"Continued hearing loss in group with continued exposure (n=150), stabilisation of hearing loss in group with terminated exposure (n=841)."* **Helfer *et al* , 2005, 2010, 2011:** *"Higher than expected incidence of hearing loss among infantrymen, in those with active war experience, in men compared to women and in those over 40 years old (sample size =87,000 to over 140,000)."* **Muhr *et al* 2006:** *"Significant hearing loss of >15dB in at least one frequency in **17%** of artillery recruits compared to 2.9% of controls (sample size =747)."* <u>Air force/pilots (4 studies)</u> **Kuronen *et al* 2004:** *"Hearing among Finnish military pilots exposed to relatively short periods of noise level of 90-100 dB in the cockpit turned out to be better than predicted by the ISO 1999 model (International Organization for Standardization, 1990). Health selection criteria for recruitment to the pilot profession were the most probable cause'.* **Ribak *et al* 1985***: "Hearing in pilots/navigators (n=777) reduced with age. However, a significant impact of aircraft noise or in relation to the numbers of hours flown could not be demonstrated".*	√ Several databases searched √ Eligibility criteria stated; PRISMA flow diagram given √ Quality criteria of included studies defined X Included articles other than English language X Proportion screened/ extracted by more than one reviewer clear	Often incomplete or poor quality noise exposure data. Many included studies were cross-sectional. Diversity of outcome measures, in particular use of different definitions of NIHL made comparisons between studies difficult. Possibility of publication bias could not be excluded.

Author, year Search cut-off date	Type of publication	Setting/ population Type of Studies included	Definition of hearing loss/tinnitus	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
				Raynal *et al* 2006*: "Abnormal hearing detected in 19% and 38% of the 20-30 and 30-40 year old pilots respectively (sample size =525). Hearing in transport pilots was slightly better than fighter and helicopter pilots".* **Job *et al* 2009:** *"Use of otoacoustic emissions was found to predict to some extent the risk of developing reduced hearing in pilots in the French Air Force (n=512), who were aged 20-40 years and exposed to a noise level of 90-140 dB."* Navy (1 study) **Trost and Shaw 2007:** *"Compared to a Caucasian male of any age, with no time spent on board a ship or at a shore duty station (RR 1.0); for persons serving in US Navy (n=267,568) and exposed to noise level of >84 dB the risk of developing a hearing loss of ≥10dB in the range of 2-4kHz increased more with every year of service on a warship (RR 1.062, 95% CI 1.056 -1.068) compared with service ashore (RR 1.035, 95% CI 1.031-1.039)."* Review's conclusion: *"**Overall it appears that the military experience is a significant risk factor for hearing impairment"***		
Theodoroff SM *et al.* 2015[9] Search cut-off date 2013	Systematic review with narrative synthesis of evidence on 1) prevalence of, 2) risk and protective factors for, and 3) functional and QoL outcomes of	US veterans and military service members from three operations in Afghanistan or Iraq (2001-2013). Studies with a sample	'Hearing loss'= based on diagnostic audiometric results or ICD-9-CM diagnosis codes; 'hearing problems'=self-reported (e.g. questionnaires) Tinnitus= any	**14 studies in total were included for the three review questions;** **13 retrospective studies were on prevalence** 3 studies representative of wider military population **Frayne *et al* 2011**: Prevalence of 'Hearing problems'=**7.3% to 26.6% (2006-2007)** ; Prevalence twice as high in males compared to females (sample size = 90,558) **Helfer *et al* 2011:** Prevalence of 'Hearing loss'= **0.8% to 2.2%** (from 2003-2009); significant hearing threshold shifts = **<0.02% to 5%** (increases over time, sample size =804,535,)	√ Several databases searched, reference list checking, expert consultation √ Eligibility criteria stated; screening in duplicate; PRISMA flow diagram; reasons	Difference in ways of assessing hearing impairment (objective vs subjective). Phrasing of questions in subjective instruments different across studies. Limited information on the process of implementing the

Author, year Search cut-off date	Type of publication	Setting/ population Type of Studies included	Definition of hearing loss/tinnitus	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
	hearing impairment and tinnitus.	size of ≥30 or systematic reviews	form of tinnitus (e.g. constant recurrent, intermittent) identified using any form of assessment (e.g. self-report; ICD-9-CM diagnosis codes)	**Helfer *et al* 2005:** Point estimate- hearing loss (moderate to severe/profound) = **15.8%;** tinnitus =**30.8%;** changes in hearing (permanent threshold shifts) = **29.3%** (2003-2004, n=806); (CI not reported). 10 studies restricted to injured sub-groups (blast exposures, TBI or both) Prevalence of hearing problems and loss (8 studies, combined sample size = 40,538) = **11.6% to 87%** Tinnitus (7 studies; combined sample size = 10,478) = **6.1% to 75.7%.** Review's conclusion: "***Auditory complaints, such as hearing loss/problems and tinnitus are highly prevalent and in some injured populations greater than 50%.***"	for exclusion given √ Duplicate data extraction X Included articles other than English language X Detail on quality assessment of primary studies reported	instruments. Hence, difficult to compare results across studies and to assess the validity of self-reported measures. No single study representative of the entire population of interest was found. Target populations and outcomes were distinct and therefore not readily comparable between studies.
Warner R *et al.* 2015[11] Search cut-off date 2014	A literature review with narrative synthesis of evidence on the effects of combined exposure of jet fuels (or its aromatic solvents) and noise (at any level) on the central auditory nervous system (CANS).	Military aviation population. Studies reporting the electrophysical and/or behavioural measurement of CANS dysfunction induced by combination of jet fuels and noise.	No information	**6 studies were included.** One study on subjects exposed to jet fuels and noise: **Kaufman *et al* 2005:** cross-sectional study of 180 noise exposed military aircraft maintenance workers. *"Subjects with 3 years of jet fuel exposure had a 70% increase in adjusted odds of hearing loss and the odds increased to 2.41 for 12 years of noise and fuel exposure***"** 5 studies on subjects exposed to aromatic solvent components of jet fuel and noise. **Prasher *et al* 2005:** compared aircraft maintenance workers exposed to solvents + noise (n=174) to noise only (n=153), solvents only (n=13) and no exposure (n=39) groups. "*Over 32% of subjects with noise +solvents exposure had abnormalities of the auditory brainstem response*	√ Several databases searched, reference list checking, √ Eligibility criteria stated; screening in duplicate X PRISMA flow diagram given X Clear if there was duplicate data extraction X Included articles other than English language	Paucity of evaluative studies along with disparity in findings and variations in study designs provide only a partial understanding of effects of combined exposure of jet fuels and noise on CANS.

Author, year Search cut-off date	Type of publication	Setting/ population Type of Studies included	Definition of hearing loss/tinnitus	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
				(ABR)…..which also indicated that CNS pathway was affected in this group". **Gopal 2008 (n=7):** **"***Six out of seven subjects in this investigation showed abnormal acoustic thresholds (elevated or absent) with ipsilateral and/or contralateral stimulation despite normal pure tone thresholds at corresponding frequencies. Poor or abnormal scores for behavioural tests (SCAN-A) was found for 4 subjects"*. **Fuente 2006, 2007 and 2009**: Workers exposed to solvents and noise <85dBA **"***These three studies suggest that occupational exposure to organic solvent mixture has an adverse effect on central auditory function assessed by behavioural means"*.	X Detail on quality assessment of primary studies reported	
Pawlaczyk-Luszczynska M *et al.* 2013[10] Search cut-off date 2012	Systematic review with narrative synthesis of evidence on NIHL	Studies carried out in Central, Eastern and South-East Europe, and newly independent states.	No information	**Around 300 studies on NIHL in any population were collected.** **5 studies carried out in Poland** focused on impact of impulse noise from weapons and explosions on hearing. *"Short-term exposure to impulse noise from small-calibre firearms during target practice or after shooting might cause temporary hearing impairment*".	√ Several databases searched √ Eligibility criteria stated √ Articles other than English included X Systematic approach to include articles (included only those articles that authors thought were addressing important issues around NIHL)	No information

Author, year Search cut-off date	Type of publication	Setting/ population Type of Studies included	Definition of hearing loss/tinnitus	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
					X PRISMA flow diagram given X Clear if there was duplicate screening, data extraction X Included articles other than English language X Detail on quality assessment of primary studies reported	
MILITARY with or without other occupational groups (Other evidence)						
Atizado A *et al*. 2014[3]	Budget and policy document created by veterans for veterans for Department of Veteran Affairs	US military Veterans	No information	*"Tinnitus is currently the most frequent service connected disability of veterans from all periods of service and is particularly prevalent in Iraq and Afghanistan veterans".* *"An estimated 3 million to 4 million veterans have tinnitus, with up to 1 million of them requiring some degree of clinical intervention".*	Not applicable.	Not applicable.

Author, year Search cut-off date	Type of publication	Setting/ population Type of Studies included	Definition of hearing loss/tinnitus	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
The Royal British Legion 2014[1]	Report that aims to outline information on service related hearing problems in UK Armed Forces.	UK Armed Forces	No information	Findings are mainly from 1) **online survey** (February and March 2014) which received 1,110 responses from serving and ex-Service personnel and 2) **Legion household survey** of ex-Service community (2014) which included 1,120 veterans. **Veterans:** *"Household survey found that 11% of veterans reported having difficulty hearing, and 6% reported experiencing tinnitus. This amounts to over 300,000 ex-Service personnel living with hearing loss".* "*Findings suggest that the prevalence of hearing problems among veterans under the age of 75 is around three and a half times that of the UK population of adults under 75".* **Serving Personnel:** "*Reported in 2009, the MOD research found that 69% of Royal Marine Commandos who served in Afghanistan had suffered severe and permanent hearing damage (based on audiograms from 181 Royal Marine and 42 Commandos)".* *"Audiometric tests on infantry troops returning from Afghanistan in 2007/08 indicated that up to 14 per cent had suffered from hearing loss".*	Not assessed	Not assessed
Reichenbach T 2014[7]	A structured review with narrative synthesis of literature on NIHL in the armed forces.	Armed forces	No information	**The review references key findings from primary studies and relevant reports.** **Pearson 2009:** *"About two-thirds of royal marines return with hearing damage".* **Legion RB 2014:** *"Hearing damage in U.K. veterans is three times more than in other U.K. citizens".* **Helfer TM et al 2005: "***Hearing loss in U.S. veterans is much more likely to be linked to deployment than to other causes".*	Not assessed	Not assessed

Author, year Search cut-off date	Type of publication	Setting/ population Type of Studies included	Definition of hearing loss/tinnitus	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
				Gondusky JS and Reiter MP 2005: *"Blast injures to the auditory system constituted about a quarter of the injuries among U.S. marines in Iraq in 2004 and were accordingly the most common single injury".*		
Ministry of Defence 2013[12]	Grey literature (correspondence from the defence statistics health head as a request for information under the Freedom of Information Act 2000)	UK Armed Forces personnel	No information	**"***As at 1 November 2013 there were 156,220 UK Armed Forces personnel. Of these:* • *3,530 personnel had impaired hearing (H3)* o *Of which 470 also had a code for NIHL on their medical record,* • *630 personnel had poor hearing (H4)* o *Of which 90 also had a code for NIHL recorded on their medical record".*	Not applicable	Not applicable
Ongoing Research						
McCormack A ***et al.*** **2013**[13]	Protocol of a systematic review aiming to assess the available evidence describing the prevalence of hearing loss internationally.	Adults aged 18 years and older Observational studies including cross sectional studies will be included	Hearing loss is defined as 25dB or more in better ear. However, there may be differences in definition amongst studies.	**Ongoing (**The authors were contacted for interim findings, but no results were available and the review is currently on hold (10/11/16)).	√ Eligibility criteria stated in protocol √ Search not limited to English language articles	Not applicable

Appendix 6: Table 2 - Primary studies on incidence and prevalence of NIHL and tinnitus– military/mixed population

Author, Year	Objective	Study Design	Setting/ Population (n)	Outcome	Definition of hearing loss/tinnitus
Hughes H and Hunting KL, 2016[54]	To evaluate the risk of hearing loss among Air Force Reserve personnel exposed to occupational noise with and without exposures to jet fuel.	Retrospective cross-sectional study	Workers from two Air Force Reserve sites in the US (n=503)	Significant threshold shifts (STS) and hearing loss	STS was defined as a change in hearing sensitivity that was ≥10 dB or more at 2000, 3000 and 4000 Hz in either ear, compared with the reference audiogram.
Johnston DW *et al.* 2016[55]	To estimate the long-term health effects of Vietnam-era military service by using Vietnam-era national service conscription lotteries in Australia that took place between 1965 and 1972.	Quasi-experimental technique	Vietnam-era military service men from Australia.	Hearing loss	Self-reported
Muhr P *et al.* 2016[56]	To evaluate the incidence of STS in male conscripts from Swedish Armed Forces, heavily exposed to noise after the implementation of the new hearing conservation program (HCP), comparing the results to those of an earlier study from 1999/2000.	Prospective cohort study	Male conscripts from Swedish Armed Forces heavily exposed to noise after the implementation of the new HCP in 2003 (n= 395) and control group of men of the same age (n=839).	Significant threshold shifts	STS defined as deterioration in hearing thresholds, between reporting and discharge, of 15 dB or more, in one or both ears, and at one or more frequencies, in the interval of 0.25 to 8 kHz.
Soderlund LL *et al.* 2016[57]	To describe changes in hearing, using the permanent threshold shift metric, among United States Air Force service members.	Cross-sectional study	United States Air Force service members from 2005–2011 using data from the Department of Defence system (n= 264,970).	Permanent threshold shift	STS constitutes a change in hearing threshold relative to the initial reference audiogram of an average of 10 dB or more at 2000, 3000, and 4000Hz in either ear. PTS occurs when an STS is measured after a second 14-hr noise-free audiogram, or if there is a failure to complete follow-up testing within the required timeline.

Author, Year	Objective	Study Design	Setting/ Population (n)	Outcome	Definition of hearing loss/tinnitus
Kim H-J *et al*. 2015[58]	To analyse the prevalence and associated risk factors of tinnitus.	Cross-sectional study	Adults including soldiers aged 20 to 98 years. Data was obtained from Korea National Health and Nutrition Examination Survey, between 2009 and 2012 (n=19,290).	Tinnitus	Self-reported
Pankaj A and Bhatia A. 2015[59]	To study the utility of distortion product otoacoustic emissions (DPOAEs) in the detection of preclinical NIHL in artillery soldiers.	Cross-sectional study	Male subjects aged 18–35 years from the Indian Army and general civilians (n=136).	Preclinical NIHL	An individual with pure tone bone conduction audiometry threshold of >20 dB at any frequency was considered to have SNHL.
Smith C *et al*. 2015[60]	To determine the noise exposure of Department of Defence (DoD) military musicians, the percentage of DoD military musicians receiving annual hearing tests, and the percentage of DoD military musicians that received an annual hearing test and were diagnosed with a hearing injury.	Cross-sectional study	Active duty musicians serving in the US Air Force, Army, Marine Corps, and Navy between 2009 and 2013 (n=430900).	Hearing loss	Hearing injury identified using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9 CM) codes.
Swan AA *et al.* 2015[61]	To describe the prevalence of tinnitus and likely associated conditions in a cohort of Iraq and Afghanistan war veterans.	Retrospective observational study	US Veterans of Iraq and Afghanistan (IAV) war (n= 311,400)	Tinnitus	ICD-9-CM codes were used to identify IAV who received care for tinnitus.
Wells TS *et al*. 2015[62]	To define the risk of hearing loss among US military members in relation to their deployment experiences.	Cohort study	Millennium Cohort study participants (n=48,540). It is a longitudinal cohort of US military service personnel with a follow up period of at least 21 years.	Hearing Loss	Self –reported and by using audiometric data. Audiometric data was defined using the veteran affairs standard for impaired hearing. According to which, impaired hearing is considered a disability when the audiometric threshold in any frequencies (500,

Author, Year	Objective	Study Design	Setting/ Population (n)	Outcome	Definition of hearing loss/tinnitus
					1000, 2000, 3000 or 4000Hz) is 40dB or greater; or when thresholds for at least three of these frequencies are 26 dB or greater.
Yurgil KA *et al.* 2015[63]	To examine whether aetiology, severity, and frequency of traumatic brain injury (TBI) increases risk of post-deployment tinnitus when accounting for comorbid posttraumatic stress disorder (PTSD).	Cross-sectional study	Active duty US Marine and Navy servicemen enrolled in the Marine Resiliency Study ((n=1647).	Tinnitus	Self-reported
Bonfort G *et al*. 2014[64]	To study the epidemiology, the evolutionary audiometric profile and the after-effects of acute acoustic trauma managed in a military environment.	Retrospective cohort study	French military cases of acute acoustic trauma hospitalised between 2003 and 2008 (n=225).	Hearing loss and tinnitus	Hearing loss was identified using audiograms at the following frequencies: 250, 500, 1000, 2,000, 4,000, 6,000, and 8,000 Hz.
Irgens-Hansen K *et al*. 2014[65]	To assess the prevalence of hearing loss among Navy personnel in the Royal Norwegian Navy (RNoN), and to investigate whether there is an association between work on board RNoN vessels and occurrence of hearing loss.	Cross-sectional study	Navy personnel working on board RNoN vessels from April 2012 to June 2013 (n= 948).	Hearing Loss	Hearing loss was defined as hearing threshold levels ≥25 dB in either ear at the frequencies 3,000, 4,000 or 6,000 Hz.
Kaewboonchoo O *et al*. 2014[66]	To examine the prevalence of hearing loss and its risk factors among Thai naval officers.	Cross-sectional study	Thai naval officers aged 20 to 56 years (n=149)	Hearing loss	Hearing loss was classified into 3 types according to results of an audiometric test. 1) If a subject had a normal hearing level at 0.5, 1, and 2 kHz and

Author, Year	Objective	Study Design	Setting/ Population (n)	Outcome	Definition of hearing loss/tinnitus
					greater abnormal hearing level in the same ear at 4 kHz than at 8 kHz, he was classified as having a 4 kHz dip. 2) If a subject had a normal hearing level at 0.5, 1, and 2 kHz and greater abnormal hearing level in the same ear at 8 kHz than at 4 kHz, he was classified as having high frequency hearing loss. 3) If a subject had an abnormal hearing level at 0.5, 1, 2, 4, and 8 kHz, he was classified as having mixed hearing loss.
Michas G *et al*. 2014[67]	To evaluate the prevalence of hearing loss among Greek army recruits.	Cross-sectional study	Males aged >18 years in Greek army (n=910)	Hearing loss	A speech-frequency pure-tone average (average of hearing thresholds at 0.5, 1, 2, and 4 kHz) of ≥25 dB HL in both ears was defined as hearing loss according to WHO criteria.
Zeigelboim B *et al*. 2014[68]	To evaluate the vestibular behaviour in military band musicians.	Retrospective cross-sectional study	Military band musicians from the Army of Paraná (Brazil) (n=19).	Hearing difficulty	Self-reported
Dougherty AL *et al,* 2013[69]	To describe blast-related ear injuries during Operation Iraqi Freedom, identify the effect of hearing protection worn at the point of injury, and explore hearing loss and tinnitus outcomes within one year after injury.	Retrospective observational study	US military personnel that served in Operation Iraqi Freedom March 2004 and August 2008 (n=3,981).	Hearing loss and tinnitus	ICD-9-CM diagnostic codes.
Gonçalves CG de O *et al*. 2013[70]	To analyse and characterize tonal auditory thresholds between 500 Hz and 16,000 Hz of professional musicians, specifically members of a	Retrospective cohort study	Professional musicians (military band) (n=50) and those without (n=44) history of professional exposure to intense sound.	Hearing impairment	The hearing normality criterion was defined for aerial tone hearing thresholds up to 25 dB HL for the frequency rate of 500 to 8,000 Hz.

Author, Year	Objective	Study Design	Setting/ Population (n)	Outcome	Definition of hearing loss/tinnitus
	military band.				
Gubata *ME et al*. 2013[71]	To identify accession and service-related risk factors for hearing-related disability in US military personnel.	Case control study	Soldiers and Marines from the US military who underwent service-specific disability evaluation between 2002 and 2010 [cases (n) = 505; control (n) = 1,860].	Hearing loss	Hearing loss was defined according to the Veterans Affairs Schedule of Rating Disabilities code (i.e VASRD code 6100).
Klamkam P *et al*. 2013[73]	To 1) determine the prevalence of sensorineural hearing loss (SNHL) and the otologic manifestations from primary blast injury among military personnel in southernmost Thailand, and to 2) evaluate the impact of explosive devices and distance from explosion on SNHL under various conditions.	Cross-sectional study	Military personnel that sustained blast injury in southernmost Thailand from November 2008 to October 2010 (n=76).	Hearing loss	Hearing loss was identified using 1) Pure tone air-conduction audiometry for 8 frequencies: 250 Hz, 500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz and 8 kHz; and 2) Pure tone bone-conduction audiometry for 4 frequencies: 500 Hz, 1 kHz, 2 kHz and 4 kHz.
MacGregor AJ *et al*, 2013[74]	To examine the association between post-concussive symptoms and mild traumatic brain injury (MTBI) among combat veterans while adjusting for posttraumatic stress disorder (PTSD) and depression.	Cross-sectional study	US Military personnel with provider-diagnosed MTBI (n = 334) or non-head injury (n = 658).	Tinnitus	Self-reported
Mahboubi H *et al*. 2013[75]	To estimate the prevalence and evaluate the associated risk factors of the noise-induced hearing threshold shift (NIHTS) in the US	Cross-sectional study	Individuals (including people in armed forces) aged 20–69 years who had complete audiological data from the NHANES	Threshold shift	NIHTS was defined using stringent criteria. A notch[1] was considered to be present when each of these criteria was met: (1) the 4 kHz threshold was worse than 20 dB

[1] Noise-induced hearing threshold shift (NITS) is the first sign of NIHL, which appears in audiometry as a notch, and is caused by inner ear's hair cell damage due to environmental noise exposure

Author, Year	Objective	Study Design	Setting/ Population (n)	Outcome	Definition of hearing loss/tinnitus
	adult population based on the National Health and Nutrition Examination Surveys (NHANES).		database (n=5,418).		HL, (2) the 4 kHz threshold was at least 10 dB worse than the 2 kHz threshold, and (3) the 4 kHz threshold was at least 10 dB worse than the 8 kHz threshold.
Orsello CA *et al*. 2013[76]	To determine whether a difference in mean annual SNHL incidence rate exists between fixed and rotary wing aviators in the U.S. Army, Navy, Air Force, and Marine.	Cross sectional study	Military pilots in US from 1977 to 2011 (n=467,064 person-years).	Hearing loss	Self-reported
Shah A *et al*. 2013[72]	To determine if tympanic membrane perforation offers any protection from inner ear damage and determine the incidence and pattern of otologic blast injury in military personnel returning from deployment.	Retrospective case series	US service members injured in Operation Iraqi Freedom and Operation Enduring Freedom from October 2006 to October 2007 (n=164).	Hearing loss and tinnitus	Hearing loss was identified using audiograms at the following frequencies: 250, 500, 1000, 2,000, 3,000, 4,000, 6,000, and 8,000 Hz.
Saedi B *et al*. 2013[77]	To evaluate transient threshold shift after gunshot noise exposure with the help of Pure Tone Audiometry in a group of military personnel.	Cohort study	Military forces from a military unit in Tehran (n=40) exposed to gunshot noise for the first time.	Transient threshold shift	No information (abstract only)

Appendix 7: Table 3 - Categorisation of included reviews and reports on detection of hearing loss and tinnitus

Study ID	Reproducibility of individual tests	Test accuracy/ level of agreement between different tests	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
Hearing Loss							
Reviews in general population without specific information on military population							
Ali S *et al.* 2015[34]							√
CADTH 2015[24]	√	√					
Reavis KM *et al.* 2015[23]	√						
Dobie RA and Clark WW 2014[35]							√
Gardiner and Dretzke 2014[6]							√
Granberg S *et al.* 2014[36]							√
Hotton M and Bergeron F 2014[20]	√						
Mahomed F *et al.* 2013[22]	√	√					
Pawlaczyk-Luszczynska M *et al.* 2013[10]							√
Chou R *et al.* 2011[29]		√			√		

Study ID	Reproducibility of individual tests	Test accuracy/ level of agreement between different tests	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
Swanepoel AW and Hall JW. 2010[33]				√	√		
Schonweiler R and Raap M 2007[27]		√					
Tlumak AI *et al.* 2007[30]		√					
Pirozzo S *et al.* 2003[21]	√	√					
Yueh B *et al.* 2003[28]		√			√		
Olsen S 1999[37]							√
Other Evidence (not specific to military)							
Helleman[31] (Prospero protocol)		√					
NICE[38] (guideline in progress)							√
Health Technology Assessment, 2009[25]	√						

Study ID	Reproducibility of individual tests	Test accuracy/ level of agreement between different tests	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
(HTA from a member of INAHATA)							
Tinnitus							
Tunkel DE *et al.* 2014[41]							√
Kamalski DM *et al* 2010[40]							√

Appendix 8: Table 4 - Primary studies on detection/measurement of hearing loss

Potentially relevant references related to detection/measurement of hearing loss (MEDLINE, 2012 to October 2016, military populations)
Buchler M, Kompis M, Hotz MA. Extended frequency range hearing thresholds and otoacoustic emissions in acute acoustic trauma. Otology & Neurotology. Oct 2012;33(8):1315-1322.
Gallun FJ, Diedesch AC, Kubli LR, et al. Performance on tests of central auditory processing by individuals exposed to high-intensity blasts. Journal of Rehabilitation Research & Development. 2012;49(7):1005-1025.
Henry JA, Griest S, Austin D, et al. Tinnitus Screener: Results From the First 100 Participants in an Epidemiology Study. American Journal of Audiology. Jun 1 2016;25(2):153-160.
Henry JA, McMillan GP, Thielman EJ, et al. Evaluating psychoacoustic measures for establishing presence of tinnitus. Journal of Rehabilitation Research & Development. 2013;50(4):573-584.
Kirk KM, McGuire A, Nasveld PE, Treloar SA. Comparison of self-reported and audiometrically-measured hearing loss in the Australian Defence Force. International Journal of Audiology. Apr 2012;51(4):294-298.
Macrae JH. Validity of the National Acoustic Laboratories procedure for determining percentage loss of hearing. International Journal of Audiology. Dec 2012;51(12):932-935.
Macrae JH. Assessment of the American Medical Association guide to the evaluation of binaural hearing impairment. International Journal of Audiology. Nov 2013;52(11):740-745.
Margolis RH, Killion MC, Bratt GW, Saly GL. Validation of the Home Hearing TestTM. Journal of the American Academy of Audiology. May 2016;27(5):416-420.
Mendel LL, Mustain WD, Magro J. Normative data for the Maryland CNC Test. Journal of the American Academy of Audiology. Sep 2014;25(8):775-781.
Panagiotopoulos G, Galanakis M, Varvogli L, Chrousos, G, Darviri C. Validation of the Greek version of Mini Tinnitus Questionnaire as a Brief Screening Test for Assessment of Tinnitus-related Distress: our experience in 301 adult patients. Aug 2015; Clinical Otolaryngology 40 (4):363-9
Raghavan D, Khan S. Use of Otoacoustic Emissions (OAE) to detect sub-clinical inner ear damage in divers of the Indian Navy. Medical Journal Armed Forces India. Oct 2014;70(4):344-348.
Reed AC, Centanni TM, Borland MS, Matney CJ, Engineer CT, Kilgard MP. Behavioral and neural discrimination of speech sounds after moderate or intense noise exposure in rats. Ear & Hearing. Nov-Dec 2014;35(6):e248-261. **(ANIMAL STUDY)**
Rezaee M, Mojtahed M, Ghasemi M, Saedi B. Assessment of impulse noise level and acoustic trauma in military personnel. Trauma Monthly. 16(4):182-7, 2012 Jan.
Williams-Sanchez V, McArdle RA, Wilson RH, Kidd GR, Watson CS, Bourne AL. Validation of a screening test of auditory function using the telephone. Journal of the American Academy of Audiology. Nov-Dec 2014;25(10):937-951.

Additional study found during wider searches for this report:
Davis A, Smith P, Ferguson M, Stephens D, Gianopoulos I. Acceptability, benefit and costs of early screening for hearing disability: a study of potential screening tests and models. Health Technology Assessment 2007;11(42).

Appendix 9: Table 5 - Review evidence related to different questions around detection of NIHL and tinnitus

Review question	Population (P), test(s) (Index {T}, reference {R}), Outcome (O), setting (S)	Reproducibility of individual tests	Test accuracy /level of agreement between different tests (PTA, OAE, other)	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
Hearing Loss								
Reviews in general population without specific information on military population								
Ali S *et al*. 2015 (Medico legal review) *To justify if it is reasonable to use 1 and 8 kHz anchor points in the medico-legal diagnosis and estimation of noise-induced hearing loss*	**P** - People with NIHL **T** - Not applicable **R** - Not applicable **O** - To justify the use 1 and 8 kHz anchor points in the medico-legal diagnosis and estimation of NIHL **S** - Not described							Aimed to validate the legitimacy and validity of using use 1 and 8 kHz as anchor points in diagnosing NIHL.
CADTH 2015 (Report) *Effectiveness of audiograms and functional auditory tests for assessing the ability to hear speech in noise*	**P** - Adults **T** - Audiograms, Functional auditory tests (HINT, SPIN, SPRINT, SPRINT$_{100}$,WINT) **R** - Audiogram **C** - Functional auditory tests **O** - Effectiveness and comparative effectiveness of tests **S** - Clinical setting in US	Yes - audiograms	Yes- Comparative effectiveness between 1.Audiograms and functional tests 2.Different functional tests					
Reavis KM *et al*. 2015 (systematic review and meta-analysis) *To synthesize the DPOAE level test-retest*	**P** - Adults **T** - DPOAE test **R** - No reference test **O** - Set of DPOAE level shift reference limits	Yes- DPOAE test–retest variability						

Review question	Population (P), test(s) (Index {T}, reference {R}), Outcome (O), setting (S)	Reproducibility of individual tests	Test accuracy /level of agreement between different tests (PTA, OAE, other)	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
literature to construct a set of DPOAE level shift reference limits that can be used clinically to define a statistically significant emission change.	**S**- Not described							
Dobie RA and Clark WW 2014 (Systematic Review)[2] *To compare the suitability of a 3-dB versus 5-dB exchange rate (ER) in predicting hearing loss from non-impulsive intermittent or fluctuating noise exposures.*	**P** - People with NIHL **T** - Audiometry **R** -Not applicable **O** - Suitability of a 3-dB versus 5-dB exchange rate (ER) in predicting hearing loss **S** - Not described							Determined the suitability of two different exchange rates (3 and 5dB) in predicting NIHL.
Gardiner D *et al*, 2014 (Systematic Review) *To identify and analyse studies investigating different techniques for diagnosing and quantifying noise-induced hearing loss*	**P** - People with NIHL **T** - Tests for diagnosing and identifying NIHL **R** - No reference test **O** - Effectiveness of various tests for screening and assessment of NIHL **S** - Not described							Provides a narrative synthesis of studies on different techniques of diagnosis and quantifying NIHL.
Granberg S *et al*. 2014	**P** - Adults with HL							Aimed to identify outcome

[2] Could not access full text even after placing order at the British Library

Review question	Population (P), test(s) (Index {T}, reference {R}), Outcome (O), setting (S)	Reproducibility of individual tests	Test accuracy /level of agreement between different tests (PTA, OAE, other)	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
(Systematic Review) *To identify the outcome measures used in research conducted in adults with HL as part of the developmental process of the ICF core sets for HL project*	**T -** All types **R** - Not applicable **O** - Outcome measures used in research on adults with hearing loss **S** - Not described							measures used in research on adults with hearing loss (HL) as part of the ICF Core Sets development project.
Hotton M and Bergeron F 2014 (systematic review in French) C*ritical literature review on the psychometric properties of the Hearing in Noise Test(HINT)*	**P -** Adults and children **T -** HINT **R -** No information **O** - Psychometric properties **S** - Not described	Yes- Hearing in Noise test						
Mahomed F *et al*. 2013 (Systematic review & Meta-analysis*)* *To review evidence on Validity (test-retest reliability and accuracy) of automated threshold audiometry compared with the gold standard of manual threshold audiometry*	**P -** Adults and children **T -** Automated threshold audiometry **R -** Manual Threshold Audiometry **O -** Test-retest reliability and accuracy **S -** Not described	Yes- Test-retest reliability of automated compared to manual audiometry	Yes- accuracy of automated threshold audiometry					
Pawlaczyk-	**P** - Adults with NIHL							Summarized the studies on

Review question	Population (P), test(s) (Index {T}, reference {R}), Outcome (O), setting (S)	Reproducibility of individual tests	Test accuracy /level of agreement between different tests (PTA, OAE, other)	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
Luszczynska M *et al.* 2013 (Review) *To summarize the studies on NIHL which were carried out in the countries of Central and Eastern Europe, South‐East Europe and newly formed independent states*	predominantly related to workplace **T -** All types of test **R -** No information **O** - No specific outcome **S** - Studies carried out in the countries of Central and Eastern Europe, South‐East Europe, and former Soviet Union countries or Newly Independent States in the period from 1970 to 2012							noise‐induced hearing loss (NIHL)
Chou R *et al*. 2011 (Systematic review) *To analyse the accuracy of hearing-loss screening methods including, questionnaires, clinical techniques (whispered voice test), and hand-held audiometry*	**P -** Asymptomatic adults aged 50+; excluded if hearing loss due to recent noise or occupational exposure **T -** Whispered voice test, finger rub test, watch tick test, single-question screening regarding perceived hearing loss, hearing loss questionnaire, and portable audiometer **R** - No information **O -** Accuracy of hearing tests **S -** Primary care		Yes– compared effectiveness of various screening tests			Yes- Accuracy of various screening methods for early detection of hearing loss		
Swanepoel AW and Hall JW, 2010 (systematic review) *To review peer-reviewed*	**P** - Infants, children and adults **T** - Telehealth technologies for screening and diagnosis **R** - Not applicable				Yes – discussed self-tests, remote and	Yes - Telehealth technologies used in		

Review question	Population (P), test(s) (Index {T}, reference {R}), Outcome (O), setting (S)	Reproducibility of individual tests	Test accuracy /level of agreement between different tests (PTA, OAE, other)	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
publications on audiology related telehealth services and patient clinician perceptions regarding their use	**O** - No specific outcome **S** - Not described				face to face application of telehealth technologies	audiological screening		
Schonweiler R and Raap M 2007 (Systematic review, article in German) To compare different test variables /parameters of NN-BERA	**P** - All ages (neonates, children, adults)-not specifically NIHL **T** - n=Notched noise BERA (brainstem evoked response audiometry) **R** - No information **O** - Test variables /parameters of NN-BERA **S**-Not described		Yes-NN-BERA				-	
Tlumak AI *et al.* 2007 (Meta-analysis) *Comprehensive examination of the manner and accuracy with which thresholds are estimated via ASSR-ERA and variation within and across modulation frequencies.*	**P -** Normal hearing or hearing impaired children (> 6 years) and adults **T -** Electric response audiometry (ERA) using auditory steady-state responses (ASSRs) **R** - Not clear **O** - Accuracy of ASSR-ERA **S** - Not described		Yes-Investigated the accuracy with which thresholds are estimated via ASSR-ERA					
Pirozzo S *et al*. 2003 (Systematic Review)	**P** - Children and adults **T -** Whispered voice test	Yes-whispered	Yes-whispered					

Review question	Population (P), test(s) (Index {T}, reference {R}), Outcome (O), setting (S)	Reproducibility of individual tests	Test accuracy /level of agreement between different tests (PTA, OAE, other)	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
To determine the accuracy of the whispered voice test in detecting hearing impairment in adults and children	**R** - Audiometry **O** - Accuracy of Whispered Voice test **S** - Primary care	voice test compared against audiometry	voice test					
Yueh B *et al.* 2003 (Review) *To review the evidence on screening and management of hearing loss of older adults in primary care setting*	**P** - Older adults (>50 to >65 years old) with hearing loss **T** - Screening tests (HHIE-S, audioscopes) **R** - Audiograms **O** - No specific outcome **S** - Primary care		Yes – Compared effectiveness of various screening tests			Yes HHIE-S and audioscopes		
Olsen S 1999 (Meta-analysis) *To determine the potential of the acoustic reflex threshold (ART) as a predictor of the uncomfortable loudness level (ULL) and to identify related areas for investigations in the future*	P - People with hearing impairment **T** - acoustic reflex threshold test **R** - No information O - the potential of the acoustic ART as a predictor of the ULL **S** - Not described							Evaluated ART as a tool for predicting ULL.
Other Evidence								
Helleman (Prospero protocol) *To investigate and structure the available*	**P** - People exposed to noise **T** - Otoacoustic Emissions **R** - Audiometry **O** - compare the effects		Yes – Otoacoustic Emissions					

Review question	Population (P), test(s) (Index {T}, reference {R}), Outcome (O), setting (S)	Reproducibility of individual tests	Test accuracy /level of agreement between different tests (PTA, OAE, other)	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
data regarding the comparison between OAEs and audiometry	of noise on hearing as measured by audiometry and OAE **S -** Not described							
NICE (guideline in progress) **Guideline Scope** *Hearing loss (adult presentation): assessment and management*	**P -** Adults > 18 years of age Will cover the following questions on assessment : 1.How should hearing and communication needs be assessed 2.Which tests and investigations should be used in secondary medical services to assess the underlying cause of hearing loss 3.Which tests and investigations should be used in secondary medical services to determine the cause of sudden-onset sensorineural hearing loss							Guideline in development.
Health Technology Assessment report (2009) *This is published health technology assessment from a member of INAHATA*		HINT (hearing in noise test)						
Tinnitus								
Tunkel 2014 *Clinical Practice*	**P – Adults with tinnitus** The guideline discusses the							It discusses the evaluation of patients with tinnitus,

Review question	Population (P), test(s) (Index {T}, reference {R}), Outcome (O), setting (S)	Reproducibility of individual tests	Test accuracy /level of agreement between different tests (PTA, OAE, other)	Incremental benefit of using more than one test	Utility of tests in different settings (e.g. clinic vs in the field)	Utility of tests at different stages of NIHL, e.g. "early" detection	Emerging techniques for detecting "hidden" hearing loss (in vitro, in vivo)	Other
Guideline: Tinnitus The purpose of the guideline is to provide evidence-based recommendations for clinicians managing patients with tinnitus	evaluation of patients with tinnitus, including selection and timing of diagnostic testing and specialty referral to identify potential underlying treatable pathology.							including selection and timing of diagnostic testing and specialty referral to identify potential underlying treatable pathology.
Kamalski DM *et al* 2010[40] *Systematic review*	**P** - Patients with tinnitus **T** - disease specific health related QoL instruments **R** - Not applicable **O** - psychometric properties of identified QoL instruments **S** - Clinical trials							Aim to identify disease specific health related QoL instruments used to assess treatment outcomes in tinnitus patients.

Appendix 10: Table 6 - Impact of NIHL and tinnitus on quality of life

Author, year	Type of publication	Setting/ population Type of Studies included	Impact of NIHL, tinnitus on QoL	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
MILITARY with or without other occupation (Review)						
Alamgir H *et al* 2016[43]	Literature review Summarises the evidence on the 1) Impact of hearing loss on QoL among a US military population. 2) Describes the QoL instruments used to quantify hearing loss on QoL. 3) Examine the national databases and report on their utility for studying hearing loss on QoL of military personnel. 4) Future recommendations	Impact of noise induced hearing loss on QoL in an active military population	Impact on QoL of military personnel.	Identified 6 studies investigating QoL and hearing loss measures among a veteran military population. Main findings were: <u>Quality of life (QoL):</u> **Hawkins *et al*. 2012** *"Hearing impairment was strongly associated with a lower quality of life from both a physical and mental health standpoint".* **Tambs 2004** *"Hearing loss is associated with substantially reduced mental health ratings among some young and middle-aged persons but usually does not significantly affect mental health among older persons".* **Mulrow *et al*. 1990** *"Hearing loss is associated with important adverse effects on the quality of life of elderly persons, effects which are reversible with hearing aids".* <u>Benefits of using Hearing Aids of QoL</u> **Yueh 2010; Abrams et al 2002 and Mulrow et al 1992:** All three studies found that QoL improved with the use of hearing aids. None of the national databases contained the data necessary to assess the association of hearing impairment and noise-induced hearing injury and QoL in US military population.	√ Several databases searched. X Included articles other than English language X Eligibility criteria stated; PRISMA flow diagram given; reasons for exclusion given X Clear if screening and data extraction was done by more than one reviewer X Clear if standard data extraction forms were used X Detail on quality assessment of primary studies reported	Lack of agreement on definition of QoL. Issues raised around using generic instruments vs disease-specific instrument for assessing QoL. Lack of consistency in the terminology used for physical, social, and mental health domains and QoL attributes used.

Author, year	Type of publication	Setting/ population Type of Studies included	Impact of NIHL, tinnitus on QoL	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
				Lack of literature on hearing impairment and QoL in the military population.		
T**heodoroff SM *et al*. 2015**[9]	Systematic review with narrative synthesis of evidence on 1) Prevalence 2) Risk and protective factors 3) Functional and QoL outcomes of hearing impairment and tinnitus.	US veterans and military service members from three operations in Afghanistan or Iraq (2001-2013).	Question 3 looked at the effects of hearing impairment and tinnitus on QoL.	14 studies in total were included for the three review questions Key question 3: What are the effects of hearing impairment and tinnitus on functioning and quality of life? Lack of evidence, none of the studies reported on functioning and QoL effects of tinnitus among US veterans and military personnel.	√ Several databases searched, reference list checking, expert consultation √ Eligibility criteria stated; screening in duplicate; PRISMA flow diagram; reasons for exclusion given √ Duplicate data extraction X Included articles other than English language X Detail on quality assessment of primary studies reported	None detailed
Stevelink SAM *et al* 2016[42]	Systematic review of mental health disorders in ex-military personnel with a physical impairment (visual, hearing or physical).	Prevalence of mental health disorders among physically, permanently impaired ex-military personnel.	Hearing impairment and mental health disorders.	Seventeen studies were included in the review. Two studies looked specifically at hearing impairment (Abrams TE *et al* 2006) and tinnitus (Fagelson MA *et al* 2007) and one study included participants with a range of impairments including hearing impairment (Reiber GE *et al* 2010). Main findings are as follows: **<u>PTSD:</u>** **Fagelson MA *et al* 2007** that examined the prevalence of PTSD among soldiers with a hearing impairment suggested that 34% of the US soldiers (n=300) fulfilled the criteria for probable PTSD.	√ Several databases searched, reference list checking, expert consultation √ Eligibility criteria stated; screening in duplicate; PRISMA flow diagram; reasons for exclusion given √ Duplicate data extraction √ quality assessment of primary studies included √ PRISMA flow diagram X Included articles other than English language	Majority of studies investigated mental well-being with an impairment at any one time. No causal inference can be made. Various methods were used to assess mental health problems. Lack of information collected i.e. time

Author, year	Type of publication	Setting/ population Type of Studies included	Impact of NIHL, tinnitus on QoL	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
				<u>Depression:</u> Abrams found 30% (n=123) of US veterans with hearing impairment were depressed compared to 6.5% US veterans without hearing loss (n=370). **Reiber GE *et al* 2010** found that military personnel with hearing loss were not more likely to report depression compared to those without hearing loss.		since being impaired or cause of impairment.
MILITARY with or without other occupation (Other evidence)						
The Royal British Legion 2014[1]	Report on UK Armed Forces that aims to outline information on service related hearing problems in UK Armed Forces.	UK Armed Forces	Experiences of Service personnel and veterans with hearing loss and tinnitus. Impact of hearing problems on quality of life.	Findings are mainly from 1) **online survey** (February and March 2014) which received 1,110 responses from serving and ex-Service personnel and 2) **Legion household survey** of ex-Service community (2014) which included 1,120 veterans. Themes that emerged were social isolation, sleep deprivation and being unable to function in a social situation. **Impact on QoL** *"Tinnitus appeared to have a significant impact on respondent's wellbeing"*. • 1 in 10 respondents said had "very big" effect on their QoL • 43% reported it had a "significant effect" on their QoL • Over a third reported a lack of sleep, with 1 in 5 not able to attend meetings related to work. • 1 in 10 said hearing loss had a significant effect on relationships with friends and family, which frequently caused misunderstandings and	Not assessed.	Not assessed.

Author, year	Type of publication	Setting/ population Type of Studies included	Impact of NIHL, tinnitus on QoL	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
				frustrations. • Almost a quarter said that noises "severely" worry, annoy or upset them when they are at their worst. • Around 40% said the noises "moderately" affected them and 24% reported "slightly". • Approximately a third with severe tinnitus felt despair. Others have coped and are no longer distracted by the constant ringing sound. • *"I have struggled with my tinnitus to the point I considered ending my days numerous times! I get it all day every day."* • *"Feel bad tempered and very irritable with everybody".* **Impact on career** • <3% reported they had been medically discharged from the Armed Forces due to hearing loss. • 12% reported having been medically downgraded and 8% had been categorised as 'P7' in their occupational health assessment due to their hearing loss. • Some had been turned down for promotion, or forced to change jobs, and loss of earnings.		
Non-military (Review)						
Kitterick P *et al* 2015[44]	Systematic review and meta-analysis	Examined the impact of hearing-assistive devices on health-related	Unable to understand speech in noisy environmen.	The review summarised the current evidence for the effects of hearing-assistive devices on health-related QoL of adults with SSD. It found that few studies have measured the impact of devices using generic instruments.	√ Several databases searched, reference list checking, expert consultation √ Eligibility criteria stated √ Duplicate data extraction	Several studies did not specify inclusion, exclusion criteria or declare whether there was any missing data.

Author, year	Type of publication	Setting/ population Type of Studies included	Impact of NIHL, tinnitus on QoL	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
		QoL of adults with severe to profound hearing loss in one ear, single-sided deafness (SSD) as measured using generic and disease-specific instruments. Observational designs.	Hearing assistive devices developed to address functional impairment.	The review concluded that **hearing devices have small to medium impact on health related QoL**.	√ No restrictions on languages √ Quality assessment of primary studies included	Majority of the reported effects may have some form of selection bias.
Miller G *et al* 2015[45]	Systematic review of clinical evidence	Determine the influence of cochlear implantation on cognition in the older adult (over 65 years) population.	Cochlear implants and the overall QoL in over 65 year olds.	• 3 studies met the inclusion criteria. • No studies evaluated changes in QoL and cognitive function after implantation with cochlear implants in older adults	√ Several databases searched, reference list checking, expert consultation √ Eligibility criteria stated; screening in duplicate; PRISMA flow diagram; reasons for exclusion given √ Duplicate data extraction X Included articles other than English language X Detail on quality assessment of primary studies reported	No information

Author, year	Type of publication	Setting/ population Type of Studies included	Impact of NIHL, tinnitus on QoL	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
Turner *et al* 2007[47]	Non-systematic	Suicide in deaf populations. Objectives: 1)Incidence/ prevalence of suicidal behaviour 2)Describe risk factors for suicidal behaviour 3)Describe approaches to intervention and suicide prevention	Incidence and prevalence of suicidal behaviour in deaf people	• 13 studies relevant, 2 studies from UK. • Little evidence to suggest that risk factors for suicide are different to the general population. But the studies report higher levels of depression.	√ Several databases searched, reference list checking, expert consultation √ Eligibility criteria stated √ Duplicate data extraction using standard forms X Included articles other than English language X Clear if screening in duplicate X PRISMA flow diagram given X Detail on quality assessment of primary studies reported	Limited number of studies and small sample sizes Definition of suicidal behaviour and deafness vary. Also variety of terms used to describe hearing loss.
Jacobson GP and McCaslin D 2001[46]	Non-systematic	Determine whether there is a direct relationship between tinnitus and suicide.	Tinnitus related suicides.	• 3 reports identified, none of these reports showed a causal relationship between tinnitus and suicide. • Patients who attempted suicide had pre-existing psychiatric conditions-the most common being "clinically depressed".	√ Several databases searched √ No restrictions on languages X Eligibility criteria stated; PRISMA flow diagram given X Clear if screening and data extraction done by more than one reviewer. X Detail on quality assessment of primary studies reported	Review is limited to articles published in peer-reviewed journals
Non –Military (Other Evidence)						
Tunkel D *et al* 2014[41]	Clinical practice Guideline: Tinnitus	Patients with tinnitus.	The guideline focused on	QoL of patients with tinnitus can vary widely, with most patients less severely affected but some could experience anxiety, depression, and extreme life	√ Guideline was developed using a priori protocol based on	No information

Author, year	Type of publication	Setting/ population Type of Studies included	Impact of NIHL, tinnitus on QoL	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by review authors
			tinnitus that is bothersome and persistent (lasting 6 months or longer), often with negative effect on patient's QoL.	change. Suicide has been reported in tinnitus patients who have coexisting psychiatric illness.	***Clinical Practice Guideline Development Manual: A Quality-Driven Approach for Translating Evidence into Action.*** √ Several databases searched, expert consultation √ Eligibility criteria stated X Included articles other than English language X PRISMA flow diagram provided X Clear whether screening, data extraction was done by more than one reviewer X Detail on quality assessment of primary studies reported	

Appendix 11: Table 7 - Impact of NIHL and tinnitus on ability to work of military or other occupational groups

Author, year	Type of publication	Outcome measure with relation to impact on work ability	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
MILITARY with or without other occupational groups (Review)						
Friberg E *et al.* 2012[49]	Systematic review with narrative synthesis of data on hearing difficulties or other ear-related diagnoses and sick leave or disability pension.	**Sickness absence** in relation to hearing difficulties or other ear-related diagnoses. This included NIHL and tinnitus and other diagnoses including sudden sensorineural loss, vertigo, otitis media and Ménière's disease.	Study population not restricted to any specific occupational group Studies presenting relevant empirical data and published in scientific peer-reviewed journals. Prospective and retrospective cohort and cross-sectional studies were included.	Sickness absence: **No study with separate data on a military population was found**. **Other or mixed occupation:** Included two studies on the effect of tinnitus, one on tinnitus and hearing impairment and three on hearing impairment, all in relation to sickness absence. **Kramer 2006 (Netherlands):** compared occupational performance in those with hearing impairment (n=150) and those with normal hearing (n=60). *"Hearing impaired had increased risk of sick leave due to distress/strain (OR, 4.6; 95% CI 1.3 to 16.5) compared to those with normal hearing."* **Haberg 2005 (Sweden)**: examined the effect of tinnitus and hearing impairment among musicians (n=655) *"13 (2%) individuals had been on sick leave due to hearing problems".* **Chau 2004 (France):** assessed the relationships between job, age and life conditions and causes and severity of occupational injuries in construction workers (n=880). *"Hearing impaired individuals had a higher risk of sick leave (OR, 1.52, CI not reported).* **Joore 2003 (Netherlands):** looked at the benefits after	√ Several databases searched; reference list checking, expert consultation √ Eligibility criteria stated; screening in duplicate; PRISMA flow diagram provided √ Not restricted to English language articles X Clear whether data extraction was done by more than one reviewer X Detail on quality assessment of primary studies reported	Hearing diagnosis/symptoms explored varied considerably between studies. Data on hearing difficulties were self-reported in many studies. Only four studies presented associations (RR or OR) between hearing difficulties and sick leave. Some studies presented data without any control or comparison groups.

Author, year	Type of publication	Outcome measure with relation to impact on work ability	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
				hearing aid fitting in first time hearing aid applicants with moderately impaired hearing. "*No reported absence from work due to hearing impairment at baseline or follow up among those employed".* **Andersson 2000 (Sweden):** examined occupational status after 5 years among patients with tinnitus (n =189). *"Number of sickness absentees had decreased (n= 13 vs 6) at follow up".* **Holgers 2000 (Sweden)**: investigated risk factors for severe tinnitus (n=172). *"18 (10%) patients had been absent from work for more than one month during the study period*".		
MILITARY with or without other occupational groups (Other Evidence)						
The Royal British Legion, 2014[1]	Report on the UK Armed Forces that aims to outline information on service related hearing problems.	Medical discharge, impact on career	Service personnel and veterans of the UK Armed Forces	Findings are based on results of the Royal British Legion household survey (2014) of the ex-Service community (which included 1120 veterans) and an online survey (2014) which received over 1,100 responses from serving and ex-Service personnel. "*Noise induced hearing loss was the principal cause for 62 individuals' medical discharge from the Army during 2007-2012."* *"Less than 3% of respondents (n= 26) reported that they had been medically discharged from the Armed Forces due to hearing loss, but 12% (n=105) reported having been medically downgraded and 8%*	No information	No information

Author, year	Type of publication	Outcome measure with relation to impact on work ability	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
				(n=70)said that they had been categorised as 'P7' in their 'PULHHEEMS[3]' (occupational health) assessment due to their hearing problems". *"40% those who had been graded to P7 responded that their hearing problems "definitely" had a detrimental effect on their career".* *"Over a quarter of respondents stated that their hearing problems had a detrimental effect on their civilian career. Under a quarter said that it had "no effect".* "*Some had been forced to give up using very technical skills, such as musical direction or translation, because of their hearing problems. Others reported that they had been turned down for promotion, had their employment limited in some way, or had been forced to change jobs".*		
General Population or any occupational group without separate military data (Review)						
Hjalte H *et al* 2012[50]	Systematic review on societal costs of hearing disorders	Loss of productivity	Children and adult with hearing disorder with a focus on Swedish studies Studies including data	Eight studies in total were included; **three of which gave data on productivity loss**. **CRC HEAR[4]/ Access Economics 2006**: Australian report on the financial costs and the loss of wellbeing from hearing loss for the year 2005. *"The cost for productivity loss accounted for the largest part, 57%, of the total financial cost ($10.49 billion). It was estimated that in 2005 158, 676 people were not employed due to their hearing loss".*	√ Several databases searched √ Eligibility criteria stated; screening in duplicate X PRISMA flow diagram provided X Included articles other than English and Swedish language	Heterogeneity in the included studies (e.g. different population, costing approaches)

[3] A grading of P7 means that an individual is "medically fit for duty with major employment limitations".
[4] Cooperative Research Centre for Cochlear Implant & Hearing Aid Innovation

Author, year	Type of publication	Outcome measure with relation to impact on work ability	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
			on both direct and/or indirect costs of hearing disorders.	**Feldman *et al* 2000***:* national estimation of the economic burden of hearing impairment in the US. *"Reduced work productivity accounted for 67% of the total life time cost of severe to profound hearing loss ($6.4 billion)"*. **Wolf *et al* 2010:** the economic effect of age-related hearing loss in the US for the years 2002 and 2030: *"The lost productivity attributable to hearing loss in people aged 65 years or older was estimated at approximately $1.75 billion in 2002 and was projected to rise to approximately $11 billion in 2030"*.	articles X Clear whether data extraction was done by more than one reviewer X Detail on quality assessment of primary studies provided	

Appendix 12: Table 8 - Cost implications of NIHL and tinnitus in military, other occupational groups and general population

Author, year	Type of publication	Aspect of cost implications assessed or reviewed	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
MILITARY with or without other occupational groups included (Review)						
Alamgir H *et al.* 2016[51]	Part of Phase I of a multiphase US Department of Defence (DoD) Epidemiologic and Economic Burden of Hearing Loss (DEEBoHI) project. Literature review as one of three main components for this piece of work.	To develop a framework and statistical model for an economic burden analysis of hearing impairment and NIHL.	Active duty US military service members.	Identified seven relevant cost items associated with hearing impairment and NIH injury: monitoring/prevention, medical treatment, assistive technology for follow-up care, medical infrastructure investment, consumer direct cost burden, frictional costs, indirect costs (consumer/ worksite productivity loss). Identified several data sources on which to base quantification of the major cost items (such as the Military Health System Data Repository). Developed a hearing pathway diagram that represents the flow of active duty service members through experiences related to hearing conservation and hearing loss. Derived a model from this pathway to represent the cumulative economic effects of these experiences.	√ literature search, expert consultation √ Eligibility criteria stated X Detailed information on the review methodology reported	Limitations associated with the model: Data necessary to calculate incidence and event probabilities across the demographic variables are often not available for active duty service members. Frequency of audiometric testing depends on the frequency and duration of deployment Hidden hearing injury and NIH injury are less likely to be reported in the presence of life threatening injuries. Might be difficult to identify appropriate data sources to estimate every cost.
Friberg E *et al.* 2012[49]	Systematic review with narrative synthesis of data on hearing difficulties or other ear-related	Sickness absence and disability pension in relation to hearing	Study population not restricted to any specific occupational group.	18 studies with a total of 45,850 and 66, 610 individual data reports on sickness absence and disability pension respectively were included. **Disability pension:** **Included one study on the effect of hearing loss in**	√ Several databases searched; reference list checking, expert consultation √ Eligibility criteria stated; screening in	Hearing diagnosis/symptoms explored varied considerably between studies

Author, year	Type of publication	Aspect of cost implications assessed or reviewed	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
	diagnoses related to sick leave or disability pension.	difficulties or other ear-related diagnoses. This included NIHL and tinnitus and other diagnoses including sudden sensorineural hearing loss, vertigo, otitis media and Méniére's disease.	Studies presenting relevant empirical data and published in scientific peer-reviewed journals. Prospective and retrospective cohort and cross-sectional studies were included.	**a military population** and two in firefighters; one study on the effect of NIHL in any occupation. **Military:** **Sewell 2004**: Compared civil war pension in US Union Army veterans and contemporary disability programs by examining the monthly dollar award. "*33% (n=5891) of the individuals receiving a pension received compensation for hearing loss*". Other or mixed occupation: **Starzynski 1993 (Poland):** looked at consequences of occupational diseases. *"62 % (n=1990) of those with NIHL had been granted a disability pension."*	duplicate; PRISMA flow diagram provided √ Not restricted to English language articles X Clear whether data extraction was done by more than one reviewer X Detail on quality assessment of primary studies reported	Data on hearing difficulties were self-reported in many studies Only four studies presented associations (RR or OR) between hearing difficulties and sick leave or disability pension Some studies presented data without any control or comparison groups.
MILITARY with or without other occupation (other evidence)						
Atizado A *et al* 2014[3]	Budget and policy document created by veterans for the Department of Veteran Affairs	Disability compensation	Veterans of all branches of US military service	*"Since 2000, the number of veterans receiving service-connected disability for tinnitus has increased by at least 16.5% each year".* *"The total number of veterans awarded disability compensation for tinnitus as of fiscal year 2012 exceeded 840,000".* *"At this rate, the year 2016 will see more than 1.5 million veterans receiving disability compensation for tinnitus, at a cost of more than $2.75 billion annually".*	Not assessed.	Not assessed.
The Royal	Report on the UK	Medical	Service	Findings are based on results of the Royal British	Not assessed.	Not assessed.

Author, year	Type of publication	Aspect of cost implications assessed or reviewed	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
British Legion, 2014[1]	Armed Forces that aims to outline information on service related hearing problems.	discharge from duty, claims for deafness and hearing loss, cost of hearing aids	personnel and veterans of the UK Armed Forces	Legion household survey (2014) of the ex-Service community (which included 1120 veterans) and an online survey (2014) which received over 1,100 responses from serving and ex-Service personnel. *"NIHL loss was the principal cause for 62 individuals' medical discharge from the Army during 2007-2012. The total figure doubled between 2010/11 and 2011/12, from 14 to 33 individuals".* *"Between April 2005 and September 2013 alone, there were 2,460 claims for deafness and hearing loss under the Armed Forces Compensation Scheme (AFCS), but only 295 were successful (12%)".* *"The majority of respondents to the Legion's survey (61%) had never applied for any compensation".* *"Around a third of respondents had been issued with one or two hearing aids, 67% had their aids issued by the NHS, 12% cent paid for themselves, and 11 % were MOD-funded".* *"Unlike the UK, disability payments are awarded by the US Veterans' Administration for tinnitus in isolation, and not just as part of hearing loss. The cost of Service-connected disability payments for tinnitus 2011 was $1.28 billion, and is projected to rise to $2.75 billion by 2016".*		
Tunkel *et al* 2014[41]	Clinical practice guideline on tinnitus	Disability compensation	US military personnel	*"By 2016, more than 1.5 million U.S. veterans are expected to receive disability compensation for tinnitus related claims, at an annual cost estimated to exceed $2.75 billion"*	√ Guideline was developed using a priori protocol based on ***Clinical***	No details

Author, year	Type of publication	Aspect of cost implications assessed or reviewed	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
					Practice Guideline Development Manual: A Quality-Driven Approach for Translating Evidence into Action. √ Several databases searched, expert consultation √ Eligibility criteria stated X Included articles other than English language articles X PRISMA flow diagram provided X Clear whether screening, data extraction was done by more than one reviewer X Detail on quality assessment of primary studies reported	
General Population or any occupational group without separate military data (Review)						
Hjalte H *et al* 2012[50]	Systematic review	Societal costs	Children and adults with hearing disorder with a focus on Swedish	Swedish Studies (not peer reviewed) **The Swedish Council on Technology Assessment in Health Care Report, 2003**: Review on utilities and risks of using hearing aids (n=58,000)	√ Several databases searched √ Eligibility criteria stated; screening in duplicate X PRISMA flow	Most of the data is from non- peer reviewed studies Heterogeneity in the included studies (e.g. different population,

Author, year	Type of publication	Aspect of cost implications assessed or reviewed	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
			studies. Studies including data on both direct and/or indirect costs of hearing disorders.	*"Direct cost for diagnosis and hearing aid fitting was estimated at $66.8 million in 2002. Average cost per person was $1,188"*. **Danermark *et al* 2008:** *"National estimate of direct purchase costs of hearing aids for adults was $55 million in 2006"*. **Handikappförbunden 2010:** *"Average cost of hearing aid and aid fitting per prescription in 2009 for adults was $685"*. Other studies: **Feldman M *et al* 2000**: societal costs of severe to profound hearing loss in the United States (n=15,400). *"Total lifetime costs $6.4 billion. Lifetime cost per person $410,000. 67% of costs indirect. Magnitude of costs directly related to age of onset of hearing loss (cost year 1998)"*. **CRC HEAR[5]/ Access Economics 2006**: Cost of hearing loss in Australia (n=3.55 million) *"Total financial cost $10.49 billion ($2,960 per person); of this, cost for productivity loss 57%. Cost for loss of wellbeing (based on DALYs) was $10.1 billion"*.	diagram provided X Included articles other than English and Swedish language X Clear whether data extraction was done by more than one reviewer X Detail on quality assessment of primary studies reported	costing approaches)
General Population or any occupational group without separate military data (other evidence)						
Departme nt of	Grey literature (correspondence	Claims for compensation	Former mineworkers	*"Number of claims received from former mineworkers in the UK in 2013 was 3589; total of*	Not applicable.	Not applicable.

[5] Cooperative Research Centre for Cochlear Implant & Hearing Aid Innovation

Author, year	Type of publication	Aspect of cost implications assessed or reviewed	Setting/ population Type of Studies included	Main findings	Methodological quality of review √ criteria met X criteria not met	Quality concerns of the included studies and/or other limitations noted by the authors
Energy & Climate Change, UK, 2013[52]	from the Department of Energy & Climate Change as a request for information under the Freedom of Information Act 2000)	for NIHL	in the UK	*£3,033,97 paid out in response to 1393 claims."*		
Davis A *et al*, 2007[53]	HTA report It aimed to show that a high prevalence of hearing loss has in the older population justifies screening where effective and acceptable methods are available; also that population take-up and benefit can result in measurable improvements to quality of life.	Costs of early screening for hearing disability.	People aged 55–74) years in the UK (n=34,362).	*"At present there are in excess of 3000 professionals working in the Hearing Aid Services in the UK, delivering about 500,000 patient journeys per year (1.5–2 million appointments and associated open access clinics) and fitting 700,000 hearing aids. This service costs in the region of £120 million per year to the NHS".* *"The study found the average cost of the screening programme to be £13 per person screened or about £100 if treatment costs were included. Making the conservative assumption that identification gives an extra 9 years using hearing aids, the costs of screening and intervention were in the range of £800–1000 per quality-adjusted life-year when using the Health Utilities Index and about £2500 using the Short Form 6 Dimensions metric".*	Not applicable.	Not applicable.
NICE[38]	Ongoing Guideline	Economic aspects of management of hearing loss in adults.	Adults with hearing loss	Not applicable	Not applicable	Not applicable