Exeter PRP Evidence Review Facility

2/6/2023

What are the risk factors for hearing loss and how are they related to socio-economic inequalities? An annotated bibliography of systematic reviews

Final report

Simon Briscoe, Liz Shaw, Michael Nunns, Noreen Orr, Jo Thompson Coon, Ruth Garside, G.J. Melendez-Torres

Exeter PRP Evidence Review Facility, University of Exeter Medical School, St Luke's Campus, University of Exeter, Exeter, Devon, EX1 2LU, UK

Corresponding author:

G.J. Melendez-Torres (email: G.J.Melendez-Torres@exeter.ac.uk; 01392 725651; South Cloisters, University of Exeter, St Luke's Campus, Heavitree Road, Exeter, EX1 2LU, UK)

Conflicts of interests

None

Funding

This study is funded by the National Institute for Health and Care Research (NIHR) Policy Research Programme (NIHR200695 - Evidence review facility to support national policy development and evaluation). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care. Jo Thompson Coon is also supported by the NIHR Applied Research Collaboration South West Peninsula.

Data-sharing statement

Requests for access to data should be addressed to the corresponding author.

Funder involvement

This work is part of an ongoing programme of work funded by the NIHR Policy Research Programme. Stakeholders from The Office for Health Improvement and Disparities at the Department of Health and Social Care collaborated on the development of the research question(s) and protocol and development of the review.

Contributions

The opinions expressed in this publication are not necessarily those of the Exeter PRP Evidence Review Facility or the funders. Responsibility for the views expressed remains solely with the authors.

Guarantor of the review

Professor G.J. Melendez-Torres

Contents

List of Figures

List of Tables

Abbreviations

ABR	Auditory brainstem response
BMI	Body mass index
cCMV	Congenital cytomegalovirus
COPD	Chronic obstructive pulmonary disease
DHSC	Department of Health and Social Care
HR	Hazard ratio
ISSNHL	Idiopathic sudden sensorineural hearing loss
HRQoL	Health Related Quality of Life
LMIC	Low- and middle-income countries
NICE	National Institute for Health and Care Excellence
MeSH	Medical Subject Headings
MS	Multiple sclerosis
NIHL	Noise induced hearing loss
OR	Odds ratio
PICo	Population/problem, phenomenon of Interest, Context
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PRP	Policy Research Programme
PTA	Pure tone audiometry
RR	Risk ratio
SNHL	Sensorineural hearing loss
SSNHL	Sudden sensorineural hearing loss
SMD	Standardised mean difference
TB	Tuberculosis
UK	United Kingdom

UNHS	Universal newborn hearing screening
USA	United States of America

Summary of findings

In this report, we undertook an annotated bibliography of systematic reviews evaluating potential risk factors for hearing loss, and related these to socio-economic inequalities where these data were reported. Our annotated bibliography drew on a search of five bibliographic databases and a range of additional search methods (e.g. topically relevant websites) to identify systematic reviews of behavioural, demographic, environmental, genetic and physiological risk factors published in English as a full-text record since 2018. We focused on systematic reviews of studies undertaken in World Bank high-income countries.[1] After rigorous selection, we appraised each systematic review and categorised risk factors, including mapping these by socio-economic inequalities using the PROGRESS-Plus criteria.[2] In total, we identified 64 systematic reviews. We deprioritised eight scoping reviews as these did not synthesise studies, and six systematic reviews focusing on genetic risk factors as these are not readily modifiable.

We categorised the remaining systematic reviews into four categories of risk factor: behavioural, demographic, environmental and physiological. Systematic reviews could address more than one type of risk factor. We wrote a brief annotation for each of these systematic reviews to summarise their focus and main findings. We also summarised data relating to socio-economic inequalities.

Only two systematic reviews considered **behavioural risk factors** (smoking and mobile phone use),[3, 4] of which one addressed socio-economic inequalities.[3] Both reviews were considered medium quality.

Demographic risk factors were considered in six systematic reviews,[5-10] of which five considered socio-economic inequalities.[5, 7-10] Three of these reviews considered a broad spectrum of demographic risk factors;[7-9] one considered age and gender;[10] and two considered birth or early life influences.[5, 6] Three reviews were considered high quality,[5, 6, 8] two were considered medium quality,[7, 10] and one was considered low quality.[9]

Environmental risk factors were considered in seven systematic reviews,[11-17] of which three addressed socio-economic inequalities.[13, 15, 16] Environmental risk factors were broadly occupation-related in five reviews (noise or chemical exposure, including all three reviews addressing inequalities)[11, 13-16] or contaminant-related in two reviews.[12, 14] One review was considered high quality,[14] five reviews were considered medium quality,[11-13, 15, 17] and one review was considered low quality.[16]

Finally, we annotated 35 systematic reviews relating to **physiological risk factors**,[18-52] of which only four addressed socio-economic inequalities.[22, 23, 35, 42] Of these reviews, 16 focused on risk factors

relating to bacterial or viral infection (i.e. communicable disease),[18-23, 26, 35, 37-39, 41, 45, 48, 50, 52] 14 focused on risk factors relating to non-communicable disease,[25, 28-34, 36, 40, 42, 43, 46, 49] and four focused on biomarkers or physiologic parameters (e.g. inflammatory biomarkers, waist circumference).[24, 27, 44, 51] One review focused on source of breast milk.[47] Eight were considered high quality,[19, 20, 25, 32, 40, 42, 46, 47] 22 were considered medium quality,[18, 21, 23, 24, 26-31, 33-37, 39, 41, 43, 44, 50-52] and five were considered low quality.[22, 38, 45, 48, 49] A summary of PROGRESS-Plus criteria identified in the included systematic reviews is presented in Table 1.

Table 1. PROGRESS-Plus criteria identified in included systematic reviews

	PROGRESS-Plus criteria										
	Place of residence	Race/ ethnicity	Occupation	Gender/ Sex	Religion	Education	Socio-economic status	Social Capital	Personal characteristics (including age, disability)	Features of relationships	Time dependent relationships
Behavioural risk factors											
Li 2020[3]				■							
Demographic risk factors											
Butcher 2019[5]				■							
Lovett 2022[7]	■	■	■	■		■	■				
Nunes 2019[8]						■	■				
Raeisi 2022[9]									■		
Schmucker 2019[10]				■							
Environmental risk factors											
Nguyen 2018[13]			■								
Teplova 2022[15]			■								
Yadav 2021[16]			■								
Physiological risk factors											
Bentivi 2020[22]				■							
Beukes 2021[23]				■				■	■	■	
Liu 2021[35]				■							
Mohammadi 2020[42]				■					■		

Background

Hearing loss can result in a reduced quality of life[53] and may also be a risk factor for non-communicable disease, such as dementia.[54] In the UK, 12 million adults live with hearing loss greater than 25 dBHL, or one in five adults.[55] This includes more than 40 percent of people over 50 years old, rising to more than 70 percent of people over the age of 70.[55]

The negative effects of hearing loss are associated with socio-economic inequalities due to isolation and limited employment opportunities.[56, 57] In particular, there is concern that ethnic minority groups suffer more with the effects of hearing loss, as uptake for screening programmes[58] and hearing aids[57] is lower for these groups than in the majority population. Furthermore, socio-economic inequalities may be causally related to hearing loss through factors such increased likelihood of working in noisy environments and life-style choices such as smoking.[57] Improving the identification of groups at risk of hearing loss could lead to more effective screening programmes, and reduce the prevalence of hearing loss and associated harms to quality of life through wider and more effectively targeted implementation of interventions.[56, 59] Furthermore, this might be an effective way of alleviating harms which are caused partly by socio-economic inequalities.

Identifying and categorising groups at risk of hearing loss is challenging because there are large numbers of potential risk factors, including physiological, environmental, and behavioural lifestyle factors.[6, 8, 21, 22, 39, 51, 60-64] A recent review directly addresses the impact of socio-economic inequalities on hearing loss, but does not take account of the full spectrum of aforementioned potential risk factors for hearing loss.[57] This might mean that potential risk factors associated with hearing loss are not identified in research which sets out to focus primarily on links between socio-economic inequalities and hearing loss. To get a broader understanding of risk factors for hearing loss and how these are associated with socio-economic inequalities, we carried out a systematic search and annotated bibliography of systematic reviews which assess associations between risk factors and hearing loss, and related these to socio-economic inequalities where these data were reported. We focused on systematic reviews as our background searches identified that the number of primary studies would be prohibitively high to report in full, and we were aware that a growing body of systematic reviews on risk factors for hearing loss has been published in recent years.

Aim and objectives

Aim

To identify risk factors for hearing loss and how are they related to socio-economic inequalities.

Objectives

1. To create an annotated bibliography of systematic reviews which evaluate potential risk factors for hearing loss.
2. To describe how the identified risk factors within individual systematic reviews are related to socio-economic inequalities wherever relevant data are reported.

Methods in brief

We carried out a systematic search for systematic reviews on risk factors for hearing loss and presented the findings as an annotated bibliography. In addition to systematic reviews, we included mapping reviews, meta-analyses, mixed-methods reviews, rapid reviews, and scoping reviews in this report. However, throughout the Methods and Findings sections of the report we refer generically to 'systematic reviews' unless referring to a specific type of review.

The methods in full are reported in Appendix A. In addition, a protocol which sets out the methods we used was prospectively registered on Open Science Framework.[65] In this section we summarise the methods in brief.

Searches and screening process

We developed a search strategy using the Ovid MEDLINE bibliographic database which aimed to identify systematic reviews on risk factors for hearing loss (see Appendix B for MEDLINE search strategy). This was translated for use in several other bibliographic databases, and the results were exported to Endnote 20 (Clarivate, Philadelphia, USA). An historical date limit of five years from date of search was set in order to manage the high volume of results (i.e. 2018), and we also limited the results to English language publications. We used predefined inclusion and exclusion criteria to screen the titles and abstracts of identified studies (see Appendix A for full details), and sought full-texts of all titles and abstracts which met our inclusion criteria. We then screened the full-texts of potential relevant systematic reviews. We used the DARE criteria to assess whether a publication was suitably rigorous to quality as a systematic review.[66] We included meta-analyses, rapid reviews, and mixed-methods reviews if they met the DARE criteria for systematic reviews; and also mapping reviews and scoping reviews which were topically relevant, although we did not scrutinise the methods of mapping and scoping reviews using the DARE criteria. Screening was undertaken by two reviewers independently and disagreements resolved by discussion.

Data-extraction and quality appraisal

We extracted relevant data from all relevant systematic reviews using a pre-defined bespoke data extraction form in Microsoft Excel. Socio-economic inequalities were categorised using the PROGRESS-Plus criteria.[2] Quality appraisal was undertaken using a modified version of the CEESAT tool by two reviewers independently and disagreements resolved by discussion.[67]

Presentation of findings

Relevant systematic reviews were grouped by risk factor using pre-defined categories (specifically, physiological, behavioural, demographic, and environmental).[68] Within these categories reviews

were subdivided into the following sections: (1) systematic reviews that address socio-economic inequalities; (2) systematic reviews that do not address socio-economic inequalities; (3) mapping and scoping reviews. Within physiological risk factors only, we also included a fourth category (4) for risk factors relating to genetic factors. Systematic reviews were listed alphabetically by first author within each of these groups. Annotations were provided for each systematic review except for mapping and scoping reviews, and systematic reviews which evaluate genetic risk factors. Data from the systematic reviews was also presented in a tabulated format. A 'traffic light' system was devised for calculating an overall quality appraisal score per study, which also facilitated the presentation of quality appraisal scores. High quality reviews were scored green, medium quality reviews were scored amber, and low quality reviews were scored red.

Findings

Results of searches and screening process

The search and screening process is depicted in the PRISMA diagram in Figure 1 (see Appendix C). In summary, the bibliographic database searches retrieved 2400 records with the original historical date limit of 2012 (see protocol).[65] Following the removal of duplicates, there remained 1435 unique records. We then applied the revised five-year date limit from date of searches, which reduced the number of records to 874. During title and abstract screening, 656 of 874 records were excluded due to not meeting the inclusion criteria. We then sought and successfully retrieved full-texts for all 218 records which were deemed to meet the inclusion criteria at title and abstract screening. During full-text screening, 155 full-texts were excluded due to not meeting the inclusion criteria. (A summary of reasons for exclusion are detailed in the PRISMA diagram in Appendix C). Thus, we identified 63 full-texts which met the inclusion criteria via bibliographic database searches. We also uniquely identified one full-text which met our inclusion criteria via checking the reference lists of eligible full-texts. In total, 64 systematic reviews were included in the report.

Characteristics of included systematic reviews

The annotated bibliography includes systematic reviews (n=19), meta-analyses (n=8), systematic reviews and meta-analyses (n=28), one rapid review and scoping reviews (n=8). No mapping reviews were identified. Of these, 46 articles review *physiological risk factors* for hearing loss, including four which address socio-economic inequalities, 31 which do not address socio-economic inequalities, and 11 which were not investigated for detail on socio-economic inequalities as these were scoping reviews (n=5), or reviews which focus on genetic risk factors (n=6). Two articles review *behavioural risk factors*, including one which addresses socio-economic inequalities. Eight articles review *demographic risk factors*, including five which address socio-economic inequalities, one which does not address socio-economic inequalities, and two which were scoping reviews. Finally, there were eight articles which review *environmental risk factors*, including three which address socio-economic inequalities, four which do not address socio-economic inequalities, and one which is a scoping review.

Additional detail on the characteristics of included systematic reviews for which annotations are provided is presented in Table 2. (Table 2 does not include scoping reviews or systematic reviews of genetic risk factors for hearing loss, which are listed without annotations within the annotated bibliography). Table 2 includes an overall quality appraisal rating for each systematic review. Quality appraisal scores for each item in the modified CEESAT checklist are presented in Table 5 (see Appendix D).

Table 2. Characteristics of included systematic reviews

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Physiological risk factors									
Alene 2021[18]	SR and MA	Tuberculosis (TB)	All age groups with any type of TB	Permanent forms of disability detected or reported after TB diagnosis	Hearing loss (unspecified)	131 (27)	Observational; evaluation	NR	🟡
Almufarrij 2021[19]	SR and MA	SARS-CoV-2; COVID-19	All age groups with audio-vestibular symptoms (or experiencing exacerbation of pre-existing symptoms) following contraction of SARS-CoV-2	Audio-vestibular symptoms	Hearing loss (unspecified); tinnitus	56 (18)	Observational	NR	🟢
Almufarrij 2020[20]	Rapid SR	Coronavirus	Patients who were diagnosed with coronavirus (i.e. SARS-CoV-2, Middle East respiratory syndrome or severe acute respiratory syndrome)	Audio-vestibular symptoms	Hearing loss including biaural SNHL, unilateral mild-to-moderate conductive hearing loss due to acute otitis media, and unspecified hearing loss; tinnitus	7 (6)	Observational	NR	🟢
Bayat 2019[21]	SR and MA	COPD	Adult COPD patients	Auditory brainstem response (ABR) wave latency; PTA thresholds; P300 latency	Hearing loss (unspecified)	16 (16)	Observational	NR	🟡

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Bentivi 2020[22]	MA	HIV/AIDS	Children with HIV/AIDS (age range NR)	(1) Risk of hearing loss in patients with HIV; (2) the association between hearing loss and HIV status; and (3) the otoscopy performed before audiological examinations	Hearing loss (unspecified)	26 (26)	Observational	Gender	🔴
Beukes 2021[23]	SR	COVID-19	Individuals of any age experiencing tinnitus during COVID-19 pandemic	Hearing loss	Tinnitus, conductive hearing loss, SSNHL, hearing loss (unspecified)	33 (33)	Observational	Gender, personal characteristics (age), social capital, features of relationships	🟡
Chen 2018[24]	SR and MA	Neutrophil-to-lymphocyte ratio (NLR)	NLR patients and healthy controls	Hearing loss	Idiopathic SSHL	19 (19)	Observational	NR	🟡
Elizinga 2021[25]	SR	Otitis media (OM)	All ages with OM and healthy controls	Hearing loss	SNHL	9 (9)	Observational	NR	🟢
Fletcher 2018[26]	SR	cCMV	Children with SNHL secondary to cCMV	Hearing loss, rehabilitative outcomes	SNHL	36 (36)	Observational	NR	🟡
Frosolini 2022[27]	SR and MA	Inflammatory biomarkers	All age groups with SSNHL	Hearing loss	SSNHL	13 (13)	Observational	NR	🟡
Garcia 2022[28]	SR and MA	Osteoporosis	Mean age under 65 with osteoporosis	Hearing loss; benign paroxysmal positional vertigo	Hearing loss (unspecified)	26 (6)	Observational; evaluation	NR	🟡

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Gotardo 2019[29]	SR and MA	Periventricular leukomalacia (PVL) and peri-intraventricular haemorrhage (PIVH)	PVL or PIVH patients born under 37 weeks GA	Incidence of cerebral palsy, sensorineural impairment and development scores	Hearing loss (unspecified)	24 (15)*	Observational	NR	🟡
Jeong 2022[30]	SR and MA	Psoriasis	Patients with psoriasis	Hearing loss; vestibular dysfunction	Hearing loss (unspecified), SNHL	13 (13)	Observational	NR	🟡
Kapoor 2021[31]	SR and MA	Sickle cell disease	Adults with sickle cell disease	Hearing loss	SNHL	12 (12)	Observational	NR	🟡
Kasemsuk 2022[32]	SR and MA	Obstructive Sleep Apnoea	Adult populations	Hearing loss	SNHL	20 (20)	Observational	NR	🟢
Le 2018[33]	SR and MA	Coronary heart disease	Adults with coronary heart disease	Hearing loss	Hearing loss (unspecified)	10 (NR)	Observational	NR	🟡
Lien 2022[34]	SR and MA	Vitiligo	People with vitiligo	Hearing loss	High-frequency SNHL	9 (9)	Observational	NR	🟡
Liu 2021[35]	MA	cCMV infection	Children with and without cCMV infection	Hearing loss	Hearing loss (unspecified), SNHL	18 (18)	Observational	Gender	🟡
Ma 2020[36]	SR and MA	Vitiligo	Participants with vitiligo and controls without vitiligo	Hearing loss	SNHL	14 (14)	Observational	NR	🟡
Maharaj 2020[37]	SR	SARS-CoV-2 (COVID-19)	Human participants	Hearing loss	Hearing loss (unspecified)	7 (7)	Observational	NR	🟡

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Maltezou 2020[38]	SR and MA	cCMV	Infants and children infected with cCMV born to mothers following primary infection (PI) and non-primary infection, with neonatal symptoms associated with cCMV	Hearing loss, specific neurologic outcomes such as psychomotor retardation and neurodevelopmental impairment	SNHL	9 (9)	Observational	NR	🔴
Meng 2022[39]	SR	SARS-CoV-2 (COVID-19)	Patients with COVID-19	Hearing loss	SSNHL	26 (26)	Observational	NR	🟡
Mirmosayyeb 2022[40]	SR and MA	Multiple Sclerosis	People with MS and hearing loss	Hearing loss	SNHL	8 (8)	Observational	NR	🟢
Mirsa 2021[41]	SR	SARS-CoV-2 (COVID-19)	Patients with COVID-19	Frequency of, and age-specific variations in neurologic manifestations reported in patients with CoVid 19	Hearing impairment	350 (6)	NR	NR	🟡
Mohammadi 2020[42]	SR and MA	Migraine	Migraineurs and non-migraineurs	Hearing loss	SSNHL	3 (3)*	Observational	Gender, personal characteristics (age)	🟢
Mohammed 2019[43]	SR and MA	Iron deficiency anaemia (IDA)	Adults and children with and without IDA	Hearing loss	SNHL	4 (4)*	Observational	NR	🟡
Ni 2021[44]	MA	Haematological parameters	Healthy individuals and patients diagnosed with SSNHL	Hearing loss	SSNHL	18 (18)	Observational	NR	🟡

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Olbrich 2018[45]	SR	Invasive meningococcal disease (IMD, septicaemia and/or meningitis)	Survivors of IMD (independent from presentation)	Invasive meningococcal disease (IMD, septicaemia and/or meningitis) long-term sequelae and quality of life	Hearing loss or impairment (unspecified), SNHL	32 (32)*	Observational	NR	🔴
Paraschou 2021[46]	SR and MA	Systemic lupus erythematosus (SLE)	Patients with SLE	Hearing loss	SNHL, conductive hearing loss, mixed hearing loss	9 (9)	NR	NR	🟢
Quigley 2019[47]	SR	Formula vs donor breast milk	Preterm (< 37 weeks' gestation at birth) or low birth weight (< 2500 g) infants	Growth, neurodevelopmental disability, mortality, necrotising enterocolitis, days post-birth to establish enteral feeding, feeding intolerance, incidence of invasive infection	Auditory impairment (Not specified)	12 (1)*	Evaluations	NR	🟢
Riga 2018[48]	SR	cCMV infection	Neonates with cCMV diagnosed with progressive, fluctuating and late-onset hearing loss	Prevalence and time of diagnosis of progressive, fluctuating and late-onset hearing loss. Degree and laterality of SNHL	Non-congenital SNHL during childhood	11 (11)*	Observational	NR	🔴
Strum 2021[49]	MA	Sickle cell disease	Children with sickle cell disease all over the world	Hearing loss	SNHL	17 (17)	Observational	NR	🔴

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Sturrock 2022[50]	SR	SARS-CoV-2 infection in pregnancy	Babies of pregnant women with a diagnosis of SARS-CoV-2 during pregnancy	Neonatal mortality and morbidity, including preterm birth, Caesarean delivery, small for gestational age, admission to neonatal intensive care unit, level of respiratory support required, diagnosis of culture-positive sepsis, evidence of brain injury, necrotising enterocolitis, visual or hearing impairment, neurodevelopmental outcomes, and feeding method	Hearing loss (unspecified)	204 (4)	Observational	NR	🟡
Yang 2020[51]	SR and MA	BMI, waist circumference	Adults	Hearing loss (PTA >25 dB)	Hearing loss (unspecified)	14 (14)	Observational	NR	🟡
Zhang 2021[52]	MA	cCMV	Neonates infected with congenital CMV, and healthy or noninfected new-borns as the control group.	Hearing loss, microcephaly, neurodevelopmental delay, mental development index and psycho-motive development index	Hearing impairment (unspecified), SNHL	13 (9)	Observational	NR	🟡
Behavioural risk factors									

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Li 2020[3]	MA	Smoking	People with history of occupational noise exposure	Hearing loss	Noise induced hearing loss (NIHL)	27 (27)	Observational	Gender	🟡
Taziki Balajelini 2021[4]	SR and MA	Mobile phone use	Community and/or appropriate samples of mobile phone users	Hearing loss	Hearing loss (unspecified), hearing problems (unspecified), tinnitus, vestibular nerve schwannoma	5 (5)	Observational	NR	🟡
Demographic risk factors									
Butcher 2019[5]	SR and MA	Factors associated with admission to neonatal intensive care unit	Children aged under 1 year at start of study	Hearing loss	Permanent childhood hearing loss	41 (41)*	Observational, evaluations	Gender	🟢
Dawes 2022[6]	SR and MA	Early life influences including birth weight and adult height	Adults (≥18 years)	Adult-onset hearing loss	Hearing loss (unspecified)	8 (8)	Observational	NR	🟢

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Lovett 2022[7]	SR	Place of residence, race/ethnicity, gender, occupation, education, socio-economic status	Populations based in the USA; included adults and children with an otologic condition	Hearing loss (unspecified), cochlear implantation, hearing aids, vertigo/dizziness, (unspecified), Meniere's disease, cholesteatoma, infection/effusion, neoplasm, and tinnitus. Surgical outcomes - surgery for otitis media, cholesteatoma resection and vestibular schwannoma	Hearing loss (unspecified)	52 (19)*	Observational	Place of residence, race/ ethnicity, gender, occupation, education, socio-economic status	
Nunes 2019[8]	SR	Multiple social, demographic, physiological and environmental factors	School age and preschool age children	Prevalence of hearing impairment	Hearing impairment (not pre-defined), SNHL, noise induced hearing loss, age-related hearing loss	26 (26)	Observational	Education, socio-economic status	
Raeisi 2022[9]	SR	Multiple social, demographic, physiological and environmental factors	Newborns	Hearing loss	Hearing loss (unspecified)	17 (17)	Observational	Personal characteristics (disability)	
Schmucker 2019[10]	SR	Age, gender	Children and adolescents (up to 19 years of age) living in Germany	Hearing loss	Any unilateral and bilateral hearing loss or permanent hearing loss	11 (11)*	Observational	Gender	

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Environmental risk factors									
Cao 2019[11]	SR and MA	Occupational and leisure noise exposure	No age, language or ethnicity restrictions	Hearing loss	Acoustic neuroma	8 (8)	Observational	NR	🟡
Dineva 2022[12]	SR	Iodine exposure	Pregnant women and children (<18 years)	Hearing loss	Hearing loss, hearing acuity, binaural processing skills, binaural memory, auditory memory, infant hearing	13 (13)	Observational, evaluation	NR	🟡
Nguyen 2018[13]	SR	Agricultural work including chemical exposure, noise and hand-arm vibration	Agricultural workers	Cancer, DNA and cytogenic damage, respiratory diseases, musculoskeletal disorders, hearing loss	Hearing loss (unspecified)	15 (1)	Observational	Occupation	🟡
Puty 2019[14]	SR	Methylmercury environmental exposure	Humans <13 years old, with methylmercury dosage at least in one type of tissue (hair and/or blood) and at least one neurological assay	Growth, neurodevelopmental disability, mortality, necrotising enterocolitis, days post-birth to establish enteral feeding, feeding intolerance, incidence of invasive infection	Hearing loss (unspecified)	6 (2)	Evaluations	NR	🟢

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Teplova 2022[15]	SR	Deployment and combat exposure	Military personnel	Dizziness, diabetes, fatigue, diarrhoea, IBS, headache, joint trauma, fractures, low back pain, muscle injuries, arthritis, back problems, joint disorders, connective tissue disorders, multiple sclerosis, seizures, stroke, pain, respiratory system including asthma, chronic lung diseases, bronchitis, sinusitis, acute respiratory illness (cough or cold), tinnitus, hearing loss, bladder infections	Hearing loss, tinnitus	32 (3)*	Observational	Occupation	🟡
Yadav 2021[16]	SR	Occupational noise exposure	Fish harvesters aged 16 years or older with occupational exposure to noise	Hearing loss, sleep, dizziness, fatigue, depression, anxiety, insomnia, agitation during sleep, sleep disturbances, noise exposure as a stressor, CVD, gastric, physical/ psychological disorders	NIHL, tinnitus, SNHL, hearing loss (unspecified)	17 (16)	Observational, evaluation	Occupation	🔴

Study	Type of review	Risk factor	Population	All outcome domains	Type(s) of hearing loss	Included studies, n (n specific to hearing loss)	Included study designs	PROGRESS-Plus criteria	QA rating
Yin 2021[17]	SR and MA	Lead (specifically, lead levels in body)	Human	Hearing loss	Hearing loss PTA>25dB	8 (8)	Observational	NR	

Abbreviations: ABR=Auditory brainstem response; BMI=Body mass index; cCMV=Congenital cytomegalovirus; COPD=Chronic obstructive pulmonary disease; CVD=Cardiovascular disease; IBS=Irritable Bowel Syndrome; IDA= Iron deficiency anaemia; ISSNHL=Idiopathic sudden sensorineural hearing loss; MA=Meta-analysis; MS=Multiple Sclerosis; N=Number; NIHL=Noise induced hearing loss; NR=Not Reported; PVL=Periventricular leukomalacia; PIVH=Peri-intraventricular haemorrhage; PTA=Pure tone audiometry; QA=Quality Appraisal; SARS-CoV-2=Severe acute respiratory syndrome coronavirus 2; SNHL=Sensorineural hearing loss; SSNHL=Sudden sensorineural hearing loss; SR=Systematic review; SR and MA=Systematic review and meta-analysis; TB=Tuberculosis; USA=United States;
*=All included studies carried out in high income countries

Annotated bibliography

This section summarises the identified systematic reviews which evaluate potential risk factors for hearing loss.

1. Physiological risk factors

1.1. Systematic reviews that address socio-economic inequalities (n=4)

Bentivi JO, Azevedo C, Lopes MKD, Rocha SCM, Silva P, Costa VM, et al. Audiological assessment of children with HIV/AIDS: a meta-analysis. J Pediatr (Rio J). 2020;96(5):537-45.

This meta-analysis aimed to assess the findings of studies on the audiological evaluation of children with HIV/AIDS. HIV/AIDS was shown to be a risk factor for hearing loss (OR = 5.364; p = 0.00). There was no difference regarding the type of hearing loss (p = 0.119). *PROGRESS-Plus (Gender):* The review found no evidence that the gender of children with HIV/AIDS was a statistically significant influence on hearing loss. ●

Beukes E, Ulep AJ, Eubank T, Manchaiah V. The Impact of COVID-19 and the Pandemic on Tinnitus: A Systematic Review. J Clin Med. 2021;10(13):2763.

This systematic review aimed to assess the relationship between COVID-19 and tinnitus. The review found that studies infrequently reported when tinnitus started following the contraction of COVID-19. No consistent patterns were found regarding the presentation of tinnitus amongst COVID-19 patients. *PROGRESS-Plus (Gender)*: Tinnitus was found to be significantly worse during the pandemic for females. *PROGRESS-Plus (Personal characteristics):* Tinnitus was found to be significantly worse for adults under the age of 50. *PROGRESS-Plus (Social capital; features of relationships):* Additional factors significantly exacerbating tinnitus included self-isolating and experiencing loneliness. ●

Liu PH, Hao JD, Li WY, Tian J, Zhao J, Zeng YM, et al. Congenital cytomegalovirus infection and the risk of hearing loss in childhood: A PRISMA-compliant meta-analysis. Medicine (Baltimore). 2021;100(36):e27057.

This meta-analysis aimed to assess the association of congenital cytomegalovirus (cCMV) infection with the risk of hearing loss in childhood. The results indicated that cCMV infection was associated with an increased risk of hearing loss irrespective of whether studies reported SNHL (OR: 5.42; 95% CI: 1.98–14.88; P=.001) or did not evaluate hearing loss types among their patients (OR: 11.04; 95% CI: 3.91–31.16; P<.001). *PROGRESS-Plus (Gender):* Populations with <60% males reported greater risk of hearing loss than those with >60% males. ●

Mohammadi M, Taziki Balajelini MH, Rajabi A. Migraine and risk of sudden sensorineural hearing loss: A systematic review and meta-analysis. Laryngoscope Investig Otolaryngol. 2020;5(6):1089-95.

This systematic review and meta-analysis aimed to assess the association of migraine and sudden sensorineural hearing loss (SSNHL). Of participants in the includes studies, 0.88% of those with migraine had SSNHL, and among those without migraine, 0.59% had SSNHL. The pooled hazard ratio (HR) for the risk of SSNHL was 1.84 (95% CI: 1.11-2.57; P<.001). All studies included in this review were carried out in high income countries. *PROGRESS-Plus (Gender):* In female cohort studies, migraine was not a significant risk of SSNHL compared to participants without migraine (HR = 1.52; 95% CI: 0.93-2.11, P=.054). In male cohort studies, migraine had a higher risk of SSNHL than no migraine (HR = 1.50; 95% CI: 1.17-1.83; P<.001). *PROGRESS-Plus (Personal characteristics):* Comparison of the pooled hazard ratio for the association of migraine with the risk of SSNHL amongst people under 40 old (1.37 [95% CI: 1.16-1.58; P<.001]) was similar to people older than 40 (1.39 [95% CI: 1.17-1.60; P<.001]). ●

1.2. Systematic reviews that do not address socio-economic inequalities (n=31)

Alene KA, Wangdi K, Colquhoun S, Chani K, Islam T, Rahevar K, et al. Tuberculosis related disability: a systematic review and meta-analysis. BMC Med. 2021;19(1):203.

This systematic review and meta-analysis aimed to assess the global prevalence of tuberculosis and types of tuberculosis related disabilities. They found that hearing loss amongst tuberculosis survivors is common, particularly amongst those with drug resistant tuberculosis or taking second-line tuberculosis medications. Only one study included in this review was carried out in a high-income country. ●

Almufarrij I, Munro KJ. One year on: an updated systematic review of SARS-CoV-2, COVID-19 and audio-vestibular symptoms. Int J Audiol. 2021;60(12):935-45.

This systematic review and meta-analysis aimed to assess the association between SARS-CoV-2, COVID-19 and audio-vestibular symptoms. They found multiple reports of hearing loss and tinnitus in adults with COVID-19. In the meta-analysis, the pooled estimate for the prevalence of hearing loss 7.6% (95% CI 2.5-15.1%) and the pooled estimate for the prevalence of tinnitus was 14.8% (95% CI 6.3-26.1%). ●

Almufarrij I, Uus K, Munro KJ. Does coronavirus affect the audio-vestibular system? A rapid systematic review. Int J Audiol. 2020;59(7):487-91.

This rapid systematic review aimed to assess the presence and incidence of audio-vestibular symptoms as a result of coronavirus. They found no records of audio-vestibular symptoms reported

with early types of coronavirus (including Middle East respiratory syndrome and SARS), and very few reports of hearing loss or tinnitus in individuals with SARS-CoV-2. ●

Bayat A, Saki N, Nikakhlagh S, Mirmomeni G, Raji H, Soleimani H, et al. Is COPD associated with alterations in hearing? A systematic review and meta-analysis. Int J Chron Obstruct Pulmon Dis. 2019;14:149-62.

This systematic review and meta-analysis aimed to assess the association of chronic obstructive pulmonary disease (COPD) with alteration in the auditory system function. Auditory brainstem response (ABR) wavelength was significantly longer in patients with COPD than in controls (SMD=0.27, 95% CI: 0.05–0.48, P=0.02). Pure tone audiometry (PTA) was significantly higher in patients with COPD when compared with controls (SMD=1.76, 95% CI: 0.43–3.08, P=0.0004). ●

Chen L, Zhang G, Zhang Z, Wang Y, Hu L, Wu J. Neutrophil-to-lymphocyte ratio predicts diagnosis and prognosis of idiopathic sudden sensorineural hearing loss: A systematic review and meta-analysis. Medicine (Baltimore). 2018;97(38):e12492.

This systematic review and meta-analysis aimed to assess the predictive value of neutrophil-to-lymphocyte ratio for the diagnosis and prognosis of patients with Idiopathic SSHNL. The meta-analysis of the relationship between neutrophil-to-lymphocyte ratio and onset of idiopathic SSNHL included 1029 idiopathic SSNHL patients (the case group) and 1020 healthy people (the control group). The neutrophil-to-lymphocyte ratio levels in the case group were observed to be higher than the control group (SMD=1.65, 95% CI=1.20–2.09, P<.001). ●

Elzinga HBE, van Oorschot HD, Stegeman I, Smit AL. Relation between otitis media and sensorineural hearing loss: a systematic review. BMJ Open. 2021;11(8):e050108.

This systematic review aimed to assess the correlation between recurrent acute otitis media, or chronic suppurative otitis media, and SNHL. Due to heterogeneity and high risk of bias of included studies, no conclusion on the correlation between otitis media and SNHL could be made. ●

Fletcher KT, Horrell EMW, Ayugi J, Irungu C, Muthoka M, Creel LM, et al. The Natural History and Rehabilitative Outcomes of Hearing Loss in Congenital Cytomegalovirus: A Systematic Review. Otol Neurotol. 2018;39(7):854-64.

This systematic review aimed to assess the natural history and rehabilitative outcomes of SNHL from cCMV infections. SNHL ranged from 8–32% of infants and was more prevalent in symptomatic than asymptomatic cases. In 9 – 68% of cases hearing loss was delayed, and in 7–71% of cases hearing loss was progressive. ●

Frosolini A, Franz L, Daloiso A, Lovato A, de Filippis C, Marioni G. Digging into the Role of Inflammatory Biomarkers in Sudden Sensorineural Hearing Loss Diagnosis and Prognosis: A Systematic Review and Meta-Analysis. Medicina (Kaunas). 2022;58(7).

This systematic review and meta-analysis aimed to assess the role of circulating inflammatory biomarkers in SSNHL. The majority of studies reported significant differences in biomarker values in SSNHL patients, of which Tumor Necrosis Factor alpha (TNF-a) and C-reactive Protein (CRP) were frequently reported. However, due to heterogeneity and low quality of evidence the findings should be treated with caution. ●

Garcia A, Rivera S, Alvear-Veas B, Goss D, Castillo-Bustamante M, Garcia JM. Association Between Early-Onset Osteoporosis With Hearing Loss and Benign Paroxysmal Positional Vertigo (BPPV): A Systematic Review and Meta-Analysis. Ann Otol Rhinol Laryngol. 2022:34894221118424.

This systematic review and meta-analysis aimed to assess the association between osteoporosis and audio-vestibular symptoms in individuals under 65 years of age. They found that persons with osteoporosis in this age group had an increased risk for developing hearing loss (OR = 1.52, 95% CI 1.06-2.19; P = .02) compared to controls. ●

Gotardo JW, Volkmer NFV, Stangler GP, Dornelles AD, Bohrer BBA, Carvalho CG. Impact of peri-intraventricular haemorrhage and periventricular leukomalacia in the neurodevelopment of preterms: A systematic review and meta-analysis. PLoS One. 2019;14(10):e0223427.

This systematic review and meta-analysis aimed to assess the impact of periventricular leukomalacia and peri-intraventricular haemorrhage in the incidence of cerebral palsy, sensorineural impairment and development scores in preterm neonates. They found no evidence of increased risk of hearing loss amongst patients with peri-intraventricular haemorrhage compared with healthy controls (RR 1.20 [0.53–2.69], I2 = 0 [95% CI 0–69%], p = 0.61). When comparing children with cystic periventricular leukomalacia and children with no periventricular leukomalacia, they found an increased risk of hearing impairment (RR 8.15 [1.45–43.82], I2 = 0, p <0.001). There was not enough data to calculate the impact of non-cystic PVL in hearing impairment among preterm infants. All studies included in this review were carried out in high income countries. ●

Jeong SS, Shih MC, Rizk HG, Lambert PR. Otologic Manifestations of Psoriasis: A Systematic Review and Meta-Analysis. Otol Neurotol. 2022;43(7):742-52.

This systematic review and meta-analysis aimed to assess the association between psoriasis, vestibular dysfunction and hearing loss. People with psoriasis had consistently worse outcomes on hearing thresholds across all frequencies, with the greatest difference at 4000 Hz (MD, 7.70 [4.46–10.94]; p < 0.00001), with similar results for speech reception and vestibular function tests. Two

additional studies of 41,681 psoriasis patients and 80,273 healthy controls found that psoriasis patients were at higher risk for SSNHL (OR, 1.50 [1.25–1.80]; p < 0.0001). At 8 Khz frequency, patients with psoriasis had mild hearing loss compared with healthy controls. ●

Kapoor E, Strum D, Shim T, Kim S, Sabetrasekh P, Monfared A. Characterization of Sensorineural Hearing Loss in Adult Patients With Sickle Cell Disease: A Systematic Review and Meta-analysis. Otol Neurotol. 2021;42(1):30-7.

This systematic review and meta-analysis aimed to assess the prevalence of SNHL attributable to sickle cell disease in the global adult population, and to identify factors contributing to its severity. There was a statistically significant increase in the prevalence of SNHL in adults with sickle cell disease compared with the general population with a cumulative risk ratio (RR) of 6.03. ●

Kasemsuk N, Chayopasakul V, Banhiran W, Prakairungthong S, Rungmanee S, Suvarnsit K, et al. Obstructive Sleep Apnea and Sensorineural Hearing Loss: A Systematic Review and Meta-analysis. Otolaryngol Head Neck Surg. 2022:1945998221120777.

This systematic review and meta-analysis aimed to assess the association between obstructive sleep apnoea and SNHL, and the effects of continuous positive airway pressure therapy on SNHL. The obstructive sleep apnoea group had a significantly worse mean hearing threshold level than the control group for midfrequency ranges (500, 1000, 2000 Hz; mean difference, 4.00 dB; 95% CI, 2.40-5.61) and high-frequency ranges (4000, 8000 Hz; mean difference, 6.24 dB; 95% CI, 2.99-9.49). When compared with controls, patients with obstructive sleep apnoea had an odds ratio of 1.52 (95% CI, 1.12-2.06) for midfrequency hearing impairment and 1.19 (95% CI, 1.05- 1.34) for high-frequency hearing impairment. No significant improvements in mid-frequency hearing threshold levels were found after continuous positive airway pressure therapy. ●

Le J, Dorstyn DS, Mpofu E, Prior E, Tully PJ. Health-related quality of life in coronary heart disease: a systematic review and meta-analysis mapped against the International Classification of Functioning, Disability and Health. Qual Life Res. 2018;27(10):2491-503.

This systematic review and meta-analysis aimed to assess health-related quality of life (HRQoL) indicators amongst adults living with coronary heart disease (CHD) in comparison to healthy peers. Adults with CHD reported lowered HRQoL, including increased incidence of hearing loss. ●

Lien KH, Ger TY, Chi CC. Association of vitiligo with high-frequency sensorineural hearing loss: a systematic review and meta-analysis. J Eur Acad Dermatol Venereol. 2022;36(3):373-9.

This systematic review and meta-analysis aimed to assess the association of vitiligo with high-frequency SNHL. The meta-analysis showed that, when compared with controls, vitiligo patients had

significantly higher pure-tone hearing thresholds at 2000, 4000, and 8000 Hz. Only one study was carried out in a high-income country. 🟡

Ma SH, Ang MD, Chang YT, Dai YX. Association between vitiligo and hearing loss. J Am Acad Dermatol. 2021;85(6):1465-72.

This systematic review and meta-analysis aimed to assess the association of vitiligo with SNHL. The findings showed that patients with vitiligo had significantly increased odds of SNHL. 🟡

Maharaj S, Bello Alvarez M, Mungul S, Hari K. Otologic dysfunction in patients with COVID-19: A systematic review. Laryngoscope Investig Otolaryngol. 2020;5(6):1192-6.

This systematic review aimed assess the otologic dysfunction in patients with COVID-19. They concluded that COVID-19 was a potential source of otologic disorders. Only one included study was carried out in a high-income country. 🟡

Maltezou PG, Kourlaba G, Kourkouni E, Luck S, Blazquez-Gamero D, Ville Y, et al. Maternal type of CMV infection and sequelae in infants with congenital CMV: Systematic review and meta-analysis. J Clin Virol. 2020;129:104518.

This systematic review and meta-analysis aimed to assess the long-term sequelae of cCMV infected children born following maternal primary infection or non-primary infection. SNHL was examined. The review found that there was no association with hearing loss. 🔴

Meng X, Wang J, Sun J, Zhu K. COVID-19 and Sudden Sensorineural Hearing Loss: A Systematic Review. Front Neurol. 2022;13:883749.

This systematic review aimed to assess the impact of COVID-19 on the incidence of sudden sensorineural hearing loss (SSNHL), and describe the clinical characteristics of COVID-19-related SSNHL. COVID-19- related SSNHL was found to be more common in adults, and symptoms typically manifested following the diagnosis of COVID-19 or during the rehabilitation period. The time from confirmation of COVID-19 to the onset of SSNHL ranged from a few days to 2 months.

Mirmosayyeb O, Naderi M, Raeisi S, Ebrahimi N, Ghaffary EM, Afshari-Safavi A, et al. Hearing loss among patients with multiple sclerosis (PwMS): A systematic review and meta-analysis. Mult Scler Relat Disord. 2022;62:103754.

This systematic review and meta-analysis aimed to assess the prevalence of hearing loss in people living with multiple sclerosis (MS). The pooled prevalence of hearing loss in MS patients was 1.1% (95% CI: [0.2%, 2.4%]; I2=80.11%; p<0.001). The findings suggest that MS might increase the risk of hearing loss. 🟢

Misra S, Kolappa K, Prasad M, Radhakrishnan D, Thakur KT, Solomon T, et al. Frequency of Neurologic Manifestations in COVID-19: A Systematic Review and Meta-analysis. Neurology. 2021;97(23):e2269-e81.

This systematic review and meta-analysis aimed to assess the frequency of neurologic manifestations reported in patients with COVID-19, and to investigate the association of these manifestations with disease severity and mortality. Hearing impairment was one of the neurologic manifestations measured in the review: the pooled prevalence of hearing impairment was 3% (95% CI 1%-5%, 6 studies). ●

Mohammed SH, Shab-Bidar S, Abuzerr S, Habtewold TD, Alizadeh S, Djafarian K. Association of anemia with sensorineural hearing loss: a systematic review and meta-analysis. BMC Res Notes. 2019;12(1):283.

This systematic review and meta-analysis aimed to assess the association of iron deficiency anaemia with SNHL. The odds of SNHL were higher by 55% in individuals with iron deficiency anaemia, compared with individuals without iron deficiency anaemia (OR = 1.55, 95% CI 1.17–2.06; P = 0.03). The age specific ORs were 1.36 (95% CI 1.15–1.61; P = 0.27) and 3.67 (95% CI 1.72–7.84) for adults and children, respectively. All studies included in this review were carried out in high income countries. ●

Ni W, Song SP, Jiang YD. Association between routine hematological parameters and sudden sensorineural hearing loss: A meta-analysis. J Otol. 2021;16(1):47-54.

This meta-analysis aimed to assess the association of hematologic biomarkers with the diagnosis and prognosis of SSNHL patients. Haematologic biomarkers, including neutrophil/lymphocyte ratio and platelet/lymphocyte ratio, but not mean platelet value, were higher in the group with SSNHL than the group without. ●

Olbrich KJ, Muller D, Schumacher S, Beck E, Meszaros K, Koerber F. Systematic Review of Invasive Meningococcal Disease: Sequelae and Quality of Life Impact on Patients and Their Caregivers. Infect Dis Ther. 2018;7(4):421-38.

This systematic review aimed to assess the impact off invasive meningococcal disease sequelae on HRQoL in survivors and their caregivers. Neurologic sequelae included hearing loss (up to 19% of infants, 13% children, 12% adolescents, 8% adults). Invasive meningococcal disease negatively affects HRQoL in patients and also in their family and close caregiver network, both in the short and long-term. All studies included in this review were carried out in high-income countries. ●

Paraschou V, Chaitidis N, Papadopoulou Z, Theocharis P, Siolos P, Festas C. Association of systemic lupus erythematosus with hearing loss: a systemic review and meta-analysis. Rheumatol Int. 2021;41(4):681-9.

This systematic review and meta-analysis aimed to assess the association of systemic lupus erythematosus with hearing loss. Systemic lupus erythematosus patients had significantly increased odds of SNHL compared with controls (OR 2.31; 95%CI 1.48–3.60; I2 = 0). However, patients did not have significantly increased odds of conductive Hearing Loss (CHL) (OR 1.30; 95% CI 0.23–7.45; I2 = 0). Only one study reported on the outcome of Mixed Hearing Loss (MHL) (3 events in SLE group vs. 0 events in control group). Subgroup analysis also showed significantly increased odds of SNHL in systemic lupus erythematosus patients. ●

Quigley M, Embleton ND, McGuire W. Formula versus donor breast milk for feeding preterm or low birth weight infants. Cochrane Database Syst Rev. 2019;7(7):CD002971.

This systematic review aimed to assess feeding with formula compared with donor breast milk on growth and development in preterm or low birth weight infants. No difference in the proportion of children diagnosed with hearing impairment between these two groups was detected (RR 1.02, 95% CI 0.30 to 3.45). All studies included in this review were carried out in high-income countries. ●

Riga M, Korres G, Chouridis P, Naxakis S, Danielides V. Congenital cytomegalovirus infection inducing non-congenital sensorineural hearing loss during childhood; a systematic review. Int J Pediatr Otorhinolaryngol. 2018;115:156-64.

This systematic review aimed to assess the design of protocols for universal newborn hearing screening (UNHS) for effective follow-up of cCMV infection induced SNHL. The review was focused on types of hearing loss that may escape diagnosis through UNHS and/or present significant changes during childhood, such as progressive, fluctuating and late-onset hearing loss. The prevalence of cCMV infection induced hearing loss was significantly higher among symptomatic children ($p < 0.0001$), who were also significantly more likely to develop bilateral hearing loss ($p = 0.001$). There was not sufficient information on the prevalence, laterality, degree and time of diagnosis of progressive, fluctuating and late-onset hearing loss that could constitute the basis toward the report of specific follow-up guidelines. All studies included in this review were carried out in high-income countries. ●

Strum D, Kapoor E, Shim T, Kim S, Sabetrasekh P, Monfared A. Prevalence of Sensorineural Hearing Loss in Pediatric Patients with Sickle Cell Disease: A Meta-analysis. Laryngoscope. 2021;131(5):1147-56.

This meta-analysis aimed to assess the prevalence of SHNL attributable to sickle cell disease in the global paediatric population and identify factors contributing to its severity. There was a statistically significant increase in the prevalence of SNHL in children with sickle cell disease compared to the general population with a cumulative risk ratio of 3.33. 🔴

Sturrock S, Ali S, Gale C, Battersby C, Doare KL. Neonatal outcomes and indirect consequences following maternal SARS-CoV-2 infection in pregnancy: A systematic review. medRxiv. 2022.

This systematic review aimed to assess the association between maternal SARS-CoV-2 infection in pregnancy and individual neonatal morbidities and outcomes, particularly longer-term outcomes such as neurodevelopment. Two studies found higher rates of abnormal auditory brainstem response hearing tests (44.9% vs 23.7%) and poorer otoacoustic emission test results in babies born to mothers infected with SARS-CoV-2. This systematic review is a pre-print which has not yet been peer reviewed. 🟡

Yang JR, Hidayat K, Chen CL, Li YH, Xu JY, Qin LQ. Body mass index, waist circumference, and risk of hearing loss: a meta-analysis and systematic review of observational study. Environ Health Prev Med. 2020;25(1):25.

This systematic review and meta-analysis aimed to assess the association between body mass index or waist circumference and hearing loss. In cross-sectional studies, weight was associated with hearing loss, but evidence was strongest for continuous measures (OR=1.14 (95% CI 1.04, 1.24) for each 5 kg/m2 increase in BMI), with similar findings in longitudinal studies (RR=1.15 (95% CI 1.01, 1.30) for each 5 kg/m2 increase in BMI). 🟡

Zhang L, Li Z, Han X, Du H, Cao Y, Liu Y, et al. Association between Congenital Cytomegalovirus Infection and Brain Injury in Neonates: A Meta-analysis of Cohort Studies. Behav Neurol. 2021;2021:9603660.

This meta-analysis aimed to assess the association between cCMV infection and brain injury in neonates. Hearing loss was included as an outcome. The rate of SNHL was significantly higher in neonates infected with cCMV than within the control group. 🟡

1.3. Scoping reviews (n=5)

- Austhof E, Boyd K, Schaefer K, McFadden C, Owusu-Dommey A, Hoffman S, et al. Scoping Review of Toxoplasma Postinfectious Sequelae. Foodborne Pathog Dis. 2021;18(10):687-701.

- Cheung ICW, Thorne PR, Hussain S, Neeff M, Sommer JU. The relationship between obstructive sleep apnea with hearing and balance: A scoping review. Sleep Med. 2022;95:55-75.
- Khoza-Shangase K. Burden of disease: A scoping review of HIV/AIDS and TB in occupational noise-induced hearing loss. S Afr J Commun Disord. 2020;67(2):e1-e9.
- Rodrigo L, Campos-Asensio C, Rodriguez MA, Crespo I, Olmedillas H. Role of nutrition in the development and prevention of age-related hearing loss: A scoping review. J Formos Med Assoc. 2021;120(1 Pt 1):107-20.
- Sebothoma B, Khoza-Shangase K. Middle ear status - structure, function and pathology: A scoping review on middle ear status of COVID-19 positive patients. S Afr J Commun Disord. 2022;69(2):e1-e7.

1.4. Systematic reviews that evaluate genetic risk factors (n=6)

- Farjami M, Assadi R, Afzal Javan F, Alimardani M, Eslami S, Mansoori Derakhshan S, et al. The worldwide frequency of MYO15A gene mutations in patients with non-syndromic hearing loss: A meta-analysis. Iran J Basic Med Sci. 2020;23(7):841-8.
- Han B, Yang X, Li Y, Hosseini DK, Tu Y, Dong Y, et al. Association of polymorphisms in grainyhead-like-2 gene with the susceptibility to age-related hearing loss: A systematic review and meta-analysis. Medicine (Baltimore). 2019;98(25):e16128.
- Han B, Zhou T, Tu Y, Wang T, He Z, Li Y, et al. Correlation between mitochondrial DNA 4977 bp deletion and presbycusis: A system review and meta-analysis. Medicine (Baltimore). 2019;98(27):e16302.
- Han S, Zhang D, Guo Y, Fu Z, Guan G. Prevalence and Characteristics of STRC Gene Mutations (DFNB16): A Systematic Review and Meta-Analysis. Front Genet. 2021;12:707845.
- Robijn SMM, Smits JJ, Sezer K, Huygen PLM, Beynon AJ, van Wijk E, et al. Genotype-Phenotype Correlations of Pathogenic COCH Variants in DFNA9: A HuGE Systematic Review and Audiometric Meta-Analysis. Biomolecules. 2022;12(2).
- Xu T, Zhu W, Wang P. The p.P240L variant of CDH23 and the risk of nonsyndromic hearing loss: a meta-analysis. Eur Arch Otorhinolaryngol. 2019;276(1):11-6.

2. Behavioural risk factors

2.1. Systematic reviews that address socio-economic inequalities (n=1)

Li X, Rong X, Wang Z, Lin A. Association between Smoking and Noise-Induced Hearing Loss: A Meta-Analysis of Observational Studies. Int J Environ Res Public Health. 2020;17(4).

This meta-analysis aimed to assess the association between smoking and noise-induced hearing loss (NIHL). They found that current smokers have a higher risk of NIHL than former smokers, and that there is a positive dose-response relationship between smoking and NIHL. *PROGRESS-Plus (Gender):* Risk of NIHL was greater amongst males than females. 🟡

2.2. Systematic reviews that do not address socio-economic inequalities (n=1)

Taziki Balajelini MH, Mohammadi M, Rajabi A. Association between mobile phone use and hearing impairment: a systematic review and meta-analysis. Rev Environ Health. 2022;37(4):501-8.

This systematic review aimed to assess association of mobile phone use with hearing impairment. No risk of hearing impairment was found. 🟡

3. Demographic risk factors

3.1. Systematic reviews that address socio-economic inequalities (n=5)

Butcher E, Dezateux C, Cortina-Borja M, Knowles RL. Prevalence of permanent childhood hearing loss detected at the universal newborn hearing screen: Systematic review and meta-analysis. PLoS One. 2019;14(7):e0219600.

This systematic review and meta-analysis aimed to assess the prevalence of permanent childhood hearing loss detected through UNHS in very highly developed countries, and examine how detected permanent childhood hearing loss prevalence varies between studies and by demographic characteristics. Permanent childhood hearing loss prevalence was 6.9 times higher among those admitted to neonatal intensive care units. All studies included in this review were carried out in high-income countries. *PROGRESS-Plus (Gender):* Sex distribution was reported for children with permanent childhood hearing loss in two studies (44% and 57% female in the individual studies). 🟢

Lovett B, Welschmeyer A, Johns JD, Mowry S, Hoa M. Health Disparities in Otology: A PRISMA-Based Systematic Review. Otolaryngol Head Neck Surg. 2022;166(6):1229-37.

This systematic review aimed to assess health disparities in otology within the USA. The review identified 19 studies on health disparities amongst people with hearing loss, including several PROGRESS-Plus relevant categories, although no quantitative data on the associated risk of hearing loss was reported in the review. All studies included in this review were carried out in a high-income country (USA). *PROGRESS-Plus (Place of residence):* Urban versus rural residence was reported as a potential risk factor, with a note that rural residents in the USA may face longer wait time to

diagnosis of hearing loss due to disproportionate number of otologists working in urban academic centres compared to rural communities. *PROGRESS-Plus (Race/Ethnicity):* Race and ethnicity were reported as potential risk factors. *PROGRESS-Plus (Gender):* Gender was reported as a potential risk factor. *PROGRESS-Plus (Occupation):* Employment was reported as a potential risk factor. *PROGRESS-Plus (Education):* education, specifically health literacy in accessing health care utilisation, was reported as a potential risk factor. *PROGRESS-Plus (Socio-economic status):* Housing status was reported as a potential risk factor. ●

Nunes A, Silva CRL, Balen SA, Souza DLB, Barbosa IR. Prevalence of hearing impairment and associated factors in school-aged children and adolescents: a systematic review. Braz J Otorhinolaryngol. 2019;85(2):244-53.

This systematic review aimed to assess the prevalence of hearing impairment and its associated factors in school-aged children and adolescents. Prevalence of hearing impairment varied between 0.88% and 46.70%. Otologic and non-otologic factors were associated with hearing impairment, such as middle ear and air passage infections, neo- and post-natal icterus, accumulation of cerumen, family history, suspicion of parents, use of earphones, age and income. *PROGRESS-Plus (Education):* Low education and maternal education level were associated with hearing loss. *PROGRESS-Plus (Socio-economic status):* Low socio-economic status was associated with hearing loss. ●

Raeisi R, Moradi A, Rahmani K, Ameri P, Shalchi Z. Risk factors for hearing loss in infants: a systematic review. Journal of Advances in Medical and Biomedical Research. 2022;30(140):200-10.

This systematic review aimed to assess risk factors for hearing loss in infants. The review found that studies reported statistically significant associations between hearing loss and loss and a variety of maternal or neonatal variables, including: ventilatory support; craniofacial anomalies; hyperbilirubinemia; meningitis; Apgar scores; sepsis; asphyxia; stay in intensive care units; respiratory distress syndrome; and pulmonary surfactant. *PROGRESS-Plus (Personal characteristics):* Factors associated with disability were considered as risk factors, including developmental delay and craniofacial anomalies. ●

Schmucker C, Kapp P, Motschall E, Loehler J, Meerpohl JJ. Prevalence of hearing loss and use of hearing aids among children and adolescents in Germany: a systematic review. BMC Public Health. 2019;19(1):1277.

This systematic review aimed assess the prevalence of hearing loss at a national level in Germany. Prevalence ranged from 0.1 to 128 per 1000 children. The prevalence of hearing loss went down when the threshold was raised, however generating a comprehensive and coherent set of estimates was challenging due to heterogeneity within studies including variation in age, the study setting, the

definition of hearing loss and the assessment method. All studies included in this review were carried out in a high-income country (Germany). *PROGRESS-Plus (Gender):* Two studies reported a slightly higher proportion of hearing loss in males than in females (ratio males/females was 1.23). ●

3.2. Systematic reviews that do not address socio-economic inequalities (n=1)

Dawes P, Newall J, Graham PL, Osmond C, von Bonsdorff MB, Gunnar Eriksson J. Early Life Influences on Hearing in Adulthood: a Systematic Review and Two-Step Individual Patient Data Meta-Analysis. Ear Hear. 2022;43(3):722-32.

This systematic review and meta-analysis aimed to assess whether early developmental indices are associated with adult hearing loss, and to quantify the strength of these associations. Odds of hearing impairment in adulthood were 13.5% lower for every 1 kg increase in birth. Every 1cm increase in height was associated with a 3% reduction in the odds of hearing impairment [OR: 0.970 (95% confidence interval: 0.968 to 0.971)]. All studies were conducted within Europe. ●

3.3. Scoping reviews (n=2)

- Lor M, Thao S, Misurelli SM. Review of Hearing Loss Among Racial/Ethnic Minorities in the United States. West J Nurs Res. 2021;43(9):859-76.
- Pender AM, Wilson WJ, Bainbridge RG, Schluter PJ, Spurling GK, Askew DA. Ear and hearing health in Aboriginal and Torres Strait Islander people aged 15 years and older: A scoping review. Int J Audiol. 2022:1-11.

4. Environmental risk factors

4.1. Systematic reviews that address socio-economic inequalities (n=3)

Nguyen TH, Bertin M, Bodin J, Fouquet N, Bonvallot N, Roquelaure Y. Multiple Exposures and Coexposures to Occupational Hazards Among Agricultural Workers: A Systematic Review of Observational Studies. Saf Health Work. 2018;9(3):239-48.

This systematic review aimed to assess the effects of multiple occupational exposures and co-exposures to chemical, biomechanical, and physical hazards on adverse health outcomes among agricultural workers. Only one of the fifteen studies, based in Canada, included hearing loss as an outcome. Forestry workers exposed to both noise 90 dBA and hand-arm vibration for a minimum duration of 25 years have been associated with an increased risk of hearing loss (prevalence ratio 2.96, $p < 0.001$). *PROGRESS-Plus (Occupation):* Forestry workers. ●

Teplova AE, Bakker H, Perry SIB, van Etten-Jamaludin FS, Plat MJ, Bekkers MBM. The Impact of Deployment and Combat Exposure on Physical Health Among Military Personnel: A Systematic Review of Incidence, Prevalence, and Risks. Mil Med. 2022;187(9-10):e1074-e85.

This systematic review aimed to assess the incidence and prevalence of physical health conditions among military personnel during and after deployment, and investigate the risks of deployment and combat exposure on physical health. Risk of new-onset hearing loss was significantly increased for deployed with combat military personnel relative to nondeployed military personnel. Of the 32 included studies, only three included hearing loss as an outcome. All studies included in this review were carried out in high income countries. *PROGRESS-Plus (Occupation):* Military personnel. 🟡

Yadav OP, Sarkar A, Shan D, Rahman A, Moro L. Occupational noise exposure and health impacts among fish harvesters: a systematic review. Int Marit Health. 2021;72(3):199-205.

This systematic review aimed to assess noise-related auditory and non-auditory health effects among fish harvesters. Noise-induced hearing loss was considered a significant health risk to fish harvesters across the studies, affecting physical and emotional well-being. The prevalence of hearing loss was observed from 6% to 80%. *PROGRESS-Plus (Occupation):* Fish harvesters. 🔴

4.2. Systematic reviews that do not address socio-economic inequalities (n=4)

Cao Z, Zhao F, Mulugeta H. Noise exposure as a risk factor for acoustic neuroma: a systematic review and meta-analysis. Int J Audiol. 2019;58(9):525-32.

This systematic review and meta-analysis aimed to assess the exposure response relationship between noise and acoustic neuroma. There was no significant relationship between overall noise exposure and acoustic neuroma. However, subgroup analysis showed that leisure noise exposure (OR: 1.73, 95% CI: 1.10–2.73), above five years' exposure (OR: 1.81, 95% CI: 1.14–2.85) and continuous exposure (OR:2.77, 95% CI: 1.70–4.49) were associated with an increased risk of acoustic neuroma. 🟡

Dineva M, Hall A, Tan M, Blaskova A, Bath SC. Iodine status during child development and hearing ability: a systematic review. Br J Nutr. 2022:1-18.

This systematic review aimed to assess the association between: (i) iodine exposure during pregnancy and hearing ability in the offspring and (ii) child iodine exposure and hearing ability in childhood or later in life. One included study evaluated iodine supplementation in mildly iodine-deficient pregnant women and found no effect on offspring hearing thresholds. Iodine supplementation of severely iodine-deficient children resulted in improved hearing thresholds, and higher iodine status in children was associated with better hearing. 🟡

Puty B, Leao LKR, Crespo-Lopez ME, Almeida A, Fagundes NCF, Maia LC, et al. Association between methylmercury environmental exposure and neurological disorders: A systematic review. J Trace Elem Med Biol. 2019;52:100-10.

This systematic review aimed to assess the association between methylmercury environmental exposure and neurologic alteration. Two of six included studies evaluated hearing loss as an outcome. People living polluted area showed a significantly higher frequency of neurological signs characteristic of methylmercury poisoning, including hearing impairment, compared with people living in a non-polluted area. ●

Yin JZ, E M, Chao H. Population-based study of environmental lead exposure and hearing loss: a systematic review and meta-analysis. Public Health. 2021;197:63-7.

This systematic review and meta-analysis aimed to assess the association between lead exposure and hearing loss. Environmental lead exposure was significantly and substantially associated with hearing loss (OR 1.42; 95% CI 1.22-1.67). ●

4.3. Scoping reviews (n=1)

- Fox MA, Niemeier RT, Hudson N, Siegel MR, Dotson GS. Cumulative Risks from Stressor Exposures and Personal Risk Factors in the Workplace: Examples from a Scoping Review. Int J Environ Res Public Health. 2021;18(11).

References

1. The World Bank. World Bank Country and Lending Groups 2023 [Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups].
2. Cochrane Methods. PROGRESS-Plus 2023 [Available from: https://methods.cochrane.org/equity/projects/evidence-equity/progress-plus].
3. Li X, Rong X, Wang Z, Lin A. Association between Smoking and Noise-Induced Hearing Loss: A Meta-Analysis of Observational Studies. Int J Environ Res Public Health. 2020;17(4).
4. Taziki Balajelini MH, Mohammadi M, Rajabi A. Association between mobile phone use and hearing impairment: a systematic review and meta-analysis. Rev Environ Health. 2022;37(4):501-8.
5. Butcher E, Dezateux C, Cortina-Borja M, Knowles RL. Prevalence of permanent childhood hearing loss detected at the universal newborn hearing screen: Systematic review and meta-analysis. PLoS One. 2019;14(7):e0219600.
6. Dawes P, Newall J, Graham PL, et al. Early Life Influences on Hearing in Adulthood: a Systematic Review and Two-Step Individual Patient Data Meta-Analysis. Ear Hear. 2022;43(3):722-32.
7. Lovett B, Welschmeyer A, Johns JD, et al. Health Disparities in Otology: A PRISMA-Based Systematic Review. Otolaryngol Head Neck Surg. 2022;166(6):1229-37.
8. Nunes A, Silva CRL, Balen SA, et al. Prevalence of hearing impairment and associated factors in school-aged children and adolescents: a systematic review. Braz J Otorhinolaryngol. 2019;85(2):244-53.
9. Raeisi R, Moradi A, Rahmani K, et al. Risk factors for hearing loss in infants: a systematic review. Journal of Advances in Medical and Biomedical Research. 2022;30(140):200-10.
10. Schmucker C, Kapp P, Motschall E, et al. Prevalence of hearing loss and use of hearing aids among children and adolescents in Germany: a systematic review. BMC Public Health. 2019;19(1):1277.
11. Cao Z, Zhao F, Mulugeta H. Noise exposure as a risk factor for acoustic neuroma: a systematic review and meta-analysis. Int J Audiol. 2019;58(9):525-32.
12. Dineva M, Hall A, Tan M, et al. Iodine status during child development and hearing ability: a systematic review. Br J Nutr. 2022:1-18.
13. Nguyen TH, Bertin M, Bodin J, et al. Multiple Exposures and Coexposures to Occupational Hazards Among Agricultural Workers: A Systematic Review of Observational Studies. Saf Health Work. 2018;9(3):239-48.
14. Puty B, Leao LKR, Crespo-Lopez ME, et al. Association between methylmercury environmental exposure and neurological disorders: A systematic review. J Trace Elem Med Biol. 2019;52:100-10.
15. Teplova AE, Bakker H, Perry SIB, et al. The Impact of Deployment and Combat Exposure on Physical Health Among Military Personnel: A Systematic Review of Incidence, Prevalence, and Risks. Mil Med. 2022;187(9-10):e1074-e85.
16. Yadav OP, Sarkar A, Shan D, et al. Occupational noise exposure and health impacts among fish harvesters: a systematic review. Int Marit Health. 2021;72(3):199-205.
17. Yin JZ, E M, Chao H. Population-based study of environmental lead exposure and hearing loss: a systematic review and meta-analysis. Public Health. 2021;197:63-7.
18. Alene KA, Wangdi K, Colquhoun S, et al. Tuberculosis related disability: a systematic review and meta-analysis. BMC Med. 2021;19(1):203.
19. Almufarrij I, Munro KJ. One year on: an updated systematic review of SARS-CoV-2, COVID-19 and audio-vestibular symptoms. Int J Audiol. 2021;60(12):935-45.
20. Almufarrij I, Uus K, Munro KJ. Does coronavirus affect the audio-vestibular system? A rapid systematic review. Int J Audiol. 2020;59(7):487-91.

21. Bayat A, Saki N, Nikakhlagh S, et al. Is COPD associated with alterations in hearing? A systematic review and meta-analysis. Int J Chron Obstruct Pulmon Dis. 2019;14:149-62.
22. Bentivi JO, Azevedo C, Lopes MKD, et al. Audiological assessment of children with HIV/AIDS: a meta-analysis. J Pediatr (Rio J). 2020;96(5):537-45.
23. Beukes E, Ulep AJ, Eubank T, Manchaiah V. The Impact of COVID-19 and the Pandemic on Tinnitus: A Systematic Review. J Clin Med. 2021;10(13):2763.
24. Chen L, Zhang G, Zhang Z, et al. Neutrophil-to-lymphocyte ratio predicts diagnosis and prognosis of idiopathic sudden sensorineural hearing loss: A systematic review and meta-analysis. Medicine (Baltimore). 2018;97(38):e12492.
25. Elzinga HBE, van Oorschot HD, Stegeman I, Smit AL. Relation between otitis media and sensorineural hearing loss: a systematic review. BMJ Open. 2021;11(8):e050108.
26. Fletcher KT, Horrell EMW, Ayugi J, et al. The Natural History and Rehabilitative Outcomes of Hearing Loss in Congenital Cytomegalovirus: A Systematic Review. Otol Neurotol. 2018;39(7):854-64.
27. Frosolini A, Franz L, Daloiso A, et al. Digging into the Role of Inflammatory Biomarkers in Sudden Sensorineural Hearing Loss Diagnosis and Prognosis: A Systematic Review and Meta-Analysis. Medicina (Kaunas). 2022;58(7).
28. Garcia A, Rivera S, Alvear-Veas B, et al. Association Between Early-Onset Osteoporosis With Hearing Loss and Benign Paroxysmal Positional Vertigo (BPPV): A Systematic Review and Meta-Analysis. Ann Otol Rhinol Laryngol. 2022:34894221118424.
29. Gotardo JW, Volkmer NFV, Stangler GP, et al. Impact of peri-intraventricular haemorrhage and periventricular leukomalacia in the neurodevelopment of preterms: A systematic review and meta-analysis. PLoS One. 2019;14(10):e0223427.
30. Jeong SS, Shih MC, Rizk HG, Lambert PR. Otologic Manifestations of Psoriasis: A Systematic Review and Meta-Analysis. Otol Neurotol. 2022;43(7):742-52.
31. Kapoor E, Strum D, Shim T, et al. Characterization of Sensorineural Hearing Loss in Adult Patients With Sickle Cell Disease: A Systematic Review and Meta-analysis. Otol Neurotol. 2021;42(1):30-7.
32. Kasemsuk N, Chayopasakul V, Banhiran W, et al. Obstructive Sleep Apnea and Sensorineural Hearing Loss: A Systematic Review and Meta-analysis. Otolaryngol Head Neck Surg. 2022:1945998221120777.
33. Le J, Dorstyn DS, Mpofu E, et al. Health-related quality of life in coronary heart disease: a systematic review and meta-analysis mapped against the International Classification of Functioning, Disability and Health. Qual Life Res. 2018;27(10):2491-503.
34. Lien KH, Ger TY, Chi CC. Association of vitiligo with high-frequency sensorineural hearing loss: a systematic review and meta-analysis. J Eur Acad Dermatol Venereol. 2022;36(3):373-9.
35. Liu PH, Hao JD, Li WY, et al. Congenital cytomegalovirus infection and the risk of hearing loss in childhood: A PRISMA-compliant meta-analysis. Medicine (Baltimore). 2021;100(36):e27057.
36. Ma SH, Ang MD, Chang YT, Dai YX. Association between vitiligo and hearing loss. J Am Acad Dermatol. 2021;85(6):1465-72.
37. Maharaj S, Bello Alvarez M, Mungul S, Hari K. Otologic dysfunction in patients with COVID-19: A systematic review. Laryngoscope Investig Otolaryngol. 2020;5(6):1192-6.
38. Maltezou PG, Kourlaba G, Kourkouni E, et al. Maternal type of CMV infection and sequelae in infants with congenital CMV: Systematic review and meta-analysis. J Clin Virol. 2020;129:104518.
39. Meng X, Wang J, Sun J, Zhu K. COVID-19 and Sudden Sensorineural Hearing Loss: A Systematic Review. Front Neurol. 2022;13:883749.
40. Mirmosayyeb O, Naderi M, Raeisi S, et al. Hearing loss among patients with multiple sclerosis (PwMS): A systematic review and meta-analysis. Mult Scler Relat Disord. 2022;62:103754.
41. Misra S, Kolappa K, Prasad M, et al. Frequency of Neurologic Manifestations in COVID-19: A Systematic Review and Meta-analysis. Neurology. 2021;97(23):e2269-e81.

42. Mohammadi M, Taziki Balajelini MH, Rajabi A. Migraine and risk of sudden sensorineural hearing loss: A systematic review and meta-analysis. Laryngoscope Investig Otolaryngol. 2020;5(6):1089-95.
43. Mohammed SH, Shab-Bidar S, Abuzerr S, et al. Association of anemia with sensorineural hearing loss: a systematic review and meta-analysis. BMC Res Notes. 2019;12(1):283.
44. Ni W, Song SP, Jiang YD. Association between routine hematological parameters and sudden sensorineural hearing loss: A meta-analysis. J Otol. 2021;16(1):47-54.
45. Olbrich KJ, Muller D, Schumacher S, et al. Systematic Review of Invasive Meningococcal Disease: Sequelae and Quality of Life Impact on Patients and Their Caregivers. Infect Dis Ther. 2018;7(4):421-38.
46. Paraschou V, Chaitidis N, Papadopoulou Z, et al. Association of systemic lupus erythematosus with hearing loss: a systemic review and meta-analysis. Rheumatol Int. 2021;41(4):681-9.
47. Quigley M, Embleton ND, McGuire W. Formula versus donor breast milk for feeding preterm or low birth weight infants. Cochrane Database Syst Rev. 2019;7(7):CD002971.
48. Riga M, Korres G, Chouridis P, et al. Congenital cytomegalovirus infection inducing non-congenital sensorineural hearing loss during childhood; a systematic review. Int J Pediatr Otorhinolaryngol. 2018;115:156-64.
49. Strum D, Kapoor E, Shim T, et al. Prevalence of Sensorineural Hearing Loss in Pediatric Patients with Sickle Cell Disease: A Meta-analysis. Laryngoscope. 2021;131(5):1147-56.
50. Sturrock S, Ali S, Gale C, et al. Neonatal outcomes and indirect consequences following maternal SARS-CoV-2 infection in pregnancy: A systematic review. medRxiv. 2022.
51. Yang JR, Hidayat K, Chen CL, et al. Body mass index, waist circumference, and risk of hearing loss: a meta-analysis and systematic review of observational study. Environ Health Prev Med. 2020;25(1):25.
52. Zhang L, Li Z, Han X, et al. Association between Congenital Cytomegalovirus Infection and Brain Injury in Neonates: A Meta-analysis of Cohort Studies. Behav Neurol. 2021;2021:9603660.
53. NICE. Hearing loss in adults: assessment and management. NICE guideline [NG98]. NICE; 2018. [Available from: https://www.nice.org.uk/guidance/ng98].
54. Livingston G, Huntley J, Sommerlad A, et al. Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. Lancet. 2020;396(10248):413-46.
55. Royal National Institute for Deaf People. Facts and figures n.d. [Available from: https://rnid.org.uk/about-us/research-and-policy/facts-and-figures/].
56. Davis A, Smith P, Ferguson M, et al. Acceptability, benefit and costs of early screening for hearing disability: a study of potential screening tests and models. Health Technol Assess. 2007;11(42):1-294.
57. Tsimpida D, Kontopantelis E, Ashcroft DM, Panagioti M. Conceptual Model of Hearing Health Inequalities (HHI Model): A Critical Interpretive Synthesis. Trends Hear. 2021;25:23312165211002963.
58. Richards M. Report of the independent review of adult screening programmes in England. NHS England; 2019. [Available from: https://www.england.nhs.uk/wp-content/uploads/2019/02/report-of-the-independent-review-of-adult-screening-programme-in-england.pdf].
59. Ellis S, Sheik Ali S, Ahmed W. A review of the impact of hearing interventions on social isolation and loneliness in older people with hearing loss. Eur Arch Otorhinolaryngol. 2021;278(12):4653-61.
60. Golmohammadi R, Darvishi E. The combined effects of occupational exposure to noise and other risk factors - a systematic review. Noise Health. 2019;21(101):125-41.
61. Kyle ME, Wang JC, Shin JJ. Ubiquitous aspirin: a systematic review of its impact on sensorineural hearing loss. Otolaryngol Head Neck Surg. 2015;152(1):23-41.

62. Mujica-Mota MA, Patel N, Saliba I. Hearing loss in type 1 diabetes: Are we facing another microvascular disease? A meta-analysis. Int J Pediatr Otorhinolaryngol. 2018;113:38-45.
63. Rodrigo L, Campos-Asensio C, Rodriguez MA, et al. Role of nutrition in the development and prevention of age-related hearing loss: A scoping review. J Formos Med Assoc. 2021;120(1 Pt 1):107-20.
64. Vasconcellos AP, Kyle ME, Gilani S, Shin JJ. Personally Modifiable Risk Factors Associated with Pediatric Hearing Loss: A Systematic Review. Otolaryngol Head Neck Surg. 2014;151(1):14-28.
65. Briscoe S, Shaw L, Lawal H, et al. What are the risk factors for hearing loss and how are they related to socio-economic inequalities? Protocol for an annotated bibliography of systematic reviews. Open Science Framework; 2022. [Available from: https://osf.io/7mxdn/].
66. Centre for Reviews and Dissemination. Database of Abstracts of Reviews of Effects (DARE): Quality-assessed Reviews 2014 [Available from: https://www.ncbi.nlm.nih.gov/books/NBK285222/].
67. Collaboration for Environmental Evidence. The Collaboration for Environmental Evidence Synthesis Appraisal Tool (CEESAT). Version 2.1.; 2020.
68. European Patients' Academy on Therapeutic Innovation. Risk factors in health and disease n.d. [Available from: https://toolbox.eupati.eu/resources/risk-factors-in-health-and-disease/].
69. Centre for Reviews and Dissemination. Systematic Reviews: CRD's guidance for undertaking reviews in health care: University of York; 2009.
70. Hosking J, Macmillan A, Jones R, et al. Searching for health equity: validation of a search filter for ethnic and socioeconomic inequalities in transport. Systematic Reviews. 2019;8(1):94.
71. Stallings E, Gaetano-Gil A, Alvarez-Diaz N, et al. Development and evaluation of a search filter to identify prognostic factor studies in Ovid MEDLINE. BMC Med Res Methodol. 2022;22(1):107.
72. Royal National Institute for Deaf People. Types and causes of hearing loss and deafness n.d. [Available from: https://rnid.org.uk/information-and-support/hearing-loss/types-of-hearing-loss-and-deafness/].

Appendix A: Methods

The methods used for searching for systematic reviews, screening and selecting systematic reviews, data-extraction, and quality appraisal followed best-practice guidance as outlined in the Centre Reviews and Dissemination guidance manual.[69] A protocol which sets out the methods we used was prospectively registered on the Open Science Framework.[65]

Searches for systematic reviews

The search for relevant systematic reviews included searches of healthcare bibliographic databases, checking reference lists, and inspection of websites of relevant organisations.

The bibliographic database search strategy was developed using MEDLINE (via Ovid) by an information specialist (SB) in consultation with the review team and stakeholders. The search terms were informed by several sources including: the titles and abstracts of relevant systematic reviews identified in our preliminary background searches; inspection of search strategies from systematic reviews on similar topics (e.g. hearing loss, risk factors); and consultation with stakeholders with expertise on hearing loss. In addition, we adapted search terms from two published search filters, including: a health equity filter comprised of search terms which describe demographic factors related to socio-economic inequalities;[70] and, a search filter for prognostic factor studies from which we adapted search terms for 'risk'.[71] Controlled headings were used wherever available (e.g. MeSH in MEDLINE) alongside free-text searching in the title and abstract fields of bibliographic records.

The final Ovid MEDLINE search strategy is presented in Appendix B. This was adapted and translated for use in ASSIA (via ProQuest), Embase and HMIC (both via Ovid) and Epistemonikos (https://www.epistemonikos.org/). The full set of bibliographic database search strategies are available on request from the authors. The results of searches were limited to English language studies and a 2012 date limit was applied as set out in the protocol. (However, we subsequently set the date limit at 2018 within the reference management software – see Protocol Deviations). The results of the bibliographic database searches were be exported to Endnote 20 (Clarivate, Philadelphia, USA) and de-duplicated using the automated de-duplication feature and manual checking.

In addition to search bibliographic databases, the reference lists of all systematic reviews that met our inclusion criteria were checked for additional relevant systematic reviews. We also searched a selection of topically relevant websites including:

- Action on Hearing Loss https://rnid.org.uk/
- British Deaf Association https://bda.org.uk/

- Health and Safety Executive – noise at work https://www.hse.gov.uk/noise/index.htm
- Royal Association for Deaf People https://www.royaldeaf.org.uk/
- Hearing Health Foundation https://hearinghealthfoundation.org/

The search strategies used for web searching are available on request from the authors.

Inclusion Criteria

Problem (Hearing loss)

Include:

All types of hearing loss, including (but not limited to):[72]

- Age-related hearing loss
- Sudden hearing loss
- Noise-induced hearing loss
- Genetic hearing loss and deafness
- Acoustic neuroma

Exclude:

None

Phenomenon of interest (Risk factors)

Include:

Behavioural, demographic, environmental, genetic and physiological risk factors for hearing loss.[68]

Some specific examples are provided below:

- Behavioural, including (but not limited to):
    - smoking
    - alcohol consumption
    - nutrition
- Demographic, including (but not limited to):
    - age
    - ethnicity/race
    - income
- Environmental, including (but not limited to):
    - access to clean water
    - air pollution
    - noise

- Physiological, i.e. diseases that occur due to combination of biology, genetics, lifestyle, and other broad factors, including (but not limited to):
    - obesity
    - high blood pressure
    - asthma
    - multiple sclerosis

Exclude:

- Medical interventions which are risk factors for hearing loss. This was a protocol deviation (see Protocol Deviations below).
- Systematic reviews of the effectiveness of interventions which mention hearing loss as a potential adverse event.

Context

n/a

In addition to the above categories, we also applied the following criteria:

Study design

Include:

Systematic reviews, including:

- Systematic reviews
- Meta analyses
- Mixed methods reviews
- Scoping reviews
- Rapid reviews
- Mapping reviews

Exclude:

- Non-systematic reviews, e.g. narrative reviews, literature reviews
- Theory-based reviews, including qualitative evidence syntheses and realist reviews

Date limit

- 2018, i.e. 5 years from date of search (this is a protocol deviation – see Protocol deviations, below)

Geographical restrictions

- At least one study per systematic review to be carried out in a high-income country as defined by the World Bank[1] to be eligible for inclusion (this is a protocol deviation – see Protocol deviations, below)

Language restrictions

- Studies published in English only.

Screening process

As an initial calibration exercise of inclusion judgments and the clarity of our inclusion criteria, all reviewers (SB, GJMT, MN, NO, LS, JTC) applied inclusion and exclusion criteria to the same sample (n=100) of title/abstract search results. Decisions were discussed in a group meeting to ensure consistent application of criteria. Where necessary, inclusion and exclusion criteria were revised to enable more consistent reviewer interpretation and judgement. The revised inclusion and exclusion criteria were then applied to the title and abstract of each identified citation independently by two reviewers, with disagreements resolved through discussion or referral to a third reviewer as required (SB, GJMT, MN, NO, LS, JTC). The full text of each record was assessed for inclusion in the same way.

Endnote 20 software (Clarivate Analytics, Philadelphia, PA, USA) was used to support study selection. A PRISMA-style flowchart was produced to detail the study selection process.

Data extraction

A basic level of data was extracted from the full-texts of relevant systematic reviews, including:

- First author
- Year of publication
- Risk factors considered
- Type/cause of deafness
- Aims
- Inclusion criteria
- Synthesis method
- Number of included studies
- Country settings of included studies
- Data relating to socio-economic inequalities.
- Summary of findings

Data-extraction was carried out by one reviewer and checked by a second reviewer.

Systematic review classification and quality assessment

We used DARE criteria to assess whether identified studies should be classified as systematic reviews, except for mapping reviews and scoping reviews (see Table 3).[66] Mapping reviews and scoping reviews were excluded from this assessment as some of the DARE criteria questions are not relevant to these types of review, specifically, whether quality assessment was carried out on included studies, and whether a synthesis of studies was carried out. We included meta-analyses, rapid reviews, and mixed-methods reviews if they met the DARE criteria for systematic reviews.

Table 3. DARE criteria and notes on application

	Criteria	**Notes**
1	Were inclusion/exclusion criteria reported?	Specifies at least the inclusion criteria.
2	Was the search adequate?	• More than one database searched • Search terms or concepts reported which map onto the research question (but not necessarily the syntax and structure)
3	Were the included studies synthesized?	Efforts to make sense of the whole of the data set, beyond describing results from individual studies in turn.
4	Was the quality of the included studies assessed?	Quality appraisal is mentioned, but scores are not necessarily reported.
5	Are sufficient details about the individual included studies presented?	EITHER • Table of characteristics of included studies OR • Narrative summary of all included studies

We used a modified form of the CEESAT criteria to quality appraise the identified systematic reviews.[67] This was restricted to four items on the CEESAT tool including items 3.1 ("Is the approach to searching clearly defined, systematic and transparent?"), 3.2 ("Is the search comprehensive?"), 5.1 ("Does the review critically appraise each study?") and 5.2 ("During critical appraisal was an effort made to minimise subjectivity?"). Quality appraisal was carried out by two reviewers independently and disagreements resolved by discussion (SB, GJMT, MN, NO, LS, JTC). A 'traffic light' system was devised for calculating an overall score per study. Items rated gold on the CEESAT tool were scored 5, items rated green were scored 3, items rated amber were scored 1, and items rated

red were score 0. The sum of the scores for each CEESAT item per systematic review was calculated, and systematic reviews scoring 0-5 were rated 'red', systematic reviews scoring 6-12 were rated 'amber' and systematic reviews scoring 13+ were rated 'green'. However, we did not quality appraise mapping or scoping reviews, or reviews where genetic factors were risk factors. The use of the CEESAT criteria for quality appraisal was a protocol deviation (see Protocol deviations, below).

Data analysis and presentation

Systematic reviews were organised by category of risk factor, including behavioural, demographic, environmental, genetic and physiological risk factors.[68] A brief description of the aims, methods and findings of each included systematic review was produced. This includes specific reference to findings within individual systematic reviews which suggest an association between risk factors for hearing loss and socio-economic inequalities, and a quality appraisal rating based on the modified CEESAT criteria.[67] PROGRESS-Plus criteria was used to categorise findings relating to socio-economic inequalities.[2] This includes the following categories:

PROGRESS criteria:

- Place of residence
- Race/ethnicity/culture/language
- Occupation
- Gender/sex
- Religion
- Socio-economic status
- Social capital

Plus criteria:

- Personal characteristics associated with discrimination, including age and disability
- Features of relationships, including smoking parents, excluded from school
- Time-dependent relationships, including leaving the hospital, respite care, other instances where a person might be temporarily at a disadvantage.

Mapping and scoping reviews, which do not present a summary of the findings of included studies, are listed rather than summarised as per other types of systematic review. In addition, systematic reviews which describe genetic risk factors are listed as these are not readily modifiable.

A short summary of the findings and a table of characteristics of included systematic reviews was produced.

Protocol deviations

There were several deviations from the protocol.[65] We describe and explain these below.

- We did not search Google Scholar due to higher volume of screening, specifically full-text screening, arising from the bibliographic database searches than anticipated.
- The date limit was changed from 2012 to 2018 to manage the high volume of records identified, particularly the high volume of full-text screening required.
- We did not include medicines as risk factors for hearing loss it became apparent that to do this rigorously we would need to search for all systematic reviews of medical interventions and inspect potential adverse events, which was deemed beyond the scope of this project.
- We only included systematic reviews which included at least one study carried out in a World Bank high income country to increase the relevance of the included systematic reviews to the UK context of the policy customer.
- We did not produce a table of full-texts with reasons for exclusion due to the high volume of full-text screening undertaken.
- We used modified CEESAT criteria for QA as we found that the DARE criteria had very limited guidance on how to operationalise.[67]
- We did not produce annotations for genetic risk factors as these are not readily modifiable.

Appendix B: Ovid MEDLINE search

Database: MEDLINE
Host: Ovid
Issue: 1946 to October 20, 2022
Date Searched: 21/10/2022
Searcher: SB
Hits: 2400
Strategy:

1. ((hearing or audiolog* or acoustic or otologic*) adj3 (health or impair* or inequalit* or loss)).tw.
2. deaf*.tw.
3. exp Hearing Loss/
4. Persons With Hearing Impairments/
5. "acoustic neuroma".tw.
6. Neuroma, Acoustic/
7. or/1-6
8. exp Risk/
9. risk*.tw.
10. exp Prognosis/
11. prognosis.tw.
12. predict*.tw.
13. exp Incidence/
14. incidence.tw.
15. "causal factor*".tw.
16. epidemiolo*.tw.
17. Epidemiology/
18. or/8-17
19. (equit* or inequit* or inequalit* or disparit* or equality).tw.
20. (ethnic* or race or racial* or racis*).tw.
21. ((social* or "socio-economic" or socioeconomic or economic or structural or material) adj3 (advantage* or disadvantage* or exclude* or exclusion or include* or inclusion or status or position or gradient* or hierarch* or class* or determinant*)).tw.
22. (health adj3 (gap* or gradient* or hierarch*)).tw.
23. Vulnerable populations/
24. socioeconomic factors/
25. poverty/
26. social class/
27. Healthcare Disparities/
28. Health Status Disparities/
29. Poverty areas/
30. Urban population/
31. (SES or SEP or sociodemographic* or "socio-demographic*" or income or wealth* or poverty or "educational level" or "level of education" or "educational attainment" or "well educated" or "better educated" or unemploy* or "home owner*" or tenure or affluen* or "well off" or "better off" or "worse off").tw.
32. or/19-31
33. 18 or 32
34. ((map or mapping or rapid or systematic or scoping or umbrella) adj2 (review* or synthes*)).tw.

35. ("meta analy*" or metaanaly* or metasynthe* or "meta synthe*").tw.
36. "evidence synthes*".tw.
37. "review* of reviews".tw.
38. systematic review.pt.
39. meta-analysis.pt.
40. or/34-39
41. 7 and 33 and 40

Table 4. Bibliographic database search results

Database	**Hits**
MEDLINE	896
Embase	1135
HMIC	0
ASSIA	14
Epistemonikos (total)	355
TOTAL RECORDS	**2400**
DUPLICATE RECORDS	**965**
TOTAL UNIQUE RECORDS	**1435***

*Prior to application of 2018 date cut-off

Appendix C: PRISMA flow diagram

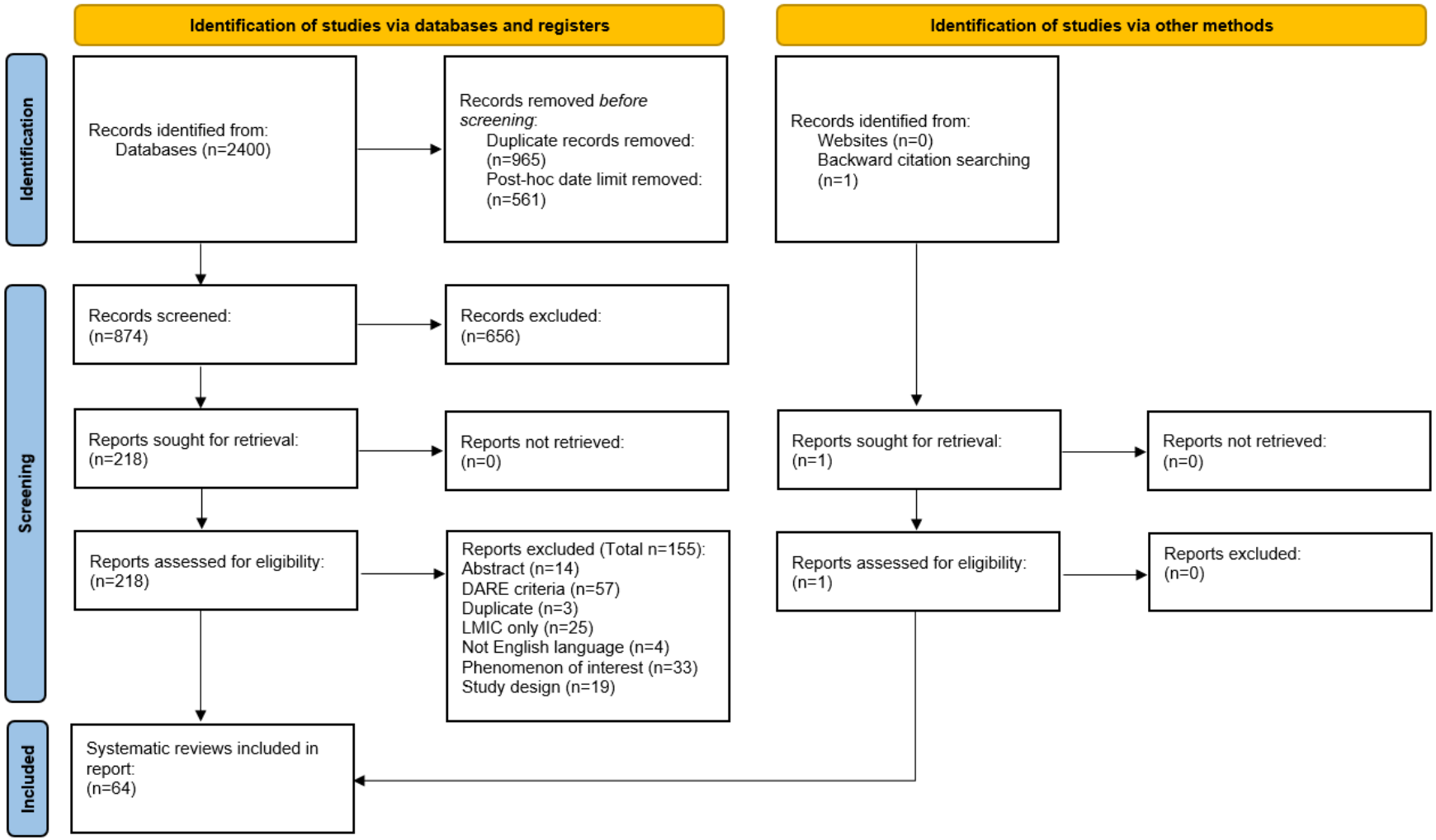

Figure 1. PRISMA flow diagram

Appendix D: Quality appraisal scores

Table 5. Quality appraisal scores of included systematic reviews per item of modified CEESAT checklist

Study	Is the approach to searching clearly defined, systematic and transparent?	Is the search comprehensive?	Does the review critically appraise each study?	During critical appraisal was an effort made to minimise subjectivity?	Overall Score*	Traffic light rating
Physiological risk factors						
Alene 2021	Green	Green	Green	Red	9	🟡
Almufarrij 2021	Gold	Green	Green	Gold	16	🟢
Almufarrij 2020	Gold	Green	Green	Gold	16	🟢
Bayat 2019	Green	Amber	Green	Red	7	🟡
Bentivi 2020	Amber	Amber	Red	Red	2	🔴
Beukes 2021	Amber	Green	Green	Gold	12	🟡
Chen 2018	Amber	Green	Green	Red	7	🟡
Elzinga 2021	Gold	Green	Green	Gold	16	🟢
Fletcher 2018	Green	Amber	Green	Red	7	🟡
Frosolini 2022	Amber	Green	Green	Red	7	🟡
Garcia 2022	Gold	Amber	Amber	Green	10	🟡
Gotardo 2019	Gold	Amber	Green	Red	9	🟡

Jeong 2022	Unavailable	Green	Green	Gold	11	🟡
Kapoor 2021	Green	Green	Green	Amber	10	🟡
Kasemsuk 2022	Gold	Green	Green	Gold	16	🟢
Le 2018	Green	Green	Amber	Green	10	🟡
Lien 2022	Green	Amber	Green	Gold	12	🟡
Liu 2021	Amber	Green	Amber	Gold	10	🟡
Ma 2020	Green	Green	Amber	Gold	12	🟡
Maharaj 2020	Amber	Green	Green	Red	7	🟡
Maltezou 2020	Amber	Amber	Green	Red	5	🔴
Meng 2022	Amber	Green	Green	Gold	12	🟡
Mirmosayyeb 2022	Gold	Green	Green	Gold	16	🟢
Misra 2021	Gold	Green	Green	Amber	12	🟡
Mohammadi 2020	Gold	Green	Green	Gold	16	🟢
Mohammed 2019	Amber	Green	Amber	Gold	10	🟡
Ni 2021	Amber	Green	Amber	Gold	10	🟡
Olbrich 2018	Green	Amber	Amber	Red	5	🔴
Paraschou 2021	Green	Green	Green	Gold	14	🟢
Quigley 2019	Gold	Gold	Green	Gold	18	🟢
Riga 2018	Amber	Amber	Red	Red	2	🔴

Strum 2021	Amber	Amber	Green	Red	5	🔴
Sturrock 2022	Green	Green	Red	Red	6	🟡
Yang 2020	Gold	Amber	Green	Red	9	🟡
Zhang 2021	Green	Amber	Red	Red	6	🟡
Behavioural risk factors						
Li 2020	Amber	Green	Amber	Amber	6	🟡
Taziki Balajelini 2021	Amber	Green	Green	Gold	12	🟡
Demographic risk factors						
Butcher 2019	Green	Gold	Green	Gold	16	🟢
Dawes 2022	Green	Green	Green	Gold	14	🟢
Lovett 2022	Amber	Green	Amber	Green	8	🟡
Nunes 2019	Gold	Green	Green	Green	14	🟢
Raeisi 2022	Amber	Amber	Red	Red	2	🔴
Schmucker 2019	Amber	Green	Green	Red	7	🟡
Environmental risk factors						
Cao 2019	Green	Amber	Green	Red	7	🟡
Dineva 2022	Green	Amber	Green	Red	7	🟡
Nguyen 2018	Amber	Green	Green	Red	7	🟡

Puty 2019	Gold	Green	Green	Green	14	🟢
Teplova 2022	Green	Amber	Green	Red	7	🟡
Yadav 2021	Amber	Green	Amber	Red	5	🔴
Yin 2021	Amber	Amber	Amber	Gold	8	🟡
*Gold=5, Green=3, Amber=1, Red=0						