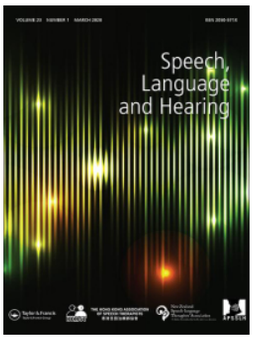

Speech, Language and Hearing

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/yslh20

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To cite this article: Rachel James, Amanda Machell, Jack DeLacy & Jacqueline Stephens (2025) Long-term outcomes of childhood otitis media and hearing loss: a systematic review, Speech, Language and Hearing, 28:1, 2420455, DOI: 10.1080/2050571X.2024.2420455

To link to this article: https://doi.org/10.1080/2050571X.2024.2420455

SPEECH, LANGUAGE AND HEARING
2025, VOL. 28, NO. 1, 2420455
https://doi.org/10.1080/2050571X.2024.2420455

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Long-term outcomes of childhood otitis media and hearing loss: a systematic review

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ABSTRACT

Otitis media (OM) is a common childhood illness which can cause hearing loss and developmental delays. This is the first systematic review to investigate the long-term, longitudinal health and social outcomes of OM and hearing loss in childhood. The study was registered in PROSPERO (CRD42023396318). A structured search strategy identified literature in the following databases: CINAHL, Scopus, Medline, PsychInfo, and EmCare. Articles were independently dual-screened and extracted data were synthesised. From 2825 potential studies, 25 were selected for inclusion. These assessed broad outcomes: physical health, audiological health academic, behavioural, social function, service use, and housing. Overall, 28% of papers found no difference between those with a childhood history of OM and those without, 40% found poorer outcomes for those with a history of OM, and 32% found mixed results. This is the first study of its kind to explore the long-term effects of otitis media and resultant hearing loss in children. Trends of poor academic, behavioural, and audiological outcomes were identified in children with OM and hearing loss. Multiple gaps in the literature were identified including a paucity of recent research, studies extending into adulthood, and studies focusing on high-risk populations.

ARTICLE HISTORY
Received 7 May 2024
Accepted 9 October 2024

KEYWORDS
Otitis media; hearing loss; social determinants of health; child health

Introduction

Otitis Media (OM) is the inflammation and infection of the middle ear, and a common illness of childhood. OM exists on a spectrum of disease from acute inflammation, to chronic middle ear disease (Kong & Coates, 2009). Acute OM (AOM) can lead to severe complications including tympanic membrane perforation, with many children going on to develop chronic disease including chronic suppurative OM (CSOM), and OM with effusion, with all types of OM having the ability to cause hearing impairment (Menzies School of Health Research, 2020). Almost all children will experience an episode of acute OM (AOM), with most children in developed countries improving with supportive treatment, however, certain populations are at greater risk of infection, and complication (Menzies School of Health Research, 2020).

Several factors contribute to an individual's risk of OM, including both host and environmental factors. Host factors include age, sex, immunosuppression, genetic predisposition, and craniofacial abnormalities, such as cleft palate and Down syndrome (Kong & Coates, 2009). Environmental factors include overcrowding and day care attendance, having older siblings, upper respiratory tract infections, and cigarette smoke exposure, with breastfeeding as a protective factor (Kong & Coates, 2009; van Ingen et al., 2020; Zhang et al., 2014). Certain populations are more at risk of OM than others as a result of the social determinants of health contributing to environmental risk factors. Poor housing, low socioeconomic status (SES), unemployment, and poor access to services all place children at higher risk of OM (Bowie, Pearson, Campbell, & Barnett, 2014; DeLacy, Dune, & Macdonald, 2020; Siddartha, Bhat, Bhandary, Shenoy, & Rashmi, 2012).

Incidence of OM varies between regions and age groups. Globally, AOM incidence rate is highest in the one to four age group at 61%, followed by the first year of life at 45% (Monasta et al., 2012). Incidence for children under five years of age varies across the world, from under 30% in areas of Southern and Andean Latin America, East Asia, and high-income Asia Pacific countries, to over 100% in Oceania, and Central and Western Sub-Saharan Africa (Monasta et al., 2012). Incidence rates of CSOM follow a similar geographical distribution, with the lowest incidence

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/2050571X.2024.2420455

seen in Latin American Andean countries (1.70 per thousand people), followed by high-income Asia Pacific countries (3.02 per thousand people), and highest incidence in Oceania and Central Sub-Saharan Africa. In CSOM however, incidence peaks in the first year of life (15.4 per thousand) (Monasta et al., 2012).

A higher burden of disease is seen amongst Indigenous groups globally (Gunasekera, Haysom, Morris, & Craig, 2008). In the Asia-Pacific region, OM is most prevalent in Aboriginal and Torres Strait Islander children, followed by Pacific Islander and Maori children living in New Zealand (Mahadevan et al., 2012), whilst similar prevalence is seen in Inuit populations (Gunasekera et al., 2008). Aboriginal and Torres Strait Islander children are more likely to have earlier onset of OM, as well as experience more persistent and severe disease, with higher rates of tympanic membrane perforation, particularly in remote communities (Jervis-Bardy, Sanchez, & Carney, 2014). Compared to non-Indigenous children, Aboriginal children are three times as likely to have OM, and 1.4 times as likely to have long-term ear and hearing problems (AIHW, 2020). Prevalence of active chronic OM varies between communities, ranging from 10% to 30%, with the World Health Organization classifying a prevalence higher than 4% to be a massive public health problem (Jervis-Bardy et al., 2014; World Health Organisation, 2004). Prevalence of OM in Aboriginal children has shown minimal improvement in more than 30 years (Jervis-Bardy et al., 2014).

In Australia, access to services for OM is limited in rural and remote settings, with access decreasing as remoteness increases (AIHW, 2018). In the past, one in five Aboriginal children living in rural and remote settings waited longer than the recommended guidelines for audiology, and one in eight for ENT services, however significant wait times are also seen in urban settings (Gunasekera, Morris, Daniels, Couzos, & Craig, 2009). Although there are significant differences in severity of disease between Aboriginal and non-Aboriginal children, in practice no significant difference is seen in referrals to audiology and ENT services, where one is to be expected (Gunasekera et al., 2007).

OM predominately occurs during key developmental years and can have detrimental effects on hearing and speech, which can have ongoing impacts throughout life (World Health Organization, 2021). Unaddressed hearing loss at a young age can significantly affect speech and language development as well as cognition, development, and behaviour, with flow on affects to academic outcomes, employability and income later in life (Burns & Thomson, 2013; Su et al., 2019; World Health Organization, 2021). Unaddressed hearing loss can further affect individual's relationships, contributes to isolation and loneliness, as well as poor mental health outcomes (World Health Organization, 2021).

Several systematic reviews have examined the relationship between hearing impairment and its association with health and social outcomes. Children with hearing impairment were found to have more emotional and behavioural difficulties than their peers without hearing impairment, performing worse on the Strengths and Difficulties Questionnaire (SDQ), a measure of behavioural difficulties in children, as well in non-SDQ measures of behavioural difficulties (Bigler et al., 2019; Stevenson, Kreppner, Pimperton, Worsfold, & Kennedy, 2015). Hearing loss is further associated with loneliness and social isolation (Shukla et al., 2020), as well as an increased risk of dementia (Ford et al., 2018). Although no systematic review has been performed in the following areas, untreated hearing impairment is further associated with challenges in listening and communication, language and speech development, cognition, education, employment, mental health, and relationship development (World Health Organization, 2021). A recent data linkage study further shows association between hearing impairment in early childhood and risk of youth offending amongst Aboriginal and Torres Strait Islander children (He et al., 2019).

No systematic review has explored longitudinal associations between OM, resultant hearing loss, and health and social outcomes. This study aims to answer the research question, how does otitis media and resultant hearing loss contribute to long-term health and social outcomes?

Methods

A systemic review was conducted on the long-term health and social outcomes of OM in childhood. This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist, and the protocol was registered in PROSEPRO, the international prospective register of systematic reviews (PROSPERO CRD42023396318).

Search strategy and information sources

The population, exposure, comparison, outcomes, and study type (PECOS) framework was used to develop the search strategy and inclusion criteria. The population was identified as children <18, and exposure as any middle ear infections and its sequelae, including AOM, effusions, CSOM, and tympanic membrane perforations, and resultant hearing loss. Comparators were identified as children with no OM diagnosis, and outcomes as health and social outcomes at least five years following OM diagnosis. Concepts of health were identified by the WHO social determinants of health (Commission on the Soical Determinants of Health, 2008) and the Aboriginal and Torres Strait Islander determinants as identified from 'Beyond

Bandaids: Exploring the Underlying Determinants of Aboriginal Health' (Anderson, Baum, & Bentley, 2007). These included physical health, psychological health, academic outcomes, social function, service use, incarceration, occupation, housing, and cultural connection. Search terms were identified by the researchers and supplemented by validated search filters to identify studies reporting outcomes by social determinants (Prady, Uphoff, Power, & Golder, 2018). A search of the literature was conducted in OVID, Medline, Emcare, Psych Info, CINAHL, and Scopus on 8 September 2022, and repeated on 11 February 2024. Searches were limited to English language, with no limit on date of publication. The search strategy was manually converted for each database, the full search strategy can be seen in Supplemental Material 1.

Eligibility criteria

Studies were excluded if participants had congenital or anatomical factors predisposing to OM, including Down syndrome or cleft palate (Kong & Coates, 2009), as well as hearing loss unrelated to otitis media. Studies reporting outcome measures after a follow-up period of less than five years, or which did not report longitudinal data as defined by the inclusion criteria, were excluded. Non-human, surgical, or microbiological studies, case reviews, cross-sectional studies, case control studies, qualitative studies, and studies not published in English were excluded.

Selection process

Search results were imported into EndNote from databases to facilitate reference importation to Covidence, an online platform for managing the screening and extraction process of systematic reviews (Covidence, 2023). All articles underwent an independent, blinded, two-party review, with all titles and abstracts screened by the first author (RJ) and one of two co-authors (JS, JD). Articles that did not meet the inclusion criteria were excluded with conflicts settled via a consensus discussion amongst the researchers. All full texts were then independently screened by the first author (RJ), and one of the authors (JS, JD, or AM).

Data collection and data items

Data were extracted in Covidence by two independent researchers (RJ, AM) with data consensus determined by the first author (RJ). Study location, methodology, OM criteria, time from OM diagnosis to outcome, study length, analysis method, outcome of interest, outcome group, age group(s) of OM diagnosis, method of recruitment, sample size, nationality, baseline population characteristics, outcome data, whether there was variation found between groups and in what direction, were extracted from all included studies. Given the heterogeneity of outcomes across studies, outcomes were grouped into physical health, psychological, academic, social function, service use, occupation, housing, cultural connection, and others. Study funding source, conflict of interest, aim, and length of study were also extracted. All data which were unavailable in the text were reported as 'not stated'.

Risk of bias assessment

The CASP Cohort Study appraisal checklist (Critical Appraisal Skills Programme, 2018) was used to assess the quality of included studies. Critical appraisal was completed independently by two assessors (RJ, AM) and consensus determined by the first author (RJ). Audiological expertise in the assessment of study quality was provided by a third independent assessment (JD). The checklist was expanded to categorise implication for the local area with options selected from 'can't tell', 'minimal implication', 'some implication', or 'significant implication'; and precision of results selected from 'can't tell', 'not very precise', 'somewhat precise', or 'very precise' to enable better comparison of papers.

Data synthesis and analysis

We intended to complete a meta-analysis however due to clinical diversity, methodological diversity and varying effect measures across all included studies, we were unable to do so. Statistical analysis of included papers is limited due to the variation of effect measures, outcomes assessed, and outcome measures, as well as lack of significance reporting. Direction of effect can be established in all papers, hence vote counting based on direction of effect has been used to synthesise results.

Results

Study selection

The original search strategy identified 4,165 studies (see Figure 1). After removal of duplicates ($n = 1564$), 2601 studies underwent title and abstract screening. Of these, 68 were identified as potentially relevant and underwent full-text review with 43 studies excluded as reported in Figure 1. One full text was unable to be sourced, and 24 studies were included in the review following the first search.

An additional 224 studies were identified and underwent title and abstract screening through the repeat search, with four studies identified for full-text review. Three texts were subsequently excluded due

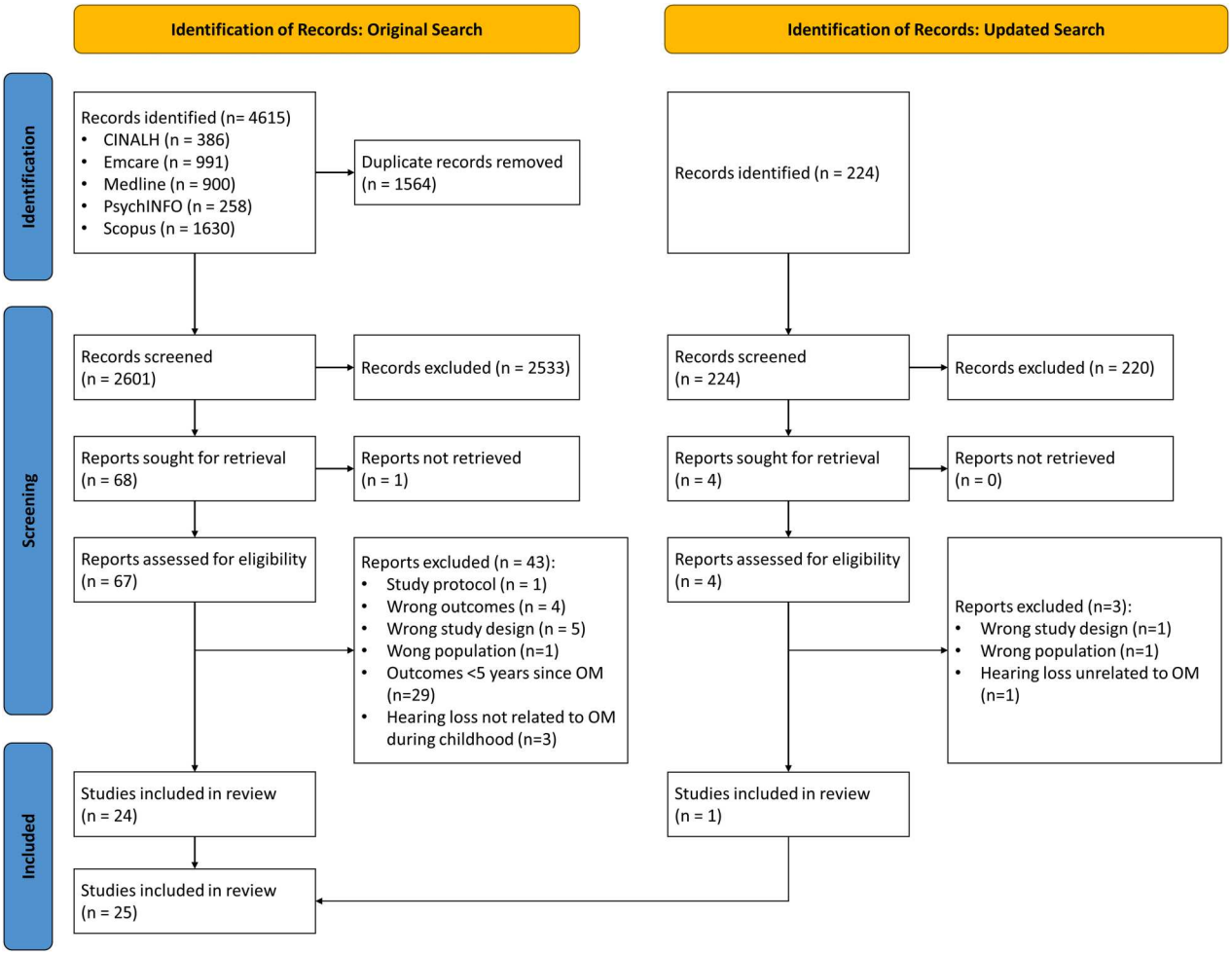

Figure 1. Prisma flow diagram.

to inappropriate study design, inappropriate population, and hearing loss being unrelated to OM respectively, with one text being included for analysis. Following the repeat search this systematic review includes a total of 25 studies.

Included studies

Characteristics of the 25 included studies are presented in Table 1. All studies included were cohort studies. Outcome groups assessed included physical health, audiological function, academic, behavioural, social function, service use, and housing, with only 24% of studies assessing outcomes into adulthood (Aarhus, Engdahl, Tambs, Kvestad, & Hoffman, 2015; Aarhus, Homoe, & Engdahl, 2020; Aarhus, Tambs, Hoffman, & Engdahl, 2016; Mortensen, Nielsen, Fisker, & Nørgaard, 2013; Pearson, Mann, Rees, Davis, & Pearce, 2015; Rudin & Svardsudd, 1987), No studies assessed mental health, cultural connection, employment, or socioeconomic status. Study characteristics varied significantly between papers. Sample size ranged from 14 participants (Gravel, Wallace, & Ruben, 1995) to 51,000 participants (Aarhus et al., 2020). Diagnostic testing for OM varied across papers and included ENT diagnosis (Aarhus et al., 2015; Aarhus et al., 2016; Aarhus et al., 2020; Zumach, Chenault, Anteunis, & Gerrits, 2011; Zumach, Gerrits, Chenault, & Anteunis, 2009; Zumach, Gerrits, Chenault, & Anteunis, 2010), tympanometry (Aithal, Yonovitz, & Aithal, 2008; Brooks, 1986; Gravel et al., 1995; Gravel, Wallace, & Ruben, 1996; Roberts, Burchinal, & Zeisel, 2002; Silva, Chalmers, & Stewart, 1986; Zumach et al., 2009; Zumach et al., 2010; Zumach et al., 2011) parental or patient reported (Bennett & Haggard, 1999; Fougner et al., 2017; Hogan, Phillips, Howard, & Yiengprugsawan, 2014; Kaplan, Fleshman, Bender, Baum, & Clark, 1973; Nittrouer & Lowenstein, 2024; Rudin & Svardsudd, 1987) and hospital records (Kaplan et al., 1973; Majerus et al., 2005; Mortensen et al., 2013; Žargi & Boltežar, 1992). The method of diagnosis was not stated for two papers (Paradise et al., 2007; Ruben, 1999). Of the papers, 76% used OM diagnosis in children <5 years of age with 16% using diagnosis <1 year of age (Gravel et al., 1995; Gravel et al., 1996; Kaplan et al., 1973; Ruben, 1999). Finally, limited recent studies were identified from the literature, with only 8 of the 25 studies included from the last 10 years (Aarhus et al., 2015; Aarhus et al., 2016; Bennett & Haggard, 1999; Fougner et al., 2017; Hogan et al., 2014; Hogan

Table 1. Characteristics of included studies ($n = 25$).

Study			Population		Exposure		Outcome			Significance
Author, Year	Study Design	Country	Sample Size	Source of Participants	Age of OM (years)	OM Diagnosis	Follow-up (years)	Outcome Group	Specific Outcome	Outcome Significance
Aarhus et al. (2015)	cohort	Norway	32430	School Screening (SHINT Study)	7, 10, 13	ENT dx; parent reported	20–56	Physical health	Tinnitus	No difference
Aarhus et al. (2016)	cohort	Norway	21962	School Screening (SHINT Study)	7, 10, 13	ENT dx	10–44	Physical health	Dizziness	Worse
Aarhus et al. (2020)	cohort	Norway	51626	School Screening (SHINT Study)	7, 10, 13	ENT dx	22–62	Physical health	Immune mediated inflammatory disorders; Otovestibular disease	Worse
Aithal et al. (2008)	cohort	Australia, Tiwi Islands	18	Selected from communities on Melville and Bathurst Island	NS	Otoscopic evidence at time of outcome	NS	Academic	Speech/phenome and consonant recognition	Worse
Bennett and Haggard (1999)	cohort	UK, England	12000	Birth Cohort	<5	Parent reported	5	Behavioural	antisocial behaviour, neurotic behaviour, hyperactivity, poor conduct. Rutter A rating scale, rutter B rating scale; picture language score, verbal BAS non-verbal BAS	Worse
Brooks (1986)	cohort	UK, England	80	School Cohort	4–5	Tympanometry	12	Academic	headmaster assessment, CSE, GCE, A levels, university degree	No difference
DiSarno and Barringer (1987)	case-control	U.S.A., Inuit	45	School District; Health Records	<5	Tympanoplasty surgery; 4 documented OM episodes <5 with treatment	9–12	Academic	Peabody Individual Achievement Test	Worse
Fougner et al. (2017)	cohort	Denmark	35946	Danish National Birth Cohort	6, 18 months	Parent reported	11	Academic	School performance	No difference
Gravel et al. (1996)	cohort	U.S.A.	74	LIFE Program	0–12 months	Pneumatic otoscopy, > 30% 1st year with OM	5–8	Physical health	peripheral hearing; auditory processing -speech in noise	Worse
Gravel et al. (1995)	cohort	U.S.A.	14	Not Stated	0–12 months	Pneumatic otoscopy, > 30% 1st year with OM	5	Academic	SIFTER, WISC-R, reading and maths skills, Conner's Rating Scale	Worse*
Hogan et al. (2014)	cohort	Australia	8411	Longitudinal study of Australian Children	0/1; 4/5	Parent reported	5	Behavioural; Social Function	SDQ	Worse*
Kaplan et al. (1973)	cohort	U.S.A., Inuit	489	Children studied by the Arctic Health Research Centre in 1960	<1	Parent reported; health records	8 -11	Academic	Verbal and performance intelligence via WISC, the Bender-Gestalt and the Darw A Person test, metropolitan Achievement test	Worse*
Majerus et al. (2005)	cohort	Belgium	40	Department of Oto-Rhino-Laryngology of the University Hospital of Liege Health Records	<3	Health records showing OM for 3 months, with ≥1 perforation with tube insertion	5–8	Physical health	Verbal short term memory, new word learning tasks, phonological processing tasks #	No difference
Mortensen et al., (2013)	cohort	Denmark	18412	Fifth Military Conscription District Registry	<8	Record of OM hospitalisation – ICD- 8 codes 381, 382	10–20	Academic	Boerge Prien test; GCSE	Worse*
Nittrouer and Lowenstein (2024)	Cohort	U.S.A.	117	Local schools and organisations	<3	Parent reported, 6+ OM episodes <3	5–10	Audiological	sustained attention, auditory function, lexical knowledge and phonological sensitivity	Worse*
Paradise et al. (2007)	cohort	U.S.A.	741	Children's Hospital of Pittsburgh, Mercy Hospital of Pittsburgh patients; Paediatric clinic patients	<3	OME <90d bilaterally, <135d unilaterally. Dx method NS.	6–8	Academic; Social Function; Physical health	Woodcock Reading Mastery tests, Oral reading fluency test, Woodcock-Johnson II, Disruptive Behaviour Disorders Rating Scale, Childrens version of the Hearing in Noise test, Comprehensive test of phonological processing	No difference
Pearson et al. (2015)	cohort	UK, England	296	Newcastle Thousand Families birth cohort via NHS register, self-contact	1, 3, 5	Paediatrician	61–63	Physical health	hearing function	Worse

(*Continued*)

Table 1. Continued.

Study			Population		Exposure		Outcome			Significance
Author, Year	Study Design	Country	Sample Size	Source of Participants	Age of OM (years)	OM Diagnosis	Follow-up (years)	Outcome Group	Specific Outcome	Outcome Significance
Roberts et al. (2002)	cohort	U.S.A.	83	Childcare programs	<4	Pneumatic otoscopy, tympanometry	6	Academic	CELF Receptive Language, CELF Expressive Language, WJ Incomplete Words, WJ Letter-Word Identification, and WJ Applied Problems	No difference
Ruben (1999)	cohort	U.S.A.	30	Not Stated	0–12 months	Dx method NS; ≥ 30% 1st year with OM bilaterally	8	Academic; Physical health	SFITOT (school readiness), SMRCAL (sentence recall), SIFTER, speech in noise	Worse
Rudin and Svardsudd (1987)	cohort	Sweden	987	Country Census Bureau	0–18	Patient reported	32–60	Academic; Service Use; Housing; Physical health; Social Function	general health and wellbeing **	Worse*
Silva et al. (1986)	cohort	New Zealand	404	Dunedin Multidisciplinary Health and Development Study	5	Tympanometry, otoscopic examination	6	Academic; Behavioural; Physical health	Hearing loss, Wechsler Intelligence Scale for Children-Revised, Burt Word Reading Test, Rutter Child Scales A and B for parents and teachers respectively	Worse*
Žargi and Boltežar (1992)	cohort	Slovenia	62	University Department of Otorhinolaryngology and Head and neck Surgery patients	<2	Medical records; parental interview	6–10	Academic; Physical health	Wechsler's Intelligence Scale for Children - Revised, Reading and Writing Test according to Sali	Worse*
Zumach et al. (2009)	cohort	Netherlands	55	MOMES^	<2	Otoscopy by otologist and audiologist; tympanometry	5–7	Audiological	Speech in Noise test	Worse
Zumach et al. (2010)	cohort	Netherlands	65	MOMES^	<2	Otoscopy by otologist and audiologist; tympanometry	5–7	Audiological	Language development	No difference
Zumach et al. (2011)	cohort	Netherlands	54	MOMES^	<2	Otoscopy by otologist and audiologist; tympanometry	5–7	Audiological	speech identification and discrimination	Worse

*A difference was found in at least one outcome measure, but not all.

^ Children from the Maastricht Otitis Media with Effusion Study (MOMES) at the Maastricht University Medical Centre.

**diabetes mellitus, intermittent claudication, gall bladder disease, peptic ulcer, pancreatitis, malignant disease, hypertension, myocardial infarction, stroke, smoking status, tobacco consumption, marital status, education, sick days, numbers of doctors' appointments, days in hospital, hearing, memory, physical fitness, appetite, temper, energy, patience, sleep, marital situation, domestic situation, financial circumstance, complaint score, indoor activities alone, indoor activities socially, outdoor activities alone, outdoor activities socially

#Central auditory processing (speech-in-noise, dichotic listening, masking level difference, pitch and duration discrimination); language tasks (speeded nonword identification task, phonological awareness, receptive vocabulary, productive vocabulary); verbal short-term memory tasks (Immediate serial recall of word and nonword lists, Immediate serial recall for high- and low-frequency word lists, Immediate serial recall for high- and low-imageability word lists, Rhyme and semantic category probe tasks); word and nonword paired associate learning tasks.

et al., 2014; Mortensen et al., 2013; Nittrouer & Lowenstein, 2024; Pearson et al., 2015).

Study location and populations assessed varied across papers. Seven studies recruited participants from school or childcare (Aarhus et al., 2015; Aarhus et al., 2016; Aarhus et al., 2020; Brooks, 1986; DiSarno & Barringer, 1987; Nittrouer & Lowenstein, 2024; Roberts et al., 2002), five studies used data from birth cohort data sets (Bennett & Haggard, 1999; Fougner et al., 2017; Hogan et al., 2014; Pearson et al., 2015; Silva et al., 1986), seven recruited from hospitals (Gravel et al., 1996; Majerus et al., 2005; Paradise et al., 2007; Zumach et al., 2009; Zumach et al., 2010; Zumach et al., 2011; Žargi & Boltežar, 1992), two recruited directly from Inuit and Tiwi communities (Aithal et al., 2008; Kaplan et al., 1973), one from military conscription (Mortensen et al., 2013), one from census data (Rudin & Svardsudd, 1987), and two not stated (Gravel et al., 1995; Ruben, 1999). Of the 25 studies included, three were conducted in Australia or New Zealand (Aithal et al., 2008; Hogan et al., 2014; Silva et al., 1986), 8 in the USA (DiSarno & Barringer, 1987; Gravel et al., 1995; Gravel et al., 1996; Kaplan et al., 1973; Nittrouer & Lowenstein, 2024; Paradise et al., 2007; Roberts et al., 2002; Ruben, 1999), and 14 in Western Europe and the UK (Aarhus et al., 2015; Aarhus et al., 2016; Aarhus et al., 2020; Bennett & Haggard, 1999; Brooks, 1986; Fougner et al., 2017; Majerus et al., 2005; Mortensen et al., 2013; Pearson et al., 2015; Rudin & Svardsudd, 1987; Zumach et al., 2009; Zumach et al., 2010; Zumach et al., 2011; Žargi & Boltežar, 1992). No studies were conducted in East Asia, Africa, or Oceania. Only three studies focussed on Indigenous Peoples; one study was conducted with Aboriginal or Torres Strait Islander Peoples (Aithal et al., 2008), and two studies with Inuit populations (DiSarno & Barringer, 1987; Kaplan et al., 1973).

Overall, 28% of papers found no difference between those with a childhood history of OM and those without (Aarhus et al., 2015; Brooks, 1986; Fougner et al., 2017; Majerus et al., 2005; Paradise et al., 2007; Roberts et al., 2002; Zumach et al., 2010), 40% found poorer outcomes for those with a history of OM, (Aarhus et al., 2016; Aarhus et al., 2020; Aithal et al., 2008; Bennett & Haggard, 1999; DiSarno & Barringer, 1987; Gravel et al., 1996; Pearson et al., 2015; Ruben, 1999; Zumach et al., 2009; Zumach et al., 2011) and 32% found mixed results (Gravel et al., 1996; Hogan et al., 2014; Kaplan et al., 1973; Mortensen et al., 2013; Nittrouer & Lowenstein, 2024; Rudin & Svardsudd, 1987; Silva et al., 1986; Žargi & Boltežar, 1992).

Results of syntheses: long-term outcomes

Physical health outcomes

Fourteen studies investigated physical health outcomes. Twelve studies investigated audiological function including auditory processing deficit including speech in noise, tinnitus, oto-vestibular disease, hearing function, speech identification and discrimination, language development and verbal short-term memory (Aarhus et al., 2015; Aarhus et al., 2016; Aarhus et al., 2020; Gravel et al., 1996; Majerus et al., 2005; Nittrouer & Lowenstein, 2024; Paradise et al., 2007; Pearson et al., 2015; Ruben, 1999; Rudin & Svardsudd, 1987; Silva et al., 1986; Zumach et al., 2009; Zumach et al., 2010; Zumach et al., 2011; Žargi & Boltežar, 1992). Of these studies, 11 showed worse audiological outcomes for people with a history of OM (Aarhus et al., 2020; Gravel et al., 1996; Nittrouer & Lowenstein, 2024; Pearson et al., 2015; Ruben, 1999; Rudin & Svardsudd, 1987; Zumach et al., 2009; Zumach et al., 2011). There was no difference in language development (Zumach et al., 2010), new word learning and verbal short-term memory (Majerus et al., 2005). Three studies analysed non-audiological physical health outcomes, including dizziness (Aarhus et al., 2016), immune-mediated inflammatory disorders (IMID) (Aarhus et al., 2020) and common health conditions found in adulthood (Rudin & Svardsudd, 1987). OM as a child was not related to adult incidence of intermittent claudication, diabetes, heart attacks, stroke, high blood pressure, peptic ulcer, gallbladder disease, pancreatitis, cancer (Rudin & Svardsudd, 1987), or IMID overall (Aarhus et al., 2020). There was an association between OM and dizziness (Aarhus et al., 2016), chronic sinusitis, and overall cardiovascular disease (Aarhus et al., 2020).

Academic outcomes

Thirteen papers investigated a broad array of academic outcomes (Aithal et al., 2008; Brooks, 1986; DiSarno & Barringer, 1987; Fougner et al., 2017; Gravel et al., 1995; Kaplan et al., 1973; Mortensen et al., 2013; Paradise et al., 2007; Roberts et al., 2002; Ruben, 1999; Rudin & Svardsudd, 1987; Silva et al., 1986; Žargi & Boltežar, 1992) Aspects of academic achievement assessed included intelligence, literacy, numeracy, school readiness, and education level. Studies used a varied and inconsistent array of tests to assess academic achievement across the studies, including the Peabody Individual Achievement test (DiSarno & Barringer, 1987), school performance (Brooks, 1986; Fougner et al., 2017), the Weschler Intelligence Scale for Children (Gravel et al., 1995; Kaplan et al., 1973; Silva et al., 1986), the Woodcock Johnson test (Paradise et al., 2007; Roberts et al., 2002), and SIFTER (Gravel et al., 1995; Ruben, 1999). In summary, four papers found worse academic outcomes for people with a history of OM (Aithal et al., 2008; DiSarno & Barringer, 1987; Ruben, 1999; Rudin & Svardsudd, 1987), five papers found mixed results (Gravel et al., 1995; Kaplan et al., 1973; Mortensen et al., 2013; Silva et al., 1986; Žargi & Boltežar, 1992), and four papers found

Table 2. Quality assessment of included studies ($n = 25$).

		VALID MEASURE OF			COFOUNDERS		FOLLOW UP^	RESULTS		LOCALISATION		
Paper	Clear aim	Recruitment	Exposure	Outcome	Identified	Included in Analysis	Sufficient	Precision*	Believability	Applicable	Evidence Alignment	Implication**
Aarhus et al., 2015	Yes	Yes	Yes	No	Yes	Yes	Yes	Somewhat precise	yes	Yes	Can't Tell	Some implication
Aarhus et al., 2016	Yes	Yes	No	Yes	Yes	Yes	No	Somewhat precise	yes	No	Can't Tell	Some implication
Aarhus et al., 2020	Yes	Yes	No	Yes	Yes	Yes	No	Not very precise	yes	Can't Tell	Can't Tell	Minimal implication
Aithal et al., 2008	Yes	Can't Tell	No	No	No	No	No	Can't tell	No	Yes	Yes	Minimal implication
Bennett & Haggard, 1999	Yes	Yes	No	Yes	Yes	Yes	Can't Tell	Very precise	yes	Yes	Yes	Some implication
Brooks, 1986	Yes	Can't Tell	Yes	Can't Tell	Can't Tell	No	Can't Tell	Can't tell	No	Can't Tell	Can't Tell	Can't tell
DiSarno & Barringer, 1987	Yes	No	Yes	Can't Tell	No	No	Yes	Not very precise	No	No	Yes	Some implication
Fougner et al., 2017	Yes	Yes	No	No	Yes	Yes	No	Can't tell	No	Yes	No	Minimal implication
Gravel et al., 1995	No	Can't Tell	Yes	Yes	No	No	Can't Tell	Can't tell	No	Can't Tell	Yes	Can't tell
Gravel et al., 1996	No	No	Yes	Yes	No	No	No	Can't tell	No	Can't Tell	Yes	Can't tell
Hogan et al., 2014	Yes	Yes	No	Yes	No	Yes	Can't Tell	Can't tell	yes	Yes	Yes	Minimal implication
Kaplan et al., 1973	Yes	Can't Tell	Yes	Yes	No	No	Yes	Can't tell	No	No	Yes	Can't tell
Majerus et al., 2005	Yes	No	Yes	Can't Tell	No	No	Yes	Can't tell	No	No	Yes	Minimal implication
Mortensen et al., 2013	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Very precise	yes	No	Yes	Minimal implication
Nittrouer & Lowenstein, 2024	Yes	Can't Tell	No	Can't Tell	Can't Tell	No	Can't Tell	Can't Tell	Can't Tell	Can't Tell	Yes	Can't Tell
Paradise et al., 2007	Yes	No	Can't Tell	Yes	Can't Tell	Yes	Yes	Can't tell	No	No	No	Can't tell
Pearson et al., 2015	Yes	Can't Tell	Yes	Yes	Yes	Yes	Yes	Not very precise	yes	Yes	Can't Tell	Minimal implication
Roberts et al., 2002	Yes	Can't Tell	Yes	Yes	Yes	Yes	Can't Tell	Can't tell	yes	No	No	Minimal implication
Ruben, 1999	No	Can't Tell	Yes	Yes	No	No	No	Can't tell	No	No	Yes	Minimal implication
Rudin & Svardsudd, 1987	Yes	Yes	No	No	No	No	Can't Tell	Can't tell	No	No	Yes	Minimal implication
Silva et al., 1986	yes	Can't Tell	Yes	Yes	yes	Can't Tell	Yes	Can't tell	yes	Yes	Yes	Significant implication
Žargi & Boltežar, 1992	Yes	No	No	Yes	No	No	Yes	Can't tell	No	No	Can't Tell	Minimal implication
Zumach et al., 2009	Yes	No	Yes	Yes	Yes	Yes	No	Can't tell	yes	Yes	Yes	Some implication
Zumach et al., 2010	Yes	Yes	Yes	Yes	Yes	Yes	Can't Tell	Can't tell	yes	No	Can't Tell	Some implication
Zumach et al., 2011	Yes	No	Yes	Yes	Yes	Yes	Can't Tell	Can't tell	yes	Yes	Yes	Some implication

* Selected from can't tell, not very precise, somewhat previse, very precise

**Selected from can't tell minimal implication, some implication, significant implication

^ Follow up assessed using the CASP checklist question 6. (a) *Was the follow up of subjects complete enough?* only. Question 6 (b) *Was the follow up of subjects long enough?* has not been reported above due to sufficient longitudinal follow up being an inclusion criterion of this review, and all being assessed as sufficient.

no difference between groups (Brooks, 1986; Fougner et al., 2017; Paradise et al., 2007; Roberts et al., 2002). However, it is challenging to compare results due to the contrasting results seen across studies for certain outcomes due to different measurement tools being used. Three papers found OM had no impact on children's literacy (Fougner et al., 2017; Paradise et al., 2007; Roberts et al., 2002), whilst another found reading and language to be impacted in those with a history of OM and current conductive hearing loss (Kaplan et al., 1973). IQ was assessed in three separate studies using the Weschler's Intelligence scale for Children (WISC) with contrasting results. Žargi and Boltežar (Žargi & Boltežar, 1992) and Gravel, Wallace (Gravel et al., 1995) found no significance between OM and WISC-Revised performance, whilst Kaplan, Fleshman (Kaplan et al., 1973) found children with OM had worse results on WISC, however the assessment was adjusted to better suit the population as determined by the researchers.

Social and behavioural outcomes

Two studies analysed behavioural outcomes (Bennett & Haggard, 1999; Hogan et al., 2014). These papers found a significant difference in behavioural outcomes of children at age 10 years who had a history of OM occurring at, or before, the age of 5. When adjusted for sex and maternal malaise, participants from the most disadvantaged homes were found to be more antisocial. Overall, children with OM were found to be significantly more antisocial, neurotic, inattentive, and clumsy as reported by their parents (Bennett & Haggard, 1999). As reported by their teachers, children from disadvantaged groups were found to be more antisocial compared to their peers from the same SES, and overall, children with OM were found to be more antisocial than their peers without OM (Bennett & Haggard, 1999). Similarly, participants with OM were more likely to have borderline or abnormal psychosocial outcomes on SDQ as reported by their primary caregiver (Hogan et al., 2014). Two additional studies investigated social skills, finding no difference between adults or 9–11-year-olds with a history of OM compared to controls (Paradise et al., 2007; Rudin & Svardsudd, 1987). One study analysed housing and service use. Participants with OM attended the doctor and used more prescription medication over their lifetime than those without OM, however there was no difference in overall health service utilisation, or number of individuals in a household (Rudin & Svardsudd, 1987).

Quality assessment/certainty of evidence

Quality assessment was completed using the CASP cohort checklist (Critical Appraisal Skills Programme, 2018) (see Table 2). The included studies were of generally low quality. 66% of studies did not sufficiently report on recruitment method (Aithal et al., 2008; Brooks, 1986; Gravel et al., 1995; Kaplan et al., 1973; Nittrouer & Lowenstein, 2024; Pearson et al., 2015; Roberts et al., 2002; Ruben, 1999; Silva et al., 1986) or used a method that was prone to bias (DiSarno & Barringer, 1987; Gravel et al., 1996; Majerus et al., 2005; Paradise et al., 2007; Zumach et al., 2009; Zumach et al., 2011; Žargi & Boltežar, 1992). OM exposure validity was able to be assessed in all but one paper (Paradise et al., 2007), with 36% of all studies identified as using an invalid measure of exposure (Aarhus et al., 2016; Aarhus et al., 2020; Aithal et al., 2008; Bennett & Haggard, 1999; Fougner et al., 2017; Hogan et al., 2014; Nittrouer & Lowenstein, 2024; Rudin & Svardsudd, 1987; Žargi & Boltežar, 1992). Outcomes measures varied significantly across all papers, however were generally of good quality, with only 32% of studies identified as using invalid measures of outcomes (Aarhus et al., 2015; Aithal et al., 2008; Fougner et al., 2017; Rudin & Svardsudd, 1987), or providing insufficient information for assessment (Brooks, 1986; DiSarno & Barringer, 1987; Majerus et al., 2005; Nittrouer & Lowenstein, 2024). Forty-eight per cent of studies reported on all important confounding variables (Aarhus et al., 2015; Aarhus et al., 2016; Aarhus et al., 2020; Bennett & Haggard, 1999; Fougner et al., 2017; Mortensen et al., 2013; Pearson et al., 2015; Roberts et al., 2002; Silva et al., 1986; Zumach et al., 2009; Zumach et al., 2010; Zumach et al., 2011), and all but one included these variables in analysis (Silva et al., 1986). Results were unreliable or poorly reported across almost all studies – almost half of the included studies had results which were deemed not believable (Aithal et al., 2008; Brooks, 1986; DiSarno & Barringer, 1987; Fougner et al., 2017; Gravel et al., 1995; Gravel et al., 1996; Kaplan et al., 1973; Majerus et al., 2005; Paradise et al., 2007; Ruben, 1999; Rudin & Svardsudd, 1987; Žargi & Boltežar, 1992), and precision could not be assessed in 68% of studies (Aithal et al., 2008; Brooks, 1986; Fougner et al., 2017; Gravel et al., 1995; Gravel et al., 1996; Hogan et al., 2014; Kaplan et al., 1973; Majerus et al., 2005; Nittrouer & Lowenstein, 2024; Paradise et al., 2007; Roberts et al., 2002; Ruben, 1999; Rudin & Svardsudd, 1987; Silva et al., 1986; Zumach et al., 2009; Zumach et al., 2010; Zumach et al., 2011; Žargi & Boltežar, 1992). Only 36% were deemed to be applicable to the Australian context (Aarhus et al., 2015; Aithal et al., 2008; Bennett & Haggard, 1999; Fougner et al., 2017; Hogan et al., 2014; Pearson et al., 2015; Silva et al., 1986; Zumach et al., 2009; Zumach et al., 2011).

Discussion

Our study is the first systematic review of the long-term outcomes of otitis media and associated hearing loss. For the first time, this systematic review

demonstrates a trend of poorer long-term outcomes for children with a history of OM. More specifically, these children have poorer behavioural health, academic achievement, and audiological health. This review further shows there is a paucity of research on the long-term outcomes of OM and resultant hearing loss. There is a lack of research in populations at high risk, as well as limited studies analysing outcomes in adulthood, with the available research generally of low quality.

No studies were conducted in Asia, Oceania, or Africa, despite being the regions with the highest incidence rates globally (Monasta et al., 2012), and only three studies focussed on Indigenous Peoples. One study was conducted with Aboriginal or Torres Strait Islander Peoples (Aithal et al., 2008), and two studies with Inuit populations (DiSarno & Barringer, 1987; Kaplan et al., 1973), with all three studies of poor quality. In Australia, Aboriginal and Torres Strait Islander children have a significantly higher burden of disease than their non-Indigenous counterparts (Jervis-Bardy et al., 2014), and similar trends can be seen in First Nation's children globally (Gunasekera et al., 2008), yet little is known about the long term implications of this. Further culturally safe research should be conducted with First Nations populations to identify the long-term implications of OM and hearing loss, to allow for targeted service provision and policy.

The literature identified in this review demonstrated children with a history of OM tended to have worse behavioural outcomes at school age than their peers, however no difference in their social skills later in life. Although limited studies explored this connection, these results align with behavioural difficulties that can be seen in children who are deaf and hard of hearing (Bigler et al., 2019; Stevenson et al., 2015) as well as children with slight to mild hearing loss (le Clercq et al., 2020). In this review, a trend of poor academic performance was further seen in 9 out of 13 studies investigating academic outcomes. Both hearing impairment and behavioural problems are associated with poor academic achievement (Idstad & Engdahl, 2019; Järvelin, Mäki-Torkko, Sorri, & Rantakallio, 1997; Kremer, Flower, Huang, & Vaughn, 2016; Lieu, 2004) which may contribute to this finding. Our results further align with a data linkage study examining hearing impairment and early academic achievement in Aboriginal children living in remote communities, a population with a high prevalence of OM (Su, Guthridge, He, Howard, & Leach, 2020). Su, Guthridge (Su et al., 2020) found Aboriginal children in remote communities with a history of hearing impairment are at higher risk of poor academic achievement, compared to those from the same population with normal hearing. Aboriginal children in remote communities of the Northern Territory with hearing impairment were further found to have worse school attendance rates than their peers (Su et al., 2019). Only one identified study investigated academic outcomes in Aboriginal children from the Tiwi Islands with OM, which found they had poorer speech than their peers (Aithal et al., 2008), however this study was of low methodological quality (see Table 2). Given the heterogeneity of measures used to assess academic outcomes, it is challenging to perform cross study comparisons and gain a full impression of the impact of OM on behaviour and academic outcomes, as well as the effect these outcomes have on each other. Further studies should be conducted measuring validated outcomes in at-risk groups to assess the impact of OM in these areas.

Children with a history of OM consistently demonstrated worse audiological function, specifically, auditory processing deficits. Poor auditory processing abilities can present with behavioural issues, and contribute to academic difficulties (Bamiou, Musiek, & Luxon, 2001; de Wit et al., 2016). In classrooms where there is competing noise, children may have issues with inattention and distractibility, whilst due to poor auditory pattern recognition they may have difficulty following instructions, contributing to poor behavioural outcomes, and impacting their ability to engage in the classroom (Bamiou et al., 2001; de Wit et al., 2016). Auditory processing deficits are also associated with poor non-verbal intelligence, language and reading skills, and cognitive function, additionally impacting academic performance (de Wit et al., 2016). This relationship aligns with the trend of poor academic achievement and behavioural outcomes in children with OM as seen in this review.

Several outcomes of interest included in the search strategy were not identified through this systematic review including mental health, unemployment, imprisonment, and socioeconomic status; factors known to be associated with hearing loss, and auditory processing. Hearing loss is associated with depression in children (Theunissen et al., 2011) and later life psychosis (Linszen, Brouwer, Heringa, & Sommer, 2016), unemployment and underemployment, economic hardship, and early retirement, (Emmett & Francis, 2015; Helvik, Krokstad, & Tambs, 2013; Jung & Bhattacharyya, 2012) and socioeconomic status is associated with auditory processing deficits (Carvalho, Novelli, & Colella-Santos, 2015; Tabone, Said, Grech, & Bamiou, 2017). The interrelation of these factors with OM should be explored further.

As OM is a common disease of childhood affecting almost all children (Menzies School of Health Research, 2020) the degree of exposure is important to consider when analysing outcome measures. There was significant variety in exposure measurements across all papers. Many papers used parent or patient-reported history of OM to group participants (Bennett &

Haggard, 1999; Fougner et al., 2017; Hogan et al., 2014; Kaplan et al., 1973; Nittrouer & Lowenstein, 2024; Rudin & Svardsudd, 1987; Žargi & Boltežar, 1992). Several papers screened patients at a single time point without differentiating history, or recurrent exposure (Aarhus et al., 2015; Aarhus et al., 2016; Aarhus et al., 2020; Brooks, 1986; Pearson et al., 2015; Silva et al., 1986). One paper used ear drum pathology at time of outcome to identify cases and controls (Aithal et al., 2008). These measures are unlikely to be reliable, and do not allow for differentiation of severity of disease. Cross-study comparison is significantly impaired by variation in diagnostic criteria, for meaningful comparison alignment of exposure measures should be attempted.

In Australia, OM is a commonly managed condition in primary care. OM makes up 6% of all general practitioner (GP) encounters in children under 15 years of age, and is the 3rd most common problem managed by GPs, after URTIs and immunisations (Britt, Charles, Harrison, & Bayram, 2015). No studies included in this review analysed data from primary care, impairing application to local practice.

Strengths

A key strength of this study is that it is the first systematic review to evaluate the long-term outcomes of OM and associated hearing loss in childhood. This review has given a broad overview of the published literature, and importantly, for the first time, identified key trends and gaps in the literature for further investigation. This review closely adhered to the PRISMA guidelines and was registered in PROSPERO prior to completion. An explicit question was answered, with well-defined inclusion and exclusion criteria. An extensive search was conducted to capture a broad array of outcomes using a search strategy supplemented by validated search filters (Prady et al., 2018). A rigorous review process was undertaken to minimise bias, using two independent reviewers at all stages of screening, and a thorough process of conflict resolution was followed throughout. Although a meta-analysis was unable to be performed, analysis was performed using vote counting as per the Cochrane handbook (McKenzie & Brennan, 2019).

Limitations

Limitations of this study can be seen in the search strategy. The search was limited as only explicit diagnosis of OM was used as inclusion criteria - several studies used hearing loss as a surrogate marker of OM to explore outcomes, with these studies excluded. Given the aetiology of hearing loss can be broad, we believe this was an important measure in ensuring results attained reflect OM-induced hearing loss. Outcomes of interest were specified in the search terms explicitly, and as a result, certain outcomes unknown to the researchers may have not been picked up in the search. Several searches were completed prior to the final search to optimise the search strategy, a literature review was completed prior to creating the search protocol to identify areas of concern, and the WHO social determinants of health were used to identify key outcomes for investigation to mitigate this issue. Limitation is further seen in restricting studies to English only – as discussed previously, areas of high incidence are largely non-English as first language countries, hence key papers may have been missed (Monasta et al., 2012).

There were limitations in the analysis and review process of this study. Due to significant heterogeneity of outcomes assessed no meta-analysis could be completed, limiting cross-study comparison. Vote counting was used for statistical analysis, however this method is limited as it does not provide information on the magnitude of effect, or account for relative size of studies (McKenzie & Brennan, 2019). Bias was potentially introduced due to consensus being completed by one of the extractors when independent data did not align. This bias was minimised however through a thorough review process in the case of conflicts.

Implications for practice, policy, and future research

Findings of this review indicate poor behavioural and academic outcomes for children with a history of OM, along with auditory processing deficits. Given the poor quality of research, definitive implications for policy and practice cannot be determined, however following further research, programs aimed at young children in school with a history of OM may be of benefit to help mitigate the long-term detrimental outcomes seen in this review.

Findings from this review suggest a low-quality body of evidence, with limited evidence in at-risk populations and outcomes into adulthood. Further research should be conducted to fill the gaps identified, specifically studies exploring outcomes into adulthood, long-term outcomes in at-risk populations, and investigation into unassessed measures known to be associated with hearing loss – SES, mental health, and employment. Future research should aim for consistency across exposure and outcome measures to allow for improved cross-study comparison. Following this review, several important questions are worth further exploration. OM is common in childhood, however certain children are more affected, is there a dose–response relationship between OM and the long-term

outcomes seen in this review? Why do some children with OM have poor longitudinal outcomes, and others do not? These questions should be answered to better understand the long-term effects of OM, and to help guide future interventions.

Conclusion

This systematic review has analysed the long-term outcomes of OM and resultant hearing loss and is the first of its kind to do so. This review has identified a trend of poor academic and behavioural outcomes, largely aligning with long-term outcomes of hearing loss, as well as ongoing poor audiological functioning. This review has further identified significant gaps in the evidence including limited recent studies, studies analysing outcomes into adulthood, and studies analysing high-risk populations, including First Nations peoples. Although a highly heterogenous, low-quality body of evidence, this review raises important implications for future practice and research to fully understand the long-term outcomes of OM and hearing loss. Future research should aim to fill the gaps in the literature using consistent exposure and outcome measures, as well as determine if number and severity of OM exposure effects long-term outcomes, to allow for appropriate intervention.

Abbreviations

OM = otitis media
AOM = acute otitis media
CSOM = Chronic suppurative otitis media
IMID = immune mediated inflammatory disorders
SDQ = Strengths and difficulties questionnaire

Disclosure statement

No potential conflict of interest was reported by the author(s).

Availability of data and materials

Search strategies can be found in the Supplementary Material.

Author contributions

RJ designed the search strategy, screened all articles for inclusion and extraction of data, interpreted and analysed the data, and drafted the manuscript.

AM screened articles, extracted data, and contributed to the editing of the manuscripts.

JD facilitated in study design and search strategy, participated in screening of articles, interpretation of data and analysis, and edited the manuscript.

JS oversaw this review, guiding study design and search strategy, interpretation of data and analysis, participated in article screening, and edited the manuscript. All authors read and approved the final manuscript.

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