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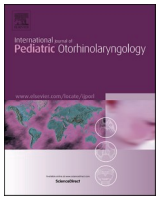

Panel 1: Epidemiology and global health, including child development, sequelae and complications

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ABSTRACT

Objective: To summarise the published research evidence on the epidemiology of otitis media, including the risk factors and sequelae associated with this condition.
Data sources: Medline (PubMed), Embase, and the Cochrane Library covering the period from 2019 to June 1st, 2023.
Review methods: We conducted a broad search strategy using otitis [Medical Subject Heading] combined with text words to identify relevant articles on the prevalence, incidence, risk factors, complications, and sequelae for acute otitis media, otitis media with effusion, and chronic suppurative otitis media. At least one review author independently screened titles and abstracts of the retrieved records for each condition to determine whether the research study was eligible for inclusion. Any discrepancies were resolved by reviewing the full text followed by discussion with a second review author. Studies with more than 100 participants were prioritised.
Results: Over 2,000 papers on otitis media (OM) have been published since 2019. Our review has highlighted around 100 of these publications. While the amount of otitis media research on the Medline database published each year has not increased, there has been an increase in epidemiological studies using routinely collected data and systematic review methodology. Most of the large incidence studies have addressed acute otitis media (AOM) in children. Several studies have described a decrease in incidence of AOM after the introduction of conjugate PCV vaccines. Similarly, a decrease was noted when rates of coronavirus disease of 2019 (COVID-19) were high and there were major public health efforts to reduce the spread of infection. There have been new studies on OM in adults and OM prevalence in a broader range of countries and population subgroups.
Conclusion: Overall, the rates of severe and/or suppurative OM appeared to be decreasing. However, there is substantial heterogeneity between populations. While better use of available data is informative, it can be difficult to predict rates of severe disease without accurate examination findings. Most memorably, the COVID-19 pandemic had an enormous impact on the research and clinical services for otitis media for most of the period under review.
Implications for practice: The use of routinely collected data for epidemiological studies will lead to greater variability in the definitions and diagnostic criteria used. The impact of new vaccines will continue to be important. Some of the lessons learned during the COVID-19 pandemic concerning behaviours that reduce spread of respiratory viruses can hopefully be used to decrease the burden of otitis media in the future. There are still many countries in the world where the burden of otitis media is not well described. In countries where otitis media has been studied over many years, new potential risk factors continue to be identified. In addition, a better understanding of the disease in specific subgroups has been achieved.

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1. Introduction

Otitis media is an inflammation in the middle ear space and is a significant cause of disease around the world. In 2019, there were an estimated 360 million incident cases of otitis media and 119 million prevalent cases affecting humans. In terms of global burden of disease, otitis media ranks 118th for disability-adjusted life years (DALYs) and 62nd for years lived with disability (YLDs) [1].

Otitis media (OM) is best considered a spectrum of disease. Traditionally, it is divided into three main categories - acute otitis media (AOM), otitis media with effusion (OME), and chronic suppurative otitis media (CSOM). Whereas AOM is a bacterial infection in the middle ear, patients with OME have non-purulent fluid behind the tympanic membrane without signs of acute inflammation. The latter condition is extremely common and occurs for example after a cold or after an episode of AOM. Most children have had at least one episode of AOM before starting school. In high income countries, an estimated 10–15 % of young children suffer from recurrent AOM (rAOM) and are considered to be otitis-prone [2,3]. CSOM is a persistent inflammation of the middle ear and mastoid cavity, usually in combination with a tympanic membrane perforation. As estimated in DALYs, the most important global burden of otitis media is due to CSOM with hearing loss. The incidence of the various categories of otitis media varies among different populations. The burden is greatest in Sub-Saharan Africa and smallest in high income countries. Of the risk factors assessed in the global burden of disease data, passive smoking was most important and had an estimated attributable risk of ~5 % of DALYs [1].

Over time, the frequency of severe disease appears to be decreasing. Recent factors that might have influenced the incidence of AOM (and possibly other forms of OM) include: i) changes in treatment guidelines; ii) the introduction of pneumococcal conjugate vaccines (PCVs); iii) the coronavirus disease of 2019 (COVID-19) pandemic; and iv) a greater emphasis on accurate diagnosis.

This panel consisted of eight clinician scientists working within the field of otitis media, who convened in association with the 22nd International Symposium on Recent Advances in Otitis Media. The Panel's focus was on articles on the epidemiology of and sequelae/complications to otitis media which were published since the last Panel reports.

2. Methods

We conducted systematic searches of Medline (PubMed), Embase, and the Cochrane Library for articles in English that were published between 1 January 2019 and 1 June 2023. Studies published outside this time frame were not included. Data from outside this time frame could be included if the publication was new. We only included studies that described the methods used to determine the incidence and/or prevalence, risk factors, complications, and sequelae of the following specific conditions: acute otitis media; otitis media with effusion; and chronic suppurative otitis media. There were no patient age or geographical limits. Articles concerning the impact of coronavirus disease of 2019 (COVID-19) on all types of otitis media were described separately. At least one review author independently screened titles and abstracts of the retrieved records to assess whether the articles fulfilled inclusion criteria. Any discrepancies were resolved by reviewing the full text followed by discussion with a second review author. Cohorts from randomised controlled trials were eligible if they met the other inclusion criteria, but any intervention effects are described elsewhere (Panel 5). The eligible studies were described in evidence tables that recorded the population in the study, the method of assessment, and the key findings.

The initial search string used was ("otitis media"[MeSH Terms] OR ("otitis"[All Fields] AND "media"[All Fields]) OR "otitis media"[All Fields]) AND ("humans"[MeSH Terms] OR "humans"[All Fields] OR "human"[All Fields]) AND "English"[All Fields] AND hasabstract[text] AND ("2019/01/01"[PDAT]: "2023/06/01"[PDAT]) AND ("epidemiologic studies"[MeSH Terms] OR "incidence"[MeSH Terms] OR "prevalence"[MeSH Terms] OR "follow up studies"[MeSH Terms] OR "cohort" [All Fields] OR "prognos*" [All Fields] OR "sequelae"[All Fields] OR "complications"[All Fields] OR "aetiology"[All Fields] OR "risk factors"[MeSH Terms] OR ("risk"[All Fields] AND "factors"[All Fields])).

This initial search was combined with condition-specific search strings: i) ("otitis media, suppurative"[Mesh Terms] OR "acute otitis media"[All Fields]); ii) ("otitis media with effusion"[Mesh Terms] OR "otitis media with effusion"[All Fields]); iii) ("otitis media, suppurative"[Mesh Terms] AND ("chronic suppurative otitis media"[All Fields] OR "chronic otitis media"[All Fields])); and iv) ("COVID-19"[MeSH Terms] OR "COVID-19"[All Fields] OR "SARS-CoV-2" [MeSH Terms] OR "SARS-CoV-2" [All Fields]).

3. Results

The initial search yielded 1,483 potentially relevant articles. After screening titles and abstracts and, in some cases the full text, for which articles actually fulfilled inclusion criteria, a total number of 121 articles were eligible for 142 evaluations (Fig. 1).

3.1. Acute otitis media (AOM)

Fifty-four studies were identified regarding epidemiology and risk factors of acute otitis media (AOM), of which 21 were excluded after screening titles and abstracts, resulting in 33 studies. The main findings in the larger studies (n > 100) are reported in Table 1, with a text summary below.

3.1.1. Prevalence and incidence

Most of the larger studies looking at AOM incidence are comprised of data harvested from health records or medical insurance claims databases. All these studies are retrospective and report on routinely collected data using standard clinical assessment as per published guidelines. Unfortunately, there is a lack of standardisation in the method of reporting, making direct comparisons of incidence/prevalence of AOM between countries difficult. The age groups studied also vary considerably, although most of the recent studies pertain to AOM in children.

Most studies from high income countries (Table 1) report a slight male preponderance for AOM and recurrent AOM (rAOM) [4,5]. They also agree that the majority of children suffering from AOM are <2 years of age [4,6]. A decreased incidence of AOM has been noted after the introduction of PCV(4, 5, 6). The actual incidences vary enormously between countries; from 5/1000 person-years in the Netherlands to 198/1000 person-years in the United States (USA). This 40x difference in incidence probably reflects different risk groups and different service patterns in different countries [4–8]. Only three studies included adult patients and, though less pronounced than in young children, two of them reported that incidences among adults have also fallen since the introduction of pneumococcal conjugate vaccine (PCV) [7,9]. The third study, conducted over only three years, did not find evidence of a decreased incidence among adults [10].

As for studies from South and Southeast Asia (Table 1), several were from South Korea. They showed a reduction in AOM incidence after the introduction of PCV, most pronounced among children aged 3–6 years [11]. Overall, the incidence was highest in children <2 years of age. AOM was most common in December, May and April, when viral upper airway infections are most common. The daily national incidence was 2.9 cases/1000 children [12]. In a large Indian screening study, AOM was found in 5 % of the children [13], compared to as many as 18 % in a screening study from Indonesia [14].

In the Middle East (Table 1), Israeli researchers studied AOM incidence before and after the introduction of PCV. Their findings were similar to those in Western countries and in South Korea in that they showed a significant decrease in AOM post-PCV(15, 16). The annual

incidence of AOM went from ~315/1,000 child-years to ~250/1,000 child-years. Another similar finding was that the majority of children with AOM (and rAOM) were <2 years of age. A hospital-based Turkish study found that among children <18 years, AOM was diagnosed in 5 % of emergency visits and that the incidence decreased by 54 % after the introduction of PCV(17).

Regarding indigenous populations living in high income countries (Table 1), several were performed in Australia. A birth cohort of Aboriginal and non-Aboriginal children <15 years of age found that the overall admission rate for otitis media was almost ten times as high for Aboriginal children (23/1,000 child-years compared to 2.4/1,000 child-years) [18]. During the study, 7.4 % of Aboriginal children were hospitalised for OM compared to only 1.6 % for non-Aboriginal children. The Aboriginal children were also slightly younger. In a cross-sectional study among the Mapuche ethnic group, tympanic membrane perforations were found in 0.2 % of school children aged 9–10 years [19].

In conclusion, AOM incidence appears to have decreased in Western countries after the introduction of PCV. The prevalence of AOM appears to be considerably less in South Asian and Southeast Asian and Middle Eastern countries than in high income countries. The factors responsible for this need to be studied in greater detail.

3.1.2. Risk factors

Several earlier studies have defined risk factors for AOM. A recent review article of RSV-associated OM described 3 major epidemiological studies on AOM that found male gender, attending day care, siblings with a history of recurrent AOM, early occurrence of AOM, and lack of breastfeeding to be important risk factors of AOM(20). We included 13 recent studies that assessed risk factors for AOM among various age groups (Table 1).

Male gender [21–23], siblings [21], day-care attendance [22] and passive smoking [21,24] were all shown to be risk factors for AOM. Breast feeding has been shown to be protective against AOM(21, 22, 25) and, conversely, artificial feeding has been associated with recurrent AOM(26). Keeping a bird has also been shown to be a risk factor for AOM(21). Most of these risk factors were found to have moderate associations-ie. relative risk (RR) or odds ratio (OR) > 0.5 or <2.0.

Early colonisation with AOM pathogens has been associated with an increased risk of AOM (RR 2.6) and with the insertion of tympanostomy tubes (RR 1.8) [27]. Children born in the summer or autumn has been shown to have decreased odds of AOM after the age of 3 years [22]. However, earlier studies has shown that the relationship between season of birth and AOM incidence is controversial [28].

Children with RSV and influenza infections have a greater risk of developing AOM(29, 30). Children with rAOM have more frequent upper airway infections and a greater risk of having bacterial infections compared to children without rAOM(26, 31).

Other authors have studied particulate matter, as an indicator of air pollution and found an increase in AOM episodes on certain days after exposure, though no difference between urban and rural settings [12]. One study assessed the correlation between mealtimes and the likelihood of developing AOM, however, the authors did not mention the age of the children with AOM, so the correlation remains unclear [32].

Adenotonsillar and turbinate hypertrophy have also been identified as risk factors for recurrent AOM(26).

One study investigated the possible association between early antibiotic use and later AOM, but failed to show a correlation between the two [33]. Previous adenotonsillectomy could not be correlated to fewer episodes of AOM later in life [34]. Another study investigated the possible association between dental caries and AOM, but could not find any [35], neither could other authors find an association between colonisation with *Streptococcus pneumoniae* in the first year of life and AOM at 8 years of age [24].

3.2. Otitis media with effusion (OME)

125 studies were identified as potentially relevant to the epidemiology and risk factors of otitis media with effusion (OME). Of these, 94 were excluded after screening titles and abstracts, resulting in 31 studies. The main findings of the twelve largest studies (>100 participants) are reported in Table 2, with a text summary of all 31 studies provided below.

The asymptomatic nature of otitis media with effusion (OME) means that the burden of disease may be underestimated if routinely collected data are used. Studies that include pneumatic otoscopy and/or tympanometry will be more accurate than those only including simple otoscopy.

3.2.1. Prevalence and incidence

Epidemiological studies on OME with >100 participants without underlying specific conditions are presented in Table 2. A study of adult flight crew in Brazil (1607 participants, age range not stated) found that around 10 % had OME at their annual medical check-up. On average, it lasted 8 days [36]. A study of Indonesian school children aged 6–15

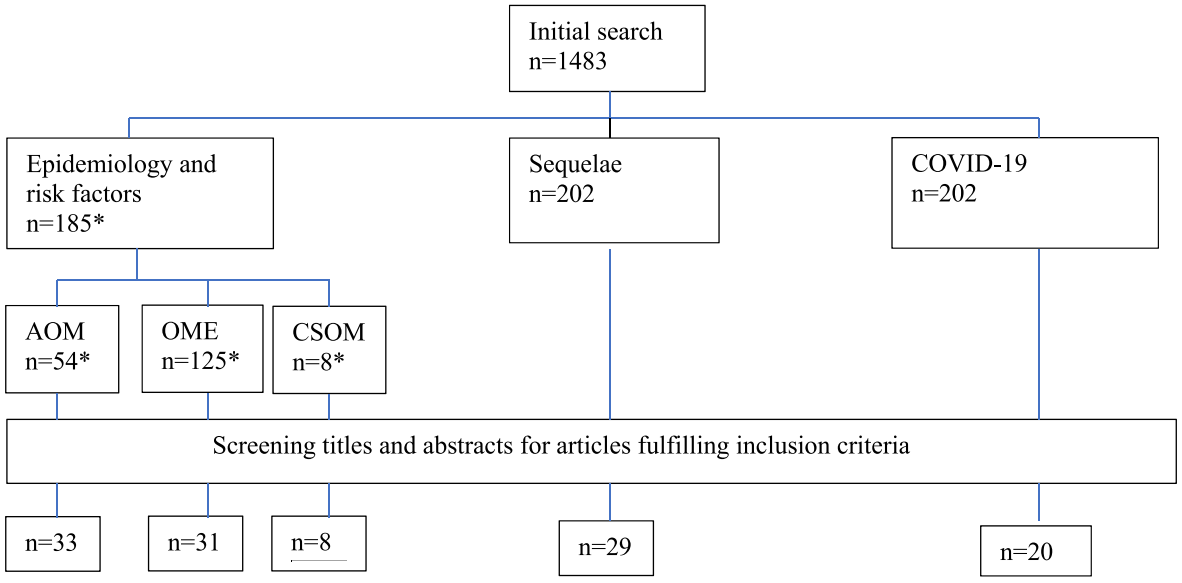

Fig. 1. Study flow chart
*Numbers do not add up, as some studies were relevant for more than one modality of otitis media.

Table 1
Epidemiology and risk factors for acute otitis media (AOM).

Author Year published *Year(s) studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
EPIDEMIOLOGY						
Western countries						
Barbieri 2019 *(Jan 2010-Dec 2015)*	0–14 years *(mean*=44 months*)*	Observational retrospective outpatient study; 125 family paediatricians in Pedianet network (Italy)	ICD-9 code AOM or pharyngitis	120,338	30,394 (25 %) children had AOM 54,943 distinct AOM diagnoses	Trend to increase broad spectrum antibiotic prescription
Christensen 2020	0–3 years	Child cohort studying asthma. Examination at 1 week, 1 month and 3 months (Denmark)	AOM symptoms registered in daily diary until 3 years. TTI data from national register	700	AOM cumulative prevalence 369/555 (66.5 %) infants experienced at least one episode of AOM before 3 years of age	P-values not provided
Gisselsson-Solen 2021 *2000–2019*	20 years+	Retrospective study of Swedish Board of Health and Welfare Statistics Database (Sweden)	ICD-10 code H66	~10 million	Suppurative OM incidence decrease 2005–8 to 2016–9: Outpatients 112.3 to 69.9; RR = 0.62 (0.61–0.63; $p < 0.0001$) Hospital admissions 5.3 to 2.6 RR = 0.49 (0.45–0.53; $p < 0.0001$)	Decrease started before introduction of conjugate pneumococcal vaccine.
Hu 2022 *1998–2018*	0–18 years	Retrospective observational cohort of administrative claims databases (IBM Marketscan commercial/ Medicaid) (USA)	AOM incidence (episodes per 1000 person years) by ICD-9-CM: 382.x; ICD-10-CM H66.xx & H67.xx codes	~90 million	AOM incidence decreased: <2 years: 1170.1 to 768.8 2–4 years: 547.4 to 410.3 5–17 years: 115.6 to 91.8	AOM remained common but incidence rates dropped across age ranges after PCV7 and PCV13
Hu 2022 *2014–2019*	0–16 years	InGef healthcare claims database (Germany)	AOM and rAOM diagnoses by primary care clinicians	916,805	327,726 AOM episodes Incl 49,011 (15 %) recurrent episodes	
Mohanty 2023 *(2003–2019)*	<17 years	Retrospective observational cohort using the GP Clinical Practice Research Datalink (CPRD)- Gold which covers ~7 % of UK population (UK).	AOM incidence by READ diagnostic code.	1,500,686 children	Overall AOM incidence 3691/100.000 person-years; children <2 years had the highest incidence. Sharp decline in incidence >5 years. rAOM most common in children 2–4 years of age (332/100.000 person-years). AOM incidence fell by 55 % during the study period.	Did not include infants <1yo.
Nasreen 2022 *2005–2018*	Children and adults	Retrospective observational cohort using the Ontario and British Columbia administrative database (Canada).	ICD-9 & ICD-10-CA and physician billing coding in health administrative data	Total cases of AOM ~ 10 million over 14 years.	AOM incidence decreased: 4192/100,000 to 3178/ 100,000	
Rijk 2021 2015–2018	>15 years	Retrospective observational cohort using the Dutch Julius General Practitioners Network database (The Netherlands)	National health care database	6,667 cases of AOM over ~1.2 million person years.	Incidence 5.3/1000 person-years. Most common among 15–39 years. No decrease after PCV.	
Thomas 2021 *2017–2018*	0–10 months	Prospective birth cohort from a single primary care study clinic in Turku during RSV season (Finland)	RSV: 2 specimens with nasopharyngeal swabs for any symptoms AOM: MEE on pneumatic otoscopy, signs of inflammation of tympanic membrane & 1+sign of acute infection.	431	AOM: 103/134 infants (76.9 %) with RSV (within 14 days of RSV detection)	Burden of RSV in first year of life was main focus of study.
South & Southeast Asia						
Anggraeni 2019	6–15 years	Cross-sectional, population-based study (Indonesia)	Screened by pneumatic otoscopy and pure tone audiometry	7005 children	AOM diagnosed in 17.5 %	
Appanaitis 2020 *2011–2012*	5–12 years (mean 8.8 years)	Secondary analysis of data from Ministry of Health School Health Programme Physical Examinations Screenings collected in 2011. Both urban (60 %) and three quarters public schools (Palau, Micronesia)	Team of clinical and public health professionals from Ministry, including Specialists from Ministry's Ear, Nose and Throat Clinic using Tympanometry (Type B and C = abnormal)	831 children (31 % school enrolment)	OM by tympanometry Type A = 71.1 % Type B = 17.0 % Type C = 11.9 %	Type of OM not described, so may be predominantly OME.

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Table 1 (*continued*)

Author Year published *Year(s) studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
Gupta 2021 *(2013–2019)*	Age not stated.	Retrospective data analysis from the social business Shruti program. Screening conducted in urban and rural slums across many states in India (India)	Video-otoscopic images plus audiometry linked to an android phone (ENTraview, Medtronic).	Screening of 810,746 (265,165 with ear problems)	AOM diagnosed in 1.5 % of the children (12,729 children). Of these children slightly more than half had suppurative AOM.	CSOM in 6 %, hearing impairment in 4 %, and wax impaction in 19 %.
Kim 2020 *2012–2017*	0–12 years	Data for patients in 2012, 2015, 2017 from Health Insurance Review and Assessment Service's Big Database (Korea)	Korean Standard Classificaiton of Disease system corresponding to H66.0; H66.90A and H66.91A	981,056 patients	AOM prevalence rate per 1000: Decrease from 152.7 in 2012 to 137.4 in 2017	0–2 years specifically: 395.5.5 to 419.3
Park 2021 *2008–2015*	0–10 years	National Health Insurance Service claims data and Korean National Institute of Environmental Research regional air pollution data (Korea)	ICD-10 codes H65.0, H65.1, H66.0	169,080	AOM daily incidence: 2.9 per 1000 children	
Samson 2020	0–8 years	Birth cohort follow up for 8 years in rural development block covering 90 villages. Monthly follow-ups until 2 years of age. This study was a one-off follow-up at 8 years of age (India)	OM: First author examination with otoscopy with diagnostic criteria applied (AOM = earache, fever and URTI with bulge or opacification of tympanic membrane with congestion or perforation	107/210 babies in original cohort	OM prevalence at 8 years: Any OM = 15/107 (14 %) CSOM = 2/107 (1.9 %) OME = 5/107 (4.7 %)	Also included in OME and CSOM review.
The Middle East						
Marom 2021	0–10 years	Retrospective study using a health insurance database. (Israel)		270,137 children	AOM slightly more common in boys (52 %). 71 % of children with AOM were <2 years. Annual incidence before PCV 315–317/1000 children compared to 247/1000 post-PCV. Largest decrease in children <1 year. 31 % had rAOM, 74 % of whom were <2 years and 55 % of whom were boys. The risk of developing rAOM decreased post-PCV; RR 0.89, 95 % CI 0.88–0.91, p < 0.001.	
Soysal 2020 *(2011–2017)*	1 month-18 years	Retrospective follow-up at emergency department (Turkey)	Clinical diagnosis	>500,000 emergency visits	4.6 % of children attending an emergency clinic had AOM and 49 % were <5 years. After PCV, AOM incidence fell by 54 % in children <5 years (p = 0.0013). The incidence of rAOM increased.	
Ziv 2019 (2005–2014)	0–8 weeks	University Medical Centre (Israel)	Retrospective review of 303 children <2mo who were admitted to hospital with AOM- clinical diagnosis.	182 babies with clinical diagnosis of AOM plus tympanocentesis.	Overall prevalence of AOM in babies <8 weeks 0.7 %. Incidence decreased from 2013 (PCV7 introduced in Israel in 2009, PCV13 in 2010).	AOM diagnosis very challenging in this age group.
Indigenous populations in colonised countries						
Tapia 2021 *1998–2012*	Group 1: 3–17 years (10 years) Group 2: 3–18 years (9.1 years)	Cross sectional study of 10 schools with over 85 % Mapuche ethnic group	Three otorhinolaryngologists and residents using light otoscope	530 and 537 schoolchildren, respectively	1/530 (0.19 %) tympanic membrane perforation (AOM not stated) 1/537 (0.19 %) tympanic membrane perforation (AOM not stated)	Also included in OME table.
Westphal 2019	0–15 years at hospitalisation	Record linkage population based cohort study	ICD-10 for hospitalizations for OM or TTI recorded as a surgical procedure	221.588 children hospitalised at least once	OM hospitalisation: Aboriginal children 23.3/1,000 (22.8–24.0 vs non-Aboriginal 2.4/1000 (2.3–2.4)	
RISK FACTORS						
Appanaitis 2020	5–12 years	Screening data	Tympanometry as surrogate marker for AOM.	831	No association between abnormal tympanograms and dental caries	

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Table 1 (*continued*)

Author Year published *Year(s) studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
Christensen 2020 *(2008–2010)*	<3 years	Prospective follow-up of birth cohort	Daily diary until 3 years of age. NPH samples 1 week, 1 month, 3 months. Airway fluid 1 month		*S. pneumoniae* colonisation at 1 month associated with increased risk of AOM; RR = 2.63 (1.25–5.54). *H. influenzae* colonisation at 3 months associated with an increased risk of tympanostomy tube insertions RR = 1.79 (1.18–2.74) Stepwise increases of IL-17 in children with more AOM episodes.	
Ciprandi 2020	3–10 years (mean = 5.8 years)	Cross-sectional Otorhinolaryngologic clinic of children presenting with upper resp symptoms (Italy)	rAOM defined as 3 AOM episodes in 6 months or 4 in a year	1002	RAOM more common in boys. Breast feeding decreased the risk of AOM (OR 0.62; 0.43–0.9; 0 = 0.01170 Children without recurrent respiratory infections were less likely to have recurrent AOM (0.33; 0.24–0.4; $p < 0.0001$) Adenoid and tonsillar hypertrophy were risk factors for recurrent AOM (OR = 1.36; 1.03–1.81; $p < 0.03$ and OR = 2.97; 2.05–4.45; $p < 0.0001$) Turbinate hypertrophy also a risk factor for recurrent AOM ($p < 0.0001$).	
Kamphorst 2023 *(2012–2019)*	<6 years	Birth cohort followed for 6 years			Antibiotic use in the first week of life was not associated with AOM at 4–6 years of age.	
Kaur 2017	6–36 months	Cohort study (USA)	Clinical diagnosis + tympanocentesis	615	Increased risk of *AOM* in children with day care attendance (OR 2.8, $p < 0.0001$), non-Hispanic white race (OR 2.9, $p = 0.005$), atopy (OR 2.3, $p < 0.001$), siblings and a family history of AOM (OR = 3.7, $p = 0.003$). Early onset of AOM was linked to more AOM epsiodes in the future ($p < 0.0001$) Increased risk of *rAOM* in males (OR 2.6, $p < 0.006$), those with a family history (OR 2.2, $p = 0.01$, and day care attendance (OR 3.2, $p = 0.0002$).	
Kim 2021	1–9 years	Case-control study with children who had undergone adenotonsillectomy compared to children who had not undergone this surgery.			No association between previous adenotonsillectomy and fewer episodes of AOM.	Large age range, many were older than the typical AOM child
Park 2021 *(2008–2015)*	<10 years	Studied the effect of particulate matter on the number of AOM episodes			AOM more common on the first, second and fifth days of exposure to particulate matter < microns and 10 μ diameter. No difference between urban and rural areas	
Pichichero 2021	6 months-5 years	Cohort study at private pediatric practice in a middle class mixed demographic suburb. (Response rate "about 50 %") (United States)	Clinical findings + middle ear cultures at tympanocentesis	39 with rAOM, 246 without rAOM	Children with rAOM had an increased frequency of pneumonia ($p = 0.001$), sinusitis ($p = 0.026$) and influenza ($p = 0.002$). In both groups, visits for respiratory infections at	

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Table 1 (*continued*)

Author Year published *Year(s) studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
					6–18 months predicted more frequent visits at 18–60 months. Children without rAOM were more likely to have viral infections.	
Samson 2020 *(2018)*	8 years	Follow-up of a birth cohort at 8 years of age			Parental smoking increased the odds of AOM in 8-year olds (OR = 4.41 (95 %CI = 1.38 to 14.08; p = 0.012)	
Scholtz 2019 *(2012–2014)*	2–5 years	Data from health insurance database (Germany)			The mean influenza-attributable AOM rate was 3.3 % (range: 1.99 %–14.41 %). When compared with controls, children with influenza developed AOM up to 14 % more often than those without.	
Thomas 2021 *(2017–2018)*	0–10 months	Followed a cohort of babies over a 10 month period (RSV season).		431	AOM was diagnosed in 103 (76.9 %) of 134 infants with RSV infection, making AOM the most common complication to RSV infection.	
Van Ingen 2020 *(2002–2006)*	2 months-6 years	Prospectively studied birth cohort (the Netherlands)		7863	Between 2 and 4 years of age, AOM was more often diagnosed in boys than in girls. Siblings increase the odds of AOM (OR 1.07 per sibling; p < 0.001) Passive smoking increased the risk of AOM (OR 1.12; p = 0.013) Keeping a bird as a pet increased the odds of developing AOM in children aged 2 months to 6 years *(OR=1.25 (1.05, 1.50)* p = 0.013)	
Van Ingen 2021 *(2002–2006)*	2 months-6 years	Prospectively studied birth cohort (the Netherlands)		7863	Boys more likely to suffer from AOM before the age of 3, OR: 1.26, CI: 1.11–1.43. Day-care associated with early onset of AOM (OR: 1.31, CI: 1.06–1.60) Breast feeding was protective against AOM both below 3 years of age (OR = 0.78; p = 0.003) and after (OR = 0.7; p = 0.002). Birth in the summer or autumn was associated with a decreased risk of AOM.	

years (7005 participants) found that otitis media was only present in 2.5 % and that <0.5 % of children had OME(14). In contrast, a Korean study found OM in 27 % of 472 children aged 7–12 years [37].

The most important data on OME in Africa was published as a systematic review of 38 studies (with over 40,000 participants) [38]. The highest prevalence (~10 %) was in North Africa and the lowest (~2 %) was in East Africa. They found no evidence that the prevalence was changing. In the studies that also assessed risk factors for OME, cleft palate was found to be most important.

A study compared 2 surveys conducted 14 years apart of mainly Mapuche Indigenous Chilean school children (total participants 1,067). Prevalence rates of OME were low in both surveys (8 % and 2 %) and much lower than previously described in other Indigenous populations [19]. A child cohort in Indian were followed up in their 8th year of life. The prevalence of OME at that age was ~5 % [24].

There were new prevalence studies in China [39], the Balkans region [40], and Vietnam [41]. The Chinese study found OME in 13 % of 189 children. The Balkans region study found OME in 22 % and type B tympanograms of 14 % of 4,768 children across 9 countries. The Vietnamese study found OME in 17 % of 274 children. All three studies also assessed risk factors. Previous respiratory tract infection, living in a rural area, and attending childcare were found to be risk factors in at least two of these studies.

There were a range of prevalence and incidence studies in subgroups of children with conditions that are either known or thought to increase the risk of otitis media with effusion. These included: i) adenoidal enlargement in 108 Ugandan children with OME prevalence of 29 % of 216 ears [42]; ii) non-syndromic craniosynostosis in 113 USA children with concurrent OME in 36 % [43]; iii) fetal alcohol spectrum disorder in 20 children (from two small studies) with chronic OME in 88 % [44];

Table 2
Epidemiology and risk factors for otitis media with effusion (OME).

Author Year published *Year(s) studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
EPIDEMIOLOGY						
Anggraeni 2019	6–15 years	Prospective survey from rural and urban areas (Indonesia).	Hearing screening in schools and otoscopy and tympanometry and audiometry in children who failed screening.	7,005	172 children (2.5 %) had OM of whom 15 % had OME (26 children). 12/26 children with OME had hearing loss.	See also AOM and CSOM tables.
Byeon 2019 ***2015***	7–12 years	Part of the Korean National Health and Nutrition Examination Survey (South Korea).	ENT specialist otoscopy and tympanometry.	472	126 of 472 (27 %) had OM. Purpose of the study was to investigate allergic rhinitis as a risk factor [OR 2.2 95 %CI 1.3, 3.1].	Did not specify whether all otitis media was OME.
Choffor-Nchinda 2020	All ages. Most studies (20/27) included children <8yo. 2 studies included adults.	Systematic review of 38 studies with 27 included in meta-analysis (Africa).	Varied between studies- simple otoscopy 2 studies, simple + pneumatic otoscopy 3 studies, simple otoscopy + tympanometry 11 studies, simple + pneumatic otoscopy + tympanometry 9 studies, unclear 2 studies.	40,331	The overall prevalence of OME in Africa was 6 % (95 % CI: 5 %–7 %; $I^2 = 97.5$ %, $P < 0.001$). The prevalence was 8 % in children and 2 % in adolescents/adults. North Africa had the highest prevalence (10 %) followed by West and Southern Africa (9 % and 9 % respectively), Central Africa (7 %) and East Africa (2 %). Cleft palate was the strongest predictor of OME (OR: 5.2; 95 % CI: 1.4–18.6, $P = 0.02$). Other risk factors were: i) type 2 diabetes; ii) HIV; and iii) allergy.	OME prevalence was similar to rates in high income country settings. There was no major variability in prevalence over the last four decades.
Kalcioglu 2021 ***April-May 2018***	4–7 years	Prospective survey across 9 countries of school children (Alabania, Bosnia Herzegovina, Kirgizistan, North Macedonia, Serbia, Tajikistan, Turkey-Erdirne, Turkey- Istanbul, Ukraine, Uzbekistan).	ENT specialist otoscopy, tympanometry, and acoustic reflex plus risk factor questionnaire. Provided data on different algorithms to diagnose OME.	4,768	OME in 1,072/4,768 (22 %). Variation between countries was substantial (6 %–46 %). Type B tympanogram prevalence was 14 %. Significant risk factors for OME were: i) secondhand smoke; ii) low level education of mother; iii) mother's occupation; iv) history of URTI in last year; v) age <7yo.	First large-scale population survey from this region. Excluded children with perforation and/or otorrhea.
Pinto 2019 ***Sept 2014-May 2015***	Not stated.	Prevalence study. Aircraft crew annual flight medical exam included 10 % pilots, 10 % co-pilots, and 80 % flight attendants (Brazil).	Tympanometry- diagnosis of OME by presence of type B tympanogram.	1607	155 (9.65 %) were diagnosed as having otitis media with effusion. The mean time to resolution of the otitis media was 8.23 (±3.02) days.	First large study of OME in aircraft crew.
Tapia 2021 ***Nov 1998 April 2012***	3–17 years (1998) 3–18 years (2012)	Cross-sectional surveys in 1998 and 2012 of school children with high proportion (~85 %) of Mapuche Indigenous ethnic group (Chile).	Otoscopy by ENT specialist.	1,047 (530–1998) (537–2012)	In 1998, 94 ears had OME (9 %). In 2012, 24 ears had OME (2 %). Despite lower rates of OME, more symptomatic ear disease (otalgia and hearing loss) in second survey (increased from 5 to 17 %). No change in myringosclerosis (~7 %).	Lower prevalence of OM compared to Northern First Nations populations. Only 1 ear had a discharging perforation in both surveys.
Satoh 2021 ***2016***	4m-2years	Random sample of children from 27 communes in Nha Trang region (Central Vietnam),	ENT specialist video pneumatic otoscopy and risk factor Questionnaire, and nasopharyngeal swabs.	274	47/274, 17 % had OME. 11 % bilateral and 6 % unilateral OME. 1 child had otorrhea. No children with AOM, atelectasis, or perforation. Significant risk factors for OME were: i) daycare attendance; ii) living in rural area; and iii) pneumococcal carriage if < 12mo.	Part of baseline assessment before conjugate pneumococcal vaccine trial.
Yang 2020 ***2018***	4–8 years	Prospective survey across 3 regions of children in kindergarten or school (China).	1st stage = ENT specialist exam with video otoscopy and risk factor Questionnaire. 2nd stage = otoscopy plus tympanometry plus audiometry.	189	OME in 25/189 (13 %). Only 6 of 25 children identified in first stage of screening. Significant risk factors for OME were: i) > 3 URTIs per year; ii) dining in childcare; and iii) living in a rural area.	Highlighted the lack of epidemiological data from rural areas of China.

(*continued on next page*)

Table 2 (*continued*)

Author Year published *Year(s) studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
RISK FACTORS (some important studies also included in Epidemiology section above)						
Arkan 2019 ***Jan-Oct 2017***	1–16 years	Case control study (Tertiary Referral Centre in Turkey)	Case group having surgery for OME with tympanogram type B/C and ENT surgeon examination. Control group having surgery for another reason and confirmed as no OME by ENT exam.	113 cases and 117 controls.	Iron deficiency anaemia was 18/113 (16 %) versus 4/117 (3 %), p = 0.001. Mean haemoglobin level was 12.2 ±1.2 versus 12.9±1.1, P < 0.001.	Reported as first study to show association with iron deficiency anaemia.
Haksever 2022	4–12 years	Prospective case series (Turkey)	Cases diagnosed with OME by otoscopy and tympanometry. Controls were age and sex matched and no significant history of URTIs or ear disease in last year. Overweight defined as >85 % BMI for age.	204 cases and 267 controls	BMI for females 18 versus 17, p < 0.001. BMI for males 18 versus 16, p < 0.001. 52/204 cases (25 %) were overweight compared with 20/267 controls (7 %). Odds ratio not provided but ~4.2.	No adjustment for other risk factors.
Tawab 2021 ***2015–2017***	3–12 years	Prospective case series (Oman)	Chronic OME in all children diagnosed clinically with tympanometry and confirmed at operation. Adenoids graded 1–4 at endoscopy. Middle ear (ME) fluid classified as serous or mucoid.	100	Grade 4 adenoids (with extension to soft palate) compared with grade 2 adenoids. All grade 4 adenoids associated with mucoid ME fluid. Nearly all grade 2 adenoids associated with serous ME fluid, p = 0.000. Tympanograms were more likely to be type B with grade 4 adenoids; R ear 58 % vs 7 %; L ear 92 % vs 38 %.	No adjustment for other risk factors.
Walker 2019	3–4 years	Prospective case series (New Zealand)	All children having placement of tympanostomy tubes. Cases had chronic OME confirmed during surgery. Controls had no OME >1 m over last year. Nasal swabs taken 16S rRNA gene amplification.	73 cases and 105 controls	The nasal swab microbiology was less diverse in the chronic OME children: Shannon Diversity Index 1.62 [0.8] vs 1.88 [0.8], p = 0.046. Chronic OME children also had higher densities of otopathogens. Corynebacterium dominant aOR 4.2 [1.7, 10.4]. Streptococcus dominant aOR 3.1 [1.1, 9.1]. Moraxella dominant aOR 4.7 [1.7, 12.8].	Clinical implications of this study are currently unclear.

primary ciliary dyskinesia in 121 children with OME in 66 % [45]; obstructive sleep apnoea in 1,021 hospitalised Chinese children with OME in 17 % [46]; and failed newborn hearing screening (NBHS) in 80 US infants with OME in 59 % [47]. There were also smaller studies (<100 participants) of congenital CMV with OME in 43 % [48] and cleft palate with OME in 91 % [49].

3.2.2. Risk factors

Several epidemiological studies also described the association with selected risk factor (see Table 2, Epidemiology section). The risk factors for OME identified in these studies were: i) living in a rural area [39,41]; upper respiratory tract infection (URTI) in last 12 months [39–41]; childcare attendance [39,41]; secondhand smoke [40]; maternal education and/or occupation [40]; allergy [36,37]; and cleft palate [37].

The evidence table provides information about the largest specific risk factor studies completed in the 4 years up to June 2023 (see Table 2, Risk factors section). There have also been several new systematic reviews of the association between OME and the following risk factors (not included in Table 2): *Helicobacter pylori* in adenoids - OR 2.75 estimated from 11 studies [50]; allergy - studies supported a link between allergy and OME, but it has not been deemed appropriate to perform meta-analysis [51]; gastro-oesophageal reflux - estimated OR 4.5 [95 % CI 2.4, 8.4] from sample size of 1,961 children [52]; laryngo-pharyngeal reflux-no estimate possible from 26 studies [53]; and cow's milk protein allergy-no estimate possible from 4 studies [54]. There has also been a systematic review of the risk factors associated with multiple tube insertion [55].

An Indonesian case control study (using 92 of 2,016 survey children and included a careful ENT assessment) found an association with laryngopharyngeal reflux (OR 3.3) but no association with adenoidal hypertrophy or allergy [56]. There were several targeted risk factor studies assessing the association with iron deficiency- RR 5.4(57), childhood obesity- OR 3.4 for recurrent OME(58), Helicobacter pylori-no association found [59], and adenoidal hypertrophy-strong correlation with size of adenoid and OME and mucoid effusions [60].

A case control study compared 77 children with chronic OME with 105 children without disease. The chronic OME children had a lower Shannon diversity index and were more likely to be colonised with otopathogens [61]. A Korean study looking at risk factors for multiple tube insertions for OME found severe retraction, middle ear discharge, and early recurrence of OME to be important predictors [62]. A study of 100 children with adenoidal hypertrophy and chronic OME found that children with grade IV enlargement were most likely to have mucoid middle ear fluid and a type B tympanogram [60].

A small study compared 42 Nigerian children with cleft palate with 42 children without cleft palate. The size of the cleft was the most important predictor of OM(63).

3.3. Chronic suppurative otitis media (CSOM)

Eight studies that addressed chronic suppurative otitis media (CSOM) were identified. Four studies described the prevalence and/or incidence of disease and four studies described the associated risk factors. All 8 studies are included in Table 3.

3.3.1. Prevalence and incidence

The main findings from the four studies are illustrated in Table 3. All studies were on children, and were performed in India, Indonesia and Zimbabwe. CSOM was present in 0.4–5.2 % of the children [14,64–66]. One study investigated how many children had CSOM related hearing loss and found that this was present in 37/10,000 children [14].

Table 3
Epidemiology and risk factors for chronic suppurative otitis media (CSOM).

Author Year published *(Year studied)*	Age range (mean)	Study design; sample (country)	Diagnostic technique *(examiner)*	Sample size	Findings (95 % Confidence Intervals)	Notes
EPIDEMIOLOGY						
Anggraeni 2019	6–15 years	Prospective survey from rural and urban areas in Indonesia	Hearing screening in schools and otoscopy and tympanometry and audiometry in children who failed screening	7,005	172 children had OM of whom 67 % has CSOM. OM related disabling HL was found at a rate of 44.2/10,000, mostly due to CSOM (37.1/10,000)	
Bellad 2019 *July-Sept 2018*	6–14 years	Community based descriptive cross-sectional survey in 7 schools in the rural area of Belagavi, South India	Descriptive with otoscopy and medical history	94 schoolchildren	CSOM was present in 36 (5.2 %) out of 694 students. 22 (6.8 %) of them lived in families with overcrowding.	
Kumar 2019 *Nov 2013-Febr2014*	Schoolchildren	Cross sectional study in schools in rural areas in India	Hearing screening and otoscopy	1,312	Ear discharge and dry perforations was found in 0.9 % on the right ear and 1.1 % on the left ear	
Pedersen 2020	4–13 years	Cross-sectional: Primary school children from the rural province of Mashonaland East, Zimbabwe	Video otoscopy and tympanometry	451	Out of 451 examined children, two (0.4 per cent) had CSOM	
RISK FACTORS						
Mohd Khairi 2019	Not presented in abstract	Case-control study Kelantan, Malaysia	Medical history and otoscopic examination. Allergen testing was done by the skin prick test	62 patients with CSOM and 62 controls	Prevalence of allergy in CSOM and control groups were 59.7 % (95 %CI: 47.5, 71.9) and 30.6 % (95 %CI: 19.1, 42.1) respectively. There was a significant association between allergy and CSOM ($p = 0.001$).	Univariate statistics
Kesari 2022	>10 years	Cross-sectional hospital-based survey from Sikkim, India	Hand-held otoscope and questionnaire	497 of whom 170 had CSOM	Upper respiratory tract infections and lower social class was more frequent in CSOM	Only univariate statistics Poor quality
Lasminingrum 2021 *(June- Sept 2020)*	Median 9.00 (6.75–12.00) years	Case contro hospital-based study in Bandung, Indonesia	Haemoglobin (Hb) levels, iron (FE) levels, total iron-binding capacity (TIBC) levels, and ferritin levels	42 children with CSOM and 42 controls	Significant higher OR (3.32; p 0.033) for iron deficiency if CSOM	Univariate statistics
Perez-Herrera 2020	42.2 years (SD: 14.44)	Cross-sectional study in two ORL centers in Bogota, Columbia	Questionnaires focusing on sociodemographic and clinical associated factors, quality of life, and patients' reported costs 0 adults with CSOM diagnosis and 144 control adults. Otoscopic evaluation and audiometric data	200 adults with CSOM diagnosis and 144 control patients without CSOM	The median length of CSOM was 26.13 years (SD: 17.06), and 79.5 % of the COM patients reported otorrhea during childhood (P-value: 0.01). The most frequently reported allergic disease among was allergic rhinitis (26.5 %). CSOM was less frequent in patients with a medium-high socioeconomic status (PR: 0.54; 95 % CI: 0.39–0.72), and more frequent in patients who reported increased ear discharge due to upper respiratory tract infections (PR: 1.69; 95 % CI: 1.68–1.70). The global score of the "Chronic Suppurative Otitis Media Questionnaire-12" showed a difference of 9 points between patients with active and inactive CSOM ($P < 0.001$). Patients spent between 12.07 % and 60.37 % of their household income on expenses related to CSOM.	Univariate statistics

3.3.2. Risk factors

The four identified studies on risk factors for CSOM were from countries in Asia and South America and their main findings are presented in Table 3. Factors that were associated with CSOM were allergy [67], iron deficiency [68] and low socioeconomic status [69]. Quality of life of patients with active CSOM was worse than in those with inactive CSOM. The largest study from Colombia (South America) included adults with a mean duration of CSOM of 26 years [70]. Disease usually started in childhood and was more frequent in adults of lower socio-economic status and those with a history of allergic rhinitis.

3.4. Complications and sequelae of otitis media (OM)

The abstracts of 202 identified articles on complications and sequelae of otitis media (OM) were screened. Of these, 29 studies were regarded as relevant. The main findings regarding the association between otitis media and various complications and sequelae, including hearing loss, are shown in Table 4.

Complications secondary to AOM are rare. A large data study from general practise in the UK assessed the incidence of mastoiditis and AOM-related brain abscesses and found that these occurred in <1/1,800 and 1/330,000, respectively [71].

One large prospective cohort study (n = 24,000) found that rAOM was associated with sudden sensorineural hearing loss [72]. A retrospective study of 517 adolescent children who had presented with AOM, tonsillitis or influenza in early childhood and who had otoacoustic emissions (OAE) screening during every visit between the age of 10 and 21 years showed that the number of AOM episodes in early childhood correlated strongly with the number of failed OAE screenings later [73]. A large data linkage study from Canada found that ventilation tube insertion was associated with the need for rehabilitative hearing devices in the long term [74]. Furthermore, the Danish National Birth Cohort study found an association between parent reported otitis media early in life and lower scores on the Strengths and Difficulties questionnaire [75]. However, a systematic review investigating the association between otitis media and sensorineural hearing loss noted that there is great heterogeneity with regards to the effect estimates and that the design of the studies addressing this question is often problematic [76].

The sequelae associated with OME can be influenced by the medical management (eg insertion of tympanostomy tubes) and the fact that persistent OME can co-exist with recurrent AOM. A study from the USA described the outcomes in 171 children who had early tympanostomy tubes after failing their newborn screening test (NBST). Around 13 % were found to have sensorineural hearing loss (SNHL) after OME resolved. 55 % needed repeat tympanostomy tubes and 25 % need 2 or more repat tympanostomy tubes. Around 40 % of children also had craniofacial abnormalities and these children were more likely to subsequent AOM and/or repeat tympanostomy tubes [77]. The follow-up at 6 years of age of a large Australian birth cohort failed to identify any clinically important language problems [78].

Long-term follow up of 345 children in the Ostrich Trial (Oral steroids for OME) [79] found that better hearing at baseline was associated with better hearing over the next 12 months. Similarly, a history of atopy, never wearing hearing aids, and male gender were associated with better outcomes [79].

A study from Japan described the long-term outcomes for 97 children with cleft palate who had tympanostomy tube surgery within the first 2 years of life compared to a similar group of 95 control children with normal palates. The children with cleft palate were more like to need replacement of tympanostomy tubes (31 %), but hearing outcomes were similar [80]. Another Japanese study described the long-term outcomes after tympanostomy tubes at 1 year of age. The mastoid air cell system size and the shorter duration of tympanostomy tube insertion, was associated with better outcomes [81]. Another Japanese study of 234 children reported that the Goode T tubes lasted ~22 months on average. About 50 % of children needed repeat surgery and ~8 % developed a perforation [82].

A large epidemiological study examined 663 children from the Copenhagen Prospective Studies on Asthma in Childhood 2010 (COPSAC2010). In this unselected mother-child cohort, they found that tympanostomy tubes were associated with better short-term outcomes in terms persistence of OME at 12 months of age with no difference in the longer-term [83].

A small, uncontrolled study found that 15 children with non-syndromic cleft palate plus OME had less canonical babbling and consonant variability than matched control children without cleft palate [84]. Another study of 76 Japanese children described the long-term outcomes of children with cleft palate who had ventilation tubes inserted at the time of palatoplasty. Children with tympanostomy tube extrusion <20 months and those with cleft lip plus palate and those with complex maxillofacial abnormalities were more likely to have recurrence of their OME(85).

One study compared 80 neonates who had OME at the time of failing their newborn hearing screen (NBHS) to 55 neonates who failed their NBHS without OME. The neonates who also had OME had less sensorineural hearing loss (11 % versus 20 %) and had a delay in confirmation of sensorineural hearing loss by 3 months and a delay in enrolment in early intervention by 2 months [47].

CSOM has shown an association with sensorineural hearing loss, tinnitus and dizziness [73,86,87]. The worse the hearing loss, the worse health-related quality of life scores [88]. In one study, hearing success rate after surgery was 75 % and was associated with age, location and size of the perforation, with the degree of inflammation of the mucosa, and with the status of the ossicles [89].

3.5. Impact of coronavirus disease of 2019 (COVID-19) on otitis media (OM)

The initial search concerning the impact of COVID-19 on otitis media (OM) epidemiology yielded 75 results, with 55 removed after abstract reading, resulting in 20 articles included in this review.

The various restrictions introduced during the COVID-19 pandemic to reduce the spread of the virus was a unique opportunity to study the association between viral and bacterial upper airway infections (like AOM). It soon became clear that the restrictions had led to fewer bacterial infections. Soon after the most acute phase of the pandemic, large studies from Sweden, the Netherlands, Italy, Korea, China and Israel were published. All studies described a decrease in incidence rates of AOM [90–108]. The extent to which the incidence had decreased varied between 33 and 67 %, depending on the setting. Some authors also studied complications to AOM, such as mastoiditis, which also decreased in incidence [90,95]. An Italian study also showed that OME incidence fell during the pandemic [109]. A summary of the studies on otitis media epidemiology and the effect of the COVID-19 pandemic is shown in Table 5.

4. Conclusions and implications for practice

AOM is an infection which primarily affects children<2 years of age. Although incidence figures vary between countries, it seems clear that AOM has decreased in Western countries after the introduction of PCVs. The epidemiology of AOM in low-income countries is poorly studied. The incidence of OME is even greater than that of AOM, but also seems to vary geographically. Studies on CSOM epidemiology are scarce and have recently only been performed in middle- or low-income countries.

Recent studies have confirmed previously identified risk factors for AOM, such as heredity, male gender, siblings, day-care attendance, lack of breast feeding, passive smoking, and an early onset of AOM. Potential risk factors for OME highlighted recently are living in a rural area, frequent upper respiratory tract infection (URTI) in last 12 months, childcare attendance, adenoidal hypertrophy, gastroesophageal reflux, allergy, iron deficiency, helicobacter pylori presence in adenoidal tissue,

Table 4
Complications and sequelae of otitis media (OM).

Author Year published *Year studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
Aarhus 2020	Mean 52 years	Population cohort study in Norway comprising 51,626 participants who underwent a hearing investigation at 7–13 years of age where 189 were diagnosed with CSOM (otorhinolaryngologist diagnose)	Previous ear examination and audiometry and ICD-10 codes in the Norwegian nationwide health register	189 with CSOM out of 51,626	The associations between CSOM in childhood and disease in adulthood were: chronic sinusitis (odds ratio 3.13, 95 % CI 1.15 to 8.52); cardiovascular disease (1.38, 1.01 to 1.88); hearing loss (5.58, 3.78 to 8.22); tinnitus (2.62, 1.07 to 6.41). The adult hearing loss among cases with childhood CSOM was most frequently registered as sensorineural. There was no statistically significant increased risk of later asthma (1.84 [0.98 to 3.48]), inflammatory bowel disease, inflammatory joint disease, systemic tissue disease, or vestibulopathy. The estimates were adjusted for age, sex, socio-economic status, and smoking.	Long-term follow-up > 40 years
Abdelmotaleb 2023	Adults	Case-control: Postural dizziness Vestibulo-spinal and vestibulo-ocular reflex in Alexandria, Egypt	otoscopy, pure-tone audiometry, posturography sensory organization test (SOT), and vHIT	65 healthy and 65 with CSOM	CSOM is accompanied with dizziness, poor postural control, and VOR abnormalities. The presence of sensory hearing loss in CSOM patients appears to be positively associated with vestibular dysfunction	High quality
Ahmad 2023 *Nov 2017-Dec 2019*	All ages above 1 year	Cross-sectional hospital-based Aligarh, India	Otoscopy	200 CSOM patients	The overall prevalence of complications in patients with COM was 6.5 % with 61.54 % complications being extracranial and 38.46 % intracranial	Low quality
Anggraeni et al 2019	*6-16 years*	Prospective survey of children at schools across mix of urban and rural sites (Indonesia)	First stage: Pneumatic otoscopy, wax removal & screening audiometry. Those with abnormalities on otoscopy or audiometry referred to Second stage: diagnostic audiometry	7005	172 (2.5 %) of children had otitis media (active or inactive CSOM most common type of OM). Overall rate of hearing loss 181/10,000. HL was 3x as high in rural areas. OME accounted for most of mild HL; CSOM for moderate HL.	
Beyea et al, 2020 ***1994–2013***	0–18 years	Retrospective cohort study of national health care records Group 1: at least one TT surgery (1994–2013); group 2: persistent ETD but no TT surgery; group 3: control group, age & sex matched to group 1, 5 to 1 (Ontario, Canada)	Diagnosis billing and administrative codes Assistive Devices Program database	1,358,331 (Group 1: 193.000 Group 2: 203.000; Group 3: 961.000)	TT cohort had higher odds of obtaining hearing aid, an FM system and implanted BC device, than no TT or control group. % receiving any hearing device: 1 % group 1; 0.23 % group 2; 0.09 % group 3 (OR 4.43 TT vs no TT; 10.76 TT vs control)	
Bright 2019 *2014*	From 6 months of age and older	Population-based prevalence survey of hearing impairment in Mahabubnagar district, Telangana state, India.	Otoacoustic emissions and pure tone audiometry if failing OAE. If hearing impairment otoscopy was performed and a structured questionnaire by WHO was provided	3,573	Ear examination suggested that the possible cause of disabling hearing impairment was chronic suppurative otitis media for 6.9 % of cases and dry perforation for 5.6 % cases.	
Brennan-Jones et al, 2020	6–10 years	Prospective Raine birth cohort study enrolled pregnant women	Ear assessment by otoscopy and	Complete ear and language	Using multivariable regression analysis at 6yo,	Important risk factors for language at 6yo

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Table 4 (*continued*)

Author Year published *Year studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
Born 1989 to 1992. ***Assessed 1995 – 2012.***		at 16–20 weeks in Perth, Australia- Generation R1. Original birth cohort 2,868 infants- Generation R2. (Australia)	tympanometry at 6yo. Language assessment by Peabody Picture Vocabulary Test- Revised (PPVT-R) at 6yo and PPVT-R and Clinical Evaluation of Language Fundamentals (CELF-3) at 10yo.	assessment in 1,333 at 6 years and 1,015 at 10 years.	bilateral OM was not associated with language problems- PPVT-R Beta: 0.56 [95 %CI -3.8, 2.7]. At 10yo, bilateral OM was associated with language problems on PPVT-R: Beta −3.17 [95 %CI -6.0, −0.31] but not on CELF-3: Beta 0.2 [95 %CI -3.9, 3.5]. No clinically important effects detected.	included maternal education and mother speaking another language than English.
Choi et al, 2020 ***Up to 2013***	0–15 years	Korean National Health Insurance Service – national sample cohort Matched those with≥5 instances of OM with control group matched for age, sex, income and region of residence, 1 to 1 (South Korea)	Health record codes	24,226 with OM, matched to a control group	The otitis media group had a higher adjusted hazard rate (HR) for sudden sensorineural hearing loss (SSNHL) than the control group (adjusted HR = 2.13, 95 % CI = 1.13–4.02). Recurrent otitis media in children was related to the onset of SSNHL.	
Chow et al, 2019 ***2018***	4–12 years	Analysis of retrospective clinical audiometric data of children diagnosed with OME at the Shenzhen Children's Hospital (China)	Otoscopy, tympanometry & pure tone audiometry (ENT specialist)	96 children (168 ears)	Comparisons among low frequency 3 PTA average (500 Hz, 1 kHz, 2 kHz), high frequency 3 PTA average (1 kHz, 2 kHz, 4 kHz), and 4 frequency PTA average (500 Hz, 1 kHz, 2 kHz, 4 kHz) showed no statistically significant differences. Frequencies tested for criterion averages for surgical treatments of children with OME may be restricted to any of the 3 frequency PTA averages.	
Edwards et al, 2020 ***2014–2016***	2–8 years	Secondary analysis of OSTRICH study data (a RCT of oral steroids vs placebo for children with a 3 month history of bilateral OME & hearing loss) (Wales)	Pure tone audiometry at 5 weeks, 6 months and 12 months post randomisation	380	Less severe baseline hearing loss across both ears most consistently predicted acceptable hearing at 5 weeks ([aOR] 0.91, 95 % CI 0.87–0.95), 6 months (0.94 [0.90–0.98]) and 12 months (0.93 [0.89–0.97]). Negative history of atopy (2.05 [1.16–3.61]), never using hearing aids (aOR 2.16 [1.04–4.48]), and being male (1.75 [1.02–2.99]) were significant at 6 months, but not at 12 months. Symptom duration was a predictor at 5 weeks, but not at 6 or 12 months. Milder baseline hearing loss consistently predicts acceptable hearing at 5 weeks, 6 and 12 months in children with chronic OME.	
Elzinga et al, 2021	All ages	Systematic review of papers comparing sensorineural hearing levels of patients with a >3 month history of rAOM/ CSOM and a control group	Otoscopy and audiometry	Screened 4168 studies. Nine studies met the inclusion criteria	Considerable risk of bias and heterogeneity across studies. Unable to draw conclusions as to whether rAOM/CSOM are predictive of later sensorineural hearing loss.	

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Table 4 (*continued*)

Author Year published *Year studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
					Need for future prognostic studies.	
Inoue et al, 2020	Children 0–2 years old and followed for maximum of 7 years.	Retrospective cohort study to compare long term hearing outcomes in children with and without cleft palate who had tympanostomy tube insertion in the first 2 years of life. (Japan)	Otoscopy, otomicroscopy, and audiometry.	97 with cleft palate (palatoplasty by 2 years) and 95 without cleft palate.	Resolution of OME in 47 % of cleft palate children and 60 % of control children. 12 % in both groups had persistent perforation of TM. Mean hearing loss was ~15 dB in both groups. The long-term outcomes were similar and generally good in both groups.	Only included children followed to 7 years old, so almost half the children with early resolution not included.
Karawani et al, 2023 ***2012–2013***	0–1 year	Analysis of retrospective audiometric records of neonates who failed the universal newborn hearing screen and were diagnosed with conductive hearing loss, over the period Jan 2012–Dec 2013, in one healthcare institution (Israel)	Air and bone conduction auditory brainstem response testing, and tympanometry by age 4–6 weeks. Behavioural audiometry, tympanometry and otoacoustic emissions every 3–4 months until age 1 year	9527 newborns were screened	144 (1.5 %) failed the newborn hearing screen. Of those failing, 46 (32 %) had conductive hearing loss due to MEE - of these, MEE spontaneously cleared in 26 %; 57 % had persistent MEE; 17 % lost to follow up Congenital MEE causing conductive hearing loss and UNHS failure is persistent and resolves at lower rates than non-congenital MEE.	
Kuma 2022 *May 2019-May 2020*	Mean age 44.08 years±SD 15	Cross-sectional hospital-based study (Pondicherry, India)	Otoscopy, audiometry and pre-validated structured questionnaire, the Hamilton Depression Rating Scale (HDRS)	142	Significant and linear correlation of depression and hearing loss to the duration of CSOM	
Lee et al, 2021 ***2012–2016***	Range not given (51 years ± 15 years)	Analysis of retrospective clinical records of those undergoing COM surgery in Daejeon St. Mary's Hospital. Surgical technique was determined based on non/cholesteatomatous OM Excluded those with unmeasurable hearing levels pre-op or with events that could damage hearing (South Korea)	Pure tone audiometry pre and post-surgery; cholesteatoma status; inflammation severity;	192	Of the sample, 82 had tympanoplasty, 26 had canal wall up mastoidectomy with tympanoplasty, and 84 underwent canal wall down mastoidectomy with tympanoplasty. In 11 % of cases, the BC hearing at 4 kHz worsened by more than 15 dB High frequency SNHL may develop after surgery to treat chronic OM, especially in young patients with cholesteatoma.	
Lempinen et al, 2022 ***2005–2008***	2–13 years (median age boys: 17 months; median age girls: 11 months)	Comparison of bacterial aetiology, hearing impairment and outcome in children with bacterial meningitis, with and without OM, who were part of a previous clinical trial at Children's Hospital of Luanda (Angola)	Lumbar puncture, ear discharge swabs, pneumatic otoscopy (paediatrician), auditory brainstem response testing, otoacoustic emissions (research nurse & Audiology expert)	512 with confirmed bacterial meningitis	No correlation between bacteriology between the ear discharge and cerebrospinal fluid. Hearing impairment common in both those with and without OM.	
Luo et al, 2022 ***2014–2015***	≥18 years	Cross-sectional, population-based Ear and Hearing Disorder Survey in four provinces of China. Sampling frame covered 200 million people, with probability proportion to size sampling method. 47,511 individuals randomly selected (China)	First stage: screening pure tone audiometry (trained examiners); those that referred on the screen had pure tone audiometry (audiologist) and otoscopy (ENT trained doctors)	36,783	20 % of the sample had hearing loss, and 0.83 % had OM. There was more hearing loss in those with OM compared to those without OM (OR 5.67, 95 % CI 4.66, 6.90). Rural residents with OM had a higher risk of hearing loss than urban residents.	
Luu et al, 2020	Median age of 2.7 months at referral and data available for 2–7 years (median age 6yo).	Retrospective case series in tertiary pediatric hospital of children with early onset OME, failed newborn screening, and referred for tympanostomy tubes (USA).	Otoscopy, tympanometry, and audiometry.	171	13 % had subsequent SNHL identified after tube placement. 56 % need 1 more set of tubes and 24 % needed >1 set. Peak episode of AOM was in second year of life	Significant decrease in hearing loss in children after first tube placement.

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Table 4 (*continued*)

Author Year published *Year studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
					(median = 1). Craniofacial anomalies present in 43 % and tube replacement and AOM was more common in this group.	
McKenna Benoit et al, 2019	48–95 months (conductive hearing loss group: 69.9 months; control group: 73.7 months)	Comparison of amplitude modulation detection in children with a history of OME related conductive hearing loss vs a control group. Children with a hearing loss >25 dB (better ear) between age 6 months and 3 years, who had TT placement, recruited from paediatric otolaryngology practice at University of Rochester Medical Centre (USA)	Otoscopic examination, tympanometry, audiometry, amplitude modulation detection using a 2 alternative forced choice task at 8 and 64 Hz modulation frequencies using a noise carrier signal and interactive touch screen interface	34 (17 with a history of OME related conductive hearing loss; 17 without)	In the younger age group (<6 years old), children with a history of OME-associated CHL were less sensitive to AM than control subjects (4.24 ± 2.07 dB; p = 0.050). By age 6–7 years (72–84 months), most subjects with a history of OME-associated CHL were performing at levels similar to age-matched peers (−2.55 ± 2.49 dB; p = 0.32) Modulation detection thresholds of children with a history of OME associated CHL were higher than control thresholds at 5 years, but corrected to expected levels between ages 6–7.	
Mehboob 2019	18–75 years	Hospital-based	Otoscopy, audiometry and depression, anxiety and stress scale (DASS)	120	Depression, anxiety and stress were correlated to degree of hearing impairment in CSOM patients	
Penaranda 2022	adults	Cross-sectional study in two ORL centers of 231 participants in Bogota, (Columbia)	Tinnitus in adults with and without COM by otoscopy and audiometry	231 adults	Factors associated with increased tinnitus severity in patients with COM were older age (aOR: 1.02; 95 % CI: 1.01–1.05), higher education (aOR: 2.24; 95 % CI: 1.03–4.87), ear discharge during childhood (aOR: 1.88; 95 % CI: 1.02–3.45), cholesteatoma in one ear (aOR: 2.26; 95 % CI: 1.05–4.88), and pure-tone air average over 15 dB (aOR: 2.08; 95 % CI: 1.28–3.36).	
Perez-Herrera 2023	adults	Cross-sectional study in two ORL centers of 231 participants in Bogota, (Columbia)	Dizziness in adults with and without COM by otoscopy and audiometry	231 adults	Dizziness more frequent in COM patients (aPR: 3.02; 95 % CI: 1.21–7.52)	The study also examined dizziness and difference in COMQ-12 scores
Racca et al, 2022	≤21 years old	Analysis of retrospective clinical hearing and ENT data from three institutions (Boston Children's Hospital, Children's Hospital of Philadelphia, and Vanderbilt University Medical Center) to identify factors associated with progressive sensorineural vs stable hearing loss (USA)	Audiometry, speech audiometry, middle ear reflexes, otoacoustic emissions, auditory brainstem response, ICD diagnostic codes	175,215 patients on the database	425 patients were identified with progressive SNHL. Diagnostic codes of cholesteatoma in children and young people were associated with progressive SNHL. 113 patients had cholesteatoma associated SNHL: the degree of shift was not related to the mastoidectomy surgery, and a high proportion had normal hearing at their first test	
Rajput 2020	Mean age 26 [12–58] years	Retrospective review, hospital-based (Pakistan and Saudi Arabia)	Medical records and audiometry	154 CSOM patients	The mean BC threshold given as an average of three speech frequencies for groups with CSOM lasting between 1 and 5	Low quality

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Table 4 (*continued*)

Author Year published *Year studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
					years, 5–10 years, and 10–15 years were 16.9, 18.7, and 22.9 dB. This was significant but without clinical importance.	
Salehuddin 2021	Adults	Cross-sectional hospital-based study in patients with normal cochlear function based on conventional pure tone audiometry (250 Hz–8 kHz) (Kelantan, Malaysia)	Conventional and high frequency audiometry (9–16 kHz) and validated Tinnitus Handicap Questionnaire (BEST) questionnaire	220 ears with CSOM	Prevalence of high frequency hearing loss (HL) in the normal cochlear function CSOM patients with tinnitus was 81.8 % (95 % CI 74.5 %, 89.1 %), whereas the prevalence in the tinnitus negative group was 30.0 % (95 % CI 21.3 %, 38.7 %). There was a significant association between extended high frequency HL and tinnitus in CSOM patients ($P < 0.001$)	Level of evidence: 4
Seidel et al, 2021 ***2010–2017***	All ages (30.3 years, 24.2 SD)	Analysis of retrospective clinical hearing and ENT data from a nationwide ENT practice database, to determine the incidence of inner ear disorders in those with AOM (Germany)	Data used: ICD diagnostic codes for AOM diagnoses, inner ear disorders (IED); diagnosis date for IED; age, sex, insurance status	286,186 with AOM	The most frequent diagnoses were ‘‘nonsuppurative otitis media, unspecified’’ (47.6 %) and ‘‘otitis media, unspecified’’ (39.0 %). The highest risk of IED after 7 days and 12 months was seen in nonsuppurative AOM where for example, 7.7 % of those with nonsuppurative AOM had any IED within 7 days following diagnosis. Incidence of IED increased with increasing age, possibly due to diagnosis of existing hearing impairment. .	Cannot imply causality
Thai 2022	49.5 [1–95] years	Retrospective review of medical records, hospital-based (Stanford, California, USA)	ICD code for chronic suppurative otitis media (H66.1, H66.2, or H66.3)	175 CSOM patients	The prevalence of all patients with CSOM displaying moderate or worse sensorineural hearing loss (SNHL) was 41 %.	
Thorsen et al, 2023 ***2010–2015***	Birth cohort followed to 3 years old.	COPSAC longitudinal study (Copenhagen Prospective Studies of Asthma in Childhood 2020) Using data linkage and clinical assessment (Denmark)	Tympanometry and Bayley’s Scale for cognitive development at 2.5yo plus assessment of milestones, language, and Ages and Stages questionnaire. Compared i) no middle ear disease; ii) middle ear disease but no VT; and iii) middle ear disease plus VT.	663	5 % had ventilation tube (VT) insertion before 1yo and 29 % by 3yo. Children with middle ear effusion (MEE) at 1 and 2yo were more likely to have ongoing MEE or VT placement the following year. Children with MEE at 1yo had slightly lower language scores at that age but no significant deficits at 3yo.	Very high rate of VT placement by 3yo. Authors recommend further study through RCTs.
Verma 2022 *Jan 2018-Jan 2019*	Median age 26,2 years	Cross-sectional prospective 1-year survey, hospital-based in Gwalior, (India)	Clinical and CT confirmed prevalence of extracranial (ECC) and intracranial (ICC) complications in CSOM	50 cases	ECC—52 % mastoid abscess most common: 50 % facial palsy: 23.07 % ICC—46 % Brain abscess: 61 % Meningitis 30 %	No epidemiology data shown but majority were from poor socioeconomic strata

childhood obesity, and cleft palate. Potential risk factors for CSOM are allergy, iron deficiency, and low socioeconomic status.

Suppurative complications following AOM occur, but they are rare. Some studies have found an association between AOM during early childhood and later sensorineural hearing loss. There have been no studies published in the 4 years up to June 2023 assessing the long-term complications of persistent OME. Complications of CSOM include hearing loss, tinnitus and dizziness. The worse the hearing, the worse the

Table 5
Impact of COVID-19 on otitis media (OM).

Author Year published *Year studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
Alde et al 2021 *May-June 2019 (n = 350) and January-February 2020 (n = 366), and the period immediately after the lockdown, May-June 2020 (n = 216)*	6 months-12 years	Tertiary audiological referral centre; Prevalence of OME in children referred for audiological or vestibular disorders during two periods before and one directly after lockdown. Also comparison of resolution in a subgroup of re-examined children. (Italy)	Retrospective chart review	932	The prevalence of OME in this clinic population was 40.6 % in May–June 2019, 52.2 % in January–February 2020, and 2.3 % in May–June 2020. Children with chronic OME had a higher rate of disease resolution in May–June 2020 (93.3 %) than those examined in May–June 2019 (20.7 %, P < 0.001).	
Allen et al 2022 *Jan 1, 2019-June 30, 2021*	Patients at children's 48 hospitals	Retrospective cohort study using the PHIS database, which consists of 48 children's hospitals. Proportion of OM to total diagnoses codes; number of mastoiditis and MT placements from all encounters. (USA)	Retrospective cohort study	Nationwide study comprising 48 of the largest childrens hospitals in the US	In April 2020, there was a decrease in mean proportion of OM cases per 100 hospital visits (7 v. 2, $p < 0.0001$) and this was sustained through 2020 and until June 2021 (6–7 v. 2–4, $p < 0.05$; $p < 0.05$). MT procedures followed similar trends. In 2020, there was no difference in mastoiditis as a proportion of OM cases compared to 2019 however there was a statistically higher rate of mastoiditis in 2020 compared to 2021.	
Barschkett et al 2021 *Second quarter of 2020 compared to second quarter of 2019*	Patients under the age of 21	Nationwide health insurance data (Germany)	Retrospective study	About 8.5 million children	Outpatient visits associated with diagnosed otitis media fell by 71 %, particularly for children up to age 5.	
Favoretto et al 2022 *March 2019-Feb 2021*	Patients under 12 years	Ped ENT in a tertiary hospital (Brazil)	Retrospective study, checking for number of children with ICD-10 code H660 or H669	2090 patients diagnosed with AOM during the study period, but unclear how large the catchment area was	AOM diagnoses fell by 85 % during March 2020–Feb 2021 compared to the previous 12 months.	
Franchella et al 2023 *Case group first evaluation in 2019 and second in 2020, control group first evaluation in 2018 and second in 2019.*	Patients 14 years or younger	Pediatric ENT, tertiary hospital	Retrospective study of children with at least two visits in April–September a year apart. Each individual compared against themself as to whether their specific condition had improved/deteriorated/was unchanged	77 (37 compared to 40)	Patients who experienced social distancing presented a significantly higher improvement rate than controls for recurrent acute otitis media episodes (35.1 % vs. 10.8 %; Fisher's exact test $p = 0.033$) and for tympanogram type (54.5 % vs. 11.1 %, Fisher's exact test $p = 0.009$).	
Gisselsson-Solen et al 2022 *2019–2020*	All ages	Nationwide study, national database (Sweden)	Retrospective study using ICD-10 codes from the national database	10 million	AOM decreased by 40 % in the entire population (43 % in 0–19 yearolds, $p < 0.0001$) and mastoiditis by 30 % and 40 %, respectively; $p < 0.0001$.	
Hullegie et al 2022 *March 2019-Feb 2021*	0–12 years	Primary care database. (Netherlands)	Data on acute otitis media (AOM), otitis media with effusion (OME), ear discharge episodes and associated antibiotic prescriptions were extracted.		AOM decreased by 63 %, OME by 57 % and ear discharge by 54 %.	
Iannella et al 2022 *March 2018-March 2021*	All ages	Retrospective chart review from five referral centers. (Italy)	Diagnosis of OME		OME decreased by 63 % and 68 %, depending on whether you compared the pandemic period to 2018 or 2019	
Jesus et al 2021 *2015–2020*	Children <9 years	Retrospective review on hospitalisations for common upper airway infections, among them AOM. (Brazil)	Diagnosis data from national database, comparing annual numbers for various diagnoses.	Entire Brazilian population <9 years?	AOM hospitalisations decreased by 85 % in 2020 compared to 2015–2019.	
Kaur et al 2021 *15 March – 31 Dec 2019 compared to 15*	Children 6–36 months old	Ongoing prospective study made it possible to compare the same period in 2019–2020 with respect to well-child and	Medical assessment, bacterial cultures	215 and 144 children in the prepandemic and pandemic cohorts, respectively.	Visits for AOM were 3.7-fold lower ($p < 0.0001$). Haemophilus influenzae and Moraxella catarrhalis more than	

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Table 5 (*continued*)

Author Year published *Year studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
March – 31 Dec 2020		AOM visits as well as nasopharyngeal cultures. (NY State, USA)			halved their presence in nasopharyngeal cultures during pandemic well-visits.	
Kim et al 2022 *Jan 2018-March 2021*	All ages	Retrospective study using ICD-10 codes from the Korea National Health Insurance Service (S Korea)	ICD-10 code otitis media by primary care clinicians	Entire Korean population (about 50 million)	AOM incidence decreased by 57 %, ($p < 0.001$)	
Marom et al 2022 *1 March 2018-28 Jan 2021*	<18 years	Secondary care centre, Israel. Retrospective review of cases (Israel)	Case review with extraction of eg diagnoses		For children < 2years, outpatient visits and admissions for AOM decreased by 67 % ($p < 0.005$) during the pandemic. For children aged 2–6 years, hospital admissions for AOM decreased by 82 % ($p < 0.005$), however, outpatient visits in this group did not change significantly, neither did any type of AOM related visit for children aged 6–18 years.	
Quraishi et al 2022 *2019–2020*	Adult patients	1 district general hospital and 2 tertiary centers. (Central England, UK)	Retrospective cohort study comparing adult admissions with various upper airway infections, eg AOM	Catchment population of over 2 million	Significant reduction in admission for acute otitis media (26.85 %; $p = 0.01$)	
Rotulo et al 2021 *March and April in 2019 and 2020*	Children attending a children's hospital	Pediatric emergency dpt in (Italy)	Retrospective analysis of medical charts		A significant reduction in rate of incidence and proportion were observed for AOM (2,6 % vs 16,2 %)	
Smith et al 2022 *1 Nov 2019 – 30 April 2021*	Children 18 years or younger	48 UK secondary care ENT departments. (UK)	National retrospective and prospective audit.		286 cases met criteria (median 4 per site, range 0–24). 9.4 cases were recorded per week in period 1 versus 2.0 in period 2, with no winter increase in cases in December 2020-Febraury 2021. Patient age differed between periods 1 and 2 (3.2 vs 4.7 years respectively, $p < 0.001$).	
Torretta et al 2021 *2019–2020*	Children mean age 41.4 ± 14.0 months	Tertiary outpatient ENT clinic. (Italy)	Telemedicine follow-up of rAOM patients scheduled for follow-up during lockdown compared to medical charts from 2019.		Consistent clinical improvement had been occurred in most (82.3 %) of children. Acute otitis media episodes were five times less common during the February–April 2020 period compared with February–April 2019, and otorrhea episodes almost fifty times less common. Clinical evaluation performed in 27.4 % cases revealed normal middle ear findings in all but three (89.3 %) children.	
Torretta et al 2021 *21 February-3 May 2019 (period 1) to 21 February-3 May 2020 (period 2).*	Under 18	Pediatric ENT dpt	Retrospective evaluation of electronic charts	About 486,770 children	Middle ear infections decreased from constituting 92.8 % of diagnoses to 7.2 % ($p < 0.001$). Non-complicated acute otitis media more frequently occurred in period 1 (92.0 % vs. 8.0 %; p-value <0.001); no significant difference in the number of complicated middle ear infections occurred (95.8 % vs. 4.2 %).	
Völk et al 2022 *1 Jan 2016-31 Dec 2020*	All ages	Multiple hospitals. (Germany)	Retrospective evaluation of ICD codes	Participating hospitals corresponding to 5–10 % of German in-patients	Among <18 year old, RR for mastoiditis 0.48 (0.37–0.61) in 2020 compared to 2019.	
Yu et al 2023 *2015–2020*	6 months to 12 years	Tertiary hospital in Shanghai, China	Daily outpatient attendance for AOM	A total of 24,543 AOM cases were included from 2015 to 2020	There was an estimated 63.6 % (54.32–70.36 %) reduction in the daily outpatient attendance of AOM associated with the introduction of social distancing in 2020	
Zloczower et al 2023 *1 March 2017-28 Feb 2022*	Children 0–15 years	Retrospective review using the Clalit Health Services	Number of AOM episodes	1,102,826 AOM unique episodes	the reduction in AOM episode rates was >2-fold (IRR 0.46, 95 % CI, 0.34–0.63, P < 0.001). The	

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Table 5 (*continued*)

Author Year published *Year studied*	Age range *(mean)*	Study design; sampling (country)	Diagnostic technique *(examiner)*	Sample size	Findings	Notes
		Database (largest healthcare maintenance organisation)			largest decrease was observed among children 1–4 years old during the first COVID year (β = −1,938 AOM episodes/100,00 children, 95 % CI, −2,038 to −1,912, P < 0.001).	

results on quality of life scores.

The restrictions introduced to reduce the spread of COVID-19 had a large effect on AOM incidence around the world.

Otitis media is a notoriously difficult diagnosis to make, especially in young children. A consistent use of definitions and an accurate diagnosis affects research results and estimations about the burden of diseases and are therefore of great importance. Studies on AOM epidemiology in low-income countries are scarce and could add valuable information.

The greatest burden of disease as measured in DALYs is due to CSOM with subsequent hearing loss, and studies on how to prevent long-term sequelae associated with CSOM would be important to reduce burden of disease.

CRediT authorship contribution statement

Marie Gisselsson-Solen: Writing – review & editing, Writing – original draft, Supervision, Data curation, Conceptualization. **Hasantha Gunasekera:** Writing – original draft, Data curation. **Amanda Hall:** Writing – original draft, Data curation. **Preben Homoe:** Writing – original draft, Data curation. **Kelvin Kong:** Writing – original draft, Data curation. **Tania Sih:** Writing – original draft, Data curation. **Vedantam Rupa:** Writing – original draft, Data curation. **Peter Morris:** Writing – review & editing, Writing – original draft, Supervision, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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