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Global, regional and national epidemiology of allergic disorders in children from 1990 to 2019: findings from the Global Burden of Disease study 2019

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ABSTRACT

Objective This modelling study aimed to estimate the burden for allergic diseases in children during a period of 30 years.

Design Population-based observational study.

Main outcomes and measures The data on the incidence, mortality and disability-adjusted life years (DALYs) for childhood allergic diseases, such as atopic dermatitis (AD) and asthma, were retrieved from the Global Burden of Disease study 2019 online database. This data set spans various groups, including different regions, ages, genders and Socio-Demographic Indices (SDI), covering the period from 1990 to 2019.

Results In 2019, there were approximately 81 million children with asthma and 5.6 million children with AD worldwide. The global incidence of asthma in children was 20 million. Age-standardised incidence rates showed a decrease of 4.17% for asthma, from 1075.14 (95% uncertainty intervals (UI), 724.63 to 1504.93) per 100 000 population in 1990 to 1030.33 (95% UI, 683.66 to 1449.53) in 2019. Similarly, the rates for AD decreased by 5.46%, from 594.05 (95% UI, 547.98 to 642.88) per 100 000 population in 1990 to 561.61 (95% UI, 519.03 to 608.29) in 2019. The incidence of both asthma and AD was highest in children under 5 years of age, gradually decreasing with age. Interestingly, an increase in SDI was associated with a rise in the incidence of both conditions. However, the mortality rate and DALYs for asthma showed a contrasting trend.

Conclusions Over the past three decades, there has been a worldwide increase in new asthma and AD cases, even though mortality rates have significantly declined. However, the prevalence of these allergic diseases among children varies considerably across regions, countries and age groups. This variation highlights the need for precise prevalence assessments. These assessments are vital in formulating effective strategies for prevention and treatment.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Uses high-quality Global Burden of Disease 2019 data sets over a 30-year period.
- ⇒ Applies integrated nested Laplace approximation predictive modelling.
- ⇒ Conducts age-period-cohort analysis spanning 1990–2045.
- ⇒ Evaluates trends across 5 Socio-Demographic Indices regions and 21 geographical regions.
- ⇒ The data used in this study lacked individual data.

INTRODUCTION

Both asthma and atopic dermatitis (AD) may present themselves clinically in a variety of ways, and these ways often shift as patients become older.[1] The prevalence of allergic diseases has experienced a significant rise over the years, currently impacting approximately 10–30% of the global populace[2–4]; they are more prevalent in preschoolers, and the prevalence is higher in developed nations than in developing nations.[5] Allergy illnesses have a major detrimental effect on both quality of life and healthcare costs due to their high incidence and related morbidity.[6] AD ranks first in the socioeconomic burden of all skin diseases, with a conservative estimate of the annual cost of AD in the USA being approximately US$5.297 billion.[7]

An increasingly urgent concern lies in the frequent development of airway allergic conditions such as asthma among adolescents and adults with AD. Research indicates that around one-third of AD patients will encounter asthma as a complication, a phenomenon commonly referred to as the 'atopic march'. Recent insights from various prospective epidemiological investigations underscore AD as a substantial risk factor for asthma development. Hence, proficient management of AD holds promise in potentially mitigating the associated risk of asthma.[8–10]

Early identification of these ailments is pivotal for effective prevention and management. Furthermore, global demographic shifts exert a substantial influence on the epidemiology of allergic diseases. Hence, regular reassessment of the Global Burden of Disease (GBD) database pertaining to childhood allergies is imperative to mitigate associated long-term complications. Notably, comprehensive long-term global analyses using the latest 2019 data sets are lacking. This study aims to fill this gap by using the GBD database to examine trends in the incidence, mortality and disability-adjusted life years (DALYs) attributable to childhood allergic diseases from 1990 to 2019, while also projecting future burdens. Our objective is to offer a comprehensive overview of the global prevalence of asthma and AD, facilitating informed decision-making for future public health interventions.

METHODS

We sourced our data from the, GBD 2019 available at[11] http://ghdx.healthdata.org/gbd-results-tool. To summarise the burden of allergic disease in children based on age distribution, we categorised patients into three groups: under 5 years, 5–9 years and 10–14 years. We then used linear regression to calculate the mean estimated annual percentage changes (EAPCs). The metric DALYs—disability-adjusted life year—is a single measure to quantify the burden of diseases, injuries and risk factors. DALYs are based on years of life lost from premature death and years of life lived in less than full health.[12] Asthma, characterised by chronic lung inflammation leading to bronchospasm and breathlessness triggered by allergic reactions or hypersensitivity, was diagnosed by physicians and identified through symptoms such as wheezing within the preceding year.[13] In the GBD 2019 list of causes, asthma is represented by specific codes from the International Classification of Disease. Specifically, the 10th revision (ICD-10) identifies asthma under codes J45 and J46, while the ninth revision (ICD-9) lists it under code 493.[14–16] AD, classified under ICD-10 code L20 and ICD-9 code L691, was characterised as a recurrent inflammatory skin condition, presenting either in localised or widespread patterns, accompanied by itching, elevated levels of serum IgE and immune dysregulation.

Socio-Demographic Index

The Socio-Demographic Index (SDI) serves as an indicator of a country's or region's developmental status.[17] The SDI was developed using the geometric mean of three indicators: per capita income, average years of education among those aged 15 and older and total fertility rate.[18] The GBD 2019 classified participating countries and territories into five SDI categories: high, high-middle, middle, low-middle and low. It is important to note that lower SDI values signify lower levels of social development.[19]

Statistical analysis

The age-standardised rate (ASR) (per 100000 population) is calculated by adding the products of the age-specific rates (a_i, where i denotes the ith age class) and number of persons (or weight) (w_i) within a given age group i within the chosen reference population, then divided by the sum of the standard population weights, that is,[20]

$$ASR = \frac{\sum_{i=1}^{A} a_i w_i}{\sum_{i=1}^{A} w_i} \times 100,000$$

To analyse the changes over time in incidence, prevalence and DALYs, we computed the EAPC rates. The EAPC is widely used in epidemiological research to track changes in ASRs of diseases. This coefficient, symbolised as β, is calculated from the natural logarithm of the ASRs. In this context, 'y' refers to ln(ASR) and 'x' represents the calendar years. We determined the EAPC, along with its 95% CI, by employing the following linear regression model:

$$y = \alpha + \beta x + \varepsilon$$

$$EAPC = 100 \times (\exp(\beta) - 1)$$

The direction of the ASR trend is determined by examining the EAPC and its 95% CI. An upward trend in the ASR is indicated when both the EAPC value and the lower limit of its 95% CI are positive. On the other hand, a downward trend in the ASR is suggested if the EAPC value and the upper limit of the 95% CI are both negative.

GBD 2019 allowed for the production of estimates with uncertainty intervals (UIs) for all locations every year, even when data were sparse or missing. The 95% UI was calculated and cited for each estimate, as previously described in the GBD methodology.[21]

The Bayesian age-period-cohort analysis (BAPC) model with integrated nested Laplace approximation (INLA) was used to predict the burden trends of allergic disorders from 2020 to 2040.[22] The BAPC model, celebrated for its exceptional accuracy in predicting disease burden, relies on population projection as its foundation. The Bayesian approach divides the deviance into age, period and cohort effects and treats the unknown parameters as random with an appropriate prior distribution. The second-order random walk smoothing the prior and guaranteeing the second differences in the models were identifiable, which was a random variance assumed to follow an independent mean-zero normal distribution. The BAPC model used the INLA methods to estimate the posterior marginal distributions directly, and then, INLA made extrapolations attributed to age, period and cohort effects.[23 24] All data analyses were performed in Software R (V.4.2.2) and R studio, and the BAPC predictive model used the 'nordpred (version 1.1)', 'BAPC (version 0.0.36)' and 'INLA (version 22.05.07)' packages.

Patient and public involvement

No patient involved.

RESULTS

Global burden of allergic disorders in children

Incidence

The global incident cases of asthma in children increased from 18 857 697.08 (95% UI, 12 709 797.1 to 26 396 036.08) in 1990 to 20 191 786.46 (95% UI, 156 477 to 313 145) in 2019, or an increase of 7.07%. However, age-standardised incidence rates had a 4.17% decrease, from 1075.14 (95% UI, 724.63 to 1504.93) per 100 000 population in 1990 to 1030.33 (95% UI, 683.66 to 1449.53) per

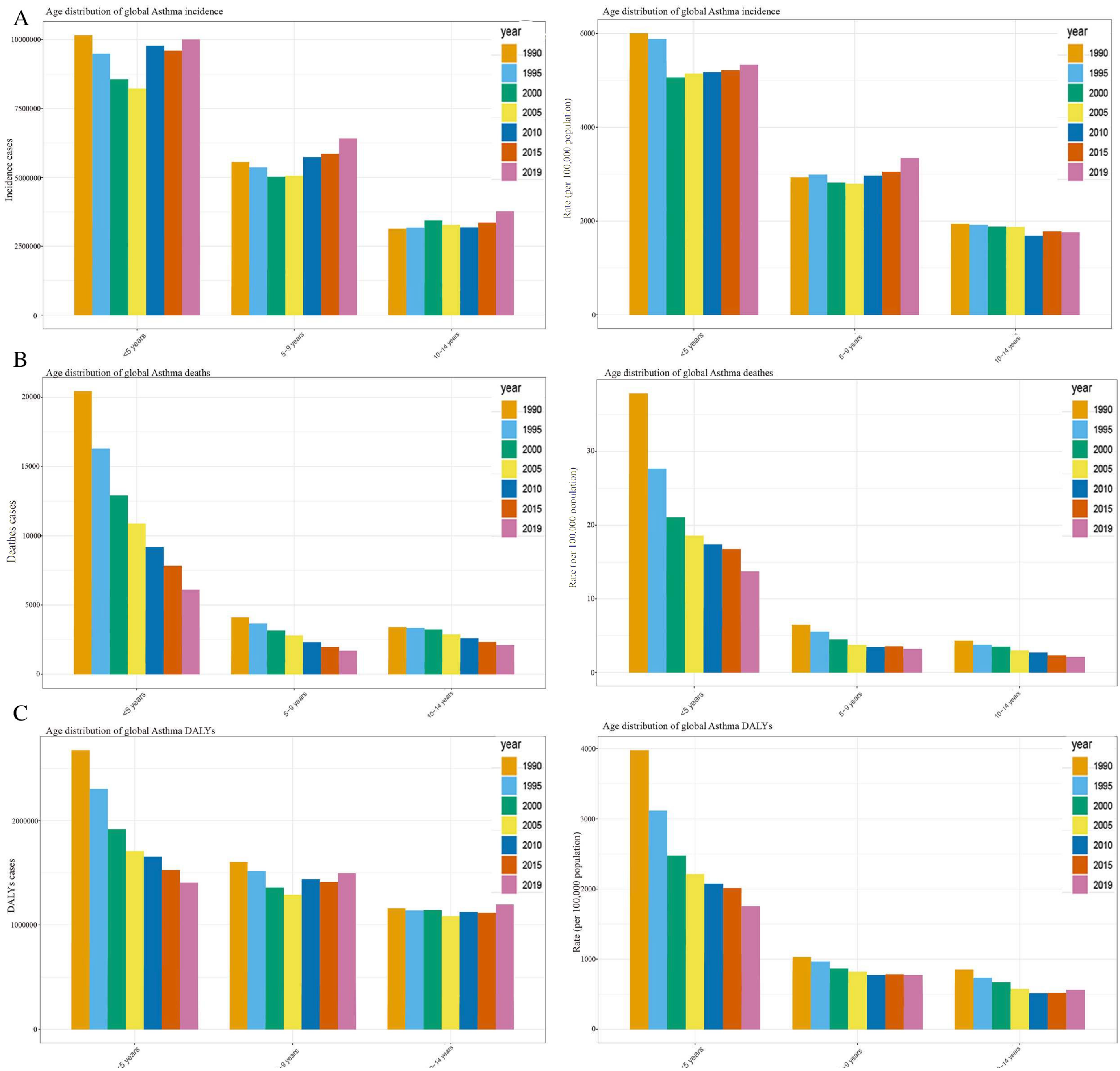

Figure 1 Trends in asthma incidence, deaths and disability-adjusted life-years (DALYs) among children from 1990 to 2019. (A) Trends in incident cases and incidence rate. (B) Trends in deaths cases and deaths rate. (C) Trends in DALYs cases and DALYs rate.

100 000 population in 2019 (online supplemental table S1). From 1990 to 2019, there was a rise in the number of reported incident cases across all age groups, with the exception of those under 5 years old. However, the age-standardised incidence rates saw a decline across all age groups (figure 1A). When examining the age-standardised incidence rates by gender, it was observed that the high SDI area recorded the highest rates for both men and women.

Also, AD shows a similar trend. From 1990 to 2019, the global incident cases of childhood AD increased by 39.4% (95% UI, 30.99% to 45.45%), age-standardised incidence rates had a 5.46% decrease, from 561.61 (95% UI, 519.03 to 608.29) per 100 000 population in 1990 to 594.05 (95% UI, 547.98 to 642.88) per 100 000 population in 2019, the EAPC was −0.14 (95% CI, −0.17 to −0.11) (online supplemental table S1). From 1990 to 2019, the number of incidences in each age group of AD showed a slight increase, while the age-standardised incidence rates of AD almost changed (refer to online supplemental figure S1A).

Mortality

Between 1990 and 2019, the number of global paediatric deaths attributable to asthma declined significantly by

64.54%: from 27 949.65 (95% UI, 18 502.82 to 35 060.16) in 1990 to 9911.18 in 2019 (95% UI, 7949.92 to 12 337) (online supplemental table S2). Moreover, there was a decline in the rate of deaths associated with asthma from 1.59 (95% UI, 1.05 to 2) per 100 000 in 1990 to 0.51 (95% UI, 0.41 to 0.63) per 100 000 in 2019, with an EAPC of −3.62 (95% CI, −3.73 to −3.52) (online supplemental table S2). A reduction in asthma-related mortality was observed across all age groups of children, with the least number of deaths reported among 5–9 years old in 2019, followed by the 10–14 years age bracket (figure 1B). Conversely, the highest incidence of deaths was noted among children under 5 years of age. However, it is significant to note that the most substantial decline in asthma-related deaths has occurred in children younger than 5 years of age over the last three decades (figure 1B). Since no deaths were directly attributed to AD, they are not shown in this section.

DALYs

Between 1990 and 2019, there was a significant reduction (24.24%) in the global number of asthma DALYs among children. Specifically, the number decreased from 5 433 991.36 (95% UI, 3 840 150.83 to 7 609 681.37) in 1990 to 4 116 909.48 (95% UI, 2 702 283.81 to 6 170 009.59) in 2019 (online supplemental table S2). Age-standardised DALYs rates due to asthma decreased from 309.81 (95% UI, 218.94 to 433.86) in 1990 to 210.08 (95% UI, 137.89 to 314.84) in 2019 (online supplemental table S2). The EAPC during this period was −1.19 (95% CI, −1.4 to −0.98) (online supplemental table S3). From the perspective of different age groups, DALYs declined in all age groups except for the 10–14 age group, with the largest decline in age groups younger than 5 years and the highest DALYs in 2019 in the 5–9 age group (figure 1C).

The DALYs for AD saw an increase of 5.79%, rising from 2 961 042.47 (95% UI, 1 582 662.98 to 4 978 106.41) in 1990 to 3 132 371.54 (95% UI, 1 680 829.55 to 5 262 941.54) in 2019. However, when adjusted for age, the DALYs rates for AD actually decreased by 5.32% during the same period, falling from 168.82 (95% UI, 90.23 to 283.82) in 1990 to 159.84 (95% UI, 85.77 to 268.55) in 2019 (refer to online supplemental table S3 for more details). The EAPC during this period was −0.18 (95% CI, −0.2 to −0.16), as shown in online supplemental table S3. In 2019, the highest DALYs across all age groups were observed in the 5–9 age bracket, while the lowest were in the 10–14 age group. It's worth noting that the age-standardised DALYs across different age groups have remained relatively stable over the past three decades (as illustrated in online supplemental figure S1B).

SDI regional burden of allergic disorders

Incidence

High SDI has the highest asthma age-standardised incidence rate 1958.75 (95% UI, 1357.47 to 2619.18) per 100 000 population in 2019 (online supplemental table S1; figure 2). Meanwhile, the EAPC of high SDI is the highest (0.65; 95% CI, 0.42 to 0.88; online supplemental table S1). The middle SDI region had the most cases of childhood asthma in 2019 (5 844 723.59; 95% UI, 3 834 729.55 to 8 307 817.95; online supplemental table S1). The incident cases of asthma in the low SDI region increased by 81.65% (online supplemental table S1). When considering age-standardised incidence rates by gender, the highest rates for both men and women were observed in high SDI regions. In 2019, the age-standardised incidence of asthma was higher in men than in women, as depicted in figure 2.

As can be seen from figure 3A, in 2019, the incidence of asthma was higher in men than women in all age groups except for the 10–14 age group. As for AD, low-middle SDI had the most AD cases and high SDI had the highest age-standardised incidence rates. Low SDI, low-middle SDI and high SDI all had negative EAPCs, and high SDI had the greatest decrease in EAPC. Similar to the asthma trend, the AD age-standardised incidence rate for men or women in high SDI was the highest of all regions, and unlike asthma, the age-standardised incidence rate was higher for women than for men in AD (figure 3B).

Mortality

All five SDI regions witnessed a decrease in asthma-related fatalities. The low SDI region recorded the highest number of such deaths in 2019, with a total of 5018.2 (95% UI, 3663.57 to 6904.7, online supplemental table S2). In contrast, the high-middle SDI and high SDI regions reported significantly fewer asthma-related deaths. The most substantial reduction in asthma-related mortality was observed in the high-middle SDI regions, which also had the lowest EAPC for asthma-related mortality (−6.15 ; 95% CI, −6.3 to −6.01; online supplemental table S2). As illustrated in online supplemental figure S2A, across all SDI regions, women aged 10–14 years exhibited a higher death rate than their male counterparts.

DALYs

In 2019, regions with low SDI recorded the highest number of DALYs associated with asthma, amounting to 1 188 174.99 (95% UI, 838 361.08 to 1 697 435.42). On the other hand, the low-middle SDI regions saw the most significant reduction. The number of asthma-related DALYs in these regions dropped from 1 362 138.96 (95% UI, 961 068.44 to 1 808 139.47) in 1990 to 788 217.65 (95% UI, 524 264.25 to 1 162 810.14) in 2019. This represents a decrease of 42.13% (refer to online supplemental table S3 for more details). The EAPC for all four regions except high SDI is negative, with low-middle SDI having the lowest EAPC of −2.26 (95% CI, −2.5 to −2.02; online supplemental table S3). In these high SDI regions, the age-standardised DALYs rates (356.08 (95% UI, 218.13 to 558.59) per 100 000 population) not only exceed the global average but also display an increasing trend. Furthermore, a closer examination of the data reveals a higher age-standardised DALYs rate in women compared with men. However, this gender disparity is only observed

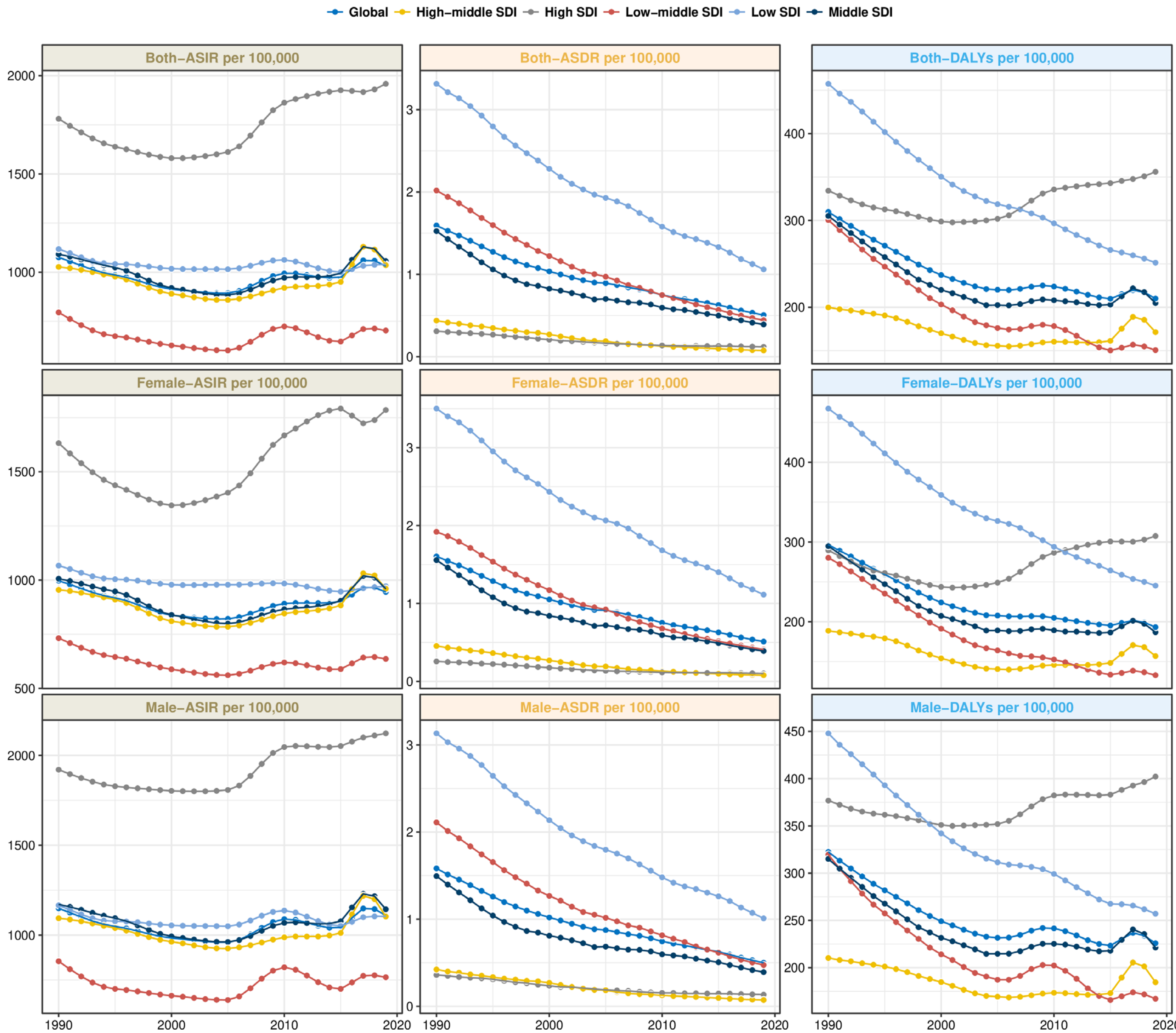

Figure 2 Epidemiologic trends of incidence, death and disability-adjusted life-years (DALYs) rates in five Socio-Demographic Index (SDI) regions of childhood asthma from 1990 to 2019. ASDR, Age-Standardised Deaths Rate; ASIR, Age-Standardised Incidence Rate.

in the under-5 age group in low SDI regions, as shown in online supplemental figure S2B.

In 2019, the region with the median SDI reported the highest number of DALYs associated with AD, totalling 772 819.22. The 95% UI for this data ranged from 414 982.13 to 1 297 609.57. As can be seen from online supplemental figure S3, online supplemental table S3, the age-standardised DALYs rates for AD in the five SDI regions were essentially flat over the 30-year period, and it is noteworthy that the age-standardised DALYs rates for high SDI were significantly higher than those for the other four regions, with the 2019 high SDI age-standardised DALYs rates of 327.69 (95% UI, 174.08 to 551.2) per 100 000 population. Unlike asthma DALYs, age-standardised DALYs rates for men were smaller than those for women in all age groups across all SDI (online supplemental figure S2C).

Geographical regions burden of allergic disorders in children

Incidence

Among the 21 geographical regions studied, Eastern sub-Saharan Africa had the highest number of asthma incident cases at 2 494 917.85 (95% UI, 1 695 097.21 to 3 487 259.5). In contrast, Oceania recorded the lowest incidence, with 53 416.23 (95% UI, 38 937.48 to 71 530.78, online supplemental table S1). Over the past three decades, South Asia has seen the most significant increase in childhood asthma incidence, with an EAPC of 1.23 (95% CI, 0.36 to 2.11). On the other hand, Australasia has experienced the most

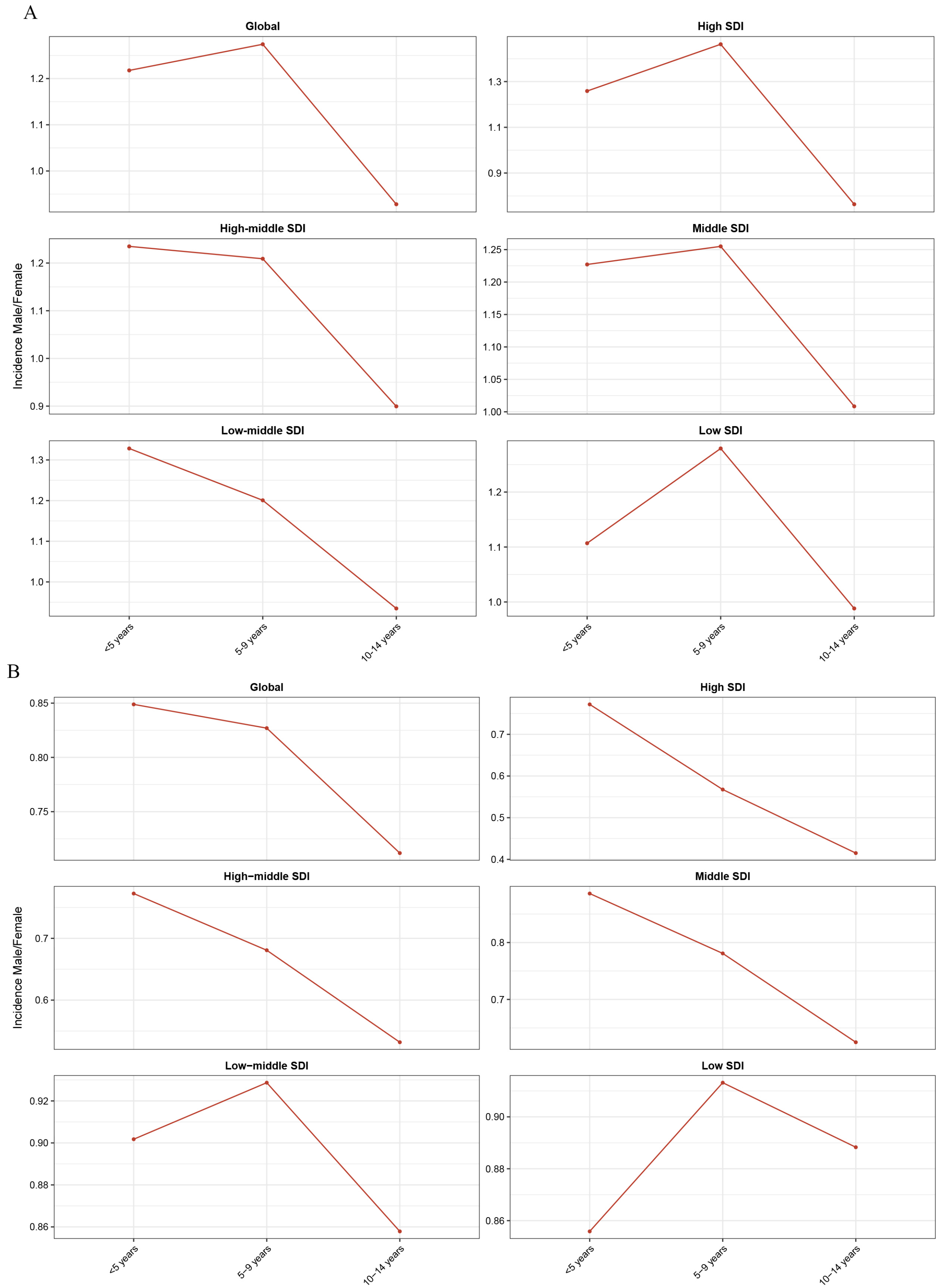

Figure 3 Ratio of male to female incidence of allergic diseases in children in different age subgroups. (A) Asthma (B) Atopic dermatitis. SDI, Socio-Demographic Index.

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substantial decrease, with an EAPC of −1.29 (95% CI, −1.52 to −1.07). The age-standardised incidence of childhood asthma was highest in high-income North America (3203.2 per 100 000 population, 95% UI, 2285.55 to 4233.42), whereas South Asia had the fewest age-standardised incidence of childhood asthma (356.38 per 100 000 population, 95% UI, 230.01 to 519.3). As can be seen from online supplemental figure S4A, the incidence of childhood asthma showed a positive correlation with the SDI (R=0.21, p<0.001) and 17 regions (eg, high-income North America, tropical Latin America and the Caribbean) had a higher incidences of childhood asthma than the global mean (1030.33). Four regions (including Western Europe and East Asia) had lower incidences than the global mean (1030.33). As for AD, South Asia had the highest number of AD cases in 2019 (3 571 391.3, 95% UI, 3 290 506.37 to 3 875 897.34), and Oceania had the lowest number of paediatric AD cases (28 108, 95% UI, 24 991.37 to 31 362.6, online supplemental table S1). Between 1990 and 2019, Eastern Europe witnessed a notable rise in the incidence of childhood AD, reflected by an EAPC of 0.83 (95% CI, 0.49 to 1.16). Conversely, high-income North America saw a significant decline, indicated by an EAPC of −0.76 (95% CI, −0.92 to −0.6, online supplemental table S1). Similar to asthma, the incidence rate of AD showed a positive correlation with SDI (R=0.48, p<0.001, figure 4B), and 11 regions (such as Central Asia, high-income Asia Pacific and Western Europe) had a higher incidences of childhood AD than the global mean (561.61). 10 regions (such as Southeast Asia and high-income North America) had lower incidences than the global mean.

Mortality

In 2019, Eastern sub-Saharan Africa reported the highest number of childhood asthma-related deaths, with a count of 2325.1 (95% UI, 1588.39 to 3597.38, online supplemental table S2). In contrast, Central Europe recorded the lowest number, with a mere 2.83 (95% UI, 2.35 to 3.39). The Caribbean, however, had the highest mortality rate associated with childhood asthma, standing at 2.91 per 100 000 population (95% UI, 1.3 to 4.99). Over the past 30 years, there has been a noticeable decrease in childhood asthma mortality rates across various regions. High-income North America, for instance, has seen the smallest decrease, with an EAPC of −1.23 (95% CI, −1.41 to −1.05). Conversely, the high-income Asia Pacific region has witnessed the most significant decrease, with an EAPC of −10.47 (95% CI, −10.86 to −10.08, online supplemental table S2). When compared with the global mean of 0.51, seven regions, including the Caribbean and Oceania, had higher childhood asthma-associated mortality rates. On the other hand, 14 regions, such as North Africa, the Middle East and South Asia, reported lower rates than the global mean.

DALYs

Eastern sub-Saharan Africa recorded the highest number of childhood asthma-associated DALYs (593 400.6, 95% UI, 409 766.98 to 851 243.65, online supplemental table S3). In contrast, Oceania reported the lowest number (17 941.89, 95% UI, 11 823.05 to 25 744.36, online supplemental table S3). When it comes to the DALYs rate per 100 000 population, the Caribbean topped the list with 672.37 (95% UI, 432.61 to 960.41), while South Asia had the lowest rate of 82.64 (95% UI, 53.02 to 127.71). Globally, 14 regions, including the Caribbean, high-income North America and Australasia, reported DALY rates exceeding the global average of 210.08. Conversely, seven regions, such as Western Europe, high-income Asia Pacific and Central Europe, registered DALY rates below this global average (online supplemental table S3).

South Asia recorded the highest number of childhood AD-associated DALYs (831 761.33, 95% UI, 445 146.28 to 1 392 580.04, as shown in online supplemental table S3). However, when considering the rate of childhood AD-associated DALYs, Central Asia topped the list with 497.49 per 100 000 population (95% UI, 261.81 to 850.74, as per online supplemental table S3). On the other hand, Eastern sub-Saharan Africa reported the lowest rate of DALYs, with 92.5 per 100 000 population (95% UI, 49.78 to 154.76, according to online supplemental table S3). Eastern Europe experienced the most significant rise in the rate of childhood AD-associated DALYs (EAPC, 0.42; 95% CI, 0.19 to 0.66). Conversely, high-income North America saw the most substantial decline in the DALYs rate (EAPC, −0.34; 95% CI, −0.42 to −0.25, online supplemental table S3). 12 regions, including Central Asia, high-income Asia Pacific and Western Europe, reported DALY rates exceeding the global average of 159.84. Conversely, nine regions, including Eastern sub-Saharan Africa, East Asia and Southeast Asia, recorded DALY rates below this global average (refer to online supplemental table S3 for details).

204 countries burden of allergic disorders in children

Incidence

In 2019, out of 204 countries, the USA had the highest incidence rate of childhood asthma, with 3357.17 cases per 100 000 population (95% UI, 2399.6 to 4433.77, online supplemental table S4). In contrast, Nepal reported the lowest rate, with 176.6 cases per 100 000 population (95% UI, 113.64 to 254.41, online supplemental table S4). Over the period from 1990 to 2019, India experienced the most significant increase in the incidence rate of childhood asthma (EAPC, 1.77; 95% CI, 0.59 to 2.97, online supplemental table S4, online supplemental figure S5A). Conversely, Guatemala saw the most substantial decrease (EAPC, −2.49; 95% CI, −2.87 to −2.10, online supplemental table S5, online supplemental figure S5A). In terms of the number of cases, Afghanistan had the largest increase (up 264%), followed by Qatar with a 215%

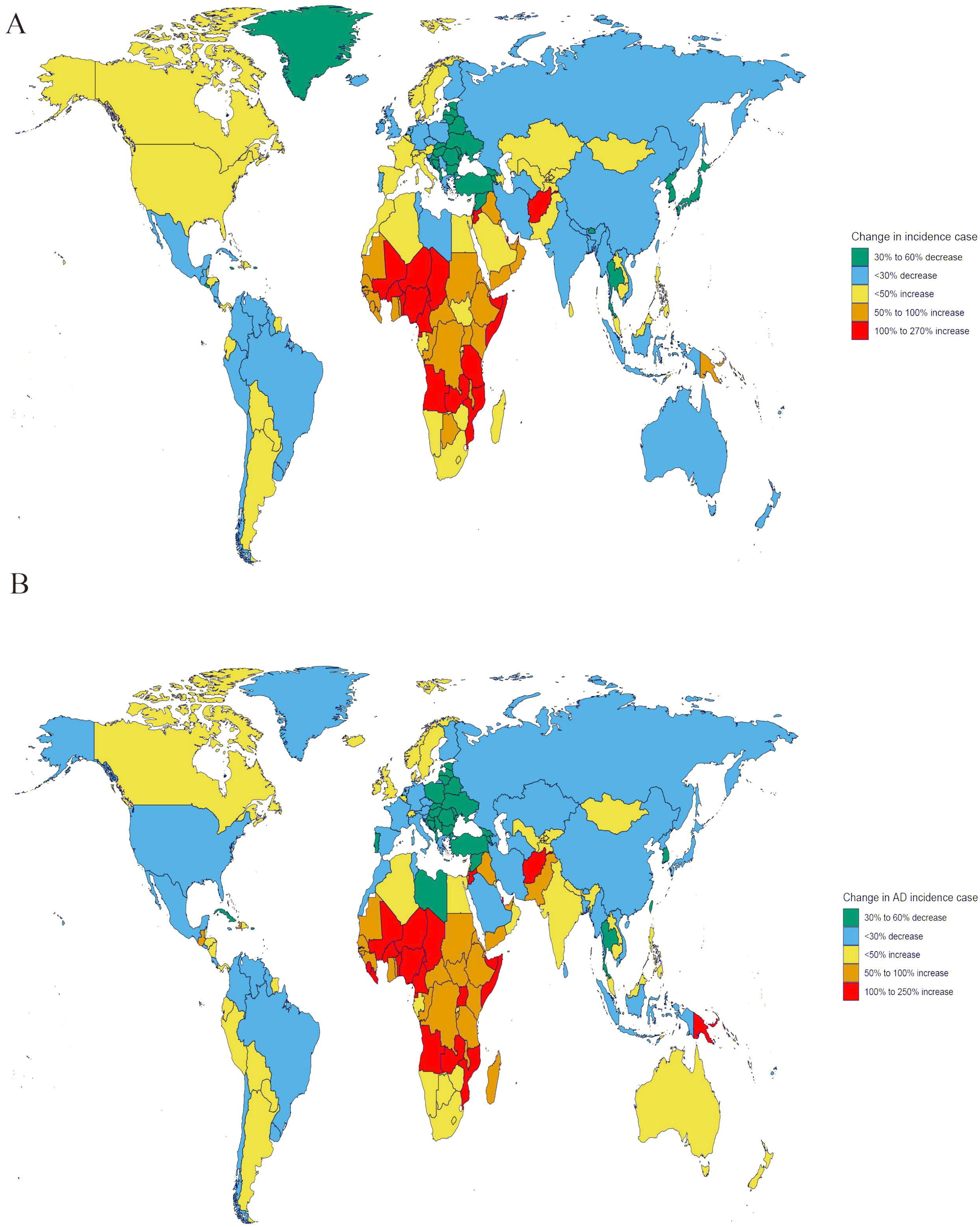

Figure 4 Change incident cases of allergic diseases in children in 204 countries and territories. (A) Asthma (B) AD. AD, atopic dermatitis.

increase. Bosnia and Herzegovina, on the other hand, reported a 55% decrease (figure 4A). Regarding childhood AD, Mongolia had the highest incidence rate in 2019, with 1685.65 cases per 100 000 population (95% UI, 1424.67 to 1984.86, online supplemental table S6). Egypt reported the lowest rate, with 238.59 cases per 100 000 population (95% UI, 210.69 to 270.35, online supplemental table S6). From 1990 to 2019, Russia saw the largest increase in the incidence rate of childhood AD (EAPC, 0.87; 95% CI, 0.52 to 1.23, online supplemental table S7, online supplemental figure S5B). In contrast, the USA experienced the most significant decrease (EAPC, −0.82; 95% CI, −1.00 to −0.64, online supplemental table S6, online supplemental figure S5B). In terms of the number of cases, Afghanistan again had the largest increase (up 244%), while Albania reported a 58% decrease (figure 4B).

Mortality

In 2019, Haiti reported the highest mortality rate from childhood asthma, with 6.6 deaths per 100 000 population (95% UI, 2.29 to 11.93; online supplemental table S8). In contrast, Armenia had the lowest rate, with 0.01 deaths per 100 000 population (95% UI, 0.01 to 0.02, online supplemental table S8). The most significant increase in mortality rate was observed in Zimbabwe, with an EAPC of 3.04 (95% CI, 1.17 to 4.94; online supplemental figure S5C). On the other hand, South Korea demonstrated the most substantial decrease, with an EAPC of −12.37 (95% CI, −12.82 to −11.92; online supplemental figure S5C). When examining the number of childhood asthma death cases, Chad experienced the most significant rise, with an increase of 56%. Mali also saw a substantial increase of 38%. Conversely, El Salvador reported a dramatic decrease of 98% (online supplemental figure S6).

DALYs

In 2019, Haiti reported the highest rate of childhood asthma-associated DALYs at 1041.21 per 100 000 population (95% UI, 608.41 to 1536.46, as shown in online supplemental figure S7A). Conversely, Nepal had the lowest rate at 34.41 per 100 000 population (95% UI, 21.51 to 55.17, online supplemental figure S7A). In terms of changes over time, Oman experienced the most significant increase in the DALYs rate (EAPC, 1.41; 95% CI, 1.12 to 1.69). On the other hand, Guatemala saw the most substantial decrease (EAPC, −5.71; 95% CI, −4.79 to −6.63), as depicted in online supplemental figure S5D. Qatar had the largest increase in childhood asthma-associated DALY, at 171%, and El Salvador had the largest decrease, at −74% (online supplemental figure S8A). Japan reported the highest rate of childhood AD-associated DALYs (532.3 per 100 000 population, 95% UI, 285.02 to 898.78), Rwanda had the lowest rate (61.59 per 100 000 population, 95% UI, 33.26 to 104.29; online supplemental figure S7B). Afghanistan had the largest increase in AD-associated DALYs, at 252%, and Albania had the largest decrease, at −58% (online supplemental figure S8B). The USA (EAPC, −0.36; 95% CI, −0.45 to −0.28) had the greatest decreases; Kenya (EAPC, 0.38; 95% CI, 0.19 to 0.69) had the greatest increase in DALYs rate (online supplemental figure S9).

Future burden of allergic disorders in children

Figure 5 presents the future projections of GBD in relation to asthma. As depicted in figure 5A, the ASR of asthma prevalence globally is expected to gradually decrease. By 2045, it is projected that the ASR of asthma prevalence globally will be 3246.75 per 100 000 (95% CI, −3530.73 to 10 024.25, online supplemental tables S9 and S10). Conversely, the prevalence in high SDI regions is on an upward trend, anticipated to exceed 9184 per 100 000 by 2045 (figure 5A, online supplemental tables S9 and S10). A similar pattern is observed in the asthma incidence rate, as shown in figure 5B. By the year 2045, it is projected that the ASR of asthma incidence globally will reach 1263 per 100 000 individuals (95% CI, −339.95 to 2867.56, see online supplemental tables S9 and S10). Similarly, in high SDI regions, the ASR of asthma incidence is expected to be 2463.40 per 100 000 individuals by 2045 (95% CI, −1009.65 to 5936.47, see online supplemental tables S9 and S10). Online supplemental table S9 presents future projections for GBD concerning AD. By the year 2045, it is anticipated that the ASR of AD incidence globally will rise to 569 per 100 000 individuals (95% CI, 128.33 to 1009.66, see online supplemental table S10). Similarly, in regions with high SDI, the projected ASR of AD incidence by 2045 is 845.82 per 100 000 individuals (95% CI, 83.84 to 1607.81, see online supplemental table S10). Additionally, the prevalence of AD globally is expected to reach 3622.63 per 100 000 individuals by 2045 (95% CI, 925.88 to 6319.37, see online supplemental table S10).

DISCUSSION

Allergic disorders in children have emerged as a pressing global public health concern. This study delves into the morbidity, mortality and DALYs attributed to asthma and AD among children aged 0–14 years spanning all regions and countries tracked by the GBD database from 1990 to 2019. Furthermore, our analysis extends to projecting future disease burdens. By examining the impact of allergic diseases on children across diverse income levels and geographical contexts over the past three decades, our research offers valuable insights. These findings align with previous research conducted from 1990 to 2019, highlighting notable disparities in the prevalence of childhood allergic diseases among various regions and countries. Hence, conducting a comprehensive global assessment of the epidemiological trends associated with these conditions could aid policymakers and healthcare practitioners in formulating effective prevention and management strategies. Between 1990 and 2019, there was a global increase in the number of childhood asthma and AD cases. However, during the same period, there was a significant decrease in the number of asthma-related deaths and DALYs. Conversely, the DALYs associated with AD exhibited an upward trend. Furthermore, our findings revealed a significant positive correlation between the SDI and both the incidence of childhood asthma and AD. Conversely, a significant negative correlation was observed between the SDI and the mortality rate of childhood asthma. Additionally, a positive correlation was found between the SDI and the DALYs of childhood AD, while a negative correlation was noted with the DALYs of childhood asthma. The regions that experienced the most significant rise in new cases of allergic diseases

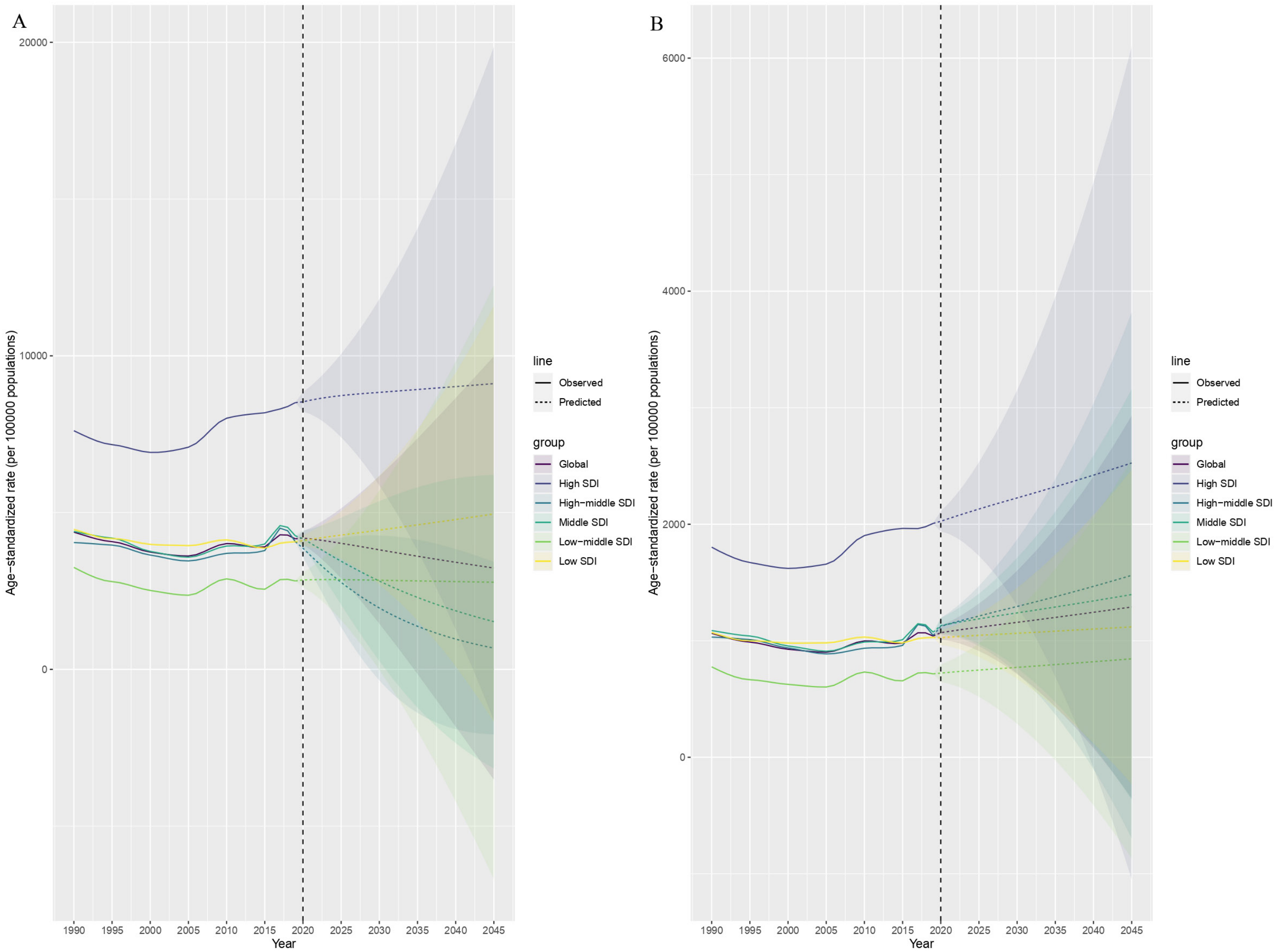

Figure 5 Future forecasts of Global Burden of Disease in asthma. (A) The age standardised prevalence rate. (B) The age standardised incidence rate. SDI, socio-Demographic Index.

among children were those with low SDI, witnessing an 81% increase. Conversely, children from high-middle SDI regions saw an 18% decrease in asthma cases and a 17% reduction in AD cases. The number of childhood asthma fatalities also saw the most significant decline in high-middle SDI regions, with an 85% decrease. Globally, the incidence of childhood asthma has decreased from 1075.14 per 100 000 population in 1990 to 1030.33 per 100 000 population in 2019, the mortality rate has decreased from 1.59 per 100 000 population in 1990 to 0.51 per 100 000 population in 2019 and the DALYs rate has decreased from 309.81 per 100 000 population to 210.08 per 100 000 population. The incidence of AD in children was relatively stable, dropping from 569.5 per 100 000 population in 1990 to 566.45 per 100 000 population and DALYs from 168.82 per 100 000 population to 159.84 per 100 000 population. The observed findings may be attributed to several factors. First, the establishment of key guidelines, such as those issued by the National Heart, Lung and Blood Institute in 1991 and the Global Initiative for Asthma in 1995, may have played a significant role.[25 26] These guidelines, coupled with increased global awareness and improved asthma management, have likely contributed to the decline. Additionally, the development and widespread use of various treatment options have also been instrumental. Furthermore, the decrease can be linked to the superior medical services available in areas with a higher SDI. For example, in Haiti, the Central African Republic had the highest rates of asthma-related death, and in Armenia, Taiwan (province of China) and Finland, the rates were lower. These services facilitate early detection of allergy disorders in children, thereby enabling more effective treatment. This suggests that the quality of healthcare services, particularly in regions with a higher SDI, significantly impacts the management and treatment of such conditions. Despite the significant disparities in incidence and mortality rates worldwide and across different regions, it remains essential to intensify efforts towards improved asthma prevention and control, particularly in resource-limited settings.

The incidence and DALYs rate for AD have seen a slight decline over the past 30 years. Unlike asthma, the prevalence of AD and DALY rates did not exhibit significant variation across countries and regions. However, Central

Asia reported the highest incidence and DALY rates, while North Africa and the Middle East had the highest incidence. Conversely, Eastern sub-Saharan Africa reported the lowest DALY rates. The relatively low disease burden reported by African countries could be partially attributed to dietary and environmental differences. However, under-reporting may also be a contributing factor. This highlights an urgent need for more epidemiological studies to illuminate phenomena closely tied to complex, globally changing factors. Further exploration of these complex and shifting environmental factors across different global regions is necessary. These factors pose significant threats to human health and require our attention. Concurrently, we must strive to empower regions with limited scientific research resources. By enhancing their ability to identify potential public health risks, we can improve their disease diagnosis and prevention capabilities. This will ultimately safeguard the lives and health of their populations on all fronts.

The present study revealed that the highest incidence of asthma and AD was observed in children under 5 years old. This finding contrasts with previous studies, which suggested a peak occurrence between the ages of 5 and 9.[27] This discrepancy could be attributed to variations in the countries and age groups considered in different studies, as well as the impact of population growth.

Previous studies have indicated a correlation between higher SDI levels and an increased incidence of asthma and AD. Interestingly, these studies also noted a reverse trend in mortality rates.[27–29] Our research, however, presents a different perspective. We discovered that a lower SDI was linked to higher mortality rates across all time frames from 1990 to 2019. Asthma is highly prevalent in many inner-city populations of low-income and middle-income countries, yet access to and affordability of essential asthma medications are limited.[30] This lack of treatment leads to significant morbidity and mortality.[13] Furthermore, the high incidence of acute respiratory infections in these countries often exacerbates asthma symptoms, contributes to underdiagnosis and results in inadequate treatment. Consequently, this leads to under-reported prevalence rates and increased morbidity. These circumstances suggest a substantial opportunity for global and community initiatives to enhance asthma outcomes in resource-limited populations.[31]

Limitations

Our study, however, is not without its limitations. First, the diagnosis of asthma and AD relied heavily on physician diagnosis and symptom data, potentially leading to variability in diagnoses across regions due to differences in local practices and terminology. This could introduce inconsistencies in prevalence estimates, especially considering the possibility of different terms used for similar symptoms in various countries. Second, the study's case definition for asthma, requiring symptoms such as wheezing in the last year and attribution to allergic reactions or hypersensitivity, might have excluded certain asthma cases, particularly non-allergic phenotypes or individuals with controlled symptoms due to medication. This could result in an underestimation of asthma prevalence, especially given improvements in asthma management over time. Additionally, the study focused solely on asthma and AD due to limitations in data availability and modelling complexities, overlooking other chronic allergic conditions that could contribute significantly to the global health burden. Furthermore, the study did not evaluate attributable risk factors for AD, limiting insights into its aetiology and prevention strategies. Data limitations, particularly in low-income and mid-income countries, may have led to under-reporting or partial registration of asthma and AD cases, potentially biasing global burden estimates. Moreover, comparisons based on country-level aggregate data might be subject to ecological bias, overlooking individual-level variations and associations. The study's inability to consider the role of ethnicity in asthma and AD burden due to data heterogeneity further complicates interpretation, given the potential impact of racial factors on health outcomes. In conclusion, while the study contributes valuable insights into the global burden of asthma and AD using GBD data, caution is warranted in interpreting its findings due to the aforementioned limitations, necessitating further research to address these gaps and provide a more comprehensive understanding of disease burden trends and determinants worldwide.

CONCLUSIONS

The epidemiological landscape of childhood allergic diseases has undergone significant changes in the past three decades. While there has been a global decrease in morbidity and mortality, high levels of disease-related mortality and associated DALYs persist in areas with low SDI. A deeper understanding of the disease burden of asthma and AD can facilitate the creation of cost-effective, targeted strategies. These strategies have the potential to significantly reduce morbidity and mortality rates, improve global disease management and alleviate the socioeconomic burden. Consequently, this could lead to a more equitable distribution of preventive measures, diagnostic procedures and treatments. This revised approach could ultimately contribute to a more balanced global health landscape, particularly in relation to childhood allergic diseases.

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valuable insights into data interpretation and the discussion of results. X-yL contributed to software development and computational tasks essential for implementing algorithms and simulations. Z-lG played a pivotal role in experimental setup, instrumentation and data acquisition. Y-jZ assisted in experimental procedures, data validation and result visualisation. Z-hC supervised the entire project, offering guidance on methodology, data analysis and manuscript preparation. Z-lG acted as the guarantor, taking full responsibility for the conduct of the study, having access to the data, and controlling the decision to publish.

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