European Archives of Oto-Rhino-Laryngology (2025) 282:2959–2970
https://doi.org/10.1007/s00405-024-09165-z

OTOLOGY

Trends in the incidence and burden of otitis media in children: a global analysis from 1990 to 2021

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Received: 2 November 2024 / Accepted: 12 December 2024 / Published online: 24 December 2024

Abstract

Background Otitis media (OM) is a prevalent and serious condition in childhood, but comprehensive global studies assessing its burden are lacking.

Methods Using data from the 2021 Global Burden of Disease (GBD) study, we analyzed OM incidence cases and disability-adjusted life years (DALYs) in children aged 0–14 from 1990 to 2021. Trends were analyzed across regions, age groups, sexes, and socio-demographic index (SDI) using estimated annual percentage changes (EAPC). Predictive models were used to forecast trends to 2050.

Results The global number of OM incidence cases in children increased from 256 million in 1990 to 297 million in 2021, a 15.97% rise. The age-standardized incidence rate (ASIR) showed a slight increase (EAPC: 0.12). Despite some variations across age, sex, and regions, the age-standardized DALY rate (ASDR) declined. ASIR and ASDR were highest in children aged < 1 year and gradually decreased with age. The largest burden was observed in low- and middle-low-SDI regions, although these regions showed the greatest declines in EAPC. Correlation analysis indicated that ASDR decreases as the SDI increases. By 2050, the number of global OM incidence cases in children is projected to reach 334 million, with most of the increase concentrated in low-SDI regions, while ASIR is expected to remain stable.

Conclusion Although progress has been made in controlling OM in children over the past 30 years, the ASIR remains high. The sustained high burden and incidence of OM in low-SDI regions, and among young children, pose a significant challenge to children's health.

Keywords Otitis media · OM · Epidemiology · Incidence · Children's health · GBD 2021

Abbreviations

OM	Otitis Media
GBD	Global Burden of Disease
SDI	Socio-Demographic Index
DALYs	Disability-Adjusted Life Years
EAPC	Estimated Annual Percentage Changes
ASR	Age-Standardized Rate
CI	Confidence Interval
UI	Uncertainty Intervals
HDI	Human Development Index
ASIR	Age-Standardized Incidence Rate
ASDR	Age-Standardized DALYs Rate

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Introduction

Otitis Media (OM) is a highly prevalent pediatric ear infection and a leading cause of hearing impairment among children worldwide [1]. In the Global Burden of Disease (GBD) Study 2021, OM is defined as an infection of the middle ear space, rather than being categorized into major specific subtypes such as acute OM (AOM), OM with effusion (OME), or chronic suppurative OM (CSOM) [2]. Among pediatric populations, AOM is the predominant form of ear infection. It ranks as the second most common childhood illness after upper respiratory tract viral infections and is a leading cause of pediatric consultations, with approximately 13.6 million annual visits worldwide [3, 4]. Consequently, AOM represents a significant global healthcare issue for children.

Research indicates that > 80% of children experience AOM multiple times before reaching 3 years of age [5], establishing it as the primary cause for antibiotic prescriptions among preschool-aged children [6]. AOM significantly affects children's emotional well-being, communication abilities, social interactions, and learning processes, and it also has long-term effects on their quality of life, potentially extending into adolescence [7]. AOM can result in conductive hearing loss, otalgia, sleep disturbances, decreased appetite, and behavioral issues. These symptoms may subsequently impede the development of speech, language, balance, and learning abilities, significantly impacting the quality of life for both affected children and their families [8]. The estimated direct medical cost of OM in the United States is $4.4 billion annually [9], positioning it among the most financially burdensome pediatric diseases in the country [10].

Inadequately treated AOM can progress to OME or CSOM, both of which carry significant risks of hearing loss and developmental delays. Among these sequelae, OME represents the most common cause of acquired hearing loss in preschool-aged children [11]. Early-onset hearing impairment in children can lead to irreversible, potentially lifelong sequelae, affecting their speech acquisition, language development, and social interactions. OME, characterized by its high prevalence and subtle symptomatology during childhood, is frequently overlooked. Nevertheless, this condition can significantly impair speech and language development in children [7]. OME affects a significant proportion of the pediatric population, with > 60% of children experiencing the condition by 2 years of age [12].

Following the introduction of pneumococcal conjugate vaccines in the United States and Europe [13, 14], the incidence of AOM and its associated complications has decreased in high-income countries. However, the prevalence of OM remains high throughout early childhood [15]. Moreover, OM remains a serious public health issue in low- and middle-income countries. In these regions, limited medical resources and inadequate preventive measures contribute to the persistently high incidence of OM in children.

Despite the high prevalence and heavy burden of OM in children, this disease receives much less attention from healthcare providers and governments. To date, no comprehensive study has assessed the long-term global trends in the epidemiology of OM in children. The Global Burden of Disease (GBD) study represents one of the most comprehensive health status assessment initiatives worldwide, encompassing the evaluation of global and regional burdens associated with a wide range of diseases, injuries, and their corresponding risk factors [1, 16].

This study uses the GBD 2021 database to systematically analyze the global epidemiology of OM in children. By examining the incidence and burden of OM across different age groups, regions, and countries, the research aims to elucidate global and regional disparities as well as specific characteristics of the disease. Notably, the COVID-19 pandemic may potentially impact the incidence of OM in children, a phenomenon this study aims to capture. Through comprehensive analyses, we seek to provide scientific evidence to inform the development of more effective global prevention strategies for OM. Additionally, this research will evaluate the efficacy of existing health policies and interventions, offering data-driven support for enhancing pediatric OM prevention strategies.

Methods

Data source

The GBD 2021 Results Database, available from the GBD Collaborative Network website (http://ghdx.healthdata.org), uses the latest epidemiological data and refined standardized methods. The GBD 2021 study provides a comprehensive, up-to-date assessment of 371 diseases and injuries across 204 countries and territories and 811 subnational locations, for different sex and age groups, from 1990 to 2021. Details about the study design and methods of GBD studies have been described in existing GBD literature [17, 18]. We extracted data on OM in children aged 0–14 years from the GBD 2021 Results Database and calculated their age-standardized rates (ASR) and estimated annual percentage changes (EAPC). For GBD studies, the Institutional Review Board of the University of Washington approved a waiver of informed consent.

Definition

In the GBD 2021 database, OM is classified as a level 3 cause and encompasses a broad range of diseases. OM is defined as an infection of the middle ear space. According to the International Classification of Diseases, 10th Revision (ICD-10), it falls under diagnostic codes H65–H75.83 and includes various types of middle ear and mastoid diseases, Eustachian tube diseases, and tympanic membrane diseases.

The SDI (Socio-Demographic Index) is a comprehensive indicator used to measure socioeconomic development, categorizing countries into five groups: low, low-middle, middle, high-middle, and high SDI, with values in the range of 0–1 [1, 19].

Statistical analysis

The incidence rate is expressed per 100,000 people with 95% uncertainty intervals (UI). To account for the effects of population age composition and ensure comparability of study metrics, we calculated the ASR. A generalized linear regression model was used to calculate the EAPC, which measures the yearly average variation in ASR. An EAPC > 0 signifies an increasing trend in ASR, whereas an EAPC < 0 indicates a decline. If the 95% confidence interval (CI) of the EAPC includes 0, the trend in the ASR is considered stable, showing no significant changes over time. The methodologies for calculating the ASR and EAPC are elaborated in referenced literature [20, 21].

To explore the association between the burden of OM in children and socio-demographic development, we conducted a frontier analysis. This analysis assessed the ideal ASR of OM across 204 countries and regions, correlating these rates with their respective SDI levels. Our analysis focused on three groups: the 15 countries with the largest deviation from the ideal OM DALY among all nations; the 5 countries closest to the frontier (ideal control value) in regions with relatively low SDI (SDI < 0.47); and the 5 countries most distant from the frontier OM DALY in regions with high SDI (SDI > 0.81). This approach highlights disparities between the observed burden and the ideal based on SDI, suggesting that these gaps might narrow or close depending on the socio-demographic resources available in each country or region [22]. Additionally, we used hierarchical clustering analysis based on EAPC values to discern patterns of disease burden shifts in each GBD region, and to identify areas with analogous changes in disease burden. All 21 GBD regions were classified into four categories: significant increase, slight increase, stable or slight decrease, and significant decrease.

Simultaneously, we used the Pearson correlation coefficient and locally weighted scatterplot smoothing (LOESS) to examine the relationship between the SDI, Human Development Index (HDI), EAPC and ASR. We used the “geom_smooth” function from the “ggplot2” package in R for this fitting [23]. The HDI, which is a critical socio-economic indicator of health, incorporates factors such as education, life expectancy, and gross national income. Additionally, we used an autoregressive integrated moving average (ARIMA) model to predict future trends. All data cleaning, computations, and graphs were conducted and created using R software (version 4.2.3).

Results

Overview of the global burden

Between 1990 and 2021, the incidence of OM in children increased from 256 million to 297 million, representing a 15.97% rise. The ASIR saw a marginal increase from 14,737.24 to 14,774.55 per 100,000 population, with an EAPC of 0.12 (95% CI: 0.08–0.17). While the number of DALYs rose from 0.97 million to 1.04 million during this period, the age-standardized DALY rate (ASDR) decreased from 55.74 to 51.48 per 100,000 population, showing an EAPC of -0.19 (95% CI: -0.23 to -0.15) (Tables 1, Table S1).

Sex specific trends

In 1990, the incidence of OM in females was 129 million, with an ASIR of 15,226.11 per 100,000. By 2021, this figure had increased to 147 million cases with an ASIR of 15,157.9 per 100,000, showing an EAPC of 0.1 (95% CI: 0.06–0.14). For males, the 1990 incidence was 127 million cases with an ASIR of 14,274.55 per 100,000, which rose to 149 million cases and an ASIR of 14,415 per 100,000 by 2021. Males exhibited a marginally higher EAPC of 0.15 (95% CI: 0.11– 0.19) compared to females (Table 1; Fig. 1A and B). Notably, the ASDR for both sexes decreased over time, with fluctuating trends observed: a decrease from 1990 to 1998, an increase from 1998 to 2012, and another decrease from 2012 to 2021 (Table 1, Table S1).

Age-specific trends

The ASIR was highest in children aged < 1 year (27,495.37 per 100,000) and declined with increasing age, reaching 5,127.74 per 100,000 in the 10–14 years age group. The peak number of cases (98 million) occurred in the 2–4 years age group. The EAPCs for the < 1 year, 2–4 years, 5–9 years, and 10–14 years age groups were 0.08, 0.14, 0.18, and 0.13, respectively. Despite an increase in the number of

Table 1 Global burden and incidence of OM in children from 1990 to 2021 by sex and age, and the incidence in five SDI regions

	1990		2021		
	Incidence cases	ASR	Incidence cases	ASR	EAPC
Characteristics	**(95%UI)**	**pre-100,000 (95%UI)**	**(95%UI)**	**pre-100,000 (95%UI)**	**(95%CI)**
Global	256,302,935 (177825908–368974181)	14737.24 (10224.87-21215.76)	297,243,470 (205198444–431726180)	14774.55 (10199.43-21459.04)	0.12 (0.08–0.17)
Sex					
Female	128,761,012 (89429158–186472161)	15226.11 (10575.08-22050.5)	147,591,856 (101904390–215427249)	15157.9 (10465.73-22124.7)	0.1 (0.06–0.14)
Male	127,541,922 (88506613–183399548)	14274.55 (9905.7-20526.16)	149,651,613 (102914854–218107805)	14,415 (9913.14-21008.96)	0.15 (0.11–0.19)
Age					
< 1 year	33,782,919 (21883714–49306322)	26445.05 (17130.43-38596.67)	34,835,119 (22510731–50968672)	27495.37 (17767.72-40229.58)	0.08 (0.05–0.1)
2–4 years	86,065,553 (48057496–135375521)	23414.59 (13074.3-36829.63)	98,615,086 (55153438–154759542)	24466.21 (13683.46-38395.54)	0.14 (0.1–0.18)
5–9 years	73,876,051 (37334484–128951820)	12660.18 (6398.03-22098.55)	90,567,020 (45493426–159140187)	13181.94 (6621.53-23162.7)	0.18 (0.15–0.21)
10–14 years	26,494,826 (13121342–48219311)	4945.99 (2449.46-9001.47)	34,183,370 (16906073–62280919)	5127.74 (2536.03-9342.57)	0.13 (0.12–0.14)
SDI region					
High SDI	21,989,645 (16385875–30074283)	11834.62 (8818.72-16185.7)	20,639,456 (15468152–27905039)	11962.37 (8965.15-16173.41)	0.1 (0.07–0.13)
High-middle SDI	32,265,944 (22183931–46873547)	11792.11 (8107.48-17130.7)	26,479,526 (17978998–38752393)	11468.44 (7786.81-16783.89)	0.2 (0.1–0.31)
Middle SDI	77,829,617 (53579831–113217937)	13483.67 (9282.49-19614.55)	75,396,824 (51482658–111323366)	13300.76 (9082.06-19638.57)	0.13 (0.07–0.2)
Low-middle SDI	82,013,836 (56166569–119273506)	17371.69 (11896.87-25263.81)	94,821,611 (65156518–138188242)	16353.03 (11236.96-23832.08)	-0.15 (-0.16–0.13)
Low SDI	42,016,185 (29003874–60092889)	18354.62 (12670.24-26251.36)	79,706,871 (54876648–114678213)	17319.09 (11923.86-24917.83)	-0.18 (-0.21–0.16)

cases and ASIR across these age groups, the ASDR for each group showed a downward trend, with the most substantial decrease seen in children aged < 1 year (Table 1, Table S1, Fig. 1C and D, Fig.S1A-1B).

SDI at the regional level

Between 1990 and 2021, the ASIR of OM varied significantly across different SDI regions (Table 1, Table S1, Fig. 1E and F, Fig.S1C-1D). The lowest ASIR was observed in the high- and high-middle-SDI regions, at 11,834.62 and 11,792.11, respectively, with both showing a downward trend in case numbers. In contrast, the highest ASIR were found in the low- and low-middle-SDI regions, at 18,354.62 and 17,371.69, respectively. These regions experienced a significant increase in cases, particularly in the low-SDI region, where cases nearly doubled, rising from 42 million (95% UI: 29–60) to 79 million (95% UI: 54–114). The EAPC exhibited a decline in both the low-SDI (-0.18; 95% CI: -0.21 to -0.16) and low-middle-SDI regions (-0.15; 95% CI: -0.16 to -0.13). In the middle-SDI region, the ASIR showed a fluctuating pattern but decreased overall from 1990 to 2021. Notably, between 2019 and 2021, both case numbers and ASIR decreased in all SDI regions except the low-SDI region, likely due to the impact of the COVID-19 pandemic. By 2021, the ASDR in low-SDI regions (59.69) was nearly

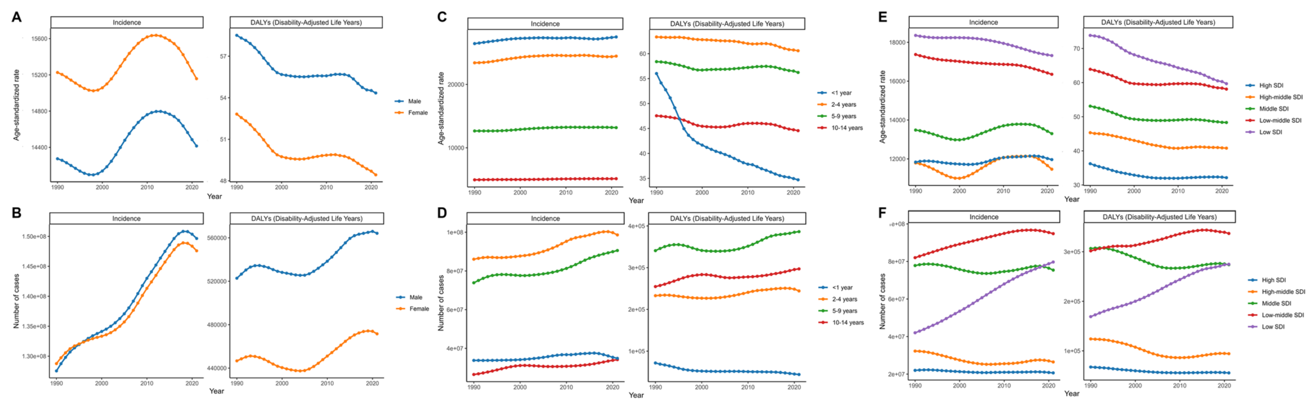

Fig. 1 Trends in the global burden of Otitis Media (OM) in children from 1990 to 2021, presented by sex, age group, and SDI region. (**A**) Age-Standardized Incidence Rate (ASIR) and Age-Standardized DALYs Rate (ASDR) trends by sex; (**B**) Number of incidence cases and Disability-Adjusted Life Years (DALYs) cases trends by sex; (**C**) ASIR and ASDR trends by age group; (**D**) Number of incidence cases and DALYs cases trends by age group; (**E**) ASIR and ASDR trends by Socio-Demographic Index (SDI) region; (**F**) Number of incidence cases and DALYs cases trends by SDI region

double that in high-SDI regions (32.14). Although ASDR declined across all regions, the most significant decrease was seen in low-SDI regions, with an EAPC of -0.68.

GBD region and country level

From 1990 to 2021, most regions and countries demonstrated either stable or declining trends (Fig.S2-S3, Table S2). Eastern Europe and high-income Asia-Pacific regions, however, showed significant increases in EAPC, with rates of 0.29 and 0.22, respectively. In contrast, regions such as Western and Central Sub-Saharan Africa, as well as Central Latin America, showed notable declines in EAPC, with rates of -0.16, -0.14, and −0.16, respectively. The highest ASIR was recorded in Eastern Sub-Saharan Africa (17,880.67), while the lowest was in Central Europe (9,827.73). Despite an overall increase in the EAPC of ASIR, the EAPC of DALYs decreased across all 21 regions, with the most significant declines occurring in Central Sub-Saharan Africa (-1.33) and Central Europe (-0.99).

In GBD regions, the burden of OM in children varies widely. To identify regions with similar changes in burden, this study used hierarchical clustering analysis. Notably, the ASIR and ASDR in Central Europe showed significant increases, while both metrics decreased significantly in Eastern Sub-Saharan Africa (Fig.S3).

At the national level, the Northern Mariana Islands, American Samoa, and Syrian Arab Republic displayed the largest declines in EAPC, with rates of -0.7, -0.57, and −0.55, respectively. Conversely, South Korea, Algeria, and Russia experienced the largest increases in EAPC, with rates of 0.43, 0.37, and 0.33, respectively. Ethiopia recorded the highest ASIR, at 18,687.09, while Taiwan (China) reported the lowest, at 7,300.39. Overall, the burden of OM in children has decreased across various countries and regions (Table S3, Fig. 2).

Correlation analysis

The relationship between ASIR and the SDI is U-shaped: ASIR decreases as SDI increases from 0 −0.75 but rises when SDI ranges from 0.75 to 1.0 (Fig. 3). There is a negative correlation between the ASR and EAPC ($P<0.01$, $\rho = -0.20$), while the HDI positively correlates with EAPC ($P<0.01$, $\rho=0.35$). The ASDR decreases as SDI decreases. No significant relationship was observed between ASDR and HDI ($P=0.11$, $\rho = -0.11$), or between ASDR and EAPC ($P=0.66$, $\rho=0.04$) (Fig. 4).

Frontier analysis of 204 countries and regions

Frontier analysis of ASIR of OM from 1990 to 2021 revealed significant heterogeneity in prevention and control across different countries and regions. Fifteen countries, including Spain, Pakistan, South Africa, Sweden, Kenya showed significantly higher rates, positioning them far from the frontier. Conversely, low-SDI countries/regions such as Niger, Somalia and Timor-Leste were closer to the frontier, indicating more effective disease control relative to their SDI levels. In contrast, nations with high SDI such as Sweden, Norway and the United Kingdom demonstrated greater distances from the frontier, suggesting inadequate control of OM. In terms of the ASDR, the burden in Papua New Guinea, Somalia, and Niger is closer to the ideal benchmark, while countries such as Lithuania, Latvia, and the Estonia still have significant room for improvement in reducing the burden of OM. Detailed data on frontier analysis for various countries is presented in Fig. 5 and Table S4.

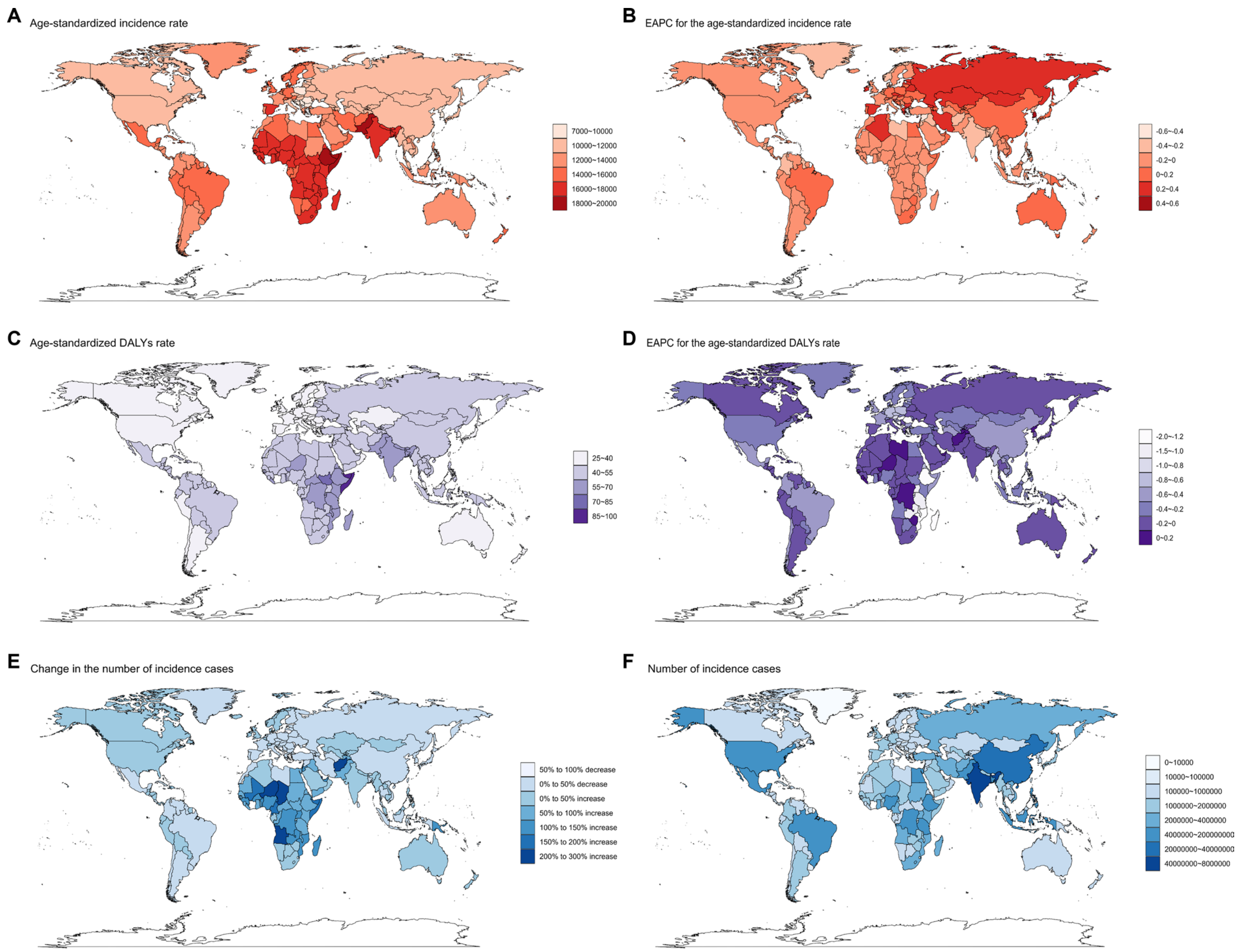

Fig. 2 The burden of Otitis Media (OM) in children across countries and regions worldwide in 2021 and trends from 1990 to 2021. (**A**) ASIR of OM in children in 2021; (**B**) EAPC for the ASIR in 2021. (**C**) ASDR of OM in children in 2021; (**D**) EAPC for the ASDR in 2021; (**E**) Number of OM cases worldwide in 2021; (**F**) Number of OM DALYs worldwide in 2021

Forecast analysis in global and five SDI regions

From 2022 to 2050, the global incidence of OM is projected to increase from 256.30 million cases in 2021 to 333.54 million by 2050, while the ASIR is expected to remain stable. The rise in case numbers is primarily attributed to low-SDI areas, in which the number of cases is projected to increase from 79.71 million in 2021 to 109.81 million in 2050. Meanwhile, case numbers in other SDI areas are expected to remain relatively stable or continue to decline. In terms of ASIR, middle- and low-SDI areas show a downward trend, while other SDI areas remain stable (Tables S5–S6, Fig.S4).

Discussion

This study is the first to systematically analyze the global trends in OM in children aged 0–14 years from 1990 to 2021, revealing significant differences and trends across sex, age groups, and regions. These insights are crucial for developing public health strategies at both global and regional levels to mitigate the burden of OM in children.

From 1990 to 2021, the number of OM cases in children aged 0–14 years increased globally from 256 million to 297 million, a growth rate of 15.97%, while the ASIR remained relatively stable. This trend likely reflects both global population growth and advances in diagnostic technologies. Although the incidence has increased, it has been effectively controlled through medical interventions and preventive measures. Concurrently, the number of DALYs slightly increased, but the ASDR showed a downward trend, suggesting a reduction in disease severity and the associated

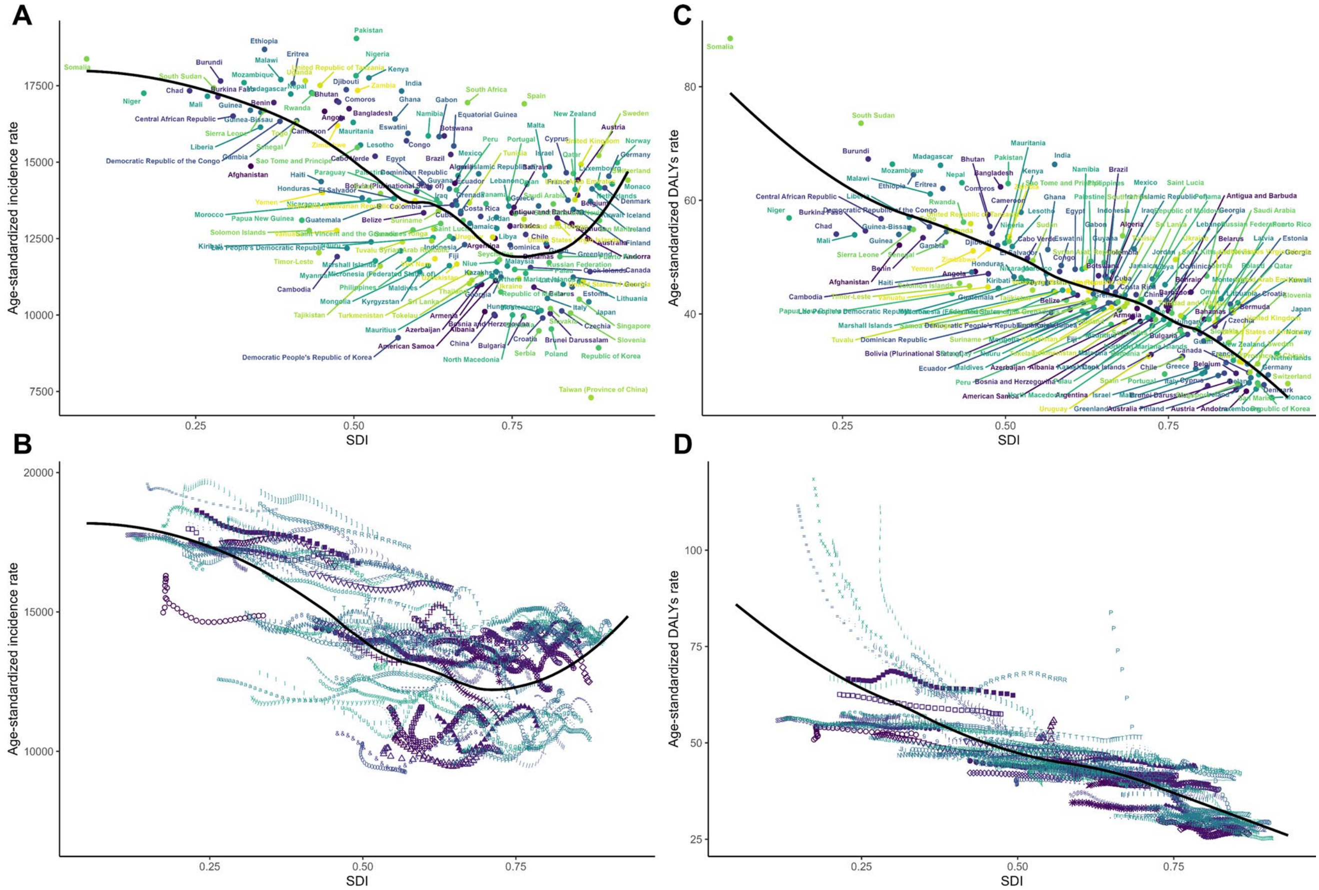

Fig. 3 Relationship between the ASR and SDI in children with OM. (**A**, **B**) ASIR and SDI; (**C**, **D**) ASDR and SDI

disability burden. This improvement can be attributed to enhanced treatment methods, the widespread adoption of early diagnosis, and stronger public health interventions. However, the high ASIR highlights the ongoing public health challenge posed by OM in children, particularly given its potential impact on hearing and quality of life. Therefore, continued focus on prevention, early diagnosis, and effective management strategies are essential. The increase in global cases also necessitates in-depth research in high-burden regions to develop targeted interventions that reduce the incidence of OM in children.

Furthermore, the number of cases among both female and male children has increased, but there is a significant sex difference in the ASIR of OM, with females exhibiting a higher rate than males. This discrepancy may reflect sex differences in the pathogenesis of OM, such as physiological structure, immune response, or behavioral exposure [24]. Anatomically, females may have shorter and more horizontal Eustachian tubes, making it easier for pathogens to enter the middle ear cavity [25].

The ASIR of OM is highest in children aged < 1 year and decreases with age, reaching its lowest point in the 10–14 years age group. This age-dependent pattern may be related to the immaturity of the Eustachian tube in children, maturation of the immune system, increased exposure to pathogens, and factors such as tobacco and environmental pollution [24, 26–28]. These findings emphasize the importance of prevention and intervention measures aimed at infants and young children. For example, promoting breastfeeding can improve an infant's immune system and reduce the risk of OM [29], and encouraging vaccination against influenza and pneumococcal infections can help prevent related infections. Meanwhile, the ASDR has shown a declining trend across all age groups, with the fastest decline observed in children aged < 1 year. This indicates that public health interventions are increasingly focusing on preschool children, particularly infants and toddlers, optimizing prevention and treatment strategies to further reduce the overall burden and incidence of OM in children.

Between 1990 and 2021, OM incidence rates showed consistent trends across sex and SDI regions, with notable ASR fluctuations observed in high-middle- and middle-SDI regions. In high-middle-SDI regions, the ASR of OM showed a decline from 1990 to 2000, likely due to widespread antibiotic use, improved sanitary conditions, and enhanced public health measures [30].

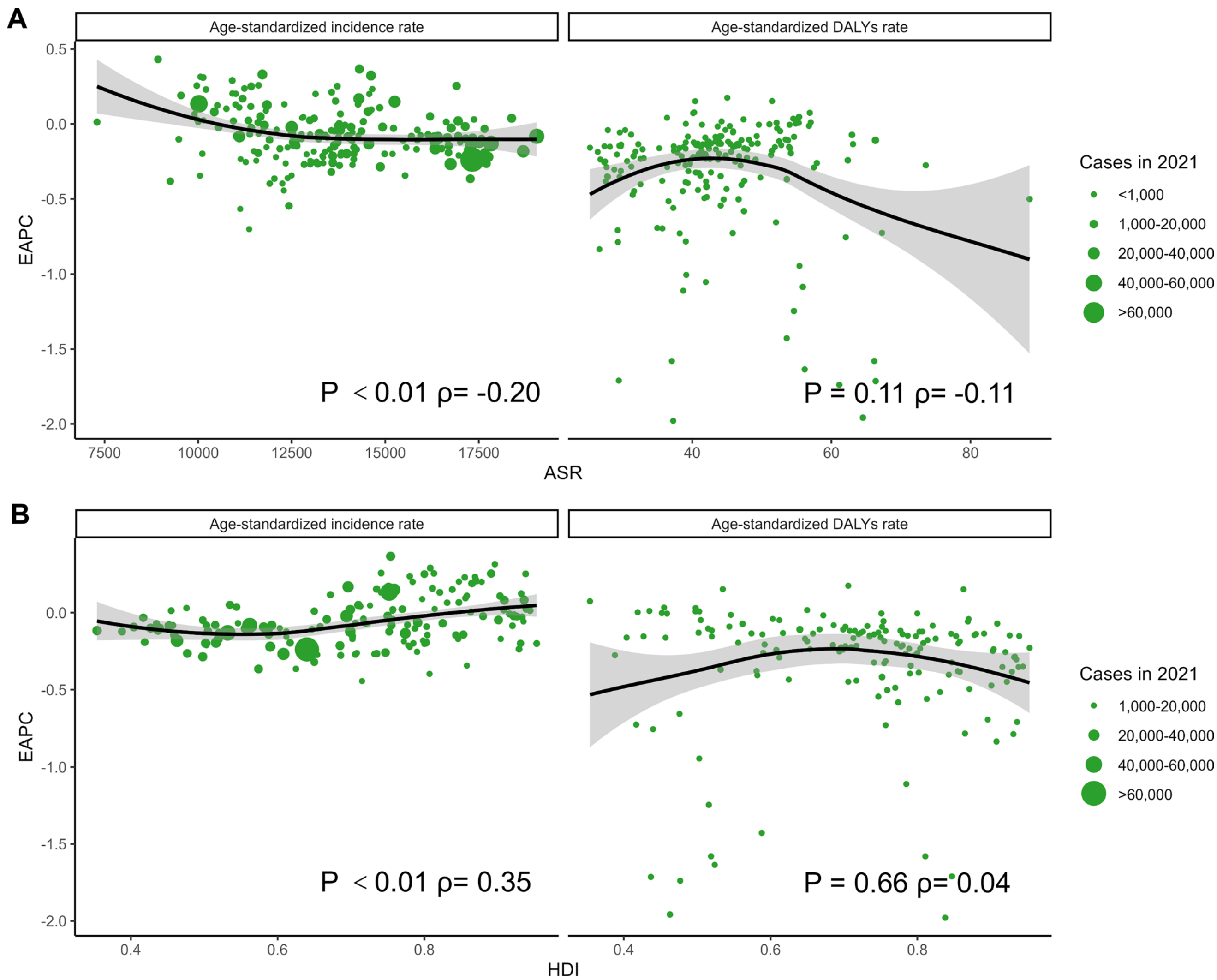

Fig. 4 Relationship between EAPC, ASR, and HDI in children with OM in 2021. (**A**) EAPC and ASR; (**B**) EAPC and HDI. The size of the spots represents different numbers of cases

However, from 2000 to 2014, the ASR increased, primarily attributed to the emergence of pneumococcal serotypes not covered by the introduced vaccines (e.g., PCV7), increased antibiotic resistance, and changes in environmental and socioeconomic factors [14, 31]. The ASR declined again from 2014 to 2021 [32], attributed to the widespread adoption of the PCV13 vaccine, which covers additional serotypes, improved antibiotic stewardship, and further public health interventions. Notably, while a 2019 study reported a consistent downward trend in OM incidence across all age groups, this trend was not observed in the pediatric population during the same period [33]. As of 2018, 145 of the 194 World Health Organization (WHO) member states had introduced the PCV into their routine infant immunization programs. Although the incidence of OM shows a downward trend with the greater coverage of the PCV vaccine, the impact of vaccination on the incidence of OM appears to be limited. The reduction in OM incidence observed in this study is not as pronounced as reported in previous literature [34].

The burden of OM is heaviest in lower-SDI regions, where the ASIR is significantly higher than in higher-SDI regions. This disparity may reflect disparities in healthcare resources and sanitary conditions across regions. For example, lower-SDI regions often lack sufficient medical and environmental resources, which can lead to higher incidence rates. Genetic or cultural factors may also play a role [35]. Moreover, with population growth, the number of cases in lower SDI-regions nearly doubled from 42 million in 1990 to 79 million in 2021, highlighting the urgent need for targeted public health interventions. These should include improvements in sanitation, enhanced health education, and broader access to healthcare services. Notably, the EAPC in these regions is -0.18, indicating that while the

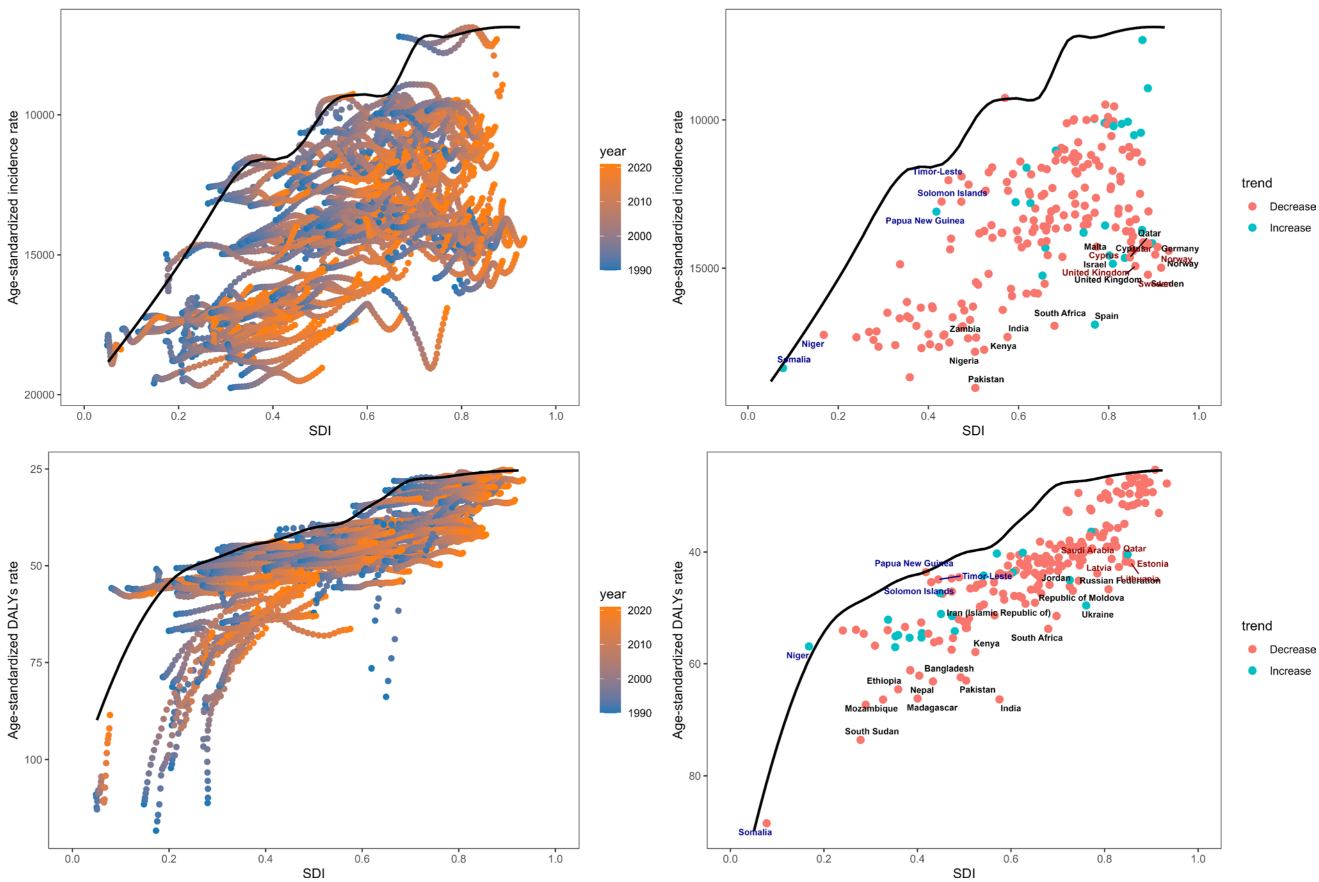

Fig. 5 Frontier analysis of OM in children in 204 countries and regions in 2021. **(A, B)** Gap in ASIR between different countries and the frontier; **(C, D)** Gap in ASDR between different countries and the frontier. The top 15 countries furthest from the frontier are marked in black; countries with low SDI (< 0.47) and nearest to the frontier are marked in blue; countries with high SDI (> 0.81) and furthest from the frontier are marked in red. Red dots indicate an increase in ASIR and ASDR from 1990 to 2021; blue dots indicate a decrease in ASIR and ASDR from 1990 to 2021

number of cases has risen, the growth in the incidence rate has slowed.

Additionally, data from 2019 to 2021 show a decrease in the number of cases and ASR in all SDI regions except low-SDI regions. This trend may be attributed to public health measures implemented during the COVID-19 pandemic, such as social distancing, mask-wearing, and hand hygiene. These measures not only reduced the spread of the coronavirus but also reduced the transmission of other respiratory pathogens, subsequently lowering the incidence of OM [36]. In young children, who are particularly vulnerable to environmental pollutants, a further decrease in AOM prevalence was seen due to these pandemic measures. However, these protective measures may lead to "immune debt" in children, where insufficient exposure to pathogens due to reduced social interactions could result in more frequent and severe upper respiratory infections and subsequent development of OM [37]. Additionally, necessary vaccinations were delayed due to social distancing [38]. There are also reports indicating a sharp increase in the incidence rate of complex OM following the lifting of health measures [39].

The ASR in children shows a U-shaped curve relative to the SDI, suggesting complex socioeconomic factors are at play. In lower-SDI regions, as conditions improve, increased access to sanitation and medical services leads to a reduction in incidence rates. Conversely, in higher-SDI regions, there has been a resurgence of cases. Furthermore, ASR is negatively correlated with EAPC, while the HDI is positively correlated with EAPC. This indicates that in regions with high HDI, despite generally better health, the rate of increase in OM incidence is faster, potentially necessitating more sophisticated health interventions. This trend could also relate to heightened health awareness, improved diagnostic rates, and the efficient use of medical resources and data collection in high-HDI regions.

Differences in OM at the regional and national levels may be linked to factors such as local sanitary conditions, access to medical resources, and public health awareness. Over the past few decades, significant changes in healthcare systems, such as the introduction of vaccines and the implementation of comprehensive disease surveillance systems, have been seen in some Eastern European and high-income Asia-Pacific countries, potentially impacting incidence rates [40, 41]. The ASIR in Eastern Europe has shown a significant upward trend, whereas both Western and Central Sub-Saharan Africa and Central America have seen notable declines. Despite these decreases, OM incidence remains relatively high in regions such as Western and Central Sub-Saharan Africa, where the high humidity and moist climatic conditions typical of tropical regions can easily lead to allergies and upper respiratory infections [42]. Nationally, the Northern Mariana Islands, American Samoa, and Syrian Arab Republic have shown the largest decreases in ASIR, while South Korea, Algeria, and Russia have experienced the most significant increases. Ethiopia recorded the highest ASIR, and Taiwan the lowest. These findings reveal complex trends that are closely tied to socioeconomic conditions. Future research should aim to develop more effective interventions and deepen the understanding of factors influencing OM incidence in children across various environmental contexts.

By 2050, the ASIR of OM in children worldwide is expected to remain relatively stable, but the number of patients is projected to continue rising, possibly reaching 334 million, driven primarily by low-SDI regions. This highlights the urgency of strengthening healthcare infrastructure, improving health education, and implementing effective preventive strategies in these regions. The number of cases in middle- and high-SDI regions may show a downward trend.

Limitations

This study had several limitations. First, the completeness and consistency of the data sources may have affected the accuracy of the results. Differences in data collection, reporting, and diagnostic standards across countries and regions may have introduced bias into the results. Second, we were unable to obtain data on pneumococcal and influenza vaccination coverage rates for different countries, which limits our assessment of the impact of vaccination on the burden of OM. In addition, the GBD treats OM as a single disease, failing to distinguish between AOM, OME, and CSOM, preventing more detailed analysis. Finally, the ARIMA model assumes linearity in the time series, overlooking nonlinear factors and external variables that may influence incidence rates.

Conclusion

In summary, while the number of OM incidence cases in children worldwide has increased over the past 30 years, the growth in incidence has been effectively managed through medical interventions and public health measures, and the severity of the disease has continued to decrease. However, the ASIR remains high, and significant regional disparities persist, particularly in low-SDI regions and among young children. This continues to pose a major challenge to global public health, especially in these vulnerable groups. Consequently, there is an urgent need for more cost-effective and targeted strategies to reduce the burden of OM in children and mitigate the associated risks.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00405-024-09165-z .

Acknowledgements We gratefully acknowledge the Global Burden of Disease Study and Institute for Health Metrics and Evaluation for providing data that made this research possible.

Author contributions Lingkang Dong, Yuchen Jin, Wenqi Dong, Yumeng Jiang, and Zhuangzhuang Li contributed to data interpretation. Lingkang Dong and Yuchen Jin contributed to data visualization and analysis, and drafted the manuscript. Wenqi Dong made significant contributions to the revision of the manuscript. Dongzhen Yu and Kaiming Su provided supervision, interpreted the results, and critically revised the manuscript. All authors contributed to the revision of the manuscript, approved the final version for publication, and agree to be accountable for all aspects of the work.

Funding The National Key Research and Development of China (Nos. 2023YFC2508000 & 2023YFC2508003) funded this study.

Data availability Data used in this study can be found on GBD: https://www.healthdata.org/gbd.

Declarations

Ethical approval This study uses publicly available data from the Global Burden of Disease (GBD) 2021 database, provided by the Institute for Health Metrics and Evaluation (IHME). The GBD study has received ethical approval from the Institutional Review Board of the University of Washington. As the data used in this study is de-identified and publicly available, no additional ethical approval or informed consent was required for this research.

Competing interests The authors declare no competing interests.

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