UK National Screening Committee

Screening for hearing loss in adults

External review against programme appraisal criteria for the UK National Screening Committee

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The UK National Screening Committee secretariat is hosted by Public Health England.

About the UK National Screening Committee (UK NSC)

The UK NSC advises ministers and the NHS in the 4 UK countries about all aspects of population screening and supports implementation of screening programmes. Conditions are reviewed against evidence review criteria according to the UK NSC's evidence review process.

Read a complete list of UK NSC recommendations.

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Plain English summary

Hearing loss is common among adults. People with hearing problems may feel isolated, depressed and have difficulties in their relationships with partners and children. They may also find it more difficult to work. Treatment involves using hearing aids. Hearing loss is a major public health problem. It is thought that about 5.5 million people aged over 60 would benefit from a hearing aid. Screening for hearing loss could be beneficial because many people often live with hearing loss for some time before seeking help.

The last UK NSC review in 2015 found that there was not enough evidence that people who have been screened for hearing loss will wear hearing aids and find some benefit from them.

This review looked for new evidence published since the last review in 2015. It aimed answer 4 questions to see whether:

- screening tests are good enough to identify people with hearing loss
- people will wear hearing aids if they have hearing loss found by a screening programme
- people have better health from using a hearing aid
- the health services that help people with hearing loss are working well in the UK.

The balance between benefits and harms remains unclear. The UK National Screening Committee does not recommend screening adults for hearing loss. This is because:

- new screening tests such as smart phone apps were identified but they were not accurate enough and would misdiagnose many healthy adults
- studies used different ways of measuring acceptability of hearing aids so it was impossible to determine whether there were any changes since the last review
- although the previous review found that treatment for hearing loss is effective, this review found no evidence on whether people were likely to have better health if they used hearing aids after being screened
- it is unclear how well hearing loss in adults is identified and managed in the UK at present.

Executive summary

Purpose of the review

This document reviews the evidence on screening for hearing loss in adults against selected UK National Screening Committee (NSC) criteria.

Background

The main types of hearing loss are caused by aging or damage to the bones and nerves needed to hear (sensorineural), or where the sound passing from the outer to inner ear is blocked, for example by ear wax (conductive). Mixed hearing loss is a combination of both sensorineural and conductive conditions. Definitions of hearing impairment vary but typically people with normal hearing can hear sounds of 20 to 25 decibels (dB) and greater whilst those with moderate hearing loss who would benefit from a hearing aid can hear a minimum of 35 to 40 dB and greater.

Adults with hearing loss can experience social isolation and stigmatisation, depression, difficulties in relationships with partners and children, restricted career choices, psychiatric disturbance and occupational stress. Hearing loss is also associated with an increased risk of dementia.

It is estimated that in the UK there are likely to be approximately 6.5 million people who would benefit from a hearing aid of whom about 5.5 million are aged 60 and over.

People often live with hearing impairment for some time before seeking help. A screening programme would aim to detect hearing loss in people before they seek help to ensure they receive interventions in a timely way to improve their listening ability, improve their quality of life and avoid the other health impacts resulting from significant periods of impaired hearing.

Focus of the review

The previous UK NSC review[1] found that the benefit of screening was unclear despite the availability of effective treatment for hearing loss. This review aimed to evaluate whether the evidence base has developed substantially since the previous UK NSC evidence summary. It includes studies published between January 2012 and January 2020. Specifically, new evidence was sought to see if it is now possible to evaluate:

- the accuracy of screening tests for hearing loss in adults
- the acceptability of treatment for hearing loss

- if screening improves health outcomes for adults with hearing loss
- how well clinical detection and management are currently implemented in the UK.

Recommendation under review

The current UK NSC policy, informed by the previous UK NSC review in 2015, is that a systematic population screening programme for hearing loss in adults is not recommended.

Findings and gaps in the evidence of this review

Twelve publications were found, examined in detail and included in the evidence synthesis. The evidence for each question is summarised below.

Since the last UK NSC review, new evidence about the accuracy of different types of screening tests was identified including 1 systematic review of 11 small prospective cohort studies, 1 additional large prospective cohort study and 4 small prospective cohort studies. However, screening test performance results reported by these studies were inconsistent and varied by screening setting and level of hearing impairment targeted. There were some methodological issues with the studies such as participant selection, whether staff administering the reference and index test were blind to the test results of whichever test was administered first, and variations in thresholds in both the reference and index tests some of which were not reported. This made the findings unreliable.

Overall, 4 cohort studies and 1 qualitative study addressed the acceptability of hearing loss treatment but used different ways to measure hearing loss, reported inconsistent results and it is questionable whether they would be applicable to the general UK population.

There was no new evidence on whether earlier initiation of treatment for hearing loss, because of screening, improves health outcomes compared to later initiation of treatment.

One study addressed the current implementation and clinical management of people with hearing loss for people resident in care homes reported by care home managers but it is questionable whether the results would be applicable to the general UK population. Review of grey literature may have found more evidence but was beyond the scope of this rapid review.

Recommendations on screening

The volume, quality and direction of new evidence is insufficient to change the current recommendation about screening for hearing loss in adults.

Limitations

This rapid review was conducted as described in the UK NSC evidence review process[2]. The review only looked for peer-reviewed scientific work and does not include work published elsewhere (grey literature). Studies not available in the English language, abstracts and poster presentations, were also not included. This means it is possible that there is evidence that might address the questions but previous comparisons of systematic and rapid reviews find that the difference is very rarely significant and would not change the recommendation. However, the consultation and peer review process aims to ask experts if there are significant studies that might have been missed.

Evidence uncertainties

The previous review found that evidence about screening tests was comprised of small questionnaire-based studies. The current review found more studies that assessed the accuracy of sound (speech or digits) in noise tests compared to the previous review. Higher performance values were achieved in a large study administering a speech in noise hearing test delivered in controlled settings. This review also reports results of studies exploring performance of new technologies reflecting the increasing interest in the use of smart phone apps to deliver screening. However, the studies suggest that a significant proportion of positive test results would be false positives. Studies were also generally small with other concerns about the study methodology. In particular, the cut off level for a positive screen was not reported and it was unclear whether the person administering the index test was blind to the result prior to administering the reference standard, introducing researcher bias. In practical terms there was concern about the way in which the testing environment and the equipment used affected the accuracy of screening test results.

Overall, there was a lack of consistency in the measures used to determine the acceptability of hearing aids and the results of the studies were variable with no consistent outcome. Evidence on the proportion of people continuing to use a hearing aid over the years following diagnosis in screen-detected or otherwise detected populations might provide a better estimate for acceptability.

There is a lack of evidence in relation to the benefit of screening. This is mainly because identified studies included adults who had already sought help for hearing problems and did not report on health-related outcomes such as quality of life. Any screening programme would increase the number of people who are referred for treatment of moderate hearing loss, however the benefit to screening this population is unclear.

Introduction and approach

Background

The main types of hearing loss are caused by aging or damage to the hearing apparatus (sensorineural), or where there is a blockage of sound passing from the outer to inner ear such as from ear wax (conductive). Mixed hearing loss is a combination of both sensorineural and conductive conditions[3].

Sensorineural hearing loss results from a degeneration of the sensitive hair cells inside the cochlea or damage to the auditory nerve, most commonly through ageing (presbycusis), or as a result of injury. Hearing loss due to presbycusis is the most common form of hearing loss and is typically gradual, progressive and affects both ears. Initial hearing loss of higher frequency sounds commonly used in speech, results in people with presbycusis having difficulty understanding people at an early stage of the disorder. Gradually hearing loss progresses to lower frequencies. Other causes of sensorineural hearing loss include exposure to excessive sound levels (noise-induced hearing loss), infections (for example measles, mumps and meningitis) and neurological disorders. Exposure to some substances including medications such as gentamicin, metals such as lead and solvents such as toluene can also induce hearing loss[3].

Conductive hearing loss results from the blockage of sound passing from the outer to the inner ear resulting in mild to moderate hearing loss and is usually treatable. Disorders resulting in conductive hearing loss include ear infection, a build-up of ear wax, a disorder of the ossicles, perforated ear drum, an object stuck in the outer ear, and Eustachian tube dysfunction[3].

Definition of hearing loss

There is no universally agreed definition for hearing loss and reference criteria vary in terms of the thresholds of intensity (loudness), measured in decibels (dB) and tone (speed of sound wave vibrations), measured in Hertz (Hz); and whether one or both ears are affected. A person with normal hearing perceives sounds at frequencies between 20 and 20,000 Hz and for language processing the most important range is between 400 and 5000 Hz[4]. Commonly used reference criteria include the Ventry and Weinstein criteria[5] (>40 dB hearing loss at either 1000 or 2000 Hz in one or both ears), the speech frequency pure-tone average (SFPTA) criteria[6,] (≥25 dB average hearing loss at 500, 1000, and 2000 Hz in the better ear) and the high-frequency pure-tone average (HFPTA) criteria (≥25 dB average

hearing loss at 1000, 2000, and 4000 Hz in the better ear)[7]. More recent definitions of hearing impairment severity have been developed and Table 1 shows the criteria used by the World Health Organisation[8], the Global Burden of Disease (GBD) Expert Group on Hearing Loss[9], the British Society of Audiology (BAS 2011)[10] and the US Centre for Disease Control (US CDC 2016)[11].

Table 1. Definitions of hearing impairment severity

Severity	BAS (2011)[10]	WHO (2019)[8]	GBD group Hearing loss (2017)[9]	US CDC (2016)[11]	Description[11]
Normal	<20dB	≤25dB	19.9dB	≤25dB	Normal hearing
Mild/Slight	20 – 40dB	26 –40dB	20-34.9dB	26 – 40dB	Infrequent difficulty in some situations, difficulty hearing soft speech, or speech from a distance or over background noise
Moderate	41 – 70dB	41– 60dB	35-49.9dB	41 – 55dB	Difficulty hearing regular speech even at close distances or sound of a refrigerator
Moderate/ Severe	-	-	50-64.9dB	56 – 70 dB	Extreme difficulty hearing normal conversations – can hear an electric toothbrush
Severe	71 – 95dB	61–80 dB	65-79.9dB	71 – 90 dB	Cannot hear most conversational speech, only loud speech or sounds (eg an alarm clock)
Profound	>95dB	≥81 dB	80-94.9dB	≥91 dB	May perceive loud sounds (eg car horn) as vibrations

BAS -British Society of Audiology, GBD – Global Burden of Disease, US CDC – United States Centre for Disease Control, WHO – World Health Organisation

Davis et al (2007)[12] reported that the threshold of mild to moderate hearing loss where a hearing aid may be of benefit is >35db.

Health impact of hearing loss and the benefits of hearing aids

In general, hearing loss has adverse consequences on interpersonal communication, psychosocial well-being, quality of life and economic independence[13]. Adults with hearing loss often experience social isolation and stigmatization, abuse, psychiatric disturbance, depression, difficulties in relationships with partners and children, restricted career choices, occupational stress and relatively low earnings[14]. Gurgel et al (2014)[15] suggests that older individuals with hearing loss have an increased risk of developing dementia and a more rapid decline, than those without hearing loss. Older adults with moderate to severe hearing loss are more likely to experience impaired activities of daily living compared with those with mild or no hearing loss and if left untreated, these effects can become an ongoing contributor to the decline of health with age[16]. There is some evidence that many people with hearing loss who would benefit from a hearing aid have lived with their symptoms for 10 years before seeking help[12].

Ferguson et al (2017)[17] carried out a Cochrane systematic review about the benefits and harms of using hearing aids for mild to moderate hearing loss in adults and reported results of 5 randomised controlled trials (RCTs). They found moderate quality evidence in 3 studies that hearing aids have a large beneficial effect in improving the ability of adults with mild to moderate hearing loss to take part in everyday situations. From 2 studies they reported that hearing aids have a small beneficial effect in improving general health-related quality of life, such as physical, social, emotional and mental well-being and have a large effect in improving the ability to listen to other people.

Prevalence

The Global Burden of Disease study[9] reported that age related and other hearing loss was the 3rd leading cause of years lived with disability in England, the 5th leading cause in Wales and 6th in Scotland and Northern Ireland.

In the UK, prevalence of hearing loss estimates are based on the Medical Research Council National Hearing Study; a cluster of epidemiological studies aiming to determine prevalence and distribution of hearing problems of adults in England, Scotland, Wales and Northern Ireland[18,19]. Using these prevalence rates, NHS England has published the NHS Hearing loss data tool[20] which estimates the number of people with hearing loss between 2015 and 2035, by local authority (LA) and Clinical Commissioning Group (CCG), to help organisations plan services. Table 2 shows prevalence by age group used to calculate the NHS Hearing loss data tool estimates.

Table 2. Prevalence rates used in the NHS Hearing loss data tool[20]

Age group (years)	Prevalence (%) of ≥25 dB	Prevalence (%) of ≥65 dB
18-30	1.8	0
31-40	2.8	0.3
41-50	8.2	0.7
51-60	18.9	0.9
61-70	36.8	2.3
71-80	60.3	4.0
>80	93.4	22.3

The Royal National Institute for Deaf People (Action on Hearing loss 2015)[21] used the same prevalence rates from Davis et al (1995)[12] to calculate the number of people in the UK by age group with hearing loss (>25dB), and those with hearing loss likely to benefit from a hearing aid (>35dB), using mid-year population estimates for 2014 (Table 3). In total, the UK was estimated to have 11,043,000 people with hearing loss >25dB and of those 6,699,500 were estimated to most likely benefit from a hearing aid (>35dB).

Table 3. Estimated number of people in the UK by with hearing loss of >25dB and >35dB by age group (Action on Hearing loss, 2015)[21]

	UK		England		Northern Ireland		Scotland		Wales	
Age group (years)	**>25dB**	**>35dB**	**>25dB**	**>35dB**	**>25dB**	**>35dB**	**>25dB**	**>35dB**	**>25dB**	**>35dB**
17-29	188,000	44,000	158,000	37,000	5,500	1,500	15,500	3,500	9,000	2,000
30-39	234,000	117,000	199,000	99,500	6,500	3,500	18,500	9,000	10,000	5,000
40-49	743,000	362,500	625,500	305,000	21,000	10,500	62,500	30,500	34,000	16,500
50-59	1,569,000	647,500	1,305,000	538,500	44,500	18,500	142,500	59,000	77,000	32,000
60-69	2,524,000	1,080,500	2,101,500	899,500	65,000	28,000	221,500	95,000	135,000	58,000
70-79	2,879,000	1,909,500	2,395,000	1,589,000	75,500	50,000	251,000	166,500	157,000	104,000
80+	2,887,000	2,518,500	2,434,500	2,124,000	68,500	59,500	232,000	202,500	152,000	132,500
Total	11,043,000	6,699,500	9,235,000	5,609,000	287,500	171,500	945,000	567,500	575,500	351,000

Current clinical guidance in the UK

The Action Plan on Hearing loss (2015)[22] was developed with input from the Department of Health and Social Care, NHS England, Public Health England, other Government Departments, key stakeholders across the voluntary, professional and private sectors and people with hearing loss. The plan sets out a case for action to tackle the rising prevalence and personal, social and economic costs of uncorrected hearing loss and the variation in access and quality of services experienced by people with hearing loss.

NHS England (2016)[23] published commissioning guidance for hearing loss services and this meets one of the key recommendations of the Action Plan on Hearing Loss (2015)[22]. This sets out commissioning best practice and case studies from CCGs which have redesigned and improved hearing loss services to secure quality improvements and efficiencies for people.

The National Institute of Health Care Excellence (NICE 2018)[24] published evidence-based guidance about the referral, diagnosis, interventions and management for adults with hearing loss. This recommends that people with hearing loss may require an immediate, urgent or routine referral depending on the presenting symptoms. Sub groups of the population, including those with suspected or diagnosed dementia or learning disability, should also be offered an audiology assessment as hearing loss may be a co-occurring condition exacerbating difficulties with communication and daily living. Following an audiological assessment people will be offered appropriate evidence-based interventions such as the removal of ear wax, steroid treatment, the use of assistive listening devices (for example, TV amplifiers, smoke alarms, and hearing loops) and hearing aids. NICE (2018)[24] also concluded that people with mild to moderate hearing loss benefitted from hearing aids as this improved their listening ability and quality of life.

Current policy context and previous reviews

A screening programme would aim to detect hearing loss in people before they sought help for a hearing problem to ensure they received interventions in a timely way to improve their listening ability, improve their quality of life and avoid the other health impacts resulting from impaired hearing.

The current UK NSC policy, based on the 2015 UK NSC review**Error! Bookmark not defined.**, is that a systematic population screening programme for hearing loss in adults is not recommended because:

- the evidence was too limited to establish an optimum approach to screening in terms of the type of test, the severity of hearing loss to target, the age of the population to be screened, the frequency of screening and where screening should be undertaken
- hearing aids were underused
- there was a lack of evidence on the effectiveness of the use of hearing aids on long-term outcomes and additional interventions aimed at improving the compliance of the hearing aid use
- screening had not been shown to provide any hearing improvement in quality of life in comparison to hearing loss identified in other ways.

Objectives

The current review aims to look at the accuracy of screening tests for hearing loss, the acceptability of treatment, whether screening improves health outcomes and whether the clinical detection and management of hearing loss is currently well implemented in the UK.

Table 4. Key questions for the evidence summary, and relationship to UK NSC screening criteria

	Criteria	Key questions	Studies included
	THE TEST		
4 **5**	There should be a simple, safe, precise and validated screening test. The distribution of test values in the target population should be known and a suitable cut-off level defined and agreed.	1. What is the diagnostic accuracy of screening tests for hearing loss in adult population?	6
	THE INTERVENTION		
9	There should be an effective intervention for patients identified through screening, with evidence that intervention at a pre-symptomatic phase leads to better outcomes for the screened individual compared with usual care. Evidence relating to wider benefits of screening, for example those relating to family members, should be taken into account where available. However, where there is no prospect of benefit for the individual screened then the screening programme shouldn't be further considered.	2. What is the evidence regarding the acceptability of treatment to adults with hearing loss?	5
	THE SCREENING PROGRAMME		
11 **13**	There should be evidence from high quality randomised controlled trials that the screening programme is effective in reducing mortality or morbidity. Where screening is aimed solely at providing information to allow the person being screened to make an "informed choice" (eg. Down's syndrome, cystic fibrosis carrier screening), there must be evidence from high quality trials that the test accurately measures risk. The information that is provided about the test and its outcome must be of value and readily understood by the individual being screened. The benefit gained by individuals from the screening programme should outweigh any harms for example from overdiagnosis, overtreatment, false positives, false reassurance, uncertain findings and complications.	3. Does screening for hearing loss in adults improve health outcomes?	0
	IMPLEMENTATION CRITERIA		
15	Clinical management of the condition and patient outcomes should be optimised in all health care providers prior to participation in a screening programme.	4. Is clinical detection and management currently well implemented in the UK?	1

Methods

The current review was conducted by Solutions for Public Health (SPH), in keeping with the UK National Screening Committee evidence review process. Database searches were conducted on 20th January 2020 (Appendix 1) to identify studies relevant to the questions detailed in Table 5.

Eligibility for inclusion in the review

The following review process was followed:

1. each title and abstract was reviewed against the inclusion/exclusion criteria by 1 reviewer. Where the applicability of the inclusion criteria was unclear, the article was included at this stage in order to ensure that all potentially relevant studies were captured
2. full-text articles required for the full-text review stage were acquired
3. each full-text article was reviewed against the inclusion/exclusion criteria by 1 reviewer, who determined whether the article was relevant to 1 or more of the review questions
4. any queries at the abstract or full-text stage were resolved through discussion with a second reviewer
5. the review was quality assured by a second senior reviewer, not involved with the writing of the review in accordance with SPH's quality assurance process.

Eligibility criteria for each question are presented in Table 5.

A total of 3850 unique references were identified and sifted by an information scientist by title and abstract for potential relevance to the review. An SPH reviewer assessed 607 titles and abstracts for further appraisal and possible inclusion in the final review.

Overall, 80 studies were identified as possibly relevant during title and abstract sifting and further assessed at full text. Appendix 2 contains a full PRISMA flow diagram (Figure 1), along with a table of the included publications and details of which questions these publications were identified as being relevant to (Table 22).

Table 5. Inclusion and exclusion criteria for the key questions

Key question	Inclusion criteria							Exclusion criteria
	Population	**Target condition**	**Intervention**	**Reference standard**	**Comparator**	**Outcome**	**Study type**	
1. What is the diagnostic accuracy of screening tests for hearing loss in adult population	Adults	Hearing loss in adults	• whispered voice test • finger rub test • watch tick test • single-item screening • multiple-item questionnaire • handheld audiometer • Weber's test • Rinne test • internet and telephone/ smartphone screening • other	Pure-tone audiometry	None or any	• sensitivity • specificity • positive predictive value • negative predictive value • positive likelihood ratio • negative likelihood ratio	Diagnostic accuracy studies in consecutively enrolled population. Systematic reviews and meta-analyses of these, should be prioritised. Other study designs should be reported if no studies of this type are available	N/A
2. What is the evidence regarding the acceptability of treatment to adults with hearing loss?	Adults with screen-detected hearing loss	Hearing loss in adults	• conventional hearing aids with or without additional education or counselling aiming to improve	N/A	N/A	• uptake of treatment • use of treatment	RCTs, cohort studies, qualitative, mixed methods, surveys and systematic reviews of the above should be prioritised.	N/A

				uptake and use of the treatment • assistive listening device with or without additional education or counselling aiming to improve uptake and use of treatment • personal sound amplification devices with or without additional education or counselling aiming to improve uptake and use of treatment					Case-control studies can be considered if no other types of studies are available	
3.	Does screening for hearing loss in adults improve health outcomes?	Asymptomatic adults	Hearing loss in adults	Screening programmes to identify individuals at high risk of hearing loss	N/A	Usual care or no screening	• hearing-related quality of life • mental health (for example, social isolation, cognitive impairment, depression, anxiety		RCTs, cohort studies, and systematic reviews of the above should be prioritised. Case-control studies can be considered if	N/A

							disorders, dementia) • frequency of falls • communication with healthcare providers	no other types of studies are available	
4.	Is clinical detection and management currently well implemented in the UK?	Adults	Hearing loss in adults	Current clinical management in the UK	N/A	For outcome 1: disease known prevalence For outcomes 2 to 5: N/A	• proportion of hearing loss detected • proportion of individuals referred for audiological assessment • proportion of individuals receiving an intervention for hearing loss • proportion of individuals complying with intervention • user experiences	Cross sectional study, cohort study prospective and retrospective, qualitative, mixed methods, surveys, systematic reviews of above, evaluation of relevant data sources (for example, audit of hearing services data)	Non-UK studies

RCT – Randomised Controlled Trials; N/A – not applicable

Appraisal for quality/risk of bias tool

The following tools were used to assess the quality and risk of bias of each study included in the review:

- systematic reviews: Amstar II a critical appraisal tool for systematic reviews of randomised and non randomised studies
- diagnostic accuracy studies: Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool
- cohort studies: Critical Appraisal Skills Programme (CASP) Cohort Study Checklist
- qualitative studies: Critical Appraisal Skills Programme (CASP) Qualitative Study Checklist

Databases/sources searched

Systematic searches of 3 databases (Medline, Embase and Cochrane) were conducted to identify studies relevant to the questions detailed in Table 5. The searches were conducted on 6th January 2020. The search strategy is presented in Appendix 1.

Question level synthesis

Criteria 4 and 5 — Diagnostic accuracy of screening tests for hearing loss in adult population

Criterion 4 — There should be a simple, safe, precise and validated screening test.

Criterion 5 — The distribution of test values in the target population should be known and a suitable cut-off level defined and agreed.

Question 1 — What is the diagnostic accuracy of screening tests for hearing loss in adult population?

This question was addressed in the previous UK NSC review in 2015**Error! Bookmark not defined.** about screening for hearing loss in older adults. The review summarised the results of the US Preventative Services Task Force (USPSTF) systematic review published in 2011[25] about screening for hearing loss which examined screening test performance. A key challenge of the USPSTF review[25] was interpreting diagnostic accuracy studies using different thresholds and criteria to define hearing loss. Four studies in the US review[25] were population based and 4 from community or primary care settings although the lack of information on enrolment criteria meant that it was not clear who were eligible to be included in the studies. No studies were based in the UK. The performance of the included tests (whispered voice test, finger rub test, watch tick test, single question screening test, screening questionnaire and hand held audiometric devices) was overall moderate to poor. The watch tick test and finger rub test showed the best screening performance but this was based on 1 study.

Eligibility for inclusion in the review

The current review prioritised studies in randomly assigned or consecutively enrolled populations of adults who had not been referred for concerns about their hearing. Studies were eligible if they assessed the performance of hearing screening tests (detailed in Table 5) against the reference standard, pure tone audiometry. Studies not in English and published before 1st January 2012 were excluded.

Full details of the eligibility criteria are presented in Table 5.

Description of the evidence

Database searches yielded 3850 results, of which 194 were judged to be relevant to this question and following abstract and title review, 34 studies met the criteria for full text review. After review of the full texts, 6 studies met the inclusion criteria for this question. Of these, 5 studies examined the performance of objective hearing tests. These consisted of 1 systematic review of smartphone-based apps, a further cohort study of a smart phone app published after the systematic review and 3 other cohort studies of screening tests including the digits or speech in noise tests, the Hum test and Weber test. The final included study explored the performance of the self report questionnaire, the Hearing Handicap Inventory – screening (HHI-S) test in a cohort of individuals.

Publications excluded after review of full-text articles are listed in Appendix 2.

Discussion of findings

A study-level summary of data extracted from each included publication is presented in the 'Summary and appraisal of individual studies' in Appendix 3 (Table 24 to 29). In Appendix 3, publications are stratified by question. Of the 6 papers included all used a pure tone audiology reference standard and none reported their results by gender.

Hearing tests using apps with smart phones, tablets and computers

One systematic review by Bright et al (2016)[26] and 1 cohort study by Livshitz et al (2017)[27], examined the validity of hearing assessment apps developed for smart phones, tablets and computers for adults and children (Table 6). Bright et al (2016)[26] identified 30 different hearing assessment apps online of which 3 apps were examined in 6 studies validating their use by adults in peer reviewed literature. A further 5 studies concerned validating the use of smart phone apps in children. The 6 relevant studies in Bright et al (2016)[26] examined the audiological accuracy of adults using a hearing assessment app (uHear (n=4), EarTrumpet (n=1), AudCal (n=1)). The cohort study by Livshitz et al (2017)[27] was a further validation study of the uHear app. All validation studies used pure tone audiology carried out in sound proof rooms as a reference standard and the index test was carried out in quiet rooms or sound proof booths.

The studies validating the uHear app were small with 25 to 100 people participating and varied in age group with 3 targeting all adults and 2 targeting

older adults (≥ 65 years). The pure tone audiology reference standard cut off for 4 of the 5 studies was hearing loss ≥35dB which equates to moderate hearing loss and worse, in people who are likely to benefit from a hearing aid. Apart from a uHear pass or fail result assessed against the reference standard, there was no description of the index test cut off. The sensitivity of uHear reported by studies in the older age groups ranged from 76.5 to 100% and specificity from 60 to 91%. For groups of adults of all ages sensitivity ranged from 76 to 100% and specificity from 64 to 90%. One study reported a sensitivity of 100% in all settings but specificity was lower in noisier settings (64% in the waiting room versus 88% in a sound proof room).

The 2 other apps EarTrumpet and AudCal were also small with 42 and 110 adult participants of all ages. Screening performance statistics were not reported for these studies.

Table 6: Screening performance of smart phone apps to assess hearing

Index Test (cut off)	PTA cut off	N	Age range (years)	Index test Setting	Sens (%) (CI)	Spec (%) (CI)	Study
uHear (NR)	3 consecutive tests with ≥2 grades HL	32	20-82	QR	76 (53-92)	91(59-99)	Bright et al (2016)[26]
uHear (NR)	>40dB	100	20-91	QR	98 (89-100)	82(75-88)	Bright et al(2016)[26]
	>40dB	100	20-91	SPR	100 (92-100)	90(83-94)	Bright et al (2016)[26]
uHear (NR)	>40dB	26	65-94	QR	100(NR)	60(NR)	Bright et al (2016)[26]
uHear (NR)	>40dB	25	15-89	WR	100(NR)	64(NR)	Bright et al (2016)[26]
	>40dB	25	15-89	QR	100(NR)	74(NR)	Bright et al (2016)[26]
	>40dB	25	15-89	SPR	100(NR)	88(NR)	Bright et al (2016)[26]
uHear (NR)	>35dB	60	≥65	Hospital	76.5 (NR)	90.7(NR)	Livishitz et al (2017)[27]
Ear Trumpet (NR)	NR	42	20-85	QR	NR	NR	Bright et al (2016)[26]
	NR	42	20-85	SPR	NR	NR	Bright et al (2016)[26]
AudCal (NR)	>20dB	110	18-90	MAN	NR	NR	Bright et al (2016)[26]

CI confidence intervals, dB-decibels, N- number, NR-Not reported, PTA – Pure tone audiometry – carried out in sound proof room, QR – quiet room, SPR – sound proof room, Sens – sensitivity, Spec – specificity, WR – waiting room

Digits in noise and speech in noise test

There were 2 cohort studies that examined speech in noise and digits in noise screening tests (Koole et al 2016 and Molander et al 2013)[28,29]. Speech in noise and digits in noise tests have been developed to get a better assessment of a

person's hearing ability in real-life circumstances (Koole et al 2016)[28]. They measure speech reception threshold (SRT) in decibels (dB) as a signal to noise ratio (SNR). SRT is defined as the difference between the level of presented speech and background noise at which the tested person can correctly reproduce 50% of words or sentences. Depending on the method of administering the test, people with normal hearing might expect an SNR of around -10.0dB whilst people with hearing loss will have values closer to -3.0dB. This reflects the increased signal required to overcome the background noise in those with hearing loss.

Speech in noise tests consist of different words presented in background noise that the listener attempts to identify whilst the digits in noise test requires the listener to repeat the numbers spoken in groups of 3 (Koole et al 2016)[28]. With 3327 participants aged ≥50 years, the digits in noise test had a sensitivity of 99% and specificity of 84% at a SNR of -3 and reference standard of >35dB. At a reference standard cut off of >20dB the sensitivity dropped to 53% (Koole et al 2016)[28]. A total of 4 SRT cut off levels were applied at both PTA reference standard thresholds (see Table 7) with sensitivities ranging from 42% to 99% and specificities from 61% to 90%. The study of the speech in noise test (n=287) had a sensitivity of 79% and specificity of 24% when the reference standard was set to detect mild hearing loss >20dB (Molander et al 2013)[29].

Table 7: Screening performance of digits in noise and speech in noise tests to assess hearing

Index Test and cut off	PTA cut off	N	Age range (years)	Index test setting	Sens (%) (CI)	Spec (%) (CI)	Study
DIN, SNR -2	>20dB	3327	≥50	SPB	42(NR)	98(NR)	Koole et al (2016)[28]
DIN, SNR -2	>35dB	3327	≥50	SPB	95(NR)	90(NR)	Koole et al (2016)[28]
DIN, SNR -3	>20dB	3327	≥50	SPB	53(NR)	97(NR)	Koole et al (2016)[28]
DIN, SNR -3	>35dB	3327	≥50	SPB	99(NR)	84(NR)	Koole et al (2016)[28]
DIN, SNR -4	>20dB	3327	≥50	SPB	65(NR)	92(NR)	Koole et al (2016)[28]
DIN, SNR -4	>35dB	3327	≥50	SPB	99(NR)	75(NR)	Koole et al (2016)[28]
DIN, SNR -5	>20dB	3327	≥50	SPB	79(NR)	76(NR)	Koole et al (2016)[28]
DIN, SNR -5	>35dB	3327	≥50	SPB	99(NR)	61(NR)	Koole et al (2016)[28]
SIN, SNR -3.54	>20dB	287	Adult	SPB	79(NR)	24(NR)	Molander et al (2013)[29]

CI confidence intervals, dB-decibels, DIN- Digits in Noise N- number, NR-Not reported, PTA – Pure tone audiometry – carried out in sound proof room, SPB – Sound proof booth, Sens – Sensitivity, SIN – Speech in noise, Spec – specificity, SNR- signal to noise ratio

The Hum and Weber tests for assessment of hearing

A single cohort study examined the accuracy of the Hum and Weber tests for screening for hearing impairment (Ahmed et al 2018)[30]. The Hum test involves

asking people to hum first at a high pitch then at a low pitch and asking if they could hear the tone equally with the left and right side. The Weber test involves striking the elbow with a 512Hz aluminium tuning fork then placing the stem of tuning fork on mid line of the forehead for 2 to 4 seconds and asking the subject if sound perception is louder in either ear. If sound perception is unequal in either the Hum or Weber tests this is considered a positive screening test result for conductive hearing loss in 1 ear.

The small study (n=29) by Ahmed et al (2018)[30] involved people aged 18-35 years with normal hearing who were given earplugs to simulate hearing loss in one ear prior to the Hum or Weber test being administered. Both tests showed sensitivities of 89.7 to 96.6% and specificities of 100% for hearing loss (Table 8).

Table 8: Screening performance of Hum and Weber tests to assess hearing (Ahmed et al 2018)[30]

Index Test and cut off (greater perception in 1 ear)	PTA cut off	N	Age range (years)	Setting for index test	Sens (%) (CI)	Spec (%) (CI)
Hum Test high pitch	≥10dB decrease from normal in ear with simulated hearing loss	29	18-35	SPR	89.7(NR)	100(NR)
Hum test low pitch	≥10dB decrease from normal in ear with simulated hearing loss	29	18-35	SPR	93.1(NR)	100(NR)
Weber test	≥10dB decrease from normal in ear with simulated hearing loss	29	18-35	SPR	96.6(NR)	100(NR)

CI confidence intervals, dB-decibels, N- number, NR-not reported, PTA – pure tone audiometry – all carried out in sound proof room, Sens – sensitivity, Spec – specificity

The Hearing Handicap Inventory – screening test

A single cohort study (Saunders et al 2019)[31] examined the accuracy of the self report HHI-S test in identifying people with hearing impairment. The test is a self administered questionnaire with 10 questions assessing perceived participation restrictions associated with hearing loss. Total scores range from 0 to 40 with higher scores indicating greater self perceived handicap. A score of ≥10 was used for referral for full audiometric assessment. With a reference standard cut off of ≥25dB to detect mild hearing loss the reviewer has calculated that sensitivity was 46.4%, specificity 78.3%, positive predictive value 72.6% and negative predictive value 75.4% and a prevalence of 36.6% (Table 9). The percentage of people aged 45-54 years who perceived they had a hearing problem and failed the HHI-S test were similar in number to those who failed the reference test (approximately 35%). However, after this age, about the same proportion of people perceived they had a hearing problem and failed the HHI-S

test regardless of age (approximately 40%), whilst the proportion failing the reference test increased as expected to almost 100% in people aged ≥85 years.

Ambient noise levels varied between screening settings and this was reflected in a significantly higher number of people failing the pure tone reference test in noisier settings (analysis of variance F=12.1; p=0.001). This was not found with people completing the HHI-S test.

Table 9: Screening performance of HHI-S questionnaire to assess hearing (Saunders et al 2019)[31]

Index Test and cut off	PTA cut off	N	Pop	Setting for index test	Prev (%)	Sens(%) (CI)	Spec(%) (CI)	PPV and NPV
HHI-S test Score≥10	≥25dB	191	Adult	Community settings	36.6	46.4 (NR)*	78.3 (NR)*	PPV 72.6%* NPV 75.4%*

CI confidence intervals, dB-decibels, HHI-S – Hearing Handicap Inventory-screening version, N-number, NPV – negative predictive value, NR-Not reported, Pop – Population, PPV - Positive predictive value, Prev – prevalence, PTA – Pure tone audiometry – carried out in sound proof room, Sens – sensitivity, Spec - specificity, *Calculated by reviewer

Overall, the volume of evidence validating different types of hearing screening tests for adults in the general population in comparable populations to the UK is limited comprising mostly small to moderate sized cohorts (range n=25 to 110) with 1 larger study (n=3327) in older adults (Koole 2016)[28]. Screening tests performed better at detecting moderate or worse hearing loss where people are likely to benefit from a hearing aid but were less good at detecting mild hearing loss. Tests in quiet or sound proof settings performed better than those in noisier environments. The uHear smartphone app was the only app with multiple studies attempting to validate its accuracy. The app showed moderate to good screening performance, but this was not consistent across all the studies. The reference standard cut off was typically set for detecting moderately impaired hearing in people who would benefit from a hearing aid. Livshitz et al (2017)[27] reported an average difference between the uHear thresholds and PTA thresholds for frequencies of 500, 1000 and 2000Hz was 24.47dB for the left ear and 26.4dB for the right ear and argued that subtracting 25dB from all uHear results for each of the frequencies accounted for background noise and visual distraction in the hospital setting. It isn't clear if mitigating for noise and distraction in the testing setting is a valid approach as it suggests the screening test wasn't carried out in the conditions recommended by the app developers which instructs users to 'go to a very quiet environment' before starting the test (Szudek et al 2012)[32].

Studies conducted tests using a single device and transducer, however, there can be variability of results with different device /transducer combinations and the need for calibration. Differences in the quality of headphones or earbuds may also result in inconsistencies across studies.

The quality of the cohort studies was variable when assessed against the QUADAS-2 tool with scores ranging from 8 to 12 out of 13 (Table 10). The key areas of possible bias for all studies included whether the reference standard was carried out without the knowledge of the results of the index test as for all studies participants carried out both tests in the same session with no detail of whether staff administering the tests knew the outcome of the first test carried out. Two studies used populations which are unlikely to be representative of people undergoing hearing screening, Livshitz et al (2017)[27] recruited inpatients with any condition from a hospital medical ward in Israel and Ahmed et al (2018)[30] used younger people with normal hearing with simulated hearing loss in a US cohort. Saunders et al (2019)

Table 10. QUADAS-2 scores summary

	Livshitz (2017)[27]	Koole (2016)[28]	Molander (2013)[29]	Saunders (2019)[31]	Ahmed (2018)[30]
Domain I Patient selection					
Consecutive or random sample of population enrolled?	Unclear	Yes	Yes	Yes	Yes
Case-control design avoided?	Yes	Yes	Yes	Yes	Yes
Inappropriate exclusions avoided?	Yes	No	Yes	Yes	Yes
Domain II: Index test					
Index test results interpreted without knowledge of reference standard results?	Yes	Unclear	Yes	Yes	Unclear
Threshold pre-specified?	Yes	Yes	No	Yes	Yes
Domain III: Reference standard					
Reference standard likely to correctly classify condition?	Yes	Yes	Yes	Yes	Yes
Reference standard results interpreted without knowledge of index test results?	No	Unclear	Unclear	No	Unclear
Domain IV: Test strategy flow and timing					
Appropriate interval between index test and reference standard?	Yes	Unclear	Yes	Yes	Yes
Did all participants receive same reference standard?	Yes	Yes	Yes	Yes	Yes
All patients included in analysis?	Yes	No	Yes	Yes	Yes
Domain V: Applicability					
Applicable to UK screening population of interest?	No	Yes	Yes	Yes	No
Applicable to UK screening test of interest?	Yes	Yes	Yes	Yes	Yes
Target condition measured by reference test applicable to UK screening condition of interest?	Yes	Yes	Yes	Yes	Yes
Total number of 'yes' (out of 13)	**10**	**8**	**11**	**12**	**10**

The Amstar II checklist was used to assess the quality of the systematic review by Bright et al (2016)[26] and no concerns about risk of bias of the way the review was carried out were identified. The authors used QUADAS-2 tool to check for risk of bias of the included papers and took this into account when discussing the study outcomes. Of the 6 studies 2 examining Ear Trumpet and AudCal achieved, a low risk of bias and low concern of applicability in all domains and the main source of bias in the remaining studies was patient selection bias. The cut off criteria used by the apps was predetermined but none were reported. Studies varied in the reference standard cut off level for performing sensitivity/specificity analyses, how the test results were presented (separate ears or by individual) and the inclusion and exclusion criteria of participants.

Summary of Findings Relevant to Criteria 4 and 5: Criteria not met*

For the question about the accuracy of screening tests for hearing loss, 1 systematic review of small cohort studies of 6 smart phone apps, 1 further cohort study of a smartphone app and 4 additional cohort studies of other types of screening tests including digits in noise, speech in noise, the Hum test Weber test and the self report Hearing Handicap Inventory – screening test were identified. In general, the studies were small and varied in the level of hearing impairment targeted and consistency of results. Screening tests that performed better were the uHear smartphone app and the digits in noise test. The uHear smartphone app showed sensitivity of 76.5 to 100% and specificity of 60 to 91% in older age group in varying settings with better performance in quieter settings. Digits in noise test showed sensitivity of 99% and specificity of 84% when completed in a sound proof room. Notably, both screening tests aimed to detect moderate hearing loss in people who could benefit from the use of a hearing aid. The performance of the self report HHI-S test indicated that perception of hearing difficulty alone was not an accurate indicator of hearing loss especially in older people.

All the cohort studies had some risk of bias, typically about how the index test and reference standard were administered. Of the studies included in the systematic review, risk of bias, was mainly concerned with patient selection

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Not Met - for example, this should be applied in circumstances where there is insufficient evidence to clearly judge an outcome or effect or where there is sufficient evidence of poor performance.
Uncertain -for example, this should be applied in circumstances in which the constraints of an evidence summary prevent a reliable answer to the question. An example of this may be when the need for a systematic review and meta-analysis is identified by the rapid review.

including the fact that none of the studies were carried out in the UK. Two of the 4 cohort studies were not applicable to the UK screening population as they were either simulating hearing loss or recruited from a hospital setting. A larger volume of evidence from high quality studies to establish the accuracy of screening tests (especially those based on new technologies) in people who have not sought help for hearing loss are needed.

Overall, these criteria are not met.

Criterion 9 — Acceptability of treatment to adults with hearing loss

Criterion 9 — There should be an effective intervention for patients identified through screening, with evidence that intervention at a pre-symptomatic phase leads to better outcomes for the screened individual compared with usual care. Evidence relating to wider benefits of screening, for example those relating to family members, should be taken into account where available. However, where there is no prospect of benefit for the individual screened then the screening programme shouldn't be further considered.

Question 2 — What is the evidence regarding the acceptability of treatment to adults with hearing loss?

The previous UK NSC review in 2015**Error! Bookmark not defined.** about screening for hearing loss in older adults did not find any studies about the acceptability of screening from the perspective of the adult population. Perceived hearing difficulty is the strongest predictor of hearing help seeking, hearing aid use and satisfaction[33]. It is important to know if the people who previously did not perceive they had a hearing problem and subsequently test positive for hearing loss are motivated to act on the information and continue along the screening pathway. If people who are screen detected with hearing loss do not perceive they have a hearing problem they may be less likely to continue on the screening pathway to diagnostic assessment and to take up the offer of treatment. Consequently there will be minimal benefit of the screening programme being implemented.

Eligibility for inclusion in the review

Studies examining the proportion of people screen detected with hearing loss, receiving a diagnostic assessment, taking up the offer of and use of hearing aids, assistive listening devices and personal sound amplification devices were included. Studies not in English and published before 1st January 2012 were excluded.

Full details of the eligibility criteria are presented in Table 5.

Description of the evidence

Database searches yielded 3850 results, of which 178 were judged to be relevant to this question and following abstract and title review 23 studies met the criteria for full text review. After review of the full texts, 5 studies met the inclusion criteria for this question. These consisted of 3 cohort studies about the impact of awareness raising sessions to inform people of hearing loss

rehabilitation methods following a positive screen and 1 qualitative study about the views of people who screened positive for hearing loss and 1 study reporting the outcomes of a screening programme.

Publications excluded after review of full-text articles are listed in Appendix 2.

Discussion of findings

A study-level summary of data extracted from each included publication is presented in 'Summary and appraisal of individual studies' in Appendix 3 (Tables 30 to 34). Publications in Appendix 3 are stratified by question.

Of the included publications, 4 focussed on people's responses to a positive screen for hearing loss, including how ready they were to seek help and implement change to improve their hearing and their use of hearing aids and other support (Laplante-Levesque (2015), Ingo et al (2016), Rothpletz et al (2016), Carlson et al (2019))[34,35,36,37]. The 5th publication reports the results of a cohort study that invited older people in Cyprus to participate in a screening programme between 2008 and 2011(Thodi et al 2013)[38].

In two publications reporting results of 1 study – (initial results by Laplante-Levesque et al (2015) and follow up by Ingo et al (2016))[34,35] the University of Rhode Island change assessment (URICA) tool was used to assess readiness to seek help by people with a positive screen for hearing loss. The URICA explores 4 stages of behaviour change (Prochaska 2008)[39] linked to 4 statements which are precontemplation (*I'm not sure I have a problem or that it's very important*), contemplation (*I think it might be a good idea to do something about the problem*), preparation (*I could do with some advice and would like some help*) and action (*I am doing something about it*). Ingo et al (2016)[35] also used 1 question called the staging algorithm to assess people's current stage of change at follow up which asked which of the 4 statements (above) best described peoples view of their current hearing status. At baseline people who knew they had a hearing problem before screening were more likely to be contemplating ($r=0.29$; $p<0.001$), preparing ($r=0.20$; $p<0.001$) and taking action to seek help ($r=0.25$; $p<0.001$), than those who were unaware they had a problem. There was no association between the hearing loss test threshold and stage of change ($r=0.12$). At follow up there were a higher proportion of people at the action stage than at baseline ($x2=122$, $p=0.004$).

A third study by Rothpletz et al (2016)[36] used the Patient Technology Acceptance Model (PTAM) used to predict acceptance of consumer health technologies among patients with chronic illnesses that incorporates knowledge, help seeking behaviour, attitudes, general perceptions of technology and social

influence. The study used the tool to evaluate if people with a positive hearing screening, recruited from a local community were more likely to take action after receiving 2.5 hours of training about hearing loss and how to find support using internet based hearing healthcare (n=13) compared to no training (n=13). People who had received the training had significantly improved scores for 2 sub scales (health care knowledge z=3.19, p=0.001 and computer self efficacy z=2.68, p=0.007) compared to people with no training. None of the other sub scales (computer anxiety, perceived usefulness, perceived ease of use, subjective norm or intention to use the internet based hearing healthcare) showed any change from baseline to follow up. No subscales showed any difference between baseline and follow up (2 to 3 weeks after baseline) for the group who did not receive any training.

Table 11. Acceptability of interventions following hearing screening

Tool country (n)	Outcome measure	Outcome result	
URICA Sweden (n=224)	Stages of change following a positive screening test	People aware compared to those unaware of hearing loss prior to screening more likely to be contemplating (Pearson's correlation coefficient r=0.29; p<0.001, preparing (r=0.20; p<0.001) or acting (r=0.25; p<0.001) to seek help No association of screening test result and stage of change (r=0.12)	Laplante-Levesque et al (2015)[34]
URICA and staging algorithm Sweden (n=122)	Help seeking at 18 months follow up	74(61%) people sought help Chi squared test showed association between staging algorithm and reported help seeking x2=7.554; p=0.043). Higher proportion of people at action stage at follow up compared to baseline (x2=122, p=0.004)	Ingo et al (2016)[35]
PTAM US (n=26)	Help seeking following training intervention	2 sub scales showed significant improvements in training group compared to untrained group at follow up (health care knowledge z=3.19, p=0.001 and computer self efficacy z=2.68, p=0.007)	Rothpletz et al (2016)[36]
Health belief model focus group questions US (n=50)	Identifying enablers and barriers to help seeking	5 emerging themes: 1.Knowledge of hearing loss, 2.Trust in the services, 3.Access to the services, 4.Quality of life, 5.Interpersonal influence of others	Carlson et al (2019)[37]
HHIE-S and Compliance questionnaire Cyprus (n=1392)	Adherence to intervention at 1-2 years after screening	160 selected for follow up of which 18% had tried a hearing aid Among hearing aid users (n=NR): 22%(n=NR) very satisfied 28%(n=NR) satisfied 11%(n=NR) not satisfied 39%(n=NR) missing	Thodi et al (2013)[38]

CI – confidence interval, HHIE-S - Hearing Handicap Inventory for the Elderly – Screening version, n- number, NR– not reported, PTAM - Patient Technology Acceptance Model, URICA - University of Rhode Island change assessment, US – United States

The 4th study (Carlson et al 2019)[37] reported the results of focus groups set up in the US to promote conversations relevant to a health belief model (Cresswell and Plano Clark 2011)[40]. This focussed on identifying perceived barriers, perceived benefits and cues to action in seeking help for hearing loss. Adults with some form of perceived hearing loss who had recently completed screening took part in 4 focus groups, whilst 2 focus groups included adults who had recently sought help for hearing loss and 1 focus group involved significant others and family members of individuals with hearing loss. There were 5 primary themes identified from the focus groups which included a total of 50 people:

- knowledge; learning more about tinnitus, general hearing loss knowledge, hearing health options, and real life implications of hearing loss
- trust; distrust of the hearing health system as it consisted of for profit companies and hearing aids were very expensive. There was more trust in the primary care providers who people stated they would be more likely to listen too. Hearing screening tests were not considered accurate
- access; convenience of healthcare and monetary incentives
- quality of life – continuing to socialise and have social roles and employment, fear of risk to personal safety or safety of others, enjoyment of sounds such as birds singing, music, etc.
- interpersonal influence; family influence and peer influence and testimony about the benefits and process of taking the next step to seeking support.

The last paper included for this question by Thodi et al (2013)[38] reports the results of a screening programme for older people in Cyprus implemented between 2008 and 2011. People were invited via posters and newsletters in pensioner organisations and municipal activity centres, to attend for screening. A total of 3025 people aged 55 to 92 years were screened using a modified version of the Hearing Handicap Inventory for the Elderly – Screening version (HHIE-S), plus otoscopy and air conduction pure tone audiometry (cut off >35dB in the worse ear). A total of 1392 (46%) people were referred for audiologic/hearing aid evaluation. An additional 12% participants had pure tone audiometry results within 5dB below the referring criteria. More than 80% of participants referred believed they had hearing loss before it was confirmed by screening but it is not clear if this was from a previous formal hearing assessment or their subjective experience.

A sample of 160 randomly selected people who were referred by the screening programme for hearing aid evaluation at 1 to 2 years post-screening were interviewed and asked questions about treatment compliance. Of these who responded to the follow up interviews (n not reported), 18% (n not reported) said they had tried a hearing aid and 11% (n not reported) said they were using a

hearing aid at the time of the interview. Despite the low hearing aid compliance rates, 95% of people contacted reported that the process had been helpful, and they would participate in similar tests in the future. Among hearing aid users, 22% (n not reported) were very satisfied with their device, 28% (n not reported) were satisfied and 11% (n not reported) were not satisfied. A further 39% (n not reported) did not respond. The authors considered that people with hearing loss were likely to have an improved quality of life when taking up an appropriate intervention such as a hearing aid.

The Critical Appraisal Skills Programme (CASP) Cohort Study Checklist was used to appraise the 4 cohort studies included addressing the question about the acceptability of treatment for hearing loss. The studies were small to moderate sized (n= 27 to 1392) and carried out in Sweden, the US and Cyprus - factors limiting the applicability to the general UK population. There was no consistency in the measures used to determine acceptability of treatment and the results of the studies overall were variable with no consistent outcome. There were some methodological and issues with the studies such as only people with a positive screen for hearing loss being followed up, reports of help seeking by participants not being confirmed by clinical records and the use of questionnaires that have not been validated. The study reported by Thodi et al (2013)[38] did not report the proportion of people who attended hearing aid evaluation after referral. The paper also did not report whether the changes to the HHIE-S tool and the structured follow up questions at between years 1 and 2 were validated.

Carlson et al (2019)[37] was assessed using the CASP checklist for qualitative research studies. There were only 50 participants in the study, however, the themes were consistent across focus groups. A large proportion of participants were veterans and the experience of this group from the US represent those of non veterans and people in the UK.

Summary of Findings Relevant to Criterion 9: Criterion not met†

The evidence to address this question about the acceptance of treatment for people with hearing loss in screen detected populations is limited in volume to 5 studies carried out in the US, Sweden and Cyprus. The applicability to a

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general UK population is likely to be limited. There was no consistency in the measures used to determine acceptability of treatment and the results of the studies overall were variable with no consistent outcome. It is not clear if treatment following a positive screening test would be acceptable to people in the UK. A larger volume of high quality evidence is needed on the proportion of people continuing to use their hearing aids over the years following diagnosis in screen-detected or otherwise detected populations.

This criterion is not met.

Criteria 11 and 13 — Health outcomes of screening for hearing loss

Criterion 11 —There should be evidence from high quality randomised controlled trials that the screening programme is effective in reducing mortality or morbidity. Where screening is aimed solely at providing information to allow the person being screened to make an "informed choice" (eg Down's syndrome, cystic fibrosis carrier screening), there must be evidence from high quality trials that the test accurately measures risk. The information that is provided about the test and its outcome must be of value and readily understood by the individual being screened.

Criterion 13 — The benefit gained by individuals from the screening programme should outweigh any harms for example from overdiagnosis, overtreatment, false positives, false reassurance, uncertain findings and complications.

Question 3 — Does screening for hearing loss in adults improve health outcomes?

This question was addressed in the previous UK NSC review in 2015 about screening for hearing loss in older adults which reported the results of 1 RCT published in 2010. The Screening for Auditory Impairment—Which Hearing Assessment Test (SAI-WHAT) trial[41] was conducted in 2002/3 and compared 3 different screening strategies with usual care (no screening; n=923). The screening strategies involved:

- using an audioscope which is a handheld instrument with a built-in audiometer which assessed people's ability to hear a 40dB tone at 2000Hz in either ear (n=462)
- administering the Hearing Handicap Inventory for the Elderly Screening (HHIE-S) tool which is a 10-item self-administered questionnaire that assesses social and emotional factors associated with hearing loss (n=461)
- using both the audioscope and administering the HHIE-S tool (n=459)

In total, 2305 (94% male) participants were recruited through outpatient clinics of a veteran affairs medical centre and screened. For those who screened positive and required a hearing aid, a follow up contact at 1 year involved asking 1 question about whether they used their hearing aid or not. The study follow up question was not validated and did not ask the proportion of time using the hearing aid or perceived improved health outcomes.

Both the UK NSC[1] and the USPTF[25] considered the volume and quality of the evidence to be too limited to address this question adequately.

Eligibility for inclusion in the review

This review prioritised studies of screening programmes aiming to screen asymptomatic adults to identify individuals with a risk of hearing loss. Studies were eligible if they assessed the outcomes of screening (detailed in Table 5) against no screening or usual care. Studies not in English and published before 1st January 2012 were excluded.

Full details of the eligibility criteria are presented in Table 5.

Description of the evidence

Database searches yielded 3850 results, of which 143 were judged to be relevant to this question and following abstract and title review 11 studies met the criteria for full text review. After review of the full texts, no studies met the inclusion criteria for this question. Of the 11 studies 10 did not include asymptomatic adults tested as part of a screening programme. The remaining study reported the results of a screening programme but this did not focus on health related quality of life outcomes.

Discussion of findings

No studies of screening programmes were identified that assessed health related outcomes of identifying people with hearing loss. One screening programme in Cyprus implemented between 2008 and 2011(Thodi 2013)[38] reported the outcomes of people with a positive screening result but these were limited to incomplete follow up of people to ask about hearing aid use and attitudes to the screening programme (see question 2).

Summary of Findings Relevant to Criteria 11 and 13: Criteria not met‡

There were no studies identified that addressed this question about the health outcomes of screening programmes of hearing loss. The implementation of a screening programme would increase the number of people referred for treatment of moderate hearing loss; high quality evidence is needed to examine the benefit of screening for this population.

These criteria are not met.

‡ **Met** -for example, this should be applied in circumstances in which there is a sufficient volume of evidence of sufficient quality to judge an outcome or effect which is unlikely to be changed by further research or systematic review.
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Criterion 15 — Implementation of current guidance

Criterion 15 — Clinical management of the condition and patient outcomes should be optimised in all health care providers prior to participation in a screening programme.

Question 4 — Is clinical detection and management currently well implemented in the UK?

Sub-question — What is the proportion of hearing loss that remains undiagnosed?

This question was addressed in the previous UK NSC review in 2015**Error! Bookmark not defined.** about screening for hearing loss in older adults and 1 key study by Davis et al (2012)[42] was included. The study reported on how the NHS Improvement Programme in England used service improvement methods to identify referral pathways and tools which were most likely to make significant improvements in diagnosing hearing loss, effective referrals and better patient outcomes for any patients. The service improvement pilots were in 18 sites across the UK. One of those looked at triage in primary care. Using an audiometric screening device GPs were reported to be able to identify patients with potential hearing loss. Patients could then be referred either to audiology for further assessment and hearing aid fitting if positive or to a one stop service. The hypothesis being that there is better uptake (whether this is acceptance of an aid or actual usage is not clear). Of the 97 people identified, 53 (55%) were considered not eligible for the new style service and of the remaining 44, 39 (40% of the total) attended and 26 (27%) were fitted with an aid. There was no longer term follow up.

Eligibility for inclusion in the review

This review prioritised studies examining the current clinical pathway for hearing loss. This includes studies about the proportion of people detected, referred, treated and adhering to treatment for hearing loss and their experiences of the clinical pathway. Studies not in English and published before 1st January 2012 were excluded.

Full details of the eligibility criteria are presented in Table 5.

Description of the evidence

Database searches yielded 3850 results, of which 34 were judged to be relevant to this question and following abstract and title review 12 studies met the criteria for full text review. After review of the full texts, 1 study met the inclusion criteria for this question (White et al 2019)[43]. This study reported results of a survey of 154 care homes to explore provision of hearing care. No studies were identified that explored the proportion of people seeking help for hearing related problems and the subsequent proportions that were referred, diagnosed and treated or remained undiagnosed. No studies were identified about people's experiences of the hearing loss clinical pathway. No studies were identified that addressed the sub question about the proportion of people with hearing loss who remain undiagnosed.

Publications excluded after review of full-text articles are listed in Appendix 2.

Discussion of findings

A study-level summary of data extracted from the included publication is presented in Appendix 3 (Table 35) 'Summary and appraisal of individual studies' where publications are stratified by question.

The single publication meeting the inclusion criteria for this question by White et al (2019) surveyed 659 (71%) of care homes in Scotland to explore access to hearing assessment, aural rehabilitation and staff training. The study was carried out in part as a response to the Scottish Care Homes Census[44] which reported the average age of residents in 2017 as 84 years yet only 9% were identified by care home staff as having hearing impairments. Hearing loss prevalence rates calculated by the NHS Hearing Loss tool[20] of mild hearing loss (>25dB) in those aged over 80 years is 93.4% and moderately severe/profound hearing loss (>65dB) is 22.4%.This would suggest that care home staff were unaware of hearing impairments in some residents who were undiagnosed.

The online survey comprised 18 questions and responses were received from 154 (23%) of the care homes contacted who were caring for 5351(17%) of the population of long stay residents in care homes for older people aged 65 years and over in Scotland. Of the 154 care homes, 12% said they routinely assessed residents hearing on entry to the home. On average 22% (range 5% to 30%) of residents wore hearing aids and most needed help using the hearing aid (80%) and maintaining the device (91%). However, only 40% (0-80%) of staff were trained in the care and maintenance of hearing aids. If an existing patient started to experience hearing difficulties, 86% of homes said they would contact a GP and 9% said they would make a direct referral to an audiology service.

The study was assessed using the CASP Cohort Study Checklist. The survey responses reported represent a minority of care homes (23%) and residents (17%) in Scotland and was only completed by care home managers and did not reflect the experience of residents themselves. There was no comparison of measures between care homes who did and did not complete the survey so it is unclear if other systematic risks of bias are present (for example, funding source, size of establishment, health board). The results from a care home setting may not be applicable to people in the general UK population.

Summary of Findings Relevant to Criterion 15: Criterion not met[§]

The volume of published evidence meeting the criterion for key question 4 is limited to a single recent publication which draws on the results of a survey that represents the situation for 5351(17%) of older people in care homes in Scotland in 2017. It is not clear if a similar survey would show the same results in other countries of the UK or in older people not resident in a care home. No studies were identified that explored the proportion of people seeking help for hearing related problems and the subsequent proportions that were referred, diagnosed and treated. No studies were identified about people's experiences of the hearing loss clinical pathway.

This criterion is not met because of a lack of published evidence. Review of grey literature may have found more evidence but was beyond the scope of this rapid review. However, at the current time, a more pressing concern in the discussion about screening may be the results of the review questions on the test and the uptake of hearing aids.

[§] **Met** -for example, this should be applied in circumstances in which there is a sufficient volume of evidence of sufficient quality to judge an outcome or effect which is unlikely to be changed by further research or systematic review.
Not Met - for example, this should be applied in circumstances where there is insufficient evidence to clearly judge an outcome or effect or where there is sufficient evidence of poor performance.
Uncertain -for example, this should be applied in circumstances in which the constraints of an evidence summary prevent a reliable answer to the question. An example of this may be when the need for a systematic review and meta-analysis is identified by the rapid review.

Review summary

Conclusions and implications for policy

This evidence summary reviews screening for hearing loss in adults against selected UK NSC criteria for appraising the viability, effectiveness and appropriateness of a screening programme.

The volume, quality and direction of new evidence is insufficient to change the current recommendation about screening for hearing loss in adults.

Since the last UK NSC review of screening for hearing loss in adults there has been a wide range of studies published about the use of screening tests but of those included here none were carried out in the UK. Overall 6 relevant studies met the inclusion criteria about accuracy of different types of screening tests for hearing loss in adults (1 systematic review of cohort studies and a further 5 cohort studies). A single systematic review and a cohort study compared outcomes of smartphone hearing screening apps and 3 further cohort studies looked at other types of tests including a hearing loss tool and perception of conduction of sound through the head. The studies reported inconsistent screening test performance results and there were methodological issues with the studies such as participant selection, whether staff administering the reference and index test were blind to the test results of which ever test was administered first, and variations in thresholds in both the reference and index tests some of which were not reported. These meant the study findings were likely to be biased and therefore not strong enough to be used as evidence for a screening programme.

The 4 cohort studies and 1 qualitative study that addressed the acceptability of treatment did not use similar measures, reported inconsistent results and were not carried out in the UK.

The previous review**Error! Bookmark not defined.** found that while there are effective hearing aids and interventions to improve hearing in older people, the benefit of screening is unclear. Therefore, this review focused only on the benefit of screening and found no evidence on whether earlier initiation of treatment for hearing loss, because of screening, improves health outcomes compared to later initiation of treatment.

One study addressed the current implementation and clinical management of people with hearing loss for people resident in care homes reported by care home managers but it is not clear if this would be applicable to the general UK population.

Limitations

The main limitation of this review is the insufficient good quality evidence to clearly judge an outcome or effect relating to the key questions about screening adults for hearing loss.

This rapid review process was conducted over a condensed period of time. Searching was limited to peer reviewed literature and did not include grey literature sources. The review was guided by a protocol developed a priori. The literature search and first appraisal of search results were undertaken by 1 information scientist, and further appraisal and study selection by 1 reviewer. Any queries at both stages were resolved through discussion with a second reviewer. Studies not available in the English language, abstracts and poster presentations were not included.

Appendix 1 — Search strategy

Electronic databases

The search strategy included searches of the databases shown in Table 12.

Table 12. Summary of electronic database searches and dates

Database	Platform	Date range of search	Searched on date
MEDLINE, MEDLINE In-Process, MEDLINE Daily, Epub Ahead of Print	Ovid SP	2012 to present	6th January 2020
Embase	Ovid SP	2012 to present	6th January 2020
The Cochrane Library, including: - Cochrane Database of Systematic Reviews (CDSR) - Cochrane Central Register of Controlled Trials (CENTRAL)	Wiley Online	Issue 1 of 12, January 2020 Issue 1 of 12, January 2020	6th January 2020 6th January 2020

Search Terms

Search terms included combinations of free text and subject headings (Medical Subject Headings [MeSH] for MEDLINE, and Emtree terms for Embase).

Search terms for MEDLINE and Embase for questions 1 to 4 are in Tables 13 to 20 (question 1: Tables 13 to 14; question 2: Tables 15 to 16; question 3: Tables 17 to 18; question 4: Tables 19 to 20) and search terms for the Cochrane Library databases are shown in Table 21 (questions 1 to 4).

Table 13. Medline search strategy for question 1

# ▲	Searches	Results
1	exp Hearing Loss/	67774
2	(hearing adj3 (loss or lose or losing or impair*)).ti,ab,kw.	53815
3	1 or 2	90290
4	Mass Screening/	100683
5	Hearing Tests/	10863
6	screen*.ti,ab,kw.	718946
7	(detect* or diagnos* or assess* or identifi*).ti.	1508334
8	(hearing adj5 (detect* or diagnos* or assess* or identifi*)).ti,ab,kw.	8885

9	(hearing and ((single or multiple) adj3 (question* or test*))).ti,ab,kw.	333
10	(screen* adj3 (question* or inventory or index or interview*)).ti,ab,kw.	10234
11	((handheld or hand-held or portable or "point of care" or poc or poct) adj3 (device? or test* or technolog*)).ti,ab,kw.	14109
12	(pure tone adj3 (audiomet* or audiogra* or audiolog*)).ti,ab,kw.	4209
13	4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12	2172707
14	exp Hearing Loss/di	14368
15	3 and 13	20055
16	14 or 15	28343
17	exp "Sensitivity and Specificity"/	569689
18	(sensitiv* or specific* or accura* or precis* or predict* or npv or ppv or reliab* or reproduc*).ti,ab,kw.	6216949
19	17 or 18	6380834
20	16 and 19	7530
21	((whispered voice or finger rub* or watch tick* or "speech in noise" or "word in noise" or "words in noise" or "digit in noise" or "digits in noise" or rinne or weber*) adj3 (test* or screen*)).ti,ab,kw.	612
22	"hearing handicap inventory for the elderly".ti,ab,kw.	154
23	((handheld or hand-held or portable or "point of care" or poc or poct or internet* or web* or telephone* or phone* or cellphone* or smartphone* or app) adj3 (audiomet* or audiogra* or audiolog*)).ti,ab,kw.	121
24	audioscop*.ti,ab,kw.	32
25	screen*.ti.	169789
26	3 and 25	1973
27	20 or 21 or 22 or 23 or 24 or 26	9407
28	(adolescent/ or child/ or exp infant/) not (exp adult/ and (adolescent/ or exp child/))	1840161
29	(neonat* or newborn* or infan* or child* or p?ediatric? or adolescen* or teen* or school*).ti.	1409836
30	28 or 29	2289731
31	27 not 30	6211
32	exp animals/ not humans/	4660573
33	31 not 32	5955
34	(comment or editorial or letter or news or "review" or case report).pt. or case report.ti,ab.	4799923
35	33 not 34	5406
36	limit 35 to ("systematic review" or systematic reviews as topic or "reviews (maximizes specificity)")	45
37	35 or 36	5406
38	limit 37 to (english language and yr="2012 -Current")	2170

Table 14. Embase search strategy for question 1

# ▲	Searches	Results
1	exp *hearing impairment/	48015
2	(hearing adj3 (loss or lose or losing or impair*)).ti,ab,kw.	68155
3	1 or 2	91238
4	screening/ or mass screening/ or screening test/	291731
5	exp Hearing Test/	44255

6	screen*.ti,ab,kw.	1016163
7	(detect* or diagnos* or assess* or identifi*).ti.	1791721
8	(hearing adj5 (detect* or diagnos* or assess* or identifi*)).ti,ab,kw.	10942
9	(hearing and ((single or multiple) adj3 (question* or test*))).ti,ab,kw.	399
10	(screen* adj3 (question* or inventory or index or interview*)).ti,ab,kw.	15554
11	((handheld or hand-held or portable or "point of care" or poc or poct) adj3 (device? or test* or technolog*)).ti,ab,kw.	20977
12	(pure tone adj3 (audiomet* or audiogra* or audiolog*)).ti,ab,kw.	5194
13	4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12	2759652
14	exp hearing impairment/di	12202
15	3 and 13	32194
16	14 or 15	38062
17	"sensitivity and specificity"/ or predictive value/ or diagnostic accuracy/	622047
18	(sensitiv* or specific* or accura* or precis* or predict* or npv or ppv or reliab* or reproduc*).ti,ab,kw.	7804254
19	17 or 18	7946472
20	16 and 19	9902
21	((whispered voice or finger rub* or watch tick* or "speech in noise" or "word in noise" or "words in noise" or "digit in noise" or "digits in noise" or rinne or weber*) adj3 (test* or screen*)).ti,ab,kw.	671
22	"hearing handicap inventory for the elderly".ti,ab,kw.	193
23	((handheld or hand-held or portable or "point of care" or poc or poct or internet* or web* or telephone* or phone* or cellphone* or smartphone* or app) adj3 (audiomet* or audiogra* or audiolog*)).ti,ab,kw.	130
24	audioscop*.ti,ab,kw.	34
25	auditory screening/	1964
26	screen*.ti.	221503
27	3 and 26	2337
28	20 or 21 or 22 or 23 or 24 or 25 or 27	13194
29	(exp adolescent/ or exp child/) not (exp adult/ and (exp adolescent/ or exp child/))	2073535
30	(neonat* or newborn* or infan* or child* or p?ediatric? or adolescen* or teen* or school*).ti.	1597762
31	29 or 30	2564260
32	28 not 31	8400
33	(exp animals/ or nonhuman/) not human/	6405779
34	32 not 33	7973
35	(editorial or letter or note or "review" or conference*).pt. or case report/ or case report.ti,ab.	11373971
36	34 not 35	5867
37	limit 36 to "reviews (maximizes specificity)"	37
38	36 or 37	5867
39	limit 38 to (english language and yr="2012 -Current")	2381

Table 15. Medline search strategy question 2

# ▲	Searches	Results
1	Hearing Aids/	8513

2	(hearing adj3 aid?).ti,ab,kw.	9075
3	(hearing and ((listening or sound? or amplifi* or assist*) adj3 (device? or technolog* or aid?))).ti,ab,kw.	886
4	1 or 2 or 3	11961
5	exp Attitude to Health/	404969
6	(barrier? or challenge? or obstacle? or facilitat* or enabl* or opportunit*).ti,ab.	1898908
7	(adhere* or compl* or concord* or uptake or nonadher* or noncompl* or nonconcord*).ti,ab,kw.	4719796
8	(attitud* or perspective? or view*).ti,ab,kw.	859840
9	5 or 6 or 7 or 8	6879439
10	4 and 9	3592
11	(adolescent/ or child/ or exp infant/) not (exp adult/ and (adolescent/ or exp child/))	1840161
12	(neonat* or newborn* or infan* or child* or p?ediatric? or adolescen* or teen* or school*).ti.	1409836
13	11 or 12	2289731
14	10 not 13	2876
15	exp animals/ not humans/	4660573
16	14 not 15	2854
17	(comment or editorial or letter or news or "review" or case report).pt. or case report.ti,ab.	4799923
18	16 not 17	2419
19	limit 10 to ("systematic review" or systematic reviews as topic or "reviews (maximizes specificity)")	75
20	18 or 19	2475
21	limit 20 to (english language and yr="2012 -Current")	1125

Table 16. Embase search strategy question 2

# ▲	Searches	Results
1	exp Hearing Aid/	26760
2	(hearing adj3 aid?).ti,ab,kw.	10670
3	(hearing and ((listening or sound? or amplifi* or assist*) adj3 (device? or technolog* or aid?))).ti,ab,kw.	1183
4	1 or 2 or 3	28690
5	attitude to disability/ or attitude to health/ or attitude to illness/ or patient attitude/ or patient compliance/	294208
6	(barrier? or challenge? or obstacle? or facilitat* or enabl* or opportunit*).ti,ab.	2358054
7	(adhere* or compl* or concord* or uptake or nonadher* or noncompl* or nonconcord*).ti,ab,kw.	6153874
8	(attitud* or perspective? or view*).ti,ab,kw.	1065918
9	5 or 6 or 7 or 8	8634632
10	4 and 9	8252
11	(exp adolescent/ or exp child/) not (exp adult/ and (exp adolescent/ or exp child/))	2073535
12	(neonat* or newborn* or infan* or child* or p?ediatric? or adolescen* or teen* or school*).ti.	1597762
13	11 or 12	2564260
14	10 not 13	6029

15	(exp animals/ or nonhuman/) not human/	6405779
16	14 not 15	5815
17	(editorial or letter or note or "review" or conference*).pt. or case report/ or case report.ti,ab.	11373971
18	16 not 17	3813
19	limit 18 to "reviews (maximizes specificity)"	28
20	18 or 19	3813
21	limit 20 to (english language and yr="2012 -Current")	1835

Table 17. Medline search terms question 3

# ▲	Searches	Results
1	exp Hearing Loss/	67774
2	(hearing adj3 (loss or lose or losing or impair*)).ti,ab,kw.	53815
3	1 or 2	90290
4	Mass Screening/	100683
5	Hearing Tests/	10863
6	screen*.ti,ab,kw.	718946
7	(detect* or diagnos* or assess* or identifi*).ti.	1508334
8	(hearing adj5 (detect* or diagnos* or assess* or identifi*)).ti,ab,kw.	8885
9	4 or 5 or 6 or 7 or 8	2160337
10	3 and 9	17893
11	exp Hearing Loss/di	14368
12	10 or 11	26793
13	"Quality of Life"/ or "Activities of Daily Living"/	236607
14	Social Isolation/	12946
15	Cognitive Dysfunction/	14784
16	exp Dementia/	160565
17	mental disorders/ or exp anxiety disorders/ or exp mood disorders/	328134
18	affective symptoms/ or depression/ or anxiety/ or stress, psychological/	275767
19	Adaptation, Psychological/	92354
20	exp Hearing Loss/px [Psychology]	4180
21	Accidental Falls/	23307
22	professional-patient relations/ or nurse-patient relations/ or physician-patient relations/	131357
23	Interpersonal Relations/	70304
24	("quality of life" or qol or "activities of daily living" or "activity of daily living" or adl).ti,ab,kw.	293912
25	((social* adj3 (isolat* or exclusion)) or lonel*).ti,ab,kw.	16006
26	(cognit* adj3 (function* or dysfunction or impair*)).ti,ab,kw.	134662
27	(dementia? or alzheimer?).ti,ab,kw.	206413
28	(depress* or anxiet* or anxious or stress*).ti,ab.	1266828
29	((mental* or psycholog*) adj2 (health or ill* or disorder*)).ti,ab,kw.	199628
30	(fall* adj5 (prevent* or rate? or frequen*)).ab,kw. or fall*.ti.	46724
31	((professional? or physician? or doctor? or nurse?) adj2 patient? adj5 (communicat* or relation*)).ab,kw. or ((professional? or physician? or doctor? or nurse?) and patient? and (communicat* or relation*)).ti.	15913
32	13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31	2443771

33	12 and 32	2975
34	(adolescent/ or child/ or exp infant/) not (exp adult/ and (adolescent/ or exp child/))	1840161
35	(neonat* or newborn* or infan* or child* or p?ediatric? or adolescen* or teen* or school*).ti.	1409836
36	34 or 35	2289731
37	33 not 36	2184
38	exp animals/ not humans/	4660573
39	37 not 38	2141
40	(comment or editorial or letter or news or "review" or case report).pt. or case report.ti,ab.	4799923
41	39 not 40	1832
42	limit 41 to ("systematic review" or systematic reviews as topic or "reviews (maximizes specificity)")	27
43	41 or 42	1832
44	limit 43 to (english language and yr="2012 -Current")	947

Table 18. Embase search terms question 3

# ▲	Searches	Results
1	exp *hearing impairment/	48015
2	(hearing adj3 (loss or lose or losing or impair*)).ti,ab,kw.	68155
3	1 or 2	91238
4	screening/ or mass screening/ or screening test/	291731
5	exp Hearing Test/	44255
6	screen*.ti,ab,kw.	1016163
7	(detect* or diagnos* or assess* or identifi*).ti.	1791721
8	(hearing adj5 (detect* or diagnos* or assess* or identifi*)).ti,ab,kw.	10942
9	4 or 5 or 6 or 7 or 8	2745038
10	3 and 9	31716
11	exp hearing impairment/di	12202
12	10 or 11	37618
13	"Quality of Life"/ or daily life activity/	517926
14	Social Isolation/	21513
15	Cognitive defect/	158692
16	exp Dementia/	348924
17	mental disease/ or exp anxiety disorder/ or exp mood disorder/	788697
18	coping behavior/	56233
19	falling/	39171
20	exp professional-patient relationship/	44891
21	("quality of life" or qol or "activities of daily living" or "activity of daily living" or adl).ti,ab,kw.	472362
22	((social* adj3 (isolat* or exclusion)) or lonel*).ti,ab,kw.	21212
23	(cognit* adj3 (function* or dysfunction or impair*)).ti,ab,kw.	206424
24	(dementia? or alzheimer?).ti,ab,kw.	298424
25	(depress* or anxiet* or anxious or stress*).ti,ab.	1631779
26	((mental* or psycholog*) adj2 (health or ill* or disorder*)).ti,ab,kw.	259660
27	(fall* adj5 (prevent* or rate? or frequen*)).ab,kw. or fall*.ti.	54898

28	((professional? or physician? or doctor? or nurse?) adj2 patient? adj5 (communicat* or relation*)).ab,kw. or ((professional? or physician? or doctor? or nurse?) and patient? and (communicat* or relation*)).ti.	23161
29	13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28	3213127
30	12 and 29	3473
31	(exp adolescent/ or exp child/) not (exp adult/ and (exp adolescent/ or exp child/))	2073535
32	(neonat* or newborn* or infan* or child* or p?ediatric? or adolescen* or teen* or school*).ti.	1597762
33	31 or 32	2564260
34	30 not 33	2670
35	(exp animals/ or nonhuman/) not human/	6405779
36	34 not 35	2598
37	(editorial or letter or note or "review" or conference*).pt. or case report/ or case report.ti,ab.	11373971
38	36 not 37	1566
39	limit 38 to "reviews (maximizes specificity)"	20
40	38 or 39	1566
41	limit 40 to (english language and yr="2012 -Current")	819

Table 19. Medline search terms question 4

# ▲	Searches	Results
1	exp Hearing Loss/	67774
2	(hearing adj3 (loss or lose or losing or impair*)).ti,ab,kw.	53815
3	1 or 2	90290
4	Mass Screening/	100683
5	Hearing Tests/	10863
6	screen*.ti,ab,kw.	718946
7	(detect* or diagnos* or assess* or identifi*).ti.	1508334
8	(hearing adj5 (detect* or diagnos* or assess* or identifi*)).ti,ab,kw.	8885
9	4 or 5 or 6 or 7 or 8	2160337
10	3 and 9	17893
11	exp Hearing Loss/di	14368
12	10 or 11	26793
13	(adolescent/ or child/ or exp infant/) not (exp adult/ and (adolescent/ or exp child/))	1840161
14	(neonat* or newborn* or infan* or child* or p?ediatric? or adolescen* or teen* or school*).ti.	1409836
15	13 or 14	2289731
16	12 not 15	18535
17	exp animals/ not humans/	4660573
18	16 not 17	17841
19	exp United Kingdom/	359649
20	(national health service* or nhs*).ti,ab,in.	184250
21	(english not ((published or publication* or translat* or written or language* or speak* or literature or citation*) adj5 english)).ti,ab.	93384

22	(gb or "g.b." or britain* or (british* not "british columbia") or uk or "u.k." or united kingdom* or (england* not "new england") or northern ireland* or northern irish* or scotland* or scottish* or ((wales or "south wales") not "new south wales") or welsh*).ti,ab,jw,in.	1998484
23	(bangor or "bangor's" or cardiff or "cardiff's" or newport or "newport's " or st asaph or "st asaph's" or st davids or swansea or "swansea's").ti,ab,in.	52723
24	(aberdeen or "aberdeen's" or dundee or "dundee's" or edinburgh or "edinburgh's" or glasgow or "glasgow's" or inverness or (perth not australia*) or ("perth's" not australia*) or stirling or "stirling's").ti,ab,in.	200897
25	(armagh or "armagh's" or belfast or "belfast's" or lisburn or "lisburn's" or londonderry or "londonderry's" or derry or "derry's" or newry or "newry's").ti,ab,in.	24844
26	(bath or "bath's" or ((Birmingham not alabama*) or ("birmingham's" not alabama*) or bradford or "bradford's" or brighton or "brighton's" or bristol or "bristol's" or carlisle* or "carlisle's" or (cambridge not (massachusetts* or boston* or harvard*)) or ("cambridge's" not (massachusetts* or boston* or harvard*)) or (canterbury not zealand*) or ("canterbury's" not zealand*) or chelmsford or "chelmsford's" or chester or "chester's" or chichester or "chichester's" or coventry or "coventry's" or derby or "derby's" or (durham not (carolina* or nc)) or ("durham's" not (carolina* or nc)) or ely or "ely's" or exeter or "exeter's" or gloucester or "gloucester's" or hereford or "hereford's" or hull or "hull's" or lancaster or "lancaster's" or leeds* or leicester or "leicester's" or (lincoln not nebraska*) or ("lincoln's" not nebraska*) or (liverpool not (new south wales* or nsw)) or ("liverpool's" not (new south wales* or nsw)) or ((london not (ontario* or ont or toronto*)) or ("london's" not (ontario* or ont or toronto*)) or manchester or "manchester's" or (newcastle not (new south wales* or nsw)) or ("newcastle's" not (new south wales* or nsw)) or norwich or "norwich's" or nottingham or "nottingham's" or oxford or "oxford's" or peterborough or "peterborough's" or plymouth or "plymouth's" or portsmouth or "portsmouth's" or preston or "preston's" or ripon or "ripon's" or salford or "salford's" or salisbury or "salisbury's" or sheffield or "sheffield's" or southampton or "southampton's" or st albans or stoke or "stoke's" or sunderland or "sunderland's" or truro or "truro's" or wakefield or "wakefield's" or wells or westminster or "westminster's" or winchester or "winchester's" or wolverhampton or "wolverhampton's" or (worcester not (massachusetts* or boston* or harvard*)) or ("worcester's" not (massachuse tts* or boston* or harvard*)) or (york not ("new york*" or ny or ontario* or ont or toronto*)) or ("york's" not ("new york*" or ny or ontario* or ont or toronto*))))).ti,ab,in.	1348597
27	19 or 20 or 21 or 22 or 23 or 24 or 25 or 26	2572408
28	(exp africa/ or exp americas/ or exp antarctic regions/ or exp arctic regions/ or exp asia/ or exp oceania/) not (exp great britain/ or europe/)	2794544
29	27 not 28	2430309
30	18 and 29	1444
31	limit 30 to (english language and yr="2012 -Current")	607

Table 20. Embase search terms question 4

# ▲	Searches	Results
1	exp *hearing impairment/	48015
2	(hearing adj3 (loss or lose or losing or impair*)).ti,ab,kw.	68155
3	1 or 2	91238
4	screening/ or mass screening/ or screening test/	291731
5	exp Hearing Test/	44255
6	screen*.ti,ab,kw.	1016163
7	(detect* or diagnos* or assess* or identifi*).ti.	1791721
8	(hearing adj5 (detect* or diagnos* or assess* or identifi*)).ti,ab,kw.	10942
9	4 or 5 or 6 or 7 or 8	2745038

10	3 and 9	31716
11	exp hearing impairment/di	12202
12	auditory screening/	1964
13	10 or 11 or 12	38229
14	(adolescent/ or child/ or exp infant/) not (exp adult/ and (adolescent/ or exp child/))	1931249
15	(neonat* or newborn* or infan* or child* or p?ediatric? or adolescen* or teen* or school*).ti.	1597762
16	14 or 15	2478112
17	13 not 16	26968
18	(exp animals/ or nonhuman/) not human/	6405779
19	17 not 18	25828
20	exp United Kingdom/	414938
21	(national health service* or nhs*).ti,ab,in.	278657
22	(english not ((published or publication* or translat* or written or language* or speak* or literature or citation*) adj5 english)).ti,ab.	41132
23	(gb or "g.b." or britain* or (british* not "british columbia") or uk or "u.k." or united kingdom* or (england* not "new england") or northern ireland* or northern irish* or scotland* or scottish* or ((wales or "south wales") not "new south wales") or welsh*).ti,ab,jw,in.	3026769
24	(bangor or "bangor's" or cardiff or "cardiff's" or newport or "newport's " or st asaph or "st asaph's" or st davids or swansea or "swansea's").ti,ab,in.	95935
25	(aberdeen or "aberdeen's" or dundee or "dundee's" or edinburgh or "edinburgh's" or glasgow or "glasgow's" or inverness or (perth not australia*) or ("perth's" not australia*) or stirling or "stirling's").ti,ab,in.	325180
26	(armagh or "armagh's" or belfast or "belfast's" or lisburn or "lisburn's" or londonderry or "londonderry's" or derry or "derry's" or newry or "newry's").ti,ab,in.	43596
27	(bath or "bath's" or ((Birmingham not alabama*) or ("birmingham's" not alabama*) or bradford or "bradford's" or brighton or "brighton's" or bristol or "bristol's" or carlisle* or "carlisle's" or (cambridge not (massachusetts* or boston* or harvard*)) or ("cambridge's" not (massachusetts* or boston* or harvard*)) or (canterbury not zealand*) or ("canterbury's" not zealand*) or chelmsford or "chelmsford's" or chester or "chester's" or chichester or "chichester's" or coventry or "coventry's" or derby or "derby's" or (durham not (carolina* or nc)) or ("durham's" not (carolina* or nc)) or ely or "ely's" or exeter or "exeter's" or gloucester or "gloucester's" or hereford or "hereford's" or hull or "hull's" or lancaster or "lancaster's" or leeds* or leicester or "leicester's" or (lincoln not nebraska*) or ("lincoln's" not nebraska*) or (liverpool not (new south wales* or nsw)) or ("liverpool's" not (new south wales* or nsw)) or ((london not (ontario* or ont or toronto*)) or ("london's" not (ontario* or ont or toronto*)) or manchester or "manchester's" or (newcastle not (new south wales* or nsw)) or ("newcastle's" not (new south wales* or nsw)) or norwich or "norwich's" or nottingham or "nottingham's" or oxford or "oxford's" or peterborough or "peterborough's" or plymouth or "plymouth's" or portsmouth or "portsmouth's" or preston or "preston's" or ripon or "ripon's" or salford or "salford's" or salisbury or "salisbury's" or sheffield or "sheffield's" or southampton or "southampton's" or st albans or stoke or "stoke's" or sunderland or "sunderland's" or truro or "truro's" or wakefield or "wakefield's" or wells or westminster or "westminster's" or winchester or "winchester's" or wolverhampton or "wolverhampton's" or (worcester not (massachusetts* or boston* or harvard*)) or ("worcester's" not (massachuse tts* or boston* or harvard*)) or (york not ("new york*" or ny or ontario* or ont or toronto*)) or ("york's" not ("new york*" or ny or ontario* or ont or toronto*))))).ti,ab,in.	2350507
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	3695163

29	(exp africa/ or exp americas/ or exp antarctic regions/ or exp arctic regions/ or exp asia/ or exp oceania/) not (exp great britain/ or europe/)	2807569
30	28 not 29	3483395
31	19 and 30	2878
32	limit 31 to (english language and yr="2012 -Current")	1149

Table 21. Search strategy for the Cochrane Library Databases

	Search terms	Results
#1	MeSH descriptor: [Hearing Loss] explode all trees	1116
#2	((hearing NEAR/3 (loss or lose or losing or impair*))):ti,ab,kw	3426
#3	#1 or #2	3555
#4	MeSH descriptor: [Mass screening] this term only	3054
#5	MeSH descriptor: [Hearing Tests] explode all trees	1026
#6	(screen*) ti,ab,kw OR ((detect* or diagnos* or assess* or identifi*)):ti,ad,kw OR((hearing and ((single or multiple)) NEAR/3 (question* or test*)))) OR ((screen* NEAR/3 (question* or index* or inventory or index or interview*))): ti,ab,kw	121343
#7	(((handheld or hand-held or portable or “point of care” or POC or POCT) NEAR/3 device? or test* or technolog*))): ti,ab,kw OR ((pure tone NEAR/3 audiomet* or audiogra* or audiolog*))):ti,ab.kw OR (((“whispered voice” or “finger rub” or “watch tick” or “speed in noise” or “word in noise” or “words in noise” or “digit in noise” or “digits in noise” or rinne or weber*) NEAR/3 (test* or screen*))):ti,ab,kw OR (“hearing handicap inventory for the elderly):ti, ab.kw OR (((handheld or hand-held or portable or “point of care” or POC or POCT or internet* or web* or telephone* or phone* or cellphone* or smart phone* or app) NEAR/3 (audiomet* or audiogram* or audiolog*))):ti,ab,kw	2698
#8	(audioscop*): ti,ab,kw	2
#9	#4 or #5 or #6 or #7 or #8	123797
#10	#3 and #9	1278

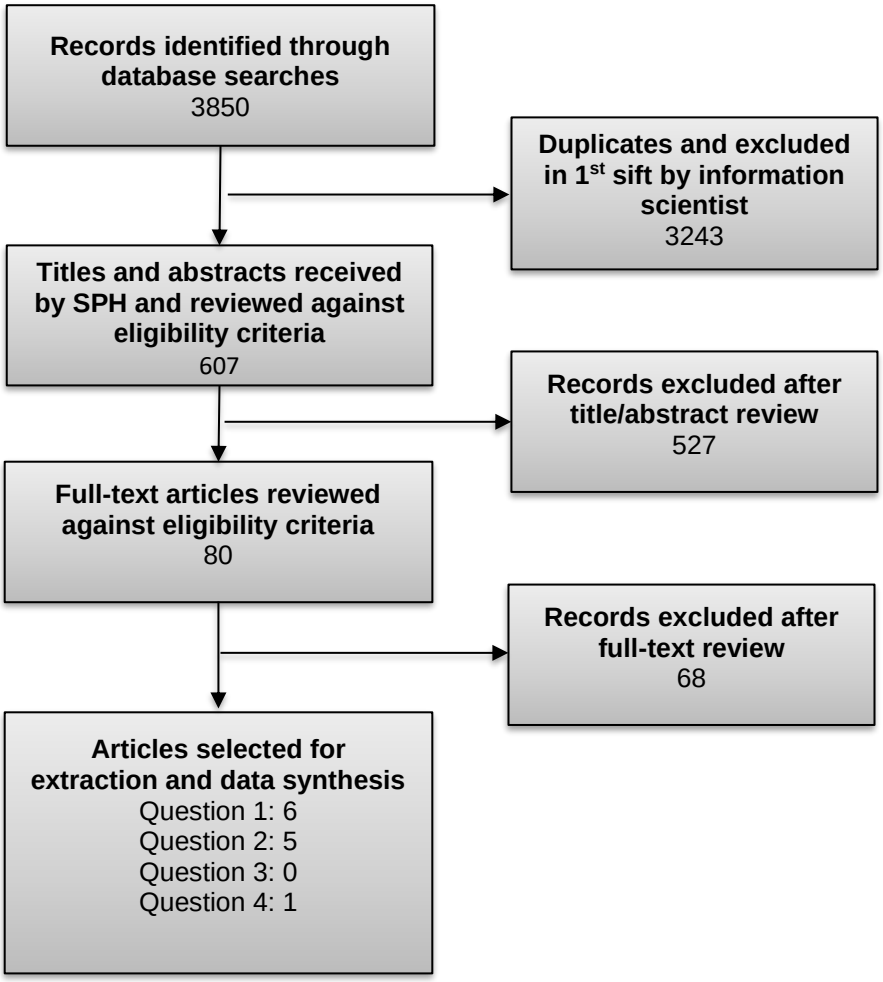
Results were imported into EndNote and de-duplicated.

Appendix 2 — Included and excluded studies

PRISMA flowchart

Figure 1 summarises the volume of publications included and excluded at each stage of the review. Of the 607 publications reviewed against the eligibility criteria 12 were ultimately judged to be relevant to 1 review questions and were considered for extraction. Publications that were included or excluded after the review of full-text articles are detailed below.

Figure 1. Summary of publications included and excluded at each stage of the review



Publications included after review of full-text articles

The 12 publications included after review of full-texts are summarised in Table 22.

Table 22. Summary of publications included for each key question after review of full-text articles

Qu N	Study	The test	The intervention	Implementation criteria
1	**Bright et al (2016)[26]**	X		
1	**Saunders et al (2019)[31]**	X		
1	**Ahmed et al (2018)[30]**	X		
1	**Livshitz et al (2017)[27]**	X		
1	**Koole et al (2016)[28]**	X		
1	**Molander et al (2013)[29]**	X		
2	**Carlson et al (2019)[37]**		X	
2	**Ingo et al (2016)[35]**		X	

2	**Rothpletz et al (2016)[36]**	X	
2	**Laplante-Levasque et al (2015)[34]**	X	
3	**Thodi et al (2013)[38]**	X	
4	**White et al (2019)[43]**		X

It was planned *a priori* that if a high number of studies met the inclusion/ exclusion criteria for each question, studies would be prioritised for extraction and data synthesis using the following approach:

1. Systematic reviews and meta-analyses would be considered the highest quality of evidence if any were found
2. Studies published after the search date of systematic reviews would also be included
3. Higher quality studies, for example, randomised controlled trials would be prioritised above lower quality studies, for example, uncontrolled studies
4. Studies relating to current clinical practice would be prioritised if they considered a UK population, followed by studies from Western populations analogous to the UK
5. Studies using UK audit/ service data from within the last 10 years were prioritised for question 4.

Publications excluded after review of full-text articles

Of the 80 publications included after the review of titles and abstracts, 68 were ultimately judged not to be relevant to this review. These publications, along with reasons for exclusion, are listed in Table 19.

Table 23. Publications excluded after review of full-text articles

	Reference	Reason for exclusion
	Question 1	
1	Cassarly C, Matthews LJ, Simpson AN, Dubno JR. The Revised Hearing Handicap Inventory and Screening Tool Based on Psychometric Reevaluation of the Hearing Handicap Inventories for the Elderly and Adults. Ear & Hearing. 2020;41(1):95-105.	Not about screening performance but about development of a tool
2	Bastianelli M, Mark AE, McAfee A, Schramm D, Lefrancois R, Bromwich M. Adult validation of a self-administered tablet audiometer. Journal of Otolaryngology: Head and Neck Surgery. 2019;48(1):59.	Population cohort of patients referred to audiology

3	Mosley CL, Langley LM, Davis A, McMahon CM, Tremblay KL. Reliability of the Home Hearing Test: Implications for Public Health. Journal of the American Academy of Audiology. 2019;30(3):208-16.	No screening performance measures included
4	Kelly EA, Stadler ME, Nelson S, Runge CL, Friedland DR. Tablet-based Screening for Hearing Loss: Feasibility of Testing in Nonspecialty Locations. Otology & Neurotology. 2018;39(4):410-6	Population already has hearing problems
5	Sheikh Rashid M, Dreschler WA. Accuracy of an internet-based speech-in-noise hearing screening test for high-frequency hearing loss: incorporating automatic conditional rescreening. International Archives of Occupational & Environmental Health. 2018;91(7):877-85.	Population is noise exposed occupational group
6	Kelly EA, Li B, Adams ME. Diagnostic Accuracy of Tuning Fork Tests for Hearing Loss: A Systematic Review. Otolaryngology - Head & Neck Surgery. 2018;159(2):220-30.	Studies included are adults and children not reported separately
7	Pickens AW, Robertson LD, Smith ML, Zheng Q, Song S. Headphone evaluation for app-based automated mobile hearing screening. International Archives of Otorhinolaryngology. 2018;22(4):358-63.	Headphone evaluation not screening test performance
8	Servidoni AB, Conterno LO. Hearing Loss in the Elderly: Is the Hearing Handicap Inventory for the Elderly - Screening Version Effective in Diagnosis When Compared to the Audiometric Test? International @rchives of Otorhinolaryngology. 2018;22(1):1-8.	Population cohort of patients with audiology problems
9	Vercammen C, Goossens T, Wouters J, van Wieringen A. Digit Triplet Test Hearing Screening With Broadband and Low-Pass Filtered Noise in a Middle-Aged Population. Ear & Hearing. 2018;39(4):825-8	Case control study – non-case control studies are available
10	Brennan-Jones CG, Eikelboom RH, Swanepoel W. Diagnosis of hearing loss using automated audiometry in an asynchronous telehealth model: A pilot accuracy study. Journal of Telemedicine & Telecare. 2017;23(2):256-62.	Population cohort of patients with hearing loss
11	Folmer RL, Vachhani J, McMillan GP, Watson C, Kidd GR, Feeney MP. Validation of a Computer-Administered Version of the Digits-in-Noise Test for Hearing Screening in the United States. Journal of the American Academy of Audiology. 2017;28(2):161-9	Case control study – non-case control studies are available
12	Labanca L, Guimaraes FS, Costa-Guarisco LP, Couto EAB, Goncalves DU. Screening of hearing in elderly people: assessment of accuracy and reproducibility of the whispered voice test. Ciencia & Saude Coletiva. 2017;22(11):3589-98.	Population cohort of patients referred with hearing problems
13	Lohler J, Grabner F, Wollenberg B, Schlattmann P, Schonweiler R. Sensitivity and specificity of the abbreviated profile of hearing aid benefit (APHAB). European Archives of Oto-Rhino-Laryngology. 2017;274(10):3593-8.	The abbreviated profile of hearing aid benefit is not a screening tool
14	Saliba J, Al-Reefi M, Carriere JS, Verma N, Provencal C, Rappaport JM. Accuracy of Mobile-Based Audiometry in the Evaluation of Hearing Loss in Quiet and Noisy Environments. Otolaryngology - Head & Neck Surgery. 2017;156(4):706-11	Population recruited from tertiary referrals to audiology. Focussed on setting of test not test itself
15	Samelli AG, Rabelo CM, Sanches SGG, Aquino CP, Gonzaga D. Tablet-Based Hearing Screening Test. Telemedicine Journal & E-Health. 2017;23(9):747-52.	Study did not use pure tone audiology as reference standard
16	Abu-Ghanem S, Handzel O, Ness L, Ben-Artzi-Blima M, Fait-Ghelbendorf K, Himmelfarb M. Smartphone-based audiometric test for screening hearing loss in the elderly. European Archives of Oto-Rhino-Laryngology. 2016;273(2):333-9.	Part of SR by Bright et al 2016

17	Fredriksson S, Hammar O, Magnusson L, Kahari K, Persson Waye K. Validating self-reporting of hearing-related symptoms against pure-tone audiometry, otoacoustic emission, and speech audiometry. International Journal of Audiology. 2016;55(8):454-62.	Selected occupational group of women with self reported hearing loss
18	Renda L, Selcuk OT, Eyigor H, Osma U, Yilmaz MD. Smartphone Based Audiometric Test for Confirming the Level of Hearing; Is It Useable in Underserved Areas? The Journal of International Advanced Otology. 2016;12(1):61-6.	Population cohort of patients referred with hearing problems and about testing in different settings
19	Whitton JP, Hancock KE, Shannon JM, Polley DB. Validation of a Self-Administered Audiometry Application: An Equivalence Study. Laryngoscope. 2016;126(10):2382-8.	Population cohort is people with hearing loss
20	Haanes GG, Kirkevold M, Hofoss D, Eilertsen G. Discrepancy between self-assessments and standardised tests of vision and hearing abilities in older people living at home: a ROC curve analysis. Journal of Clinical Nursing. 2015;24(23-24):3380-8.	Combined vision and hearing screening test to assess sensory impairment
21	Larrosa F, Rama-Lopez J, Benitez J, Morales JM, Martinez A, Alanon MA, et al. Development and evaluation of an audiology app for iPhone/iPad mobile devices. Acta Oto-Laryngologica. 2015;135(11):1119-27.	Population cohort is people with hearing loss
22	Paglialonga A, Tognola G, Grandori F. A user-operated test of suprathreshold acuity in noise for adult hearing screening: The SUN (Speech Understanding in Noise) test. Computers in Biology & Medicine. 2014;52:66-72.	No description of the population
23	Cardoso CL, Bos AJ, Goncalves AK, Olchik MR, Flores LS, Seimetz BM, et al. Sensitivity and specificity of portable hearing screening in middle-aged and older adults. International @rchives of Otorhinolaryngology. 2014;18(1):21-6.	Population in Brazil – not comparable population to the UK
	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. 2014;25(10):937-51.	Population cohort of people referred with hearing problems
24	Becerril-Ramirez PB, Gonzalez-Sanchez DF, Gomez-Garcia A, Figueroa-Moreno R, Bravo-Escobar GA, Garcia de la Cruz MA. Hearing loss screening tests for adults. Acta Otorrinolaringologica Espanola. 2013;64(3):184-90.	Population in Mexico – not comparable to the UK
25	McShefferty D, Whitmer WM, Swan IR, Akeroyd MA. The effect of experience on the sensitivity and specificity of the whispered voice test: a diagnostic accuracy study. BMJ Open. 2013;3(4).	Population cohort of people referred with hearing problems and not about screening performance.
26	Paglialonga A, Grandori F, Tognola G. Using the speech understanding in noise (SUN) test for adult hearing screening1. American Journal of Audiology. 2013;22(1):171-4.	Paper not available
27	Gan KB, Azeez D, Umat C, Ali MA, Wahab NA, Mukari SZ. Development of a computer-based automated pure tone hearing screening device: a preliminary clinical trial. Biomedizinische Technik. 2012;57(5):323-32.	Population cohort of people referred with hearing problems
28	Szudek J, Ostevik A, Dziegielewski P, Robinson-Anagor J, Gomaa N, Hodgetts B, et al. Can Uhear me now? Validation of an iPod-based hearing loss screening test. Journal of Otolaryngology: Head and Neck Surgery. 2012;41 Suppl 1:S78-84.	In the SR by Bright et al 2016
	Question 2	

1	Punch R, Horstmanshof L. Hearing loss and its impact on residents in long term care facilities: A systematic review of literature. Geriatric Nursing. 2019;40(2):138-47.	Not a screen detected cohort
2	Ruusuvuori JE, Aaltonen T, Koskela I, Ranta J, Lonka E, Salmenlinna I, et al. Studies on stigma regarding hearing impairment and hearing aid use among adults of working age: a scoping review. Disability & Rehabilitation. 2019:1-11.	Not a screen detected cohort
3	Maidment DW, Ali YHK, Ferguson MA. Applying the COM-B Model to Assess the Usability of Smartphone-Connected Listening Devices in Adults with Hearing Loss. Journal of the American Academy of Audiology. 2019;30(5):417-30.	Not a screen detected cohort
4	Sawyer CS, Munro KJ, Dawes P, O'Driscoll MP, Armitage CJ. Beyond motivation: identifying targets for intervention to increase hearing aid use in adults. International Journal of Audiology. 2019;58(1):53-8.	Not a screen detected cohort
5	Simpson AN, Matthews LJ, Cassarly C, Dubno JR. Time From Hearing Aid Candidacy to Hearing Aid Adoption: A Longitudinal Cohort Study. Ear & Hearing. 2019;40(3):468-76.	Not a screen detected cohort
6	Barker F, Lusignan S, Deborah C. Improving Collaborative Behaviour Planning in Adult Auditory Rehabilitation: Development of the I-PLAN Intervention Using the Behaviour Change Wheel. Annals of Behavioral Medicine. 2018;52(6):489-500.	Not a screen detected cohort
7	Scholes S, Biddulph J, Davis A, Mindell JS. Socioeconomic differences in hearing among middle-aged and older adults: cross-sectional analyses using the Health Survey for England. BMJ Open. 2018;8(2):e019615.	General population cohort tested but no outcomes of uptake of intervention as a result of positive test
8	Barker AB, Leighton P, Ferguson MA. Coping together with hearing loss: a qualitative meta-synthesis of the psychosocial experiences of people with hearing loss and their communication partners. International Journal of Audiology. 2017;56(5):297-305	Not a screen detected cohort.
9	Bisgaard N, Ruf S. Findings From EuroTrak Surveys From 2009 to 2015: Hearing Loss Prevalence, Hearing Aid Adoption, and Benefits of Hearing Aid Use. American Journal of Audiology. 2017;26(3S):451-61.	Not a screen detected cohort
10	Rolfe C, Gardner B. Experiences of hearing loss and views towards interventions to promote uptake of rehabilitation support among UK adults. International Journal of Audiology. 2016;55(11):666-73.	Not a screen detected cohort
11	Saunders GH, Frederick MT, Silverman SC, Nielsen C, Laplante-Levesque A. Description of Adults Seeking Hearing Help for the First Time According to Two Health Behavior Change Approaches: Transtheoretical Model (Stages of Change) and Health Belief Model. Ear & Hearing. 2016;37(3):324-33.	Not a screen detected cohort
12	Saunders GH, Frederick MT, Silverman SC, Nielsen C, Laplante-Levesque A. Health behavior theories as predictors of hearing-aid uptake and outcomes. International Journal of Audiology. 2016;55 Suppl 3:S59-68.	Not a screen detected cohort
13	Barker F, MacKenzie E, Elliott L, de Lusignan S. Outcome Measurement in Adult Auditory Rehabilitation: A Scoping Review of Measures Used in Randomized Controlled Trials. Ear & Hearing. 2015;36(5):567-73.	Scoping review
14	Bennett RJ, Taljaard DS, Brennan-Jones CG, Tegg-Quinn S, Eikelboom RH. Evaluating hearing aid handling skills: A systematic and descriptive review. International Journal of Audiology. 2015;54(11):765-76.	Not a screen detected cohort
15	Ng JH, Loke AY. Determinants of hearing-aid adoption and use among the elderly: a systematic review. International Journal of Audiology. 2015;54(5):291-300.	Not a screen detected cohort

16	Schneider J, Dunsmore M, McMahon CM, Gopinath B, Kifley A, Mitchell P, et al. Improving access to hearing services for people with low vision: piloting a "hearing screening and education model" of intervention. Ear & Hearing. 2014;35(4):e153-6	About measuring unmet need in people with vision impairment
17	McCormack A, Fortnum H. Why do people fitted with hearing aids not wear them? International Journal of Audiology. 2013;52(5):360-8.	Not a screen detected cohort
18	McCullagh MC, Frank K. Addressing adult hearing loss in primary care. Journal of Advanced Nursing. 2013;69(4):896-904.	Not a screen detected cohort
19	Meyer C, Hickson L. What factors influence help-seeking for hearing impairment and hearing aid adoption in older adults? International Journal of Audiology. 2012;51(2):66-74.	Not a screen detected cohort
	Question 3	
1	Applebaum J, Hoyer M, Betz J, Lin FR, Goman AM. Long-term subjective loneliness in adults after hearing loss treatment. International Journal of Audiology. 2019;58(8):464-7.	Not a screening programme
2	Dawes P, Wolski L, Himmelsbach I, Regan J, Leroi I. Interventions for hearing and vision impairment to improve outcomes for people with dementia: a scoping review. International Psychogeriatrics. 2019;31(2):203-21.	Not a screening programme
3	Leroi I, Simkin Z, Hooper E, Wolski L, Abrams H, Armitage CJ, et al. Impact of an intervention to support hearing and vision in dementia: The SENSE-Cog Field Trial. International Journal of Geriatric Psychiatry. 2019;11:11.	Not a screening programme
4	Mahmoudi E, Basu T, Langa K, McKee MM, Zazove P, Alexander N, et al. Can Hearing Aids Delay Time to Diagnosis of Dementia, Depression, or Falls in Older Adults? Journal of the American Geriatrics Society. 2019;67(11):2362-9.	Not a screening programme
5	Hyams AV, Hay-McCutcheon M, Scogin F. Hearing and quality of life in older adults. Journal of Clinical Psychology. 2018;74(10):1874-83.	Not a screening programme
6	Maharani A, Dawes P, Nazroo J, Tampubolon G, Pendleton N, group SE-CW. Longitudinal Relationship Between Hearing Aid Use and Cognitive Function in Older Americans. Journal of the American Geriatrics Society. 2018;66(6):1130-6.	Not a screening programme
7	Mamo SK, Reed NS, Price C, Occhipinti D, Pletnikova A, Lin FR, et al. Hearing Loss Treatment in Older Adults With Cognitive Impairment: A Systematic Review. Journal of Speech Language & Hearing Research. 2018;61(10):2589-603	Not a screening programme
8	Qian ZJ, Wattamwar K, Caruana FF, Otter J, Leskowitz MJ, Siedlecki B, et al. Hearing Aid Use is Associated with Better Mini-Mental State Exam Performance. American Journal of Geriatric Psychiatry. 2016;24(9):694-702	Not a screening programme
9	Niemensivu R, Manchaiah V, Roine RP, Kentala E, Sintonen H. Health-related quality of life in adults with hearing impairment before and after hearing-aid rehabilitation in Finland. International Journal of Audiology. 2015;54(12):967-75.	Not a screening programme
10	Barker F, Mackenzie E, Elliott L, Jones S, de Lusignan S. Interventions to improve hearing aid use in adult auditory rehabilitation. Cochrane Database of Systematic Reviews. 2014(7):CD010342.	Not a screening programme
	Question 4	
1	Tao KFM, Brennan-Jones CG, Capobianco-Fava DM, Jayakody DMP, Friedland PL, Swanepoel W, et al. Teleaudiology Services for Rehabilitation With Hearing Aids in Adults: A Systematic Review. Journal of Speech Language & Hearing Research. 2018;61(7):1831-49.	Not a UK study

2	Barnett M, Hixon B, Okwiri N, Irungu C, Ayugi J, Thompson R, et al. Factors involved in access and utilization of adult hearing healthcare: A systematic review. Laryngoscope. 2017;127(5):1187-94	Not about proportion of people clinically detected and management of hearing loss
3	Timmer BHB, Hickson L, Launer S. Hearing aid use and mild hearing impairment: Learnings from big data. Journal of the American Academy of Audiology. 2017;28(8):731-41.	Not a UK study
4	Rolfe C, Gardner B. Experiences of hearing loss and views towards interventions to promote uptake of rehabilitation support among UK adults. International Journal of Audiology. 2016;55(11):666-73.	Not about user experiences of using services
5	O'Neill C, Lamb B, Archbold S. Cost implications for changing candidacy or access to service within a publicly funded healthcare system? Cochlear Implants International. 2016;17 Suppl 1:31-5.	Not about take up and use of services
6	Dawes P, Fortnum H, Moore DR, Emsley R, Norman P, Cruickshanks K, et al. Hearing in middle age: a population snapshot of 40- to 69-year olds in the United Kingdom. Ear and hearing. 2014;35(3):e44-e51.	Not about prevalence in relation to rates of clinical detection
7	Barker F, de Lusignan S, Baguley D, Gagne JP. An evaluation of audiology service improvement documentation in England using the chronic care model and content analysis. International Journal of Audiology. 2014;53(6):377-82	Not proportions of people clinically detected hearing loss and their management
8	Edmondson-Jones M, McCormack A, Fortnum H, Moore DR. Investigating the interaction between cognition and speech-in-noise hearing using data from UK Biobank. European Journal of Epidemiology. 2013;28(1):S169-S70.	Not about clinical detection and management of hearing loss
9	Morris AE, Lutman ME, Cook AJ, Turner D. An economic evaluation of screening 60- to 70-year-old adults for hearing loss. Journal of Public Health. 2013;35(1):139-46.	Not about clinical detection and management
10	Rosenhall U, Moller C, Hederstierna C. Hearing of 75-year old persons over three decades: Has hearing changed? International Journal of Audiology. 2013;52(11):731-9.	Not a UK study
11	Turton L, Smith P. Prevalence & characteristics of severe and profound hearing loss in adults in a UK National Health Service clinic. International Journal of Audiology. 2013;52(2):92-7.	Not about detection, referral, treatment and adherence to intervention

Appendix 3 — Summary and appraisal of individual studies

Data Extraction

Studies relevant to criteria 4 and 5, key question 1: What is the diagnostic accuracy of screening tests for hearing loss in adult population?

Table 24. Bright et al (2016)[26]

Publication	Bright T, Pallawela D. Validated Smartphone-Based Apps for Ear and Hearing Assessments: A Review. JMIR Rehabilitation And Assistive Technologies. 2016;3(2):e13.
Study details	Systematic review of smart-phone based apps for ear and hearing assessments
Study objectives	To identify and review available apps to assess hearing loss and peer-reviewed validation studies for these apps published between June 2007 and July 2015
Inclusions	Apps for self-administered or professionally administered tests of ear or hearing function and peer reviewed studies comparing an app to the gold standard
Exclusions	Apps not focussed on ear examination or audiological testing; apps not in English; apps included in the categories entertainment and music or used for educational purposes
Population	Apps for the general population focussed on adults or children
Index test	Smart phone based applications to assess hearing
Reference standard	Pure tone audiometry - air conduction thresholds
Outcomes	Of 30 apps to assess hearing, 6 were identified in peer reviewed literature. Of these, 4 studies examined the app uHear, 1 examined the app Ear Trumpet and 1 examined the app AudCal in adults. Another 5 studies focussed on hearing screening in children with 3 apps, hearScreen, CellScope and shoeBOX.

Index test (app)	**Cohort**	**Reference standard**	**Sensitivity Specificity (95% CI)**
uHear Self administered with iPod touch researcher supervised	N=32 Age 20-82 M=75%F=25%	PTA in sound proof room	Sens;76% (53-92) Spec: 91% (59-99)
uHear Self administered with iPod touch researcher supervised	N=100 Age= 20-91 M=33% F=67%	PTA in sound proof room	Quiet room Sens:98% (89-100) Spec: 82% (75-88)

			Soundproof room Sens: 100% (92-100) Spec: 90% (83-94)
uHear Self administered with iPhone	N=26 Age=65-94 Male=31% F=69%	PTA in sound proof room	Sens:100% (CI not reported) Spec:60% (CI not reported)
uHear Self administered with iPhone Investigator present	N=25 Age=15-89 N=52% F=48%	PTA in sound proof room	Waiting room Sens:100% (CI not reported) Spec:64% (CI not reported) Quiet room Sens:100% (CI not reported) Spec:74% (CI not reported) Soundproof room Sens:100% (CI not reported) Spec:88% (CI not reported)
Ear trumpet Self administered with iPhone or iPod	N=42, Age =20-85 M=55% F=45%	PTA in sound proof room	Not reported
AudCal Audiologist administered with iPhone and/or iPad	N=110 Age 18-91 M=54% F=46%	PTA in sound proof room	Not reported

Abbreviations: CI – Confidence interval, F – Female, M- Male, N- number, PTA – Pure tone audiometry, Sens – sensitivity, Spec - specificity

Quality appraisal	The study was assessed using the Amstar II a critical appraisal tool for systematic reviews of randomised and non randomised studies and no concerns were identified. The authors used QUADAS 2 to check for risk of bias of the individual papers and took this into account when discussing the study outcomes. Studies varied in cut off level for performing sensitivity/specificity analyses, how the test results were presented (separate ears or by individual) and the inclusion and exclusion criteria of participants.

	Several studies demonstrated that the testing environment had a significant impact on the accuracy of results as ambient noise levels can exceed the recommended minimum of 40dB. Studies conducted tests using a single device and transducer however there can be variability of results with different device /transducer combinations and the need for calibration. Differences in the quality of headphones or earbuds may also result in poor accuracy. Of the 6 studies 2 examining Ear Trumpet and AudCal achieved a low risk of bias and low concerns about applicability in all QUADAS-2 domains.

Table 25. Ahmed et al (2018)[30]

Publication	Ahmed OH, Gallant SC, Ruiz R, Wang B, Shapiro WH, Voigt EP. Validity of the Hum Test, a Simple and Reliable Alternative to the Weber Test. Annals of Otology, Rhinology & Laryngology. 2018;127(6):402-5.
Study details	Cohort study
Study objectives	To test the diagnostic performance of the hum test against the Weber test using pure tone audiometry as the gold standard comparator
Inclusions	People aged 18 to 35
Exclusions	People with history of unresolved hearing problems, otologic conditions or ear surgery, current hearing complaints or upper respiratory infection in the last month
Population	Participants were recruited from New York University School of Medicine and the surrounding community (n=29)
Index test	**Hum test:** participants asked to hum at a high pitch for a few seconds and asked if they could hear the tone equally on the left or right. This was repeated at a low pitch. **Weber test:** striking the elbow with a 512Hz aluminium tuning fork then placing stem of tuning fork on forehead for 2 to 4 seconds and asked if the sound was lateralising Both tests were carried out twice – once with unimpeded hearing and once with simulated unilateral conductive hearing loss using an ear plug in one ear
Reference standard	**Pure tone audiometry** (PTA) was performed using a standard clinical audiometer in a sound proof room and air conduction thresholds from 500Hz to 4kHz measured
Outcomes	All 29 participants underwent both index tests and the reference test. PTA confirmed normal air conduction thresholds bilaterally in all subjects and confirmed the simulated unilateral conductive hearing loss (using an ear plug) in all subjects defined as ≥10dB air conduction threshold decrease. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value were calculated (NPV) and shown in the table below. **Sensitivity / Specificity / PPV / NPV** Hum test high pitch: 89.7% / 100% / 100% / 90.6% Hum test low pitch: 93.1% / 100% / 100% / 93.5% Weber test: 96.6% / 100% / 100% / 96.7% A McNemars test showed no difference in the high pitched or low pitched Hum test results compared to the Weber test results.

The simulation of hearing loss may not replicate hearing loss that has naturally developed and may lead to better screening performance results in a similar way to a case control trial.

Quality appraisal using Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool			
Question	**Assessment (Y, N, unclear)**	**Risk of Bias (low, high, unclear)**	**Supporting info**
Domain I: Patient selection			
Consecutive or random sample of population enrolled?	Yes	Low	Convenience sample of participants recruited by advertising across the New York University and wider community
Case-control design avoided?	Yes	Low	This was a cohort of people with no past or present hearing issues
Inappropriate exclusions avoided?	Yes	Low	People only excluded if previous/current risk of hearing problems
Domain II: Index Test			
Index test results interpreted without knowledge of reference standard results?	Unclear	Unclear	All tests were carried out in the same session but the order of the tests is unclear and whether they were all carried out by the same staff member
Threshold pre-specified?	Yes	Low	Hearing loss was simulated conductive hearing loss with a 10dB air conduction threshold lower than participants unimpeded hearing thresholds
Domain III: Reference standard			
Reference standard likely to correctly classify condition?	Yes	Low	Pure tone audiometry is a commonly used gold standard test
Reference standard results interpreted without knowledge of index test results?	Unclear	Unclear	All tests were carried out in the same session but the order of the tests is unclear and whether they were all carried out by the same staff member
Domain IV: Test strategy flow and timing			
Appropriate interval between index test and reference standard?	Yes	Low	All tests were carried out in the same session
Did all participants receive same reference standard?	Yes	Low	29/29 participants completed all tests
All patients included in analysis?	Yes	Low	All 29 patients are included in the analysis
Domain V: Applicability			
Applicable to UK screening population of interest?	No	High	The population screened was 18 to 35 with simulated unilateral conductive hearing loss. In the UK the population of interest is

			likely to be older age groups where the prevalence of hearing loss is higher with a proportion with bilateral hearing loss
Applicable to UK screening test of interest?	Yes	Low	Yes – the tests could be used across the UK population
Target condition measured by reference test applicable to UK screening condition of interest?	Yes	Low	Pure tone audiology is used as an accurate measure of hearing loss in the UK
Other comments	The hum test is a subjective understanding of what is perceived as high or low pitch and will result in frequency variability from subject to subject. It is unclear whether the simulation of unilateral hearing loss in younger adults is likely to be representative of the nature of hearing loss in older groups of adults where hearing loss is more prevalent. The Weber test and hum test detect differences in air and bone conduction in 1 ear relative to the other and should not be applied to subjects with bilateral hearing change as this will result in false negative results.		

Table 26. Saunders et al (2019)[31]

Publication	Saunders GH, Frederick MT, Silverman SC, Penman T, Gardner A, Chisolm TH, et al. Hearing Screening in the Community. Journal of the American Academy of Audiology. 2019;30(2):145-52.
Study details	US based cohort study
Study objectives	To compare self reported screening tests with pure tone audiometry
Inclusions	Adults in community settings
Exclusions	People who did not complete the Hearing Handicap Inventory screening (HHI-S) test people wearing hearing aids, people who did not provide their age
Population	People screened at 1 of 191 community based screening events in Portland and Tampa in the US between June 2015 and November 2016 (n=1954, age range 20-89, mean age 64.1 years)
Index test	The index test comprised 2 elements: otoscopy to check for cerumen and other abnormalities and completion of the HHI-S test
Reference standard	Pure tone hearing testing for frequencies of 1, 2 and 4kHz at 25dB tested separately in both ears
Outcomes	Ambient noise at each event was measured to assess if the setting (for example, library or health fair) affected the results.

	Pure tone test		
HHI-S test	**Pass**	**Fail**	**Total**
Pass	520(26.6%)	638(32.7%)	**1,158(59.3%)**
Fail	196(10.0%)	600(30.7%)	**796(40.7%)**
Total	**716(36.6%)**	**1,238(63.4%)**	

Reviewer calculated screening performance

Sensitivity	**Specificity**	**PPV**	**NPV**
46.4%	78.3%	72.6%	75.4%

The percentage of people aged 45 -54 years who failed the HHI-S test were similar in number to those who failed the reference test (approximately 35%). However, after this age about the same proportion of people failed

the HHI-S test regardless of age (approximately 40%) whilst the proportion failing the reference test increased to almost 100% in people aged ≥85.

Ambient noise levels varied between screening settings and this was reflected in a significantly higher number of people failing the pure tone reference test in noisier settings (analysis of variance F=12.1; p=0.001). This was not found with people completing the HHI-S test.

Quality appraisal using Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool			
Question	**Assessment (Y, N, unclear)**	**Risk of Bias (low, high, unclear)**	**Supporting info**
Domain I: Patient selection			
Consecutive or random sample of population enrolled?	Yes	Low	Convenience sample of people offered screening at community events
Case-control design avoided?	Yes	Low	Cohort of people attending community events
Inappropriate exclusions avoided?			
Domain II: Index Test			
Index test results interpreted without knowledge of reference standard results?	Yes	Low	The index test was completed before the reference test was carried out in the same session
Threshold pre-specified?	Yes	Low	The threshold score for the HHI-S test was ≥10
Domain III: Reference standard			
Reference standard likely to correctly classify condition?	Yes	Low	The pure tone audiometry is used as the gold standard for determining hearing loss
Reference standard results interpreted without knowledge of index test results?	No	High	The Index test was carried out first and scores calculated before pure tone audiometry was carried out by the same person in the same session
Domain IV: Test strategy flow and timing			
Appropriate interval between index test and reference standard?	Yes	Low	Both index test and reference standard were carried out at the same session
Did all participants receive same reference standard?	Yes	Low	All participants were tested with pure tone audiometry
All patients included in analysis?	Yes	Low	Analysis included all participants
Domain V: Applicability			
Applicable to UK screening population of interest?	Yes	Low	Community events chosen were those likely to be visited by older people from the general population which would be similar to the screening population of interest in the UK
Applicable to UK screening test of interest?	Yes	Low	This screening test could be used in a UK population

Target condition measured by reference test applicable to UK screening condition of interest?	Yes	Low	The condition was hearing loss which is the target condition in the UK
Other comments			

Table 27. Livshitz et al (2017)[27]

Publication	Livshitz L, Ghanayim R, Kraus C, Farah R, Even-Tov E, Avraham Y, et al. Application-Based Hearing Screening in the Elderly Population. Annals of Otology, Rhinology & Laryngology. 2017;126(1):36-41.
Study details	Cohort study
Study objectives	To examine the accuracy of the uHear application based screening audiometry in comparison to a standard audiogram
Inclusions	Patients aged ≥ 65
Exclusions	People unable to perform the test or refusing to participate
Population	Patients aged ≥ 65 hospitalised for any reason in a hospital in Israel (n=60)
Index test	uHear application based screening test using an iPad tablet
Reference standard	Pure tone audiometry with a threshold of 35dB HL in the better ear at 500, 1000, 2000, 4000 and 6000Hz
Outcomes	60 patients completed the index and reference tests The uHear application consistently overestimated hearing loss by approximately 25dB. This was attributed to ambient noise and visual distractions despite the application measuring ambient noise to adjust for this factor. When the results were adjusted to take this into account the uHear application had a sensitivity of 76.5% and specificity of 90.7%. Using these figures for this group, 4 people would be unnecessarily referred for full audiometry who had no hearing problems and 4 would have been missed by the uHear application.

Quality appraisal using Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool			
Question	**Assessment (Y, N, unclear)**	**Risk of Bias (low, high, unclear)**	**Supporting info**
Domain I: Patient selection			
Consecutive or random sample of population enrolled?	Unclear	Unclear	Patients recruited had been hospitalised for any reason on a medical ward
Case-control design avoided?	Yes	Low	This was a cohort study
Inappropriate exclusions avoided?	Yes	Low	People were only excluded if they refused to participate or could not carry out the test (n=17)
Domain II: Index Test			
Index test results interpreted without knowledge of reference standard results?	Yes	Low	The index test was carried out before the reference test in the same session
Threshold pre-specified?	Yes	Low	The uHear test has a pass fail threshold but this was not specified
Domain III: Reference standard			
Reference standard likely to correctly classify condition?	Yes	Low	Pure tone audiometry is used as the gold standard for assessing hearing loss

Reference standard results interpreted without knowledge of index test results?	No	High	The index test was completed directly before the reference test in the same session and its possible staff would know the result of the test
Domain IV: Test strategy flow and timing			
Appropriate interval between index test and reference standard?	Yes	Low	Both tests were carried out consecutively in the same session
Did all participants receive same reference standard?	Yes	Low	All participants completed a pure tine audiometry test
All patients included in analysis?	Yes	Low	All 60 patients were included in the analysis
Domain V: Applicability			
Applicable to UK screening population of interest?	No	High	The older population tested are likely to be the similar to the target population for hearing screening in the UK. However, this was a hospitalised cohort so there is an assumption that they would be more unwell than the general UK population of the same age
Applicable to UK screening test of interest?	Yes	Low	This screening test is available in the UK
Target condition measured by reference test applicable to UK screening condition of interest?	Yes	Low	This study was testing for hearing loss which is the UK screening condition of interest
Other comments	Adjustments were made to the results to account for a 25dB overestimation of the uHear app resulting in the app appearing to be more accurate than it actually is.		

Table 28. Koole et al (2016)[28]

Publication	Koole A, Nagtegaal AP, Homans NC, Hofman A, Baatenburg de Jong RJ, Goedegebure A. Using the Digits-In-Noise Test to Estimate Age-Related Hearing Loss. Ear & Hearing. 2016;37(5):508-13.
Study details	Population based cohort study
Study objectives	To evaluate the ability of the digits in noise test to screen for mild and moderate hearing loss in older people
Inclusions	People aged ≥50
Exclusions	People with a reference standard air and bone gap of ≥15dB in their best ear
Population	People invited from the population of Ommord, a suburb of Rotterdam in the Netherlands (n=3327)
Index test	**Digits in noise test (DIN):** using the best ear (lowest air conduction threshold) a 3 minute DIN test consisting of a male spoken speech signal of 3 consecutive digits with background speech shaped noise at 60dB. Each DIN test comprised 24 digit triplets starting at 0dB signal to noise ratio(SNR). If the triplet was repeated incorrectly the next triplet was 2db more intense. The speech reception threshold (SRT) is the measure used defined as the difference between the level of presented speech and background noise at which the tested person can correctly reproduce 50% of words or sentences
Reference standard	**Pure tone audiometry:** air conduction thresholds in both ears at 0.25, 0.5, 1,2,4 and 8Hz. Bone conduction thresholds obtained at 0.5 and 4Hz were carried out to assess the presence of the bone/air gap
Outcomes	Using 4 index test speech reception thresholds (SRT) measured as decibels of signal to noise ratio (SNR) authors calculated sensitivity and specificity for the

DIN compared with reference test pure tone thresholds for mild and worse (>20dB) and moderate and worse (≥35dB) hearing loss.

	PTA>20dB		PTA >35dB	
SRT (dB SNR)	**Sensitivity (%)**	**Specificity (%)**	**Sensitivity (%)**	**Specificity (%)**
-5.0	79	76	99	61
-4.0	65	92	99	75
-3.0	53	97	99	84
-2.0	42	98	95	90

Quality appraisal using Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool			
Question	**Assessment (Y, N, unclear)**	**Risk of Bias (low, high, unclear)**	**Supporting info**
Domain I: Patient selection			
Consecutive or random sample of population enrolled?	Yes	Low	Enrolled from the general population as part of an ongoing study started in 1990 to look at risk factors for common diseases in older people
Case-control design avoided?	Yes	Low	This is a cohort study
Inappropriate exclusions avoided?	No	High	71 people who failed to understand what the test entailed and did not complete it were excluded from the analysis – it is likely that in any screening programme a proportion of people will find testing challenging and it is important to understand the characteristics of this cohort. 158 people with an average sound to noise ratio deviation of more than 3.7dB(+2 standard deviations above mean) were considered outliers and excluded from the analysis
Domain II: Index Test			
Index test results interpreted without knowledge of reference standard results?	Unclear	Unclear	It is not clear if staff knew the outcome of the reference standard before the index test was carried out
Threshold pre-specified?	Yes	Low	A total of 4 thresholds were pre-specified to compare with the reference standard to detect pure tone thresholds >20dB (mild or worse hearing loss) and >35dB (moderate or worse hearing loss)
Domain III: Reference standard			
Reference standard likely to correctly classify condition?	Yes	Low	Pure tone audiometry is a commonly used gold standard test

Reference standard results interpreted without knowledge of index test results?	Unclear	Unclear	It is not clear if staff know the outcome of the index test before the reference standard was carried out
Domain IV: Test strategy flow and timing			
Appropriate interval between index test and reference standard?	Unclear	Unclear	It is not clear whether the index test and reference standard were carried out in the same session.
Did all participants receive same reference standard?	Yes	Low	All received pure tone audiology
All patients included in analysis?	No	High	People were excluded (n=71) if they failed to complete the DIN test. The reasons were: not understanding the instructions in the Dutch language and limited cognition to understand the test procedure
Domain V: Applicability			
Applicable to UK screening population of interest?	Yes	Low	The cohort of people are likely to be similar to a UK screening population
Applicable to UK screening test of interest?	Yes	Low	This is a screening test that could be used in the UK
Target condition measured by reference test applicable to UK screening condition of interest?	Yes	Low	This study was testing for hearing loss which is the UK screening condition of interest
Other comments	Despite the digits in noise test being carried out in Dutch the process of repeating the sounds of the digits does not require individuals to understand what the sound means.		

Table 29. Molander et al (2013)[29]

Publication	Molander P, Nordqvist P, Oberg M, Lunner T, Lyxell B, Andersson G. Internet-based hearing screening using speech-in-noise: validation and comparisons of self-reported hearing problems, quality of life and phonological representation. BMJ Open. 2013;3(9):e003223.
Study details	Cohort study
Study objectives	To validate an internet based hearing screening test and to examine the differences in people who passed and failed the screening test
Inclusions	Opportunity sample of adults recruited at the Stockholm central train station
Exclusions	Not reported
Population	287 participants with a mean age of 61 years
Index test	Internet based speech in noise hearing screening carried out using headphones and a computer. Speech in noise tests consist of different words presented in background noise that the listener attempts to identify.
Reference standard	Pure tone audiometry was carried out in a sound proof booth. Both ears were tested at frequencies of 250,500,1.0,2.0,3.0,4.0 and 6.0kHz. People were considered to have normal or mild hearing loss at <35dB and moderate or worse hearing loss at >35dB
Outcomes	The internet based hearing screening speech in noise test had a sensitivity of 79% and specificity of 24% using a cut off speech reception threshold (SRT) of -3.54dB
Quality appraisal using Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool	

Question	Assessment (Y, N, unclear)	Risk of Bias (low, high, unclear)	Supporting info
Domain I: Patient selection			
Consecutive or random sample of population enrolled?	Yes	Low	Recruitment was of passers by at Stockholm train station
Case-control design avoided?	Yes	Low	This was a cohort study
Inappropriate exclusions avoided?	Yes	Low	People who completed the tests were all included
Domain II: Index Test			
Index test results interpreted without knowledge of reference standard results?	Yes	Low	The index test was carried out prior to the reference test during the same session
Threshold pre-specified?	No	High	This was determined by plotting the receiver operating curve(ROC) after testing
Domain III: Reference standard			
Reference standard likely to correctly classify condition?	Yes	Low	The reference standard was the pure tone test used to diagnose hearing loss
Reference standard results interpreted without knowledge of index test results?	Unclear	Unclear	The reference standard was completed in the same session as the internet based screening test and it isn't clear if staff were blind to the results of the first test carried out.
Domain IV: Test strategy flow and timing			
Appropriate interval between index test and reference standard?	Yes	Low	Both tests were carried out at recruitment in the same session
Did all participants receive same reference standard?	Yes	Low	All participants received the same reference test in a sound proof booth
All patients included in analysis?	Yes	Low	All people who completed the screening and reference tests are included in the analysis
Domain V: Applicability			
Applicable to UK screening population of interest?	Yes	Low	Internet based screening using the speech in noise test would be applicable to the screening population of interest (adults in the general population) in the UK
Applicable to UK screening test of interest?	Yes	Low	Internet based screening using the speech in noise test is one of the screening tests of interest for this screening programme
Target condition measured by reference test applicable to UK screening condition of interest?	Yes	Low	Hearing loss was measured by the reference standard and this is the UK target condition of interest

Studies relevant to criterion 9, key question 2: What is the evidence regarding the acceptability of treatment to adults with hearing loss*?*

Table 30. Carlson et al (2019)[37]

Publication	Carlson KF, Sell S, Vachhani J, Folmer RL, Saunders G, Feeney MP. Enhancing Screening Systems to Facilitate Hearing-Healthcare Access: A Qualitative Study. Journal of the American Academy of Audiology. 2019;30(4):250-63.
Study details	Qualitative research: focus groups in the US
Study objectives	To identify ways to facilitate access to hearing healthcare after screening that could be used by automated systems
Inclusions	People recruited through newspaper adverts and flyers in the community, veteran association clinics and an urban academic health centre
Exclusions	Not reported
Population	50 participants: 39 with self perceived hearing loss who used a recent screening test, 8 who had recently sought help for hearing loss and 3 significant others/family members of individuals with hearing loss
Intervention	7 focus groups – 4 for people with hearing loss recently identified through screening, 2 for people who had recently sought help for hearing loss and 1
Comparator	N/A
Outcomes	Focus groups involved 3 to 11 individuals. Five primary themes emerged based on emotion, emphasis and extensiveness and the weight of participants comments and frequency with which themes were voiced. These were: • knowledge – learning more about tinnitus, general hearing loss knowledge, hearing health options, and real life implications of hearing loss • trust – distrust of the hearing health system as it consisted of for profit companies and hearing aids were very expensive. There was more trust in the primary care providers. Hearing screening tests were not considered accurate • access – location convenience of healthcare provider, advertisements and monetary incentives – had made a difference in some people accessing support • quality of life – continuing to socialise and have social roles and employment was an important motivator for seeking help. Motivation to seek help due to fear of risk of personal safety or safety of others due to the environment and to enjoy the noises of the environment – birds singing, music etc • interpersonal influence – Family influence and peer influence were motivating factors to seek help – as was testimony about the benefits and process of taking the next step to seeking support.
Quality appraisal	The study was assessed using the Critical Appraisal Skills Programme (CASP) tool for qualitative research studies. There was a relatively small number of participants in some focus groups although themes were consistent across groups. Participants were from the US may not reflect opinions in the UK. A relatively large proportion of participants were veterans (42%) and their experience may not represent those of non-veterans.

Table 31. Ingo et al (2016)[35]

Publication	Ingo E, Brannstrom KJ, Andersson G, Lunner T, Laplante-Levesque A. Measuring motivation using the transtheoretical (stages of change) model: A follow-up study of people who failed an online hearing screening. International Journal of Audiology. 2016;55 Suppl 3:S52-8.
Study details	Swedish based cohort study
Study objectives	To describe the stages of change of adults who have failed an online hearing screening test 18 months after conducting online hearing screening and participating in the initial study (Laplante-Levesque et al 2015)
Inclusions	224 participants from the first part of the study
Exclusions	NA

Population	122 of the 224 people invited to take part in the follow up study
Intervention	NA
Comparator	NA
Outcomes	There was no difference in the age, gender, education, living situation, speech and noise recognition threshold result, and amount of years with a perceived hearing problem, of the people who did participate in the follow up study compared to those who did not. A chi square test comparing baseline and follow up scores (number of people with the highest score at each stage) showed a significant difference (p=0.0018). A greater proportion of people at follow up had their highest scores in the pre-contemplation, contemplation and action groups and a smaller proportion of people had their highest scores at preparation stage than at baseline. The study also used a measure called a 'staging algorithm' a one-item questionnaire assessing stages of change that asked: 'which of the following statements best describes your view of your current hearing status?'. This also showed a significant difference between baseline and follow up (p=0.004) with a higher proportion of people in the action stage at follow up compared to baseline. There was a weak significant association between staging algorithm scores at baseline and whether the participants had sought help (n=74) or not (n=48) by 18 months follow up (x^2=7.554, p=0.043) but not between stages of change (highest score at this stage) and help seeking actions (x^2=1.69, p=0.638).

Stages of change (staging algorithm)	**Highest score at Baseline N(%)**	**Highest score at Follow up N(%)**	**Staging algorithm Baseline N(%)**	**Staging algorithm Follow up N(%)**
Precontemplation stage (I do not think I have a hearing problem and therefore nothing should be done about it)	7(5.7)	10(8.2)	3(2.5)	3(2.5)
Contemplation (I think I have a hearing problem. However I am not yet ready to take action to solve the problem but I might do so in the future)	43(35.2)	48(39.3)	55(45.1)	48(39.3)
Preparation – (I know I have a hearing problem and I intend to take action to solve it soon.)	68(55.7)	50(41.0)	54(44.3)	42(34.4)
Action – (I know I have a hearing problem and I am here to take action to solve it now)	4(3.3)	14(11.5)	10(8.2)	29(23.8)
Significance between pattern of stage with highest score at baseline and Follow up at 18 months	X^2 =122, p=0.0018		X^2 =122 p=0.004	

Quality appraisal	The study was assessed using the Critical Appraisal Skills Programme (CASP) tool for cohort studies Only people who took up the offer of screening who then had a positive screening results were followed up. There was no follow up of those with a negative result to ask about their experience of screening, whether they would participate again and their views of help seeking. It is unclear whether the subset of people who took up the offer of screening, had a positive result and agreed to participate in the follow up study are likely to reflect the views of the general UK population. The measure of transtheoretical stage of change most closely associated with actual help seeking behaviour in this study was the stage of change algorithm which has not been validated. Reports of help seeking by participants was not confirmed by checking clinical records.

Table 32. Rothpletz et al (2016)[36]

Publication	Rothpletz AM, Moore AN, Preminger JE. Acceptance of internet-based hearing healthcare among adults who fail a hearing screening. International Journal of Audiology. 2016;55(9):483-90.
Study details	A US based cohort study
Study objectives	To characterise people who have a positive screening test in terms of the help-seeking readiness to seek hearing loss intervention and gauge acceptance of internet based hearing healthcare
Inclusions	People >55 years who passed a mental status screening who failed hearing screening(>35dB at 100 or 2000Hz in either ear)
Exclusions	People using hearing aids, people with obvious outer or middle ear disorders, people passing the hearing screening test
Population	People >55 years responding to flyers, email adverts promoting hearing screening in Louisville US (n=26)
Intervention	Hearing screening plus 2.5 hours training on internet based hearing health care (IHHC) training (n=13) included signs and symptoms of hearing impairment, types of amplification devices, types of hearing assistive technologies, communication strategies and auditory training plus 2 homework assignments
Comparator	Hearing screening only (n=13)
Outcomes	At the outset of the study all participants(n=26) completed the URICA (University of Rhode Island Change Assessment) questionnaire to calculate mean score for each stage of change for the group. **Stages of change** / **Mean score (±Standard deviation)** Pre-contemplation: 1.74(0.49) Contemplation: 4.17(0.49) Preparation: 4.16(0.37) Action: 3.77(0.70) Seven subscales of the patient technology acceptance model (PTAM) questionnaire was used to evaluate effectiveness of training on IHHC acceptance. Patients scores at baseline was compared following training or no training using Wilcoxon signed rank tests. Two of the sub scales, health care knowledge and computer self efficacy were significantly improved in the training group between baseline and follow up after training (health care knowledge z=3.19 p=0.001, computer self efficacy z=2.68 p=0.007). None of the other sub scales; computer anxiety, perceived usefulness, perceived ease of use, subjective norm or intention to use, showed any change from baseline to follow up for the training group. No subscales showed any difference between baseline and follow up for the group who did not receive any training.
Quality appraisal	The study was assessed using the Critical Appraisal Skills Programme (CASP) tool for cohort studies.

	This was a small underpowered study with a small sample size that precluded between group comparisons. The group comprised US citizens and may not be generalisable to a larger population of people failing screening tests or to the general UK population.

Table 33. Laplante-Levesque et al (2015)[34]

Publication	Laplante-Levesque A, Brannstrom KJ, Ingo E, Andersson G, Lunner T. Stages of change in adults who have failed an online hearing screening. Ear & Hearing. 2015;36(1):92-101.
Study details	Cohort study
Study objectives	To describe the stages of change of adults who have failed an online hearing screening test
Inclusions	Participants who had completed online hearing screening in 2012/13 who had failed the speech in noise recognition test
Exclusions	People whose first language is not Swedish, people under the age of 18 and people who have previously been fitted with a hearing aid
Population	365 people were invited to be part of the study of which 224 completed all the questionnaires
Intervention	NA
Comparator	NA
Outcomes	People completed the University of Rhode Island Change Assessment (URICA) 42.4% participants were female, and the average age was 68. Scoring for the questions relating to each stage of the transtheoretical model were averaged (mean score). Scoring of the questions relating to each stage of the transtheoretical model were totalled for each individual and the number of people with the highest score at each stage were grouped (eg 21 people scored their highest scores for the precontemplation stage rather than any other stage).

Stage	**Mean score (±standard deviation)**	**No (%) people with highest score at this stage**
Precontemplation stage (I'm not sure I have a problem or that it's very important)	2.25+/- 0.72	21(9.4%)
Contemplation (I think it might be a good idea to do something about the problem)	3.90+/-0.97	85 (37.9%)
Preparation – (I could do with some advice and would like some help)	3.95+/-0.83	112 (50.0%)
Action – (I am doing something about it)	2.87+/-0.98	6 (2.7%)

Analysis using Pearsons correlation coefficient indicated no stage of change was significantly associated with the speech-in-noise-threshold (r=-0.12). People with self reported hearing disability scored significantly higher mean scores than those without self reported hearing disability for the contemplation stage (r=0.29; p<0.001) the preparation stage (r=0.20; p<0.001) and the action stage (r=0.25; p<0.001). Authors concluded that screening alone is unlikely to be enough to improve rates of help seeking.

Quality appraisal	The study was assessed using the Critical Appraisal Skills Programme (CASP) tool for cohort studies Only people who took up the offer of screening who then had a positive screening results were followed up. There was no follow up of those with a negative result to ask about their experience of screening, whether they would participate again and their views of help seeking. It is unclear whether the subset of people who took up the offer

	of screening, had a positive result and agreed to participate in the follow up study are likely to reflect the views of the general UK population.

Table 34. Thodi et al (2013)[38]

Publication	Thodi C, Parazzini M, Kramer SE, Davis A, Stenfelt S, Janssen T, et al. Adult hearing screening: follow-up and outcomes1. American Journal of Audiology. 2013;22(1):183-5
Study details	Cohort study
Study objectives	To screen hearing and evaluate outcomes in community-dwelling older adults
Inclusions	Older community dwelling adults in Cyprus
Exclusions	None described
Population	3025 adults aged 55 to 92 years
Intervention	Otoscopy, pure tone audiometry at 250Hz to 4000Hz with referral for hearing aid evaluation in people with hearing loss >35dB in the worse ear
Comparator	None
Outcomes	A total of 2025 adults aged 55 to 92 (mean age 78) were screened 46%(n=NR) of those screened were referred for audiological assessment for hearing aid use 17%(n=NR) of those screened were referred for cerumen removal or other medical evaluation An additional 12%(n=NR) of people had screening results within 5dB of the referral criteria Of people referred and followed up after 1 to 2 years 18%(n=NR) reported having tried a hearing aid, 11%(n=NR) reported using the hearing aid at the time of the interview. Among hearing aid users 22%(n=NR) were very satisfied with their device, 28%(n=NR) were satisfied and 11% (n=NR) were not satisfied. A further 39% (n=NR) did not respond. 82%(n=NR) said they discussed the results with their families. 95%(n=NR) of participants reported that the process was helpful. Age band and mean Pure Tone Average

Age group (years)	n	Pure tone average of both ears per person (mean value)
<60	161	<34dB
60-70	856	38dB
71-80	1491	45dB
>80	517	54dB

Quality appraisal	The study was assessed using the Critical Appraisal Skills Programme (CASP) tool for cohort studies The screening programme was undertaken in Cyprus and may not be generalisable to a UK setting. It is not clear how many people referred following a positive screening result sought help as despite 92% of participants referred saying they had receiving a hearing evaluation some respondents thought this referred to the screening process. The health outcomes reported were limited, for example the proportion of participants who already knew they had hearing problems was 80% but it is not clear if that was because of a previous hearing assessment or their perception. and applicability to the UK population is limited.

Studies relevant to criterion 15, key question 4: Is clinical detection and management currently well implemented in the UK?

Table 35. White et al (2019)[43]

Publication	White JD, Johnson C, Deplacido CG, Matthews B, Steenkamp EH. Inequality in access to hearing care for older adults in residential homes. Journal of Public Health. 2019;31:31.	
Study details	Survey of care homes	
Study objectives	Explore provision of hearing care in Scottish care homes for older people	
Inclusions	All care homes for older people with contact email addresses in Scotland	
Exclusions	N/A	
Population	659 (71%) care homes for older people in Scotland	
Intervention	Survey comprising 18 questions about geographical location, numbers of residents, provision of hearing assessments, hearing aid use, cerumen management, aids to communication and staff training.	
Comparator	N/A	
Outcomes	**Question**	**Response**
	1. Geographical location	Responses were received from care homes in all health boards.
	2.1 How many older adults are currently resident in your care home?	Total - 5351
	2.2 How many of your residents require nursing care?	Total - 3216
	2.3 Does the care plan used for your residents include a section on communication needs?	Yes - 100%
	3.1 Do residents routinely have their hearing tested when they first enter the home?	Yes - 12%
	3.1a If you answered Yes, who normally carries out the hearing test? Eg NHS Audiologist; Private Hearing Aid Dispenser; Nursing Home Staff; GP/Health Centre Nurse;	NHS audiologist - 47% GP and private - 53%
	3.2a If any of your existing residents was suspected of having hearing difficulties, how would you go about arranging for a hearing assessment? Eg Contact the resident's GP; Refer directly to your local NHS Audiology service; Refer to a Private Hearing Aid Dispenser; Arrange for care home staff to carry out a hearing assessment; Suggest that the resident or his/her family arranges a hearing assessment	GP contacted - 86% Direct referral to NHS audiology service – 9%
	3.2b Where would this hearing assessment normally take place? In your care home; The resident travels to another location (e.g. GP, NHS department, Private dispenser's premises);	Care home - 25% Other location - 75%

	4.1 How many of your residents have hearing aids?	22% (range 5% to 30%)
	4.2 Of those residents who have hearing aids, how many have hearing aids for both ears?	Not reported
	4.3 How many of your residents use their hearing aid(s) every day?	Yes - 79%
	4.4 How many of your residents require assistance with putting their hearing aid(s) in their ear(s)?	Yes - 80%
	4.5 How many of your residents require assistance with hearing aid maintenance (e.g. changing batteries, cleaning)?	Yes - 91%
	5.1 Does your care home have a formal procedure for managing problem ear wax in your residents?	Not reported
	5.2 How would you go about arranging for a resident to have problem ear wax removed? Eg Contact the resident's general practitioner; Refer directly to your local NHS Audiology service; Refer to a Private Hearing Aid Dispenser; Arrange for care home nursing staff to remove the wax; Suggest that the resident or his/her family arranges for wax removal;	Not reported
	6.1 Are any of the following available in the communal areas of the home? Eg A loop amplifier (Telecoil) system; a sound field system with speakers; TV listening headsets; an FM system; a flashing light alert system for fire alarms; a flashing light alert system to alert residents to e.g. doorbells, telephones; a vibrating alert system; a picture-based communication system; Internet and email facilities; Video telephones; Visual message boards;	Visual message board – 56% Picture based communication – 45% Internet and email – 40% Loop amplifier – 29%
	7.1 Have staff in the home received any formal training in the care and maintenance of hearing aids?	Yes - 40%
	7.2 Have staff in the home received any formal training in the use of communication aids?	Yes - 27%
	7.3 Have staff in the home received any formal training in strategies for communication with adults who are hearing impaired?	Yes - 50%
Quality appraisal	The study was assessed using the CASP tool for cohort studies. The survey could only be sent to 659 (71%) of the 931 Scotland's care homes due to lack of contact information. 154 care responded to the survey, equating to 23% of the total number of Scottish care homes. The results are based solely on the views of care home managers and do not capture the experiences of care home residents themselves. There was no comparison of measures between care homes who did and did not complete the survey so it's unclear if other systematic risks of bias are present (eg funding source, size of establishment, health board). The results from a care home setting may not be applicable to people in the general UK population.	

Appendix 4 – UK NSC reporting checklist for evidence summaries

All items on the UK NSC Reporting Checklist for Evidence Summaries have been addressed in this report. A summary of the checklist, along with the page or pages where each item can be found in this report, is presented in Table 32.

Table 36. UK NSC reporting checklist for evidence summaries

	Section	Item	Page no.
1.	TITLE AND SUMMARIES		
1.1	Title sheet	Identify the review as a UK NSC evidence summary.	Title page
1.2	Plain English summary	Plain English description of the executive summary.	5
1.3	Executive summary	Structured overview of the whole report. To include: the purpose/aim of the review; background; previous recommendations; findings and gaps in the evidence; recommendations on the screening that can or cannot be made on the basis of the review.	6
2.	INTRODUCTION AND APPROACH		
2.1	Background and objectives	Background – Current policy context and rationale for the current review – for example, reference to details of previous reviews, basis for current recommendation, recommendations made, gaps identified, drivers for new reviews Objectives – What are the questions the current evidence summary intends to answer? – statement of the key questions for the current evidence summary, criteria they address, and number of studies included per question, description of the overall results of the literature search. Method – briefly outline the rapid review methods used.	9
2.2	Eligibility for inclusion in the review	State all criteria for inclusion and exclusion of studies to the review clearly (PICO, dates, language, study type,	15

		publication type, publication status etc.) To be decided *a priori*.	
2.3	Appraisal for quality/risk of bias tool	Details of tool/checklist used to assess quality, e.g. QUADAS 2, CASP, SIGN, AMSTAR.	19
3.	SEARCH STRATEGY AND STUDY SELECTION (FOR EACH KEY QUESTION)		
3.1	Databases/ sources searched	Give details of all databases searched (including platform/interface and coverage dates) and date of final search.	43
3.2	Search strategy and results	Present the full search strategy for at least one database (usually a version of Medline), including limits and search filters if used. Provide details of the total number of (results from each database searched), number of duplicates removed, and the final number of unique records to consider for inclusion.	43
3.3	Study selection	State the process for selecting studies – inclusion and exclusion criteria, number of studies screened by title/abstract and full text, number of reviewers, any cross checking carried out.	53
4.	STUDY LEVEL REPORTING OF RESULTS (FOR EACH KEY QUESTION)		
4.1	Study level reporting, results and risk of bias assessment	For each study, produce a table that includes the full citation and a summary of the data relevant to the question (for example, study size, PICO, follow-up period, outcomes reported, statistical analyses etc.). Provide a simple summary of key measures, effect estimates and confidence intervals for each study where available. For each study, present the results of any assessment of quality/risk of bias.	Study level reporting: 61 Quality assessment is with each study table
5.	QUESTION LEVEL SYNTHESIS		
5.1	Description of the evidence	For each question, give numbers of studies screened, assessed for eligibility, and included in the review, with summary reasons for exclusion.	21, 29,36,38
5.2	Combining and presenting the findings	Provide a balanced discussion of the body of evidence which avoids over reliance on one study or set of studies. Consideration of four components should inform the reviewer's judgement on whether the criterion is 'met', 'not met' or 'uncertain': quantity; quality; applicability and consistency.	21, 30,36,39
5.3	Summary of findings	Provide a description of the evidence reviewed and included for each question,	27,33,37,40

		with reference to their eligibility for inclusion. Summarise the main findings including the quality/risk of bias issues for each question. Have the criteria addressed been 'met', 'not met' or 'uncertain'?	
6.	REVIEW SUMMARY		
6.1	Conclusions and implications for policy	Do findings indicate whether screening should be recommended? Is further work warranted? Are there gaps in the evidence highlighted by the review?	41
6.2	Limitations	Discuss limitations of the available evidence and of the review methodology if relevant.	42

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