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Review article

Global burden of asthma among children and adolescents with projections to 2050: a comprehensive review and forecasted modeling study

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Understanding pediatric asthma is crucial to its effective diagnosis and intervention, as it may alleviate the adulthood disease burden. This epidemiological review describes the prevalence of asthma among individuals under 20 years of age by categorizing them into 3 age groups: 1–4, 5–9, and 10–19 years. Estimates were obtained from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021, which covered the prevalence of asthma from 1990 to 2021 across 21 GBD regions with 95% uncertainty intervals (UIs). We also projected the prevalence of pediatric asthma in 2050 by using a logistic regression predictive model from the existing literature and incorporating body mass index as a covariate with fixed coefficients over time. Overall, a continuous decline in asthma prevalence rates among children and adolescents was observed from 1990 to 2021, with higher rates in males and a peak prevalence rate in the 5–9 years group. Central Europe showed significantly increased prevalence rates compared to those of other regions. Our projection suggests that the prevalence rate of pediatric asthma will decline to approximately 2,608.05 per 100,000 population by 2050 (95% UI, 1,632.94–3,868.26), representing a 39.5% decrease from the 2021 figures. Despite these trends, asthma remains a substantial health burden for children and adolescents that may persist into adulthood. Therefore, proactive diagnosis and intervention are essential to mitigating the associated disease burden.

Key words: Asthma, Prevalence, Child, Adolescent

Key message

Pediatric asthma can persist to adulthood and must be effectively managed. This review examined the prevalence of asthma among individuals younger than 20 years and revealed a decline from 1990 to 2021, higher rates in males, and a peak in children aged 5–9 years. Despite a projected continued decrease in prevalence by 2050, asthma will remain a significant health concern for children and adolescents.

Introduction

Asthma, a chronic noncommunicable disease characterized by dyspnea and wheezing, is caused by airway obstruction triggered by external stimuli such as cold air, allergens, or viruses.[1)] This obstruction is accompanied by mucus production, airway remodeling, and bronchial hyperresponsiveness.[2)] Advances in our understanding of the immunological mechanisms of asthma have facilitated the development of various treatments, including biologics targeting relevant immune factors, effectively alleviating symptoms, and preventing irreversible airway remodeling.[3,4)] These advancements have contributed to significant reductions in asthma morbidity and mortality rates over the past few decades.[5)] However, despite these improvements, many patients' conditions remain inadequately controlled, and the economic burden associated with acute exacerbations and chronic management continues to increase.[6,7)] Asthma accounts for over 1% of global disability-adjusted life years (DALYs), highlighting its importance as a critical health concern that requires

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sustained attention and research.[8)]

Although asthma is classified as a chronic respiratory disease, it exhibits characteristics that are distinct from those of other related diseases. Unlike other chronic conditions that typically increase in incidence and prevalence with age, asthma has a notably higher prevalence and incidence from infancy to young adulthood.[9)] Moreover, asthma accounts for most DALYs associated with chronic respiratory diseases in individuals younger than 35 years.[10)] Consequently, pediatric asthma significantly contributes to healthcare expenditures owing to frequent hospital visits, medications, and emergency care that are compounded by considerable indirect costs.[11)] Early-life wheezing is a strong predictor of a future asthma diagnosis, and recurrent bronchial obstructions during early life are correlated with reduced lung function at 16 years of age.[12-14)] Given the high incidence and prevalence of asthma in pediatric populations along with its potential to persist into adulthood, a comprehensive understanding of asthma during childhood and adolescence is essential for its effective diagnosis and intervention.

The global epidemiology of asthma varies significantly across countries and regions with inconsistent trends over time.[15)] These patterns also vary by age and income group, highlighting the need for a comprehensive analysis of global and regional trends as well as various stratifications to effectively evaluate the pediatric asthma prevalence. Therefore, this review examined the trends in asthma prevalence among children and adolescents from 1990 to 2021 to provide insights into its evolving epidemiology. Given that asthma characteristics differ by age within the pediatric population,[16)] we categorized the study population into 3 age brackets: 1–4 (preschool), 5–9 (early school), and 10–19 (late school/adolescence) groups. We then assessed the prevalence of asthma and described the distinctive features of each group. We also investigated the risk factors contributing to asthma in children and adolescents and projected the prevalence of pediatric asthma through the year 2050. This study aimed to enhance our understanding of asthma epidemiology in these age groups and highlight the need for strategies to address its anticipated burden in the pediatric population and beyond.

Methods

We utilized the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021, a comprehensive global database quantifying the burden of 371 diseases and injuries and 88 risk factors across 204 countries and territories.[17)] Since 1996, the Institute for Health Metrics and Evaluation has systematically modeled the burden of various diseases and attributable risk factors contributing to health recommendations at the regional and local levels.[18)] This research adhered to the Guidelines for Accurate and Transparent Health Estimate Reporting (Supplementary Table 1).

The input data for the GBD 2021 consisted of systematic reviews, population-based surveys, medical expenditure panel surveys, and insurance and hospital claim data. The relevant International Classification of Disease (ICD) codes included ICD-10 J45 and J46 and ICD-9 493. Asthma was defined as having received a physician's diagnosis and experienced wheezing during the past year. An alternative definition encompasses self-reported asthma or cases in which either a doctor diagnosed asthma or wheezing occurred in the past year. Statistics based on the alternative definition were adjusted using Bayesian meta-regression, regularized, and trimmed to align with results from the reference definition. Asthma prevalence was estimated using a disease-model Bayesian meta-regression. In the absence of raw data, a cascading approach was applied to the estimation.[19)]

We used estimates of asthma prevalence rates for populations aged 1–4, 5–9, and 10–19 years along with 95% uncertainty intervals (UIs). Assessing and diagnosing asthma in children younger than 1 year of age are challenging; thus, the GBD 2021 does not provide prevalence values for this age group.[20)] Regional prevalence patterns were categorized into 21 GBD regions, with estimates stratified by World Bank income levels (high, upper middle, lower middle, and low) and sociodemographic indices (SDIs; low, low-middle, middle, high-middle, and high), which reflect a country's development level by integrating income, education, and fertility.[21)] We conducted a correlation analysis to assess the relationship between SDI and asthma prevalence.

Based on GBD estimates, we conducted an analysis to predict the asthma prevalence in the pediatric population by 2050. We utilized the summary exposure value (SEV), which indicates the proportion of the population exposed to risk factors as first defined in the GBD 2015, to quantify the relative risk associated with specific risk factors. The SEV ranges from 0 to 1, where 0 indicates no exposure to a risk factor and 1 signifies maximum risk. To derive the SEV for each disease, the SEV for each risk factor was divided by the number of diseases attributable to that risk factor. To forecast the future asthma prevalence, we linearly projected the SEV based on the annual rate of change in the logit SEV stratified by location, age, and sex.

The GBD 2021 identified 3 risk factors for pediatric asthma: a high body mass index, nitrogen dioxide pollution, and occupational exposure. We calculated the population-attributable fraction (PAF) based on the SEV associated with each risk factor. The PAF indicates the contribution of a specific risk factor to a particular population. Because the SEV does not reflect the relationship between risk factors and associated diseases, we applied a correction factor. We also integrated the PAF for each risk factor using mediating factors as detailed in the GBD 2021 forecast capstone.[22] To incorporate additional risk factors beyond those addressed in the GBD 2021, we included other covariates from the GBD into our model, specifically SDI and indoor air pollution, using fixed coefficients over time.

Finally, we calculated the scalar risk factor, which represents the ratio of cause-specific to overall prevalence. We predicted asthma prevalence not attributable to GBD risk factors using linear regression with the following equation: Logit (asthma prevalence)=$\alpha+\beta 1*$ SDI+$\beta 2*$indoor air pollution +ϵ. This predicted value was then multiplied by the scalar risk factor to obtain the final forecast prevalence. To validate the asthma prevalence predicted by this model, we used data from 1990 to 2010 to forecast the pediatric asthma prevalence from 2010 to 2021 and compared these predictions with the actual GBD estimates.[23,24]

We conducted a decomposition analysis to understand projected changes in the prevalence of pediatric asthma. We utilized Das Gupta's decomposition methodology, which assesses the impact of changes in population structure and age distribution on disease prevalence.[25] The analysis was categorized into 3 key factors: aging, which reflects changes in age distribution; population size, which accounts for changes in population count; and epidemiological changes, which represent other variations. All analyses were performed using Python (version 3.10.4) and R software (ver. 4.2.1).

To describe the age-specific characteristics of asthma and high-risk populations, we conducted a systematic search of previous studies using the following search terms: "asthma," "children," "adolescent," "youth," "risk factors," and "prevalence." We searched the Google Scholar, Scopus, and PubMed/Medline databases for studies published between January 1990 and January 2025 and screened the titles, abstracts, full texts, and reference lists of the retrieved studies for relevance.

Global and regional prevalence of asthma in children and adolescents

According to GBD 2021, the global prevalence of asthma among children and adolescents younger than 20 years was 4,313.76 per 100,000 population (95% UI, 3,338.65–5,573.97) in 2021, representing a 29.78% decrease (95% UI, -27.16 to -32.42) since 1990. This decreasing trend was evident across most countries and consistent across all pediatric age groups (Fig. 1). The prevalence rate was higher in males (4,604.29 per 100,000 population [95% UI, 3,562.54–5,951.81]) than in females (4,004.77 per 100,000 population [95% UI, 3,102.83–5,173.41]).

The incidence of asthma increased with increasing SDI, whereas DALYs decreased with increasing SDI.[26] This trend in incidence appeared to be similar to its prevalence in the pediatric population (Fig. 2). In 2021, our analysis indicated that a higher SDI is associated with an increased asthma prevalence, particularly in older pediatric age groups (1–4 years: β=1,925.882, P<0.001; 5–9 years: β=2,633.535, P<0.001; 10–19 years: β=4,059.251, P<0.001). The positive association

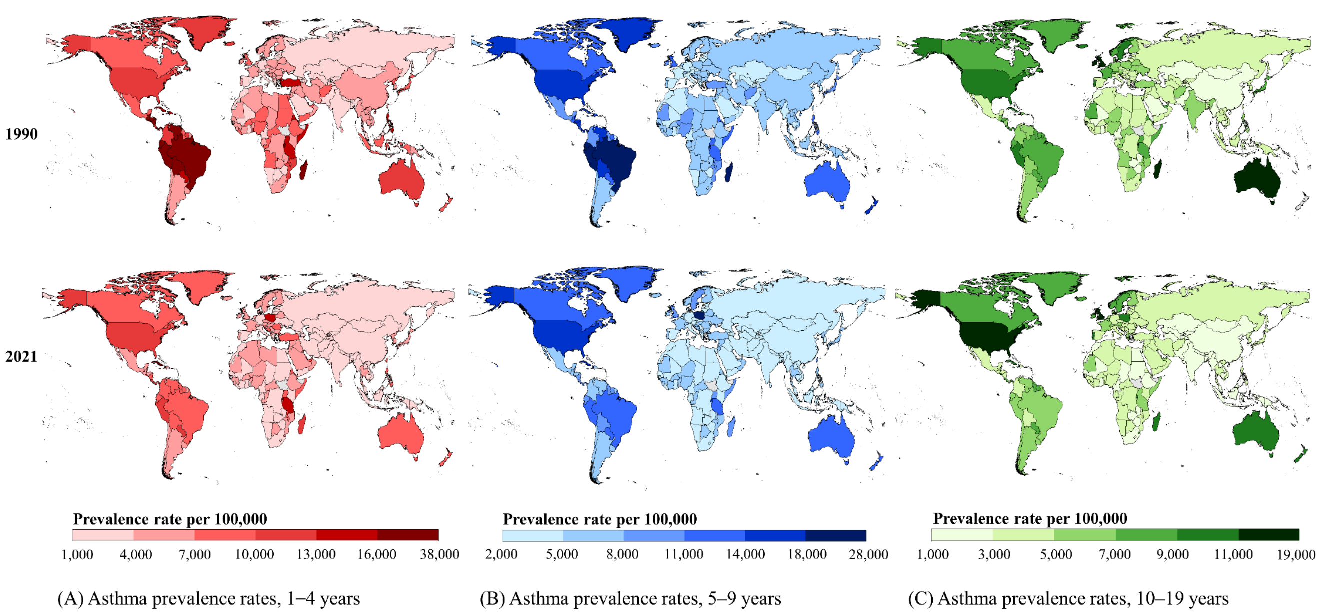

Fig. 1. World map of asthma prevalence rates for individuals 1–4 years (A), 5–9 years (B), and 10–19 years (C) old in 1990 and 2021.

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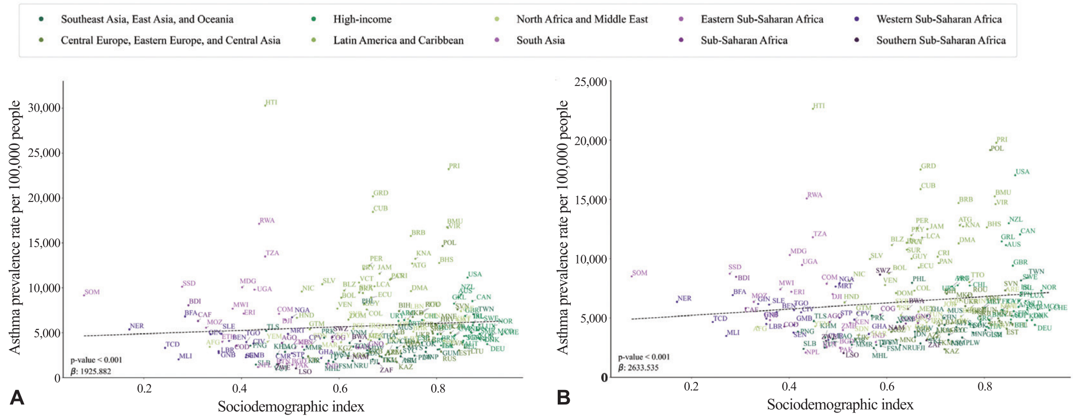

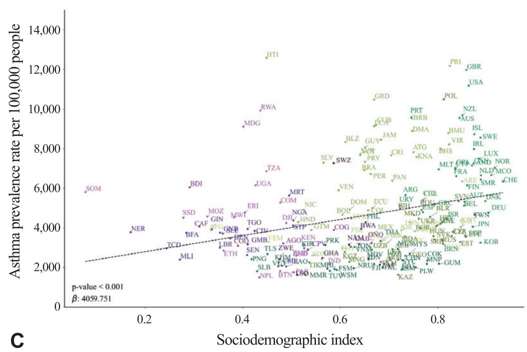

Fig. 2. Prevalence rates of asthma and the sociodemographic index for individuals 1–4 years (A), 5–9 years (B), and 10–19 years (C) in 2021.

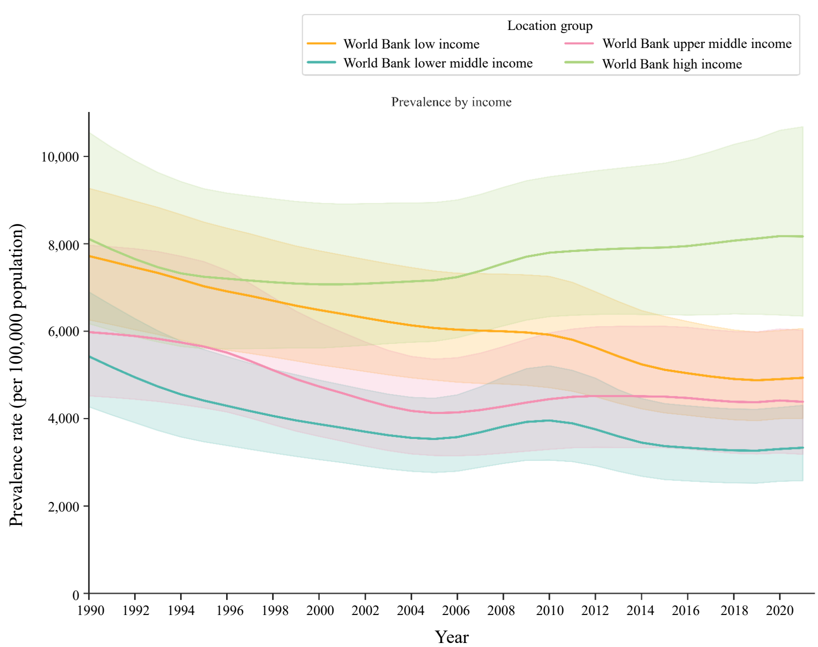

Fig. 3. Trends in asthma prevalence rate (per 100,000 population) among individuals younger than 20 years by World Bank income group, 1990–2021.

between the SDI and asthma prevalence may be attributed to increased industrialization and exposure to environmental allergens in high-SDI regions.[27] Improved healthcare access and higher health awareness contribute to a more accurate asthma diagnosis. Conversely, the reduction in DALYs and mortality rates with increasing SDI suggests that, while the asthma prevalence rate may be higher in high-SDI countries, its impact on overall health is mitigated by effective disease management.[28] Therefore, it is essential to provide adequate support for asthma management in countries with low SDI scores to alleviate the burden of pediatric asthma and prevent its persistence into adulthood.

In 2021, high-income group (8,168.45 per 100,000 population [95% UI, 6,344.85–10,678.31]) had the highest prevalence rate, followed by the low-income group (4,932.29 per

100,000 population [95% UI, 4,003.42–6,062.18]), upper middle-income group (4,383.90 per 100,000 population [95% UI, 3,181.81–6,022.55]), and lower middle-income group (3,332.27 per 100,000 population [95% UI, 2,577.93–4,304.11]). Although the overall trend indicated a decrease, the high-income group showed an increased prevalence since 2005 (Fig. 3). This shift may be linked to simplification of the diagnostic criteria that emphasizes clinical control over severity classification. Furthermore, the heightened focus on asthma management in children younger than 5 years may have contributed to this rise, particularly in high-income countries in which such approaches were swiftly implemented. However, socioeconomic disparities persist within high-income countries. For instance, a study in the United States found that a higher median household income was associated with a lower asthma incidence, suggesting that within-country income inequality influences asthma risk differently than global income inequality.[29] Therefore, careful interpretation of these findings is essential.

When examining the regional patterns of asthma prevalence among children and adolescents, it is essential to focus on Latin America, high-income regions, and Central Europe. Latin America (including Andean, Central, and

Table 1. Global asthma prevalence rates (per 100,000 population) in 1990 and 2021 and percentage change (1990–2021) for individuals 1–4 years, 5–9 years, and 10–19 years of age

Variable	Prevalence rate (95% UI) for individuals aged 1–4 years			Prevalence rate (95% UI) for individuals aged 5–9 years			Prevalence rate (95% UI) for individuals aged 10–19 years		
	1990	2021	Percentage change in prevalence rates, 1990-2021	1990	2021	Percentage change in prevalence rates, 1990-2021	1990	2021	Percentage change in prevalence rates, 1990-2021
Global	6,792.61 (5,028.00–9,069.83)	4,471.29 (3,192.32–6,118.03)	-34.17 (-36.70 to -31.42)	7,665.21 (5,648.17–10,693.21)	5,427.19 (3,904.24–7,735.84)	-29.20 (-32.81 to -25.53)	4,936.46 (3,660.07–6,832.79)	3,640.69 (2,698.67–5,030.15)	-26.25 (-28.64 to -23.62)
Sex									
Male	7,334.05 (5,400.94–9,774.48)	4,767.34 (3,391.93–6,555.85)	-35.00 (-37.67 to -32.25)	8,527.84 (6,319.50–11,883.86)	6,754.35 (4,944.41–9,455.84)	-29.77 (-33.42 to -26.08)	5,229.02 (3,844.20–7,259.98)	3,781.39 (2,768.44–5,205.62)	-27.68 (-30.17 to -25.01)
Female	6,216.67 (4,582.32–8,298.17)	4,154.97 (3,000.34–5,634.02)	-33.16 (-35.91 to -30.15)	5,989.43 (4,312.39–8,507.38)	4,827.92 (3,468.21–6,918.75)	-28.52 (-32.24 to -24.87)	4,631.92 (3,427.91–6,360.00)	3,491.57 (2,574.25–4,839.97)	-24.62 (-27.12 to -21.87)
SDI									
High	7,803.61 (5,044.28–1,1153.23)	7,669.71 (4,929.79–1,0970.47)	-1.72 (-5.09 to 2.64)	10,385.20 (7,217.40–15,502.07)	10,552.85 (7,494.46–15,317.00)	1.61 (-4.08 to 9.52)	8,106.66 (5,940.01–11,040.50)	7,952.10 (5,900.82–10,675.95)	-1.91 (-7.31 to 4.65)
High-middle	4,958.38 (3,337.85–6,881.29)	3,877.71 (2,407.46–5,719.76)	-21.79 (-29.39 to -15.22)	5,797.45 (3,930.44–8,721.93)	47,89.75 (3,154.55–7,464.02)	-17.38 (-22.97 to -11.08)	3791.56 (2627.89–5360.25)	3293.92 (2244.83–4828.63)	-13.12 (-18.27 to -6.06)
Middle	7,173.32 (5,255.92–9,618.04)	4,281.70 (2,913.58–5,968.53)	-40.31 (-44.63 to -36.24)	7,708.75 (5,608.49–10,866.46)	5,102.47 (3,563.23–7,457.94)	-33.81 (-38.48 to -29.31)	4,243.63 (3,055.11–5,966.60)	3,166.74 (2,221.71–4,509.94)	-25.38 (-29.70 to -21.48)
Low-middle	5,990.17 (4,506.54–7,769.83)	2,908.91 (2,043.67–3,972.99)	-51.44 (-55.16 to -47.78)	7,182.70 (5,242.05–9,839.08)	3,935.91 (2,838.56–5,628.34)	-45.20 (-50.00 to -39.77)	4,899.48 (3,548.96–6,863.18)	2,709.11 (1,942.42–3,762.41)	-44.71 (-48.99 to -39.77)
Low	8,652.69 (6,583.49–11,007.39)	5,678.17 (4,334.35–7,171.97)	-34.38 (-38.53 to -29.90)	8,560.19 (6,487.92–11,255.40)	6,108.63 (4,600.32–8,203.08)	-28.64 (-33.44 to -24.08)	5,607.89 (4,268.14–7,349.05)	3,876.31 (2,947.12–5,062.01)	-30.88 (-34.32 to -27.62)
Income									
High	7,510.58 (4,915.06–10,579.58)	7,415.94 (4,796.90–10,620.95)	-1.26 (-4.50 to 3.55)	9,687.91 (6,789.41–14,415.06)	9,997.67 (7,057.69–14,527.96)	3.20 (-2.14 to 10.87)	7,638.84 (5,564.37–10,416.36)	7,620.22 (5,642.76–10,246.01)	-0.24 (-6.21 to 7.33)
Upper middle	7815.16 (5688.84–10558.74)	4,774.59 (3,100.91–6,773.86)	-38.91 (-45.22 to -33.21)	7,996.68 (5,623.75–11,504.26)	5,637.28 (3,781.80–8,535.87)	-29.50 (-35.55 to -24.03)	4,036.93 (2,816.39–5,725.95)	3,503.33 (2,364.47–5,152.95)	-13.22 (-18.57 to -7.22)
Lower middle	5,319.25 (3,951.52–7,029.60)	3,474.22 (2,517.66–4,692.53)	-34.69 (-38.04 to -31.25)	6,697.63 (4,847.20–9,265.64)	4,278.11 (3,107.14–6,020.77)	-36.12 (-40.87 to -30.91)	4,708.93 (3,399.97–6,624.95)	2,768.76 (1,989.43–3,789.03)	-41.20 (-45.23 to -36.09)
Low	9,640.98 (7,312.68–1,2212.05)	5,438.77 (4,202.77–6,849.54)	-43.59 (-47.39 to -39.56)	8,703.68 (6,676.71–11,600.49)	5,919.73 (4,469.38–7,972.12)	-31.99 (-37.79 to -26.19)	5,526.40 (4,339.84–7,030.45)	4,030.81 (3,129.60–5,190.40)	-27.06 (-30.85 to -23.22)

(continued)

Table 1. Global asthma prevalence rates (per 100,000 population) in 1990 and 2021 and percentage change (1990–2021) for individuals 1–4 years, 5–9 years, and 10–19 years of age (Continued)

Variable	Prevalence rate (95% UI) for individuals aged 1–4 years			Prevalence rate (95% UI) for individuals aged 5–9 years			Prevalence rate (95% UI) for individuals aged 10–19 years		
	1990	2021	Percentage change in prevalence rates, 1990-2021	1990	2021	Percentage change in prevalence rates, 1990-2021	1990	2021	Percentage change in prevalence rates, 1990-2021
GBD super region									
Southeast Asia, East Asia, and Oceania									
East Asia	4,700.96 (2,973.43–6,794.97)	3,404.30 (1,960.62–5,169.28)	-27.58 (-35.36 to -19.61)	5,848.75 (3,874.49–9,258.74)	4,467.31 (2,866.90–7,184.45)	-23.62 (-29.61 to -18.34)	2,813.02 (1,868.10–4,067.11)	2,443.72 (1,604.99–3,664.01)	-13.13 (-18.80 to -6.98)
Oceania	5,234.88 (3,963.74–6,741.71)	3,269.69 (2,530.20–4,068.56)	-37.54 (-44.46 to -30.09)	5,734.76 (4,484.02–7,465.22)	3,648.35 (2,863.48–4,654.23)	-36.38 (-41.42 to -30.70)	3,582.85 (2,858.63–4,363.89)	2,353.73 (1,871.63–2,884.78)	-34.31 (-39.87 to -28.01)
South Asia	3,359.91 (2,368.67–4,583.66)	1,568.39 (1,047.87–2,268.84)	-53.32 (-58.65 to -47.89)	6,185.62 (4,193.41–8,855.10)	2,873.59 (1,915.19–4,210.75)	-53.54 (-58.53 to -47.83)	5,059.87 (3,414.10–7,308.35)	2,125.96 (1,442.38–3,133.42)	-57.98 (-62.33 to -52.84)
Central Europe, Eastern Europe, and Central Asia									
Central Asia	2,672.16 (1,699.22–3,893.87)	2,531.40 (1,543.23–3,736.52)	-5.27 (-10.62 to -1.23)	3,511.33 (2,367.11–5,365.96)	3,366.91 (2,236.94–5,208.47)	-4.11 (-9.82 to 1.79)	2,623.67 (1,860.52–3,659.81)	2,428.79 (1,607.96–3,536.64)	-7.43 (-15.54 to 0.33)
Central Europe	5,969.13 (3,853.16–8,627.49)	8,871.01 (5,666.76–12,778.03)	48.61 (35.18 to 64.57)	5,987.49 (3,881.52–9,060.90)	10,288.97 (6,997.35–1,5533.34)	71.84 (54.49 to 90.04)	4,550.08 (3,066.92–6,396.94)	6,152.37 (4,300.46–8,651.01)	35.21 (18.79 to 52.90)
Eastern Europe	3,606.58 (2,094.24–5,461.72)	3,153.62 (1,850.22–4,791.81)	-12.56 (-15.72 to -10.12)	5,640.29 (,3668.03–9,018.59)	4,850.06 (3,166.33–7,692.23)	-14.01 (-17.92 to -9.92)	4,799.72 (3,310.78–6,947.03)	3,635.80 (2,406.24–5,464.46)	-24.25 (-30.16 to -17.44)
High-income									
Australasia	11,778.28 (9,177.60–14,677.53)	9,013.81 (5,916.78–12,868.45)	-23.47 (-43.02 to -5.36)	1,3696.56 (1,1384.34–1,6721.50)	1,1451.22 (7,631.92–16,483.27)	-16.39 (-34.04 to 1.97)	13,132.95 (11,224.44–15,462.86)	9,581.40 (7,106.88–12,698.18)	-27.04 (-39.83 to -13.47)
High-income Asia Pacific	7,852.30 (5,198.31–11,173.56)	4,827.93 (2,924.26–7,148.88)	-38.52 (-44.70 to -32.39)	8,647.67 (5,974.86–1,2709.40)	5,917.42 (3,932.74–9,295.59)	-31.57 (-38.18 to -24.14)	6,201.87 (4,397.12–8,618.64)	3,819.45 (2,575.98–5,600.88)	-38.41 (-45.64 to -31.44)
High-income North America	10,929.20 (6,583.22–16,048.53)	10,898.35 (7,036.63–15,391.36)	-0.28 (-9.63 to 10.18)	16,886.09 (11,554.39–25,617.19)	16,553.86 (11,860.02–23,762.08)	-1.97 (-11.74 to 9.56)	10,166.83 (7,150.93–14,565.28)	10,835.06 (8,129.60–14,527.74)	6.57 (-2.99 to 20.90)
Southern Latin America	6,038.41 (4,052.37–8,417.49)	6,413.29 (3,878.59–9557.26)	6.21 (-10.78 to 42.94)	6,962.64 (5,138.59–9,794.88)	7,658.82 (5,089.59–11,770.28)	10.00 (-9.16 to 58.36)	5,169.79 (3,745.71–7,367.42)	5,553.44 (3,797.92–8,026.38)	7.42 (-11.94 to 55.03)
Western Europe	48,04.80 (3,171.09–6,973.38)	4,655.69 (2,935.01–6,859.24)	-3.10 (-10.40 to 12.68)	5,974.87 (4,083.23–8,684.28)	5,855.23 (3,861.70–8,677.04)	-2.00 (-10.56 to 19.27)	7,905.17 (5,910.06–10,446.28)	6,685.35 (4,788.11–9,129.39)	-15.43 (-23.89 to 3.27)
Latin America and Caribbean									
Andean Latin America	26,553.67 (20,851.69–33,241.13)	10,827.64 (76,60.07–14,925.39)	-59.22 (-66.44 to -52.63)	19,969.31 (15,338.59–26,666.79)	10,896.83 (7,726.53–15,464.49)	-45.43 (-54.70 to -35.29)	8,271.30 (6,311.29–10,596.59)	5,846.48 (4,000.76–8,413.52)	-29.32 (-42.46 to -17.42)
Caribbean	21,321.21 (17,015.49–26,437.45)	19,186.15 (15,568.28–23,519.56)	-10.01 (-15.67 to -4.52)	17,127.34 (13,347.14–22,033.91)	15,681.49 (12,531.10–19,923.49)	-8.44 (-13.98 to -3.27)	9,993.33 (7,702.79–12,895.82)	9,243.16 (7,341.44–11,655.29)	-7.51 (-14.08 to -0.85)
Central Latin America	13,506.46 (10,275.92–17,018.09)	5,955.45 (4,177.13–8,166.69)	-55.91 (-61.03 to -51.44)	11,071.34 (8,133.11–14,977.25)	6,453.27 (4,469.13–9,545.56)	-41.71 (-48.53 to -34.24)	5,747.49 (4,042.46–7,989.57)	4,423.09 (3,028.53–6,410.94)	-23.04 (-29.52 to -17.12)
Tropical Latin America	22,820.39 (16,926.14–29,726.80)	9,525.00 (6,609.48–13,123.80)	-58.26 (-61.77 to -55.08)	18,734.46 (1,3319.85–2,6338.37)	11,665.36 (8,072.17–17,347.12)	-37.73 (-44.62 to -30.10)	8,574.34 (5,806.09–12,557.29)	6,934.66 (4,763.46–10,308.34)	-19.12 (-26.50 to -10.80)

(continued)

Table 1. Global asthma prevalence rates (per 100,000 population) in 1990 and 2021 and percentage change (1990–2021) for individuals 1–4 years, 5–9 years, and 10–19 years of age (Continued)

Variable	Prevalence rate (95% UI) for individuals aged 1–4 years			Prevalence rate (95% UI) for individuals aged 5–9 years			Prevalence rate (95% UI) for individuals aged 10–19 years		
	1990	2021	Percentage change in prevalence rates, 1990-2021	1990	2021	Percentage change in prevalence rates, 1990-2021	1990	2021	Percentage change in prevalence rates, 1990-2021
Latin America and Caribbean									
Andean Latin America	26,553.67 (20,851.69–33,241.13)	10,827.64 (76,60.07–14,925.39)	-59.22 (-66.44 to -52.63)	19,969.31 (15,338.59–26,666.79)	10,896.83 (7,726.53–15,464.49)	-45.43 (-54.70 to -35.29)	8,271.30 (6,311.29–10,596.59)	5,846.48 (4,000.76–8,413.52)	-29.32 (-42.46 to -17.42)
Caribbean	21,321.21 (17,015.49–26,437.45)	19,186.15 (15,568.28–23,519.56)	-10.01 (-15.67 to -4.52)	17,127.34 (13,347.14–22,033.91)	15,681.49 (12,531.10–19,923.49)	-8.44 (-13.98 to -3.27)	9,993.33 (7,702.79–12,895.82)	9,243.16 (7,341.44–11,655.29)	-7.51 (-14.08 to -0.85)
Central Latin America	13,506.46 (10,275.92–17,018.09)	5,955.45 (4,177.13–8,166.69)	-55.91 (-61.03 to -51.44)	11,071.34 (8,133.11–14,977.25)	6,453.27 (4,469.13–9,545.56)	-41.71 (-48.53 to -34.24)	5,747.49 (4,042.46–7,989.57)	4,423.09 (3,028.53–6,410.94)	-23.04 (-29.52 to -17.12)
Tropical Latin America	22,820.39 (16,926.14–29,726.80)	9,525.00 (6,609.48–13,123.80)	-58.26 (-61.77 to -55.08)	18,734.46 (1,3319.85–2,6338.37)	11,665.36 (8,072.17–17,347.12)	-37.73 (-44.62 to -30.10)	8,574.34 (5,806.09–12,557.29)	6,934.66 (4,763.46–10,308.34)	-19.12 (-26.50 to -10.80)
Sub-Saharan Africa									
Central Sub-Saharan Africa	7,049.04 (5,204.56–9,115.64)	3,749.99 (2,763.22–4,794.70)	-46.80 (-53.11 to -41.41)	6,468.15 (4,813.04–8,804.00)	4,478.82 (3,260.85–6,106.72)	-30.76 (-38.68 to -21.58)	4,231.08 (3,245.66–5,377.68)	3,199.88 (2,430.44–4,130.97)	-24.37 (-31.43 to -16.94)
Eastern Sub-Saharan Africa	12,366.05 (9,500.64–15,585.96)	7,610.61 (5,832.30–9,653.69)	-38.46 (-42.94 to -33.05)	10,837.17 (8,274.11–14,509.24)	7,596.05 (5,679.97–10,161.05)	-29.91 (-35.45 to -24.61)	6,727.21 (5,233.31–8,563.68)	4,907.07 (3,748.85–6,366.13)	-27.06 (-31.01 to -23.50)
Southern Sub-Saharan Africa	3,532.41 (2,448.03–4,908.61)	1,698.27 (1,198.06–2,334.12)	-51.92 (-55.12 to -48.41)	5,458.04 (3,990.43–7,720.66)	3,286.19 (2,310.84–4,743.35)	-39.79 (-44.50 to -35.19)	3,632.18 (2,674.68–4,974.39)	2,372.24 (1,731.33–3,226.28)	-34.69 (-38.35 to -30.59)
Western Sub-Saharan Africa	6,416.15 (4,691.05–8,594.91)	5,092.08 (3,721.45–6,832.37)	-20.64 (-24.53 to -17.47)	7,640.49 (5,590.79–10,723.61)	6,347.35 (4,654.61–8,994.43)	-16.92 (-20.30 to -12.84)	4,582.75 (3,328.15–6,255.63)	3,752.29 (2,774.54–5,034.91)	-18.12 (-21.18 to -14.80)
North Africa and Middle East									
North Africa and Middle East	7,425.69 (5,578.42–9,624.54)	4,371.34 (3,063.62–6,045.40)	-41.13 (-47.48 to -34.92)	6,433.64 (4,766.78–8,473.75)	4,530.58 (3,238.55–6,419.89)	-29.58 (-37.17 to -22.31)	4,341.07 (3,199.34–5,701.19)	3,362.27 (2,413.10–4,537.46)	-22.55 (-28.85 to -15.82)
Southeast Asia	7,386.66 (5,536.55–9,577.80)	4,162.27 (3,094.08–5,467.31)	-43.65 (-46.21 to -40.66)	6,888.00 (5,188.18–9,157.86)	4,564.19 (3,403.33–6,287.28)	-33.74 (-38.19 to -28.89)	3,782.41 (2,855.34–5,008.22)	2,851.20 (2,138.02–3,744.03)	-24.62 (-28.60 to -20.57)

GBD, Global Burden of Diseases, Injuries, and Risk Factors Study; SDI, sociodemographic indices; UI, uncertainty interval.

Tropical regions) and South Asia have shown significant reductions in the pediatric asthma prevalence. In 1990, Latin America exhibited an exceptionally high prevalence of asthma. However, the substantial reduction in prevalence in these regions merits further investigation.

Although the specific policies and factors contributing to the decline in asthma prevalence remain unclear, educational campaigns initiated in Latin America in the late 1990s and early 2000s have notably reduced asthma-related hospitalization and mortality rates.[30] Additionally, the public smoking regulations implemented during this period likely decreased asthma-related hospitalizations among children.[31] These observations suggest that efforts to manage the burden of asthma may indirectly improve the prevalence of pediatric asthma.

In contrast, high-income regions classified according to the GBD regional hierarchy, including high-income countries in North America, Southern Latin America, and Western Europe, did not show a decreased asthma prevalence. Notably, Central Europe showed an increased prevalence of asthma in children and adolescents (Table 1). This is particularly noteworthy given the overall decrease of 27.4% in the age-standardized asthma prevalence rate in Central Europe since 1990 as reported by the GBD 2021.[20,32]

A study conducted in Poland, a country in Central Europe, identified family history as the most significant risk factor for childhood asthma. However, it also suggested that increased exposure to air pollution may be a contributing factor.[33] Furthermore, the implementation of an asthma prevention program in Poland from 2000 to 2003 led to a marked increase in early diagnosis rates among children and adolescents, resulting in a more than doubled prevalence rate.[34] This focus on early diagnosis likely explains the increased prevalence in this age group.

Central European countries, while not exhibiting the same upward trend as Poland, displayed a stable or slight increased pediatric asthma prevalence. This pattern is notable given the general decline reported in most other countries. Central Europe is significantly affected by air pollution, which may have contributed to the observed trends.[35] Additionally, countries in Europe that have undergone substantial westernization have shown a higher prevalence of asthma.[36] These findings suggest possible explanations for the rising pediatric asthma rates in Central Europe; however, further detailed epidemiological studies of asthma prevalence in individual countries within the region are necessary.

Asthma in preschoolers (1–4 years)

In 2021, the global prevalence rate of asthma among preschoolers younger than 5 years was 4,471.29 per 100,000 (95% UI, 3,192.32–6118.03). This reflects a 34.17% decrease since 1990, the largest reduction among the pediatric age groups (95% UI, -36.70 to -31.42). The prevalence was higher in males (4,767.34 [95% UI, 3,391.93–6,555.85]) than in females (4,154.97 [95% UI, 3,000.34–5,634.02]). Only the Central Europe region experienced an increase of 48.61% (95% UI, 35.18–64.57), while the Caribbean region reported the highest asthma prevalence among preschoolers.

Diagnosing asthma in preschoolers aged 1–4 years is challenging because of the limited feasibility of objective lung function tests such as spirometry.[37] As a result, the diagnosis relies primarily on a patient's clinical history and symptom patterns. Recurrent wheezing, particularly in the absence of respiratory infections (e.g., triggered by exercise, laughter, or crying), strongly suggests underlying asthma.[38,39] The presence of atopic conditions such as allergic rhinitis or eczema further supports this diagnosis. Although a trial of short-acting beta-2 agonists or inhaled corticosteroids (ICS) can be used to assess the treatment response, it should be viewed as part of clinical management rather than a definitive diagnostic test.[40]

In summary, diagnosing asthma in preschoolers younger than 5 years based on a single episode is challenging; however, it is crucial to consider asthma based on a patient's history and clinical assessment.[41] Asthma phenotypes can vary with allergic status, with eosinophilic, allergic, or type 2 (T2) high asthma generally responding well to ICS.[42] The early recognition of these patterns can significantly enhance the appropriate management of pediatric asthma.

The GBD study employed a modeling approach to estimate asthma prevalence in preschoolers by integrating data from diverse sources including survey reports, clinical diagnoses, and hospitalization records. To ensure consistency with reference definitions, alternative diagnostic criteria were adjusted using statistical weighting. While this approach enhances the comparability of asthma prevalence estimates across regions, it is essential to acknowledge that making the diagnosis of asthma in children younger than 5 years in clinical practice remains inherently complex.

Asthma risk factors are diverse, with significant emphasis placed on exposure to external agents. However, in preschoolers aged 1–5 years, intrinsic factors such as prenatal exposure and family history play an important role. A family history of asthma is a well-established risk factor for childhood asthma. Both maternal and paternal asthma contribute to this increased risk, with paternal asthma having a more pronounced effect in older children.[43] This may be attributed to genetic susceptibility related to airway hyperresponsiveness.[44] In contrast, maternal asthma may influence early-childhood asthma risk through both genetic inheritance and prenatal environmental factors such as the maternal immune responses during pregnancy.[45]

Intrauterine exposure to fine particulate matter ($PM_{2.5}$), particularly during the first and second trimesters, is associated with an increased risk of childhood asthma.[46] $PM_{2.5}$ exposure may contribute to asthma development by inducing maternal systemic inflammation, which can disrupt fetal immune system maturation and lung development.[47] Additionally, maternal exposure to ozone and nitrogen dioxide during pregnancy is linked to increased susceptibility to asthma in the offspring.[48] Maternal antibiotic use during pregnancy has been linked to an increased risk of childhood asthma, potentially due to its impact on the maternal microbiome. Antibiotics can alter the maternal gut flora, which may in turn affect the development of the infant's microbiome. Disruptions in early microbial colonization may contribute to immune dysregulation, thereby increasing the likelihood of early-childhood asthma and wheezing.[49]

Asthma in school-aged children (5–9 years)

Children aged 5–9 years had the highest asthma prevalence rate among the pediatric population (5,427.19 per 100,000 population [95% UI, 3,904.24–7,735.84]) (Table 1). The asthma prevalence rate was significantly higher in males (6,754.35 per 100,000 population [95% UI, 4,944.41–9,455.84]) than in females (4,827.92 per 100,000 population [95% UI, 3,468.21–6,918.75]), with this trend being the most pronounced in this age group. Among global regions, only

Central Europe showed a significant increase in asthma prevalence from 1990 to 2021 (71.84% [95% UI, 54.49–90.04]). Notably, while the Caribbean region reported the highest prevalence among preschoolers, the prevalence rate for the 5–9 years group was comparatively lower. Conversely, high-income North America had the highest asthma prevalence in this age group, at 16,553.86 per 100,000 population (95% UI, 11,860.02–23,762.08).

Research indicates that half of all children younger than 6 years of age experience wheezing episodes; 40% of these children subsequently report recurrent wheezing episodes.[50] This suggests that early asthmatic features may lead to a formal asthma diagnosis as the children grow, underscoring the need for a prompt diagnosis and early intervention to mitigate the disease burden.[51] Nonetheless, many children do not receive appropriate diagnosis and treatment for asthma, indicating the need for improvement.[52]

To enhance the accuracy of pediatric asthma diagnostics, a comprehensive approach that objectively confirms reversible airway obstruction is recommended rather than depending solely on symptom monitoring or controller medication trials from this age group onward.[53] Spirometry plays a crucial role in the evaluation of flow-volume curves to detect central airway obstructions. The ratio of a forced expiratory volume in 1 second (FEV_1) to a forced vital capacity below 80% generally indicates airway obstruction; however, pediatric populations require *z* score adjustments to avoid misinterpretation due to developmental differences in lung function.[54,55] A positive bronchodilator response, defined as an increase in FEV_1 of at least 12% or 200 mL post-bronchodilator administration (with some pediatric guidelines suggesting an 8% threshold), supports the diagnosis of asthma.[56-62]

Asthma is commonly categorized into T2-high and T2-low subtypes, with the former (eosinophilic inflammation) being more prevalent in pediatric patients and typically presenting with allergic features.[63,64] The absence of atopic conditions should prompt the consideration of alternative diagnoses, necessitating further investigations such as high-resolution computed tomography or bronchoscopy or bronchoalveolar lavage (BAL).[65,66] The use of BAL is particularly valuable for identifying various airway inflammation phenotypes in children with severe asthma and aiding treatment selection by confirming the possibility of T2-low asthma.[67,68]

When T2-high asthma is suspected, additional assessments such as skin prick tests for aeroallergens, serum total and specific immunoglobulin E levels, and fractional exhaled nitric oxide (FeNO) measurements can help identify key exacerbating factors.[69] If initial pulmonary function tests are inconclusive but asthma remains suspected, a methacholine challenge test may be considered.[70] For children who struggle to perform spirometry, blood eosinophil levels or FeNO may serve as alternative markers of allergic inflammation; however, these should be interpreted cautiously and not used as the sole diagnostic criteria.[71]

Asthma in children can result from a genetic predisposition and environmental exposure, with an accumulation of risk factors that influence disease development. The GBD 2021 identifies nitrogen dioxide pollution and a high body mass index as major risk factors for pediatric asthma. Obesity, a modifiable risk factor, is strongly associated with asthma, although the precise underlying mechanisms remain unclear.[72] While obesity is a well-established risk factor in adults, its relationship with childhood asthma is complex, with studies highlighting its association with metabolic syndrome, insulin resistance, and altered pulmonary function.[73,74] These relationships suggest that factors beyond body mass index, such as body fat distribution or metabolic alterations, may contribute to an individual's asthma risk, warranting further investigations.[75]

Although direct exposure to smoking and occupational asthma is rare in children, indirect exposure remains a concern. Secondhand smoke exposure is linked to increased asthma exacerbation and poor asthma control, demonstrating a dose-response relationship even at low exposure levels.[76] Additionally, prenatal and early-life exposures, including maternal exposure to air pollution, antibiotic use, and recurrent lower respiratory tract infections, are significant contributors to an individual's asthma risk.[27,77] Indoor PM exposure is associated with a greater reduction in lung function than outdoor PM exposure, leading to increased asthma morbidity rates.[78] Breastfeeding is a potential protective factor, with insufficient or absent breastfeeding being linked to an increased risk of asthma.[79]

While symptom control may appear good according to parental reports, objective lung function assessments such as lung clearance index measurements often reveal residual abnormalities. Therefore, relying solely on subjective symptom scores to evaluate asthma control in this age group may be insufficient.[80]

Asthma in older school-aged children and adolescents (10–19 years)

The asthma prevalence rate among children and adolescents aged 10–19 years was 3,640.69 per 100,000 population (95% UI, 2,698.67–5,030.[15]) in 2021, exhibiting a 26.25% decrease since 1990 (95% UI, -28.64 to -23.62; Fig. 1C, Table

1). This decrease was the smallest among the pediatric age groups. The prevalence rates were 3,781.39 per 100,000 population (95% UI, 2,768.44–5,205.62) for males and 3,491.57 per 100,000 population (95% UI, 2,574.25–4,839.97) for females, indicating minimal sex-based differences compared to other age groups. The regional distribution patterns were similar to those observed in the 5–9 years age group.

A defining feature of adolescents is their ability to recognize, assess, and articulate one's symptoms, the absence of which can complicate the diagnosis and evaluation of asthma.[81] Adolescents may conceal their asthma history or exhibit behavioral components of their symptoms due to psychosocial influences, potentially leading to an overestimation of asthma severity. Therefore, the diagnosis and assessment of asthma in adolescents should involve a thorough history-taking, clinical examination, and objective measurement of airway obstruction, airway hyperresponsiveness, and atopy.

Asthma prevalence shows substantial sex-based differences, with contrasting patterns in pediatric and adult populations. Asthma is more prevalent in boys and women than in girls and men.[82] This shift may be attributed to factors such as sex hormones, genetic variations, and gene expression.[83] Elevated testosterone levels have been associated with reduced airway inflammation and improved lung function, which may contribute to a lower risk of asthma in men.[84] In contrast, the decline in testosterone levels and increase in estradiol levels in females may lead to greater airway hyperresponsiveness, potentially explaining the higher prevalence of asthma in women over time.[85,86] The significant reduction in the difference in asthma prevalence by sex among children and adolescents aged 10–19 years compared to younger children aged 5–9 years may reflect the influence of hormonal factors during this developmental stage.

Adolescents are increasingly influencing their lifestyle choices, and their health requires careful attention. As they seek autonomy and move away from parental control, they become increasingly exposed to various environmental factors. The prevalence of obesity is increasing in this age group, and many adolescents begin smoking rather than being exposed to secondhand smoke.[87,88] Obesity is significantly linked to asthma prevalence, while smoking, although its direct causal relationship remains unclear, contributes to asthma incidence and significantly impacts its exacerbations.[89] Therefore, controlling and preventing lifestyle-related risk factors is essential.

Most newly diagnosed adolescents with asthma have previously unrecognized asthmatic features and wheezing episodes.[90] However, it is important to consider the possibility of late-onset asthma, which may be diagnosed for the first time during this period without a history of previous wheezing episodes.[91] Although it typically manifests in adulthood, late-onset asthma is significant and generally classified as T2-low asthma in contrast to T2-high asthma, which is characterized by pronounced allergic features.[92] Environmental exposure is likely a key risk factor for this group, making its effective management essential. As this phenotype may not respond well to ICS or biologics, diagnostic accuracy, tailored management strategies, and ongoing monitoring are critical.[93]

Projected asthma prevalence among children and adolescents by 2050

While a previous study using the GBD 2021 forecasted the overall asthma prevalence by 2050, it did not specifically address the pediatric population.[94] Given that childhood asthma often persists into adulthood, it is critical to forecast the asthma prevalence among indivi-

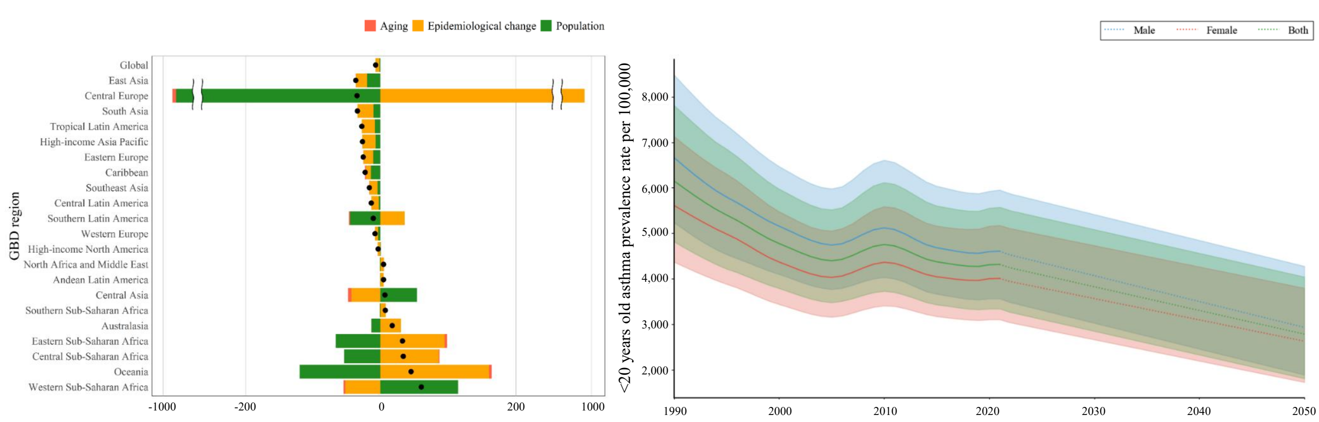

Fig. 4. Projection of asthma prevalence rate (per 100,000 population) for individuals younger than 20 years by 2050 and decomposition of projected changes in asthma from 2021 to 2050. Each dot represents the total percentage change from 2021 to 2050. GBD, Global Burden of Diseases, Injuries, and Risk Factors Study.

duals younger than 20 years to accurately assess its future disease burden. Accordingly, we employed a predictive model used in a previous study to estimate the prevalence of pediatric asthma (Fig. 4). By 2050, the global prevalence in this demographic is projected to be 2,780.87 per 100,000 population (95% UI, 1,805.76–4,041.08), maintaining a consistent downward trend. Moreover, the higher prevalence observed in males will likely persist.

A decomposition analysis indicated that the number of pediatric asthma cases globally will decrease by approximately 6.8% by 2050 compared with 2021. The GBD forecast predicts that the population younger than 20 years will begin to decline by 2028, linking the reduction in asthma prevalence to this demographic shift.[95] However, the anticipated decrease in asthma prevalence within this population is expected to exceed the effects attributable solely to changes in the population structure. East Asia is projected to experience the most significant decrease in asthma cases, whereas increases are anticipated in Africa, Asia, and Oceania.

In East Asia, China will have a substantial impact on population dynamics, with a projected decline in the population younger than 20 years. Nonetheless, our analysis suggested that the reduction in asthma prevalence in East Asia will surpass the degree attributable to the population decline. Efforts to improve air quality in China and initiatives such as "The Plan of Obesity Control and Prevention in Children and Adolescents" are expected to facilitate further reductions in the pediatric asthma prevalence.[96,97]

A decreased asthma prevalence is anticipated in Central Europe and Southern Latin America; however, this will likely be driven primarily by a reduction in the pediatric population. The reduction in the absolute number of prevalent asthma cases may not fully correspond to the decline in the pediatric population, indicating that more proactive interventions are required to effectively reduce the overall asthma burden. Although various policies to curb asthma have been implemented in Central Europe, the increasing rates of overweight and obesity—key risk factors for pediatric asthma among children and adolescents–underscore the importance of managing these lifestyle-related factors to reduce the regional pediatric asthma burden.[98]

Conversely, in Central Asia and Western Sub-Saharan Africa, an increased number of asthma cases is expected that reflects the growth in the pediatric population. Despite the decline in the asthma prevalence rate in Central Asia noted between 1990 and 2021, this trend can be explained by demographic changes. Furthermore, previous studies evaluating NO_2-attributable asthma indicated that the rising incidence of asthma in Western Sub-Saharan Africa is largely driven by an expanding pediatric population.[99]

Conclusion

Asthma is a chronic respiratory disease that carries a significant global burden, particularly because of its early onset during childhood and adolescence. Although the prevalence of pediatric asthma has declined in recent decades, regional disparities persist. Contributing factors include improved air quality, reduced smoking rates, and changes in early life exposure such as increased breastfeeding rates and altered patterns of childhood infections. Moreover, advancements in asthma management, particularly the widespread use of ICS, are likely to enhance disease control and reduce the number of severe cases. However, variations in healthcare access and diagnostic practices among countries impact the reported prevalence trends. In high-income countries, greater awareness and evolving diagnostic criteria may facilitate more frequent case identification, whereas underdiagnosis remains a challenge in low-income settings. These findings highlight the need to consider environmental, behavioral, and healthcare-related factors when interpreting global asthma trends and developing effective public health strategies to alleviate its burden.

Footnotes

Supplementary material: Supplementary Table 1 is available at https://doi.org/10.3345/10.3345/cep.2025.00423.

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References

1. Porsbjerg C, Melén E, Lehtimäki L, Shaw D. Asthma. Lancet 2023;401:858-73.
2. Hammad H, Lambrecht BN. The basic immunology of asthma. Cell 2021;184:1469-85.
3. McGregor MC, Krings JG, Nair P, Castro M. Role of biologics in asthma. Am J Respir Crit Care Med 2019;199:433-45.
4. Varricchi G, Ferri S, Pepys J, Poto R, Spadaro G, Nappi E, et al. Biologics and airway remodeling in severe asthma. Allergy 2022;77:3538-52.
5. Shin YH, Hwang J, Kwon R, Lee SW, Kim MS, Shin JI, et al. Global, regional, and national burden of allergic disorders and their risk factors in 204 countries and territories, from 1990 to 2019: a systematic analysis for the Global Burden of Disease Study 2019. Allergy 2023;78:2232-54.
6. Busse WW, Kraft M. Current unmet needs and potential solutions to uncontrolled asthma. Eur Respir Rev 2022;31:210176.
7. Yaghoubi M, Adibi A, Safari A, FitzGerald JM, Sadatsafavi M. The projected economic and health burden of uncontrolled asthma in the United States. Am J Respir Crit Care Med 2019;200:1102-12.
8. Soriano JB, Abajobir AA, Abate KH, Abera SF, Agrawal A, Ahmed MB, et al. Global, regional, and national deaths, prevalence, disability-adjusted life years, and years lived with disability for chronic obstructive pulmonary disease and asthma, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet Respir Med 2017;5:691-706.
9. Soriano JB, Kendrick PJ, Paulson KR, Gupta V, Abrams EM, Adedoyin RA, et al. Prevalence and attributable health burden of chronic respiratory diseases, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet Respir Med 2020;8:585-96.
10. GBD 2019 Chronic Respiratory Diseases Collaborators. Global burden of chronic respiratory diseases and risk factors, 1990–2019: an update from the Global Burden of Disease Study 2019. EClinicalMedicine 2023;59:101936.
11. Perry R, Braileanu G, Palmer T, Stevens P. The economic burden of pediatric asthma in the United States: literature review of current evidence. Pharmacoeconomics 2019;37:155-67.
12. Ruotsalainen M, Heikkilä P, Backman K, Korppi M. An increased asthma risk continued until young adulthood after early-childhood hospitalisation for wheezing. Acta Paediatr 2022;111:157-62.
13. Hovland V, Riiser A, Mowinckel P, Carlsen KH, Lødrup Carlsen KC. The significance of early recurrent wheeze for asthma outcomes in late childhood. Eur Respir J 2013;41:838-45.
14. Yon DK, Hwang S, Lee SW, Jee HM, Sheen YH, Kim JH, et al. Indoor exposure and sensitization to formaldehyde among inner-city children with increased risk for asthma and rhinitis. Am J Respir Crit Care Med 2019;200:388-93.
15. Asher MI, Rutter CE, Bissell K, Chiang CY, El Sony A, Ellwood E, et al. Worldwide trends in the burden of asthma symptoms in school-aged children: Global Asthma Network Phase I cross-sectional study. Lancet 2021;398:1569-80.
16. Miligkos M, Oh J, Kwon R, Konstantinou G, Kim S, Yon DK, et al. Epidemiology of asthma across the ages. Ann Allergy Asthma Immunol 2024 Dec 12:S1081-1206(24)01727-7. doi: 10.1016/j.anai.2024.12.004. [Epub].
17. Ferrari AJ, Santomauro DF, Aali A, Abate YH, Abbafati C, Abbastabar H, et al. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet 2024;403:2133-61.
18. Murray CJL. The Global Burden of Disease Study at 30 years. Nat Med 2022;28:2019-26.
19. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet 2024;403:2133-61.
20. Wang Z, Li Y, Gao Y, Fu Y, Lin J, Lei X, et al. Global, regional, and national burden of asthma and its attributable risk factors from 1990 to 2019: a systematic analysis for the Global Burden of Disease Study 2019. Respir Res 2023;24:169.
21. Liu Y, Wang Z, Rader B, Li B, Wu CH, Whittington JD, et al. Associations between changes in population mobility in response to the COVID-19 pandemic and socioeconomic factors at the city level in China and country level worldwide: a retrospective, observational study. Lancet Digit Health 2021;3:e349-59.
22. Burden of disease scenarios for 204 countries and territories, 2022-2050: a forecasting analysis for the Global Burden of Disease Study 2021. Lancet 2024;403:2204-56.
23. Naghavi M, Ong KL, Aali A, Ababneh HS, Abate YH, Abbafati C, et al. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet 2024;403:2100-32.
24. Brauer M, Roth GA, Aravkin AY, Zheng P, Abate KH, Abate YH, et al. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–

2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet 2024;403:2162-203.
25. Global, regional, and national burden of low back pain, 1990-2020, its attributable risk factors, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. Lancet Rheumatol 2023;5:e316-29.
26. Lv JJ, Kong XM, Zhao Y, Li XY, Guo ZL, Zhang YJ, et al. Global, regional and national epidemiology of allergic disorders in children from 1990 to 2019: findings from the Global Burden of Disease study 2019. BMJ Open 2024;14:e080612.
27. Murrison LB, Brandt EB, Myers JB, Hershey GKK. Environmental exposures and mechanisms in allergy and asthma development. J Clin Invest 2019;129:1504-15.
28. Li X, Cao X, Guo M, Xie M, Liu X. Trends and risk factors of mortality and disability adjusted life years for chronic respiratory diseases from 1990 to 2017: systematic analysis for the Global Burden of Disease Study 2017. BMJ 2020;368:m234.
29. Zanobetti A, Ryan PH, Coull B, Brokamp C, Datta S, Blossom J, et al. Childhood asthma incidence, early and persistent wheeze, and neighborhood socioeconomic factors in the ECHO/CREW Consortium. JAMA Pediatr 2022;176:759-67.
30. Soto-Martínez M, Avila L, Soto N, Chaves A, Celedón JC, Soto-Quiros ME. Trends in hospitalizations and mortality from asthma in Costa Rica over a 12- to 15-year period. J Allergy Clin Immunol Pract 2014;2:85-90.
31. Forno E, Gogna M, Cepeda A, Yañez A, Solé D, Cooper P, et al. Asthma in Latin America. Thorax 2015;70:898-905.
32. Safiri S, Carson-Chahhoud K, Karamzad N, Sullman MJM, Nejadghaderi SA, Taghizadieh A, et al. Prevalence, deaths, and disability-adjusted life-years due to asthma and its attributable risk factors in 204 countries and territories, 1990-2019. Chest 2022;161:318-29.
33. Liebhart J, Malolepszy J, Wojtyniak B, Pisiewicz K, Plusa T, Gladysz U. Prevalence and risk factors for asthma in Poland: results from the PMSEAD study. J Investig Allergol Clin Immunol 2007;17:367-74.
34. Stelmach W, Majak P, Jerzynska J, Stelmach I. Early effects of Asthma Prevention Program on asthma diagnosis and hospitalization in urban population of Poland. Allergy 2005; 60:606-10.
35. Garrido-Perez JM, Ordóñez C, García-Herrera R, Barriopedro D. Air stagnation in Europe: spatiotemporal variability and impact on air quality. Sci Total Environ 2018;645:1238-52.
36. Lawson JA, Brozek G, Shpakou A, Fedortsiv O, Vlaski E, Beridze V, et al. An international comparison of asthma, wheeze, and breathing medication use among children. Respir Med 2017;133:22-8.
37. Louis R, Satia I, Ojanguren I, Schleich F, Bonini M, Tonia T, et al. European Respiratory Society guidelines for the diagnosis of asthma in adults. Eur Respir J 2022;60:2101585.
38. Pavord ID, Beasley R, Agusti A, Anderson GP, Bel E, Brusselle G, et al. After asthma: redefining airways diseases. Lancet 2018;391:350-400.
39. Price OJ, Simpson AJ. Exercise and asthma - trigger or treatment? Respir Med 2023;213:107247.
40. Levy ML, Bacharier LB, Bateman E, Boulet LP, Brightling C, Buhl R, et al. Key recommendations for primary care from the 2022 Global Initiative for Asthma (GINA) update. NPJ Prim Care Respir Med 2023;33:7.
41. Konstantinou GN, Xepapadaki P, Manousakis E, Makrinioti H, Kouloufakou-Gratsia K, Saxoni-Papageorgiou P, et al. Assessment of airflow limitation, airway inflammation, and symptoms during virus-induced wheezing episodes in 4- to 6-year-old children. J Allergy Clin Immunol 2013;131:87-93.e1-5.
42. Bacharier LB, Guilbert TW, Jartti T, Saglani S. Which wheezing preschoolers should be treated for asthma? J Allergy Clin Immunol Pract 2021;9:2611-8.
43. Raby BA, Van Steen K, Celedón JC, Litonjua AA, Lange C, Weiss ST. Paternal history of asthma and airway responsiveness in children with asthma. Am J Respir Crit Care Med 2005;172:552-8.
44. Leaves NI, Bhattacharyya S, Wiltshire S, Cookson WO. A detailed genetic map of the chromosome 7 bronchial hyperresponsiveness locus. Eur J Hum Genet 2002;10:177-82.
45. Medsker BH, Brew BK, Forno E, Olsson H, Lundholm C, Han YY, et al. Maternal depressive symptoms, maternal asthma, and asthma in school-aged children. Ann Allergy Asthma Immunol 2017;118:55-60.e1.
46. Jung CR, Chen WT, Tang YH, Hwang BF. Fine particulate matter exposure during pregnancy and infancy and incident asthma. J Allergy Clin Immunol 2019;143:2254-62.e5.
47. Korten I, Ramsey K, Latzin P. Air pollution during pregnancy and lung development in the child. Paediatr Respir Rev 2017;21:38-46.
48. Liu X, Fu L, Yang X, Wang Z. Exposure to O(3) during pregnancy and offspring asthma induced by OVA: Sensitive window identification. Environ Pollut 2021;270:116297.
49. Uldbjerg CS, Miller JE, Burgner D, Pedersen LH, Bech BH. Antibiotic exposure during pregnancy and childhood asthma: a national birth cohort study investigating timing of exposure and mode of delivery. Arch Dis Child 2021;106:888-94.
50. Tenero L, Tezza G, Cattazzo E, Piacentini G. Wheezing in preschool children. Early Hum Dev 2013;89 Suppl 3:S13-7.
51. Martin J, Townshend J, Brodlie M. Diagnosis and management of asthma in children. BMJ Paediatr Open 2022;6:e001277.
52. Papadopoulos NG, Čustović A, Cabana MD, Dell SD, Deschildre A, Hedlin G, et al. Pediatric asthma: an unmet need for more effective, focused treatments. Pediatr Allergy Immunol 2019;30:7-16.
53. Gaillard EA, Kuehni CE, Turner S, Goutaki M, Holden KA, de Jong CCM, et al. European Respiratory Society clinical practice guidelines for the diagnosis of asthma in children aged 5-16 years. Eur Respir J 2021;58:2004173.
54. de Jong CCM, Pedersen ESL, Mozun R, Goutaki M, Trachsel D, Barben J, et al. Diagnosis of asthma in children: the contribution of a detailed history and test results. Eur Respir J 2019;54:1901326.
55. Lo DK, Beardsmore CS, Roland D, Richardson M, Yang Y, Danvers L, et al. Lung function and asthma control in school-age children managed in UK primary care: a cohort study. Thorax 2020;75:101-7.
56. Miller MR, Crapo R, Hankinson J, Brusasco V, Burgos F, Casaburi R, et al. General considerations for lung function testing. Eur Respir J 2005;26:153-61.

57. Tse SM, Gold DR, Sordillo JE, Hoffman EB, Gillman MW, Rifas-Shiman SL, et al. Diagnostic accuracy of the bronchodilator response in children. J Allergy Clin Immunol 2013;132:554-9.e5.
58. Kim J, Yim Y, Park S, Kim H, Smith L, López Sánchez GF, et al. National trends in asthma prevalence among adolescents in South Korea, 2007-2023: a national representative serial study. Int Arch Allergy Immunol 2025 Feb 13:1-17. doi: 10.1159/000544734. [Epub].
59. Yim Y, Jo H, Park S, Son Y, Park J, Kim HJ, et al. Sex-specific and long-term trends of asthma, allergic rhinitis, and atopic dermatitis in South Korea, 2007-2022: a nationwide representative study. Int Arch Allergy Immunol 2025;186:166-83.
60. Papadopoulos NG, Custovic A, Deschildre A, Gern JE, Nieto Garcia A, Miligkos M, et al. Recommendations for asthma monitoring in children: A PeARL document endorsed by APAPARI, EAACI, INTERASMA, REG, and WAO. Pediatr Allergy Immunol 2024;35:e14129.
61. Papadopoulos NG, Mathioudakis AG, Custovic A, Deschildre A, Phipatanakul W, Wong G, et al. Current and optimal practices in childhood asthma monitoring among multiple international stakeholders. JAMA Netw Open 2023;6:e2313120.
62. Son Y, Park J, Choi Y, Kim H, Kang J, Smith L, et al. National trends of allergic diseases and pandemic-related factors among individuals with obesity in South Korea: a nationwide representative serial study, 2005-2021. Heliyon 2024;10:e29921.
63. Bush A, Fitzpatrick AM, Saglani S, Anderson WC 3rd, Szefler SJ. Difficult-to-treat asthma management in school-age children. J Allergy Clin Immunol Pract 2022;10:359-75.
64. Bossley CJ, Fleming L, Gupta A, Regamey N, Frith J, Oates T, et al. Pediatric severe asthma is characterized by eosinophilia and remodeling without T(H)2 cytokines. J Allergy Clin Immunol 2012;129:974-82.e13.
65. Cosío BG, Shafiek H, Mosteiro M, Iglesias A, Gómez C, Toledo-Pons N, et al. Redefining the role of bronchoscopy in the workup of severe uncontrolled asthma in the era of biologics: a prospective study. Chest 2023;164:837-45.
66. Gupta S, Siddiqui S, Haldar P, Raj JV, Entwisle JJ, Wardlaw AJ, et al. Qualitative analysis of high-resolution CT scans in severe asthma. Chest 2009;136:1521-8.
67. Teague WG, Lawrence MG, Shirley DT, Garrod AS, Early SV, Payne JB, et al. Lung lavage granulocyte patterns and clinical phenotypes in children with severe, therapy-resistant asthma. J Allergy Clin Immunol Pract 2019;7:1803-12.e10.
68. Oh J, Lee M, Kim M, Kim HJ, Lee SW, Rhee SY, et al. Incident allergic diseases in post-COVID-19 condition: multinational cohort studies from South Korea, Japan and the UK. Nat Commun 2024;15:2830.
69. Casale TB, Pedersen S, Rodriguez Del Rio P, Liu AH, Demoly P, Price D. The role of aeroallergen sensitization testing in asthma management. J Allergy Clin Immunol Pract 2020;8:2526-32.
70. Cockcroft DW. Methacholine challenge testing in the diagnosis of asthma. Chest 2020;158:433-4.
71. Bacharier LB, Pavord ID, Maspero JF, Jackson DJ, Fiocchi AG, Mao X, et al. Blood eosinophils and fractional exhaled nitric oxide are prognostic and predictive biomarkers in childhood asthma. J Allergy Clin Immunol 2024;154:101-10.
72. Yuan L, Tao J, Wang J, She W, Zou Y, Li R, et al. Global, regional, national burden of asthma from 1990 to 2021, with projections of incidence to 2050: a systematic analysis of the global burden of disease study 2021. EClinicalMedicine 2025:80:103051.
73. Miethe S, Karsonova A, Karaulov A, Renz H. Obesity and asthma. J Allergy Clin Immunol 2020;146:685-93.
74. Forno E, Han YY, Muzumdar RH, Celedón JC. Insulin resistance, metabolic syndrome, and lung function in US adolescents with and without asthma. J Allergy Clin Immunol 2015;136:304-11.e8.
75. Chen Z, Salam MT, Alderete TL, Habre R, Bastain TM, Berhane K, et al. Effects of childhood asthma on the development of obesity among school-aged children. Am J Respir Crit Care Med 2017;195:1181-8.
76. Neophytou AM, Oh SS, White MJ, Mak ACY, Hu D, Huntsman S, et al. Secondhand smoke exposure and asthma outcomes among African-American and Latino children with asthma. Thorax 2018;73:1041-8.
77. Penders J, Kummeling I, Thijs C. Infant antibiotic use and wheeze and asthma risk: a systematic review and meta-analysis. Eur Respir J 2011;38:295-302.
78. Breysse PN, Diette GB, Matsui EC, Butz AM, Hansel NN, McCormack MC. Indoor air pollution and asthma in children. Proc Am Thorac Soc 2010;7:102-6.
79. den Dekker HT, Sonnenschein-van der Voort AM, Jaddoe VW, Reiss IK, de Jongste JC, Duijts L. Breastfeeding and asthma outcomes at the age of 6 years: the generation R study. Pediatr Allergy Immunol 2016;27:486-92.
80. Kowalik K, Dai R, Safavi S, Reyna ME, Lou W, Lepine C, et al. Persistent ventilation inhomogeneity after an acute exacerbation in preschool children with recurrent wheezing. Pediatr Allergy Immunol 2020;31:608-15.
81. Chang C. Asthma in children and adolescents: a comprehensive approach to diagnosis and management. Clin Rev Allergy Immunol 2012;43:98-137.
82. Chowdhury NU, Guntur VP, Newcomb DC, Wechsler ME. Sex and gender in asthma. Eur Respir Rev 2021;30:210067.
83. El-Husseini ZW, Gosens R, Dekker F, Koppelman GH. The genetics of asthma and the promise of genomics-guided drug target discovery. Lancet Respir Med 2020;8:1045-56.
84. Han YY, Forno E, Celedón JC. Sex steroid hormones and asthma in a nationwide study of U.S. adults. Am J Respir Crit Care Med 2020;201:158-66.
85. Wang E, Wechsler ME, Tran TN, Heaney LG, Jones RC, Menzies-Gow AN, et al. Characterization of severe asthma worldwide: data from the international severe asthma registry. Chest 2020;157:790-804.
86. Sathish V, Martin YN, Prakash YS. Sex steroid signaling: implications for lung diseases. Pharmacol Ther 2015;150:94-108.
87. Hong S, Son Y, Lee M, Park J, Lee H, Lee H, et al. Temporal changes in smoking prevalence among adolescents across 23 countries. Acta Paediatr 2024 Dec 11. doi: 10.1111/apa.17543. [Epub].
88. Worldwide trends in underweight and obesity from 1990 to

2022: a pooled analysis of 3663 population-representative studies with 222 million children, adolescents, and adults. Lancet 2024;403:1027-50.
89. Thomson NC, Polosa R, Sin DD. Cigarette smoking and asthma. J Allergy Clin Immunol Pract 2022;10:2783-97.
90. Dharmage SC, Perret JL, Custovic A. Epidemiology of asthma in children and adults. Front Pediatr 2019;7:246.
91. de Nijs SB, Venekamp LN, Bel EH. Adult-onset asthma: is it really different? Eur Respir Rev 2013;22:44-52.
92. Kuruvilla ME, Lee FE, Lee GB. Understanding asthma phenotypes, endotypes, and mechanisms of disease. Clin Rev Allergy Immunol 2019;56:219-33.
93. Hinks TSC, Levine SJ, Brusselle GG. Treatment options in type-2 low asthma. Eur Respir J 2021;57:2000528.
94. GBD 2021 Asthma and Allergic Diseases Collaborators. Global, regional, and national burden of asthma and atopic dermatitis, 1990-2021, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. Lancet Respir Med 2025 Mar 24:S2213-2600(25)00003-7. doi: 10.1016/S2213-2600(25)00003-7. [Epub].
95. Institute for Health Metrics and Evaluation. Population forecasting [Internet]. Seattle (WA): Institute for Health Metrics and Evaluation; 2020 [cited 2025 Feb 16]. Available from: https://vizhub.healthdata.org/population-forecast/.
96. Zhou D, Yang Y, Zhao Z, Zhou K, Zhang D, Tang W, et al. Air pollution-related disease and economic burden in China, 1990-2050: a modelling study based on Global burden of disease. Environ Int 2025;196:109300.
97. Hong Y, Ullah R, Wang JB, Fu JF. Trends of obesity and overweight among children and adolescents in China. World J Pediatr 2023;19:1115-26.
98. Garrido-Miguel M, Cavero-Redondo I, Álvarez-Bueno C, Rodríguez-Artalejo F, Moreno LA, Ruiz JR, et al. Prevalence and trends of overweight and obesity in European children from 1999 to 2016: a systematic review and meta-analysis. JAMA Pediatr 2019;173:e192430.
99. Anenberg SC, Mohegh A, Goldberg DL, Kerr GH, Brauer M, Burkart K, et al. Long-term trends in urban NO(2) concentrations and associated paediatric asthma incidence: estimates from global datasets. Lancet Planet Health 2022;6:e49-58.

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