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

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Summary

Background Asthma and atopic dermatitis are common allergic conditions that contribute to substantial health loss, economic burden, and pain across individuals of all ages worldwide. Therefore, as a component of the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021, we present updated estimates of the prevalence, disability-adjusted life-years (DALYs), incidence, and deaths due to asthma and atopic dermatitis and the burden attributable to modifiable risk factors, with forecasted prevalence up to 2050.

Methods Asthma and atopic dermatitis prevalence, incidence, DALYs, and mortality, with corresponding 95% uncertainty intervals (UIs), were estimated for 204 countries and territories from 1990 to 2021. A systematic review identified data from 389 sources for asthma and 316 for atopic dermatitis, which were further pooled using the Bayesian meta-regression tool. We also described the age-standardised DALY rates of asthma attributable to four modifiable risk factors: high BMI, occupational asthmagens, smoking, and nitrogen dioxide pollution. Furthermore, as a secondary analysis, prevalence was forecasted to 2050 using the Socio-demographic Index (SDI), air pollution, and smoking as predictors for asthma and atopic dermatitis. To assess trends in the burden of asthma and atopic dermatitis before (2010–19) and during (2019–21) the COVID-19 pandemic, we compared their average annual percentage changes (AAPCs).

Findings In 2021, there were an estimated 260 million (95% UI 227–298) individuals with asthma and 129 million (124–134) individuals with atopic dermatitis worldwide. Asthma cases declined from 287 million (250–331) in 1990 to 238 million (209–272) in 2005 but increased to 260 million in 2021. Atopic dermatitis cases consistently rose from 107 million (103–112) in 1990 to 129 million (124–134) in 2021. However, age-standardised prevalence rates decreased—by 40·0% (from 5568·3 per 100 000 to 3340·1 per 100 000) for asthma and 8·3% (from 1885·4 per 100 000 to 1728·5 per 100 000) for atopic dermatitis. In 2021, there were substantial variations in the burden of asthma and atopic dermatitis across different SDI groups, with the highest age-standardised DALY rate found in south Asia for asthma (465·0 [357·2–648·9] per 100 000) and the high-income super-region for atopic dermatitis (3552·5 [3407·2–3706·1] per 100 000). During the COVID-19 pandemic, the decline in asthma prevalence had stagnated (AAPC pre-pandemic –1·39% [–2·07 to –0·71] and during the pandemic 0·47% [–1·86 to 2·79]; p=0·020); however, there was no significant difference in atopic dermatitis prevalence in the same period (pre-pandemic –0·28% [–0·33 to –0·22] and during the pandemic –0·35% [–0·78 to 0·08]; p=0·20). Modifiable risk factors were responsible for 29·9% of the global asthma DALY burden; among them, high BMI was the greatest contributor (39·4 [19·6–60·2] per 100 000), followed by occupational asthmagens (20·8 [16·7–26·5] per 100 000) across all regions. The age-standardised DALY rate of asthma attributable to high BMI was highest in high-SDI settings, whereas the contribution of occupational asthmagens was highest in low-SDI settings. According to our forecasting models, we expect 275 million (224–330) asthma cases and 148 million (140–158) atopic dermatitis cases in 2050, with population growth driving this increase. However, age-standardised prevalence rates are expected to remain stable (–23·2% [–44·4 to 5·3] for asthma and –1·4% [–9·1 to 7·0] for atopic dermatitis) from 2021 to 2050.

Interpretation Although the increases in the total number of asthma and atopic dermatitis cases will probably continue until 2050, age-standardised prevalence rates are expected to remain stable. A considerable portion of the global burden could be managed through efforts to address modifiable risk factors. Additionally, the contribution of risk factors to the burden substantially varied by SDI, which suggests the need for tailored initiatives for specific SDI settings. The growing number of individuals expected to be affected by asthma and atopic dermatitis in the future suggests that it is essential to improve our understanding of risk factors for asthma and atopic dermatitis and collect disease prevalence data that are globally generalisable.

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Research in context

Evidence before this study

The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) estimates global, regional, and country-level disease burden. A systematic review of asthma and atopic dermatitis was conducted for GBD 2016, using the search terms "asthma", "atopic dermatitis", "prevalence", and "cross-sectional studies". Further examination from 2016 to 2021 was performed to update estimates. These data were pooled into the GBD meta-regression model to estimate the burden of asthma and atopic dermatitis in 2021. Two studies reported the estimates of asthma and atopic dermatitis and chronic respiratory diseases from 1990 to 2019 as part of GBD 2019; however, the potential for COVID-19-related influences on asthma and atopic dermatitis during the pandemic suggests the urgent need for an updated study encompassing recent years. Additionally, to our knowledge, no projection of the global prevalence of asthma or atopic dermatitis to 2050 has been published.

Added value of this study

The present study analysed estimates from GBD 2021, to provide updated estimates of the current burden of asthma and atopic dermatitis, including prevalence, incidence, death, and disability-adjusted life-years (DALYs), and the disease prevalence projection to the year 2050. Although the number of asthma and atopic dermatitis cases has increased in recent years, their age-standardised prevalence rates have decreased over time. We found that higher asthma prevalence was associated with a higher Socio-demographic Index (SDI), whereas its DALY burden was inversely associated with SDI. In comparison, higher atopic dermatitis prevalence and DALYs were associated with higher SDI. Modifiable GBD risk factors are responsible for nearly 30% of the global asthma DALYs, which indicates the proportion of asthma burden that can be reduced by modifying risk factors. This presents a significant opportunity for positive change. High BMI was the most critical contributor globally, particularly pronounced in high-SDI settings. By contrast, asthma attributable to smoking and occupational asthmagens was significantly higher in limited-resource settings. There was a significant difference in the prevalence rate of asthma, but not of atopic dermatitis, during the COVID-19 pandemic. In 2050, our forecasts projected 275 million cases of asthma and 148 million cases of atopic dermatitis. The decomposition analysis showed that population growth was the principal and positive contributor to this global forecasted increase.

Implications of all the available evidence

The burden of asthma and atopic dermatitis did not decrease between 1990 and 2021, and based on the forecast for 2050, the absolute number of disease cases will significantly increase. Considering the substantial variation in the asthma burden attributable to each risk factor by the level of SDI, it is highly recommended that SDI-specific intervention strategies to address modifiable risk factors be implemented. Additionally, estimates on risk factors for atopic dermatitis are scarce, underscoring the urgent need for enhanced collection of standardised data at the national or regional level.

Introduction

Asthma and atopic dermatitis are allergic diseases of the airways and skin, respectively, characterised by shared underlying mechanisms, such as disrupted epithelial barriers, genetics, allergic sensitisation, and environmental triggers.[1] These diseases often follow a progressive sequence, in which patients with atopic dermatitis are likely to develop asthma and other atopic diseases at certain ages.[2] Whereas some individuals experience persistent symptoms for several years, others might see resolution as they grow older. It is common to mischaracterise these diseases as conditions of childhood; however, they, especially asthma, could increase the risk of mortality and morbidity in older patients relative to younger people.[3,4]

Although asthma and atopic dermatitis have been investigated extensively in high-income countries,[5] there is an urgent need to assess these disease burdens in low-income and middle-income countries. This is particularly important because of the substantial changes in lifestyle and industry that might contribute to this burden. Additionally, treatment for asthma and atopic dermatitis has improved considerably over time,[6] albeit with substantial variation in access to treatment across the globe. To effectively provide adequate management and prevention, we conducted an updated and comprehensive analysis of asthma and atopic dermatitis burden by age, sex, year, and location,[7,8] encompassing the COVID-19 pandemic era, using estimates from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021. Furthermore, this study sought to report on asthma burden attributable to high BMI, nitrogen dioxide pollution, occupational asthmagens, and smoking.

In addition to current estimates, an understanding of the future burden of this disease is crucial for various stakeholders, including health-care providers, policy makers, and researchers. Notably, as increasing exposure to environmental triggers such as airborne allergens can exacerbate allergic conditions over time,[9] forecasting the future burden becomes essential. We projected asthma and atopic dermatitis prevalence by 2050 using the Socio-demographic Index (SDI) and risk factors (eg, cigarette exposure and air pollution) as predictors.

This manuscript was produced as part of the GBD Collaborator Network and in accordance with the GBD Protocol.

Methods

Overview

This GBD study established comprehensive estimates of prevalence, incidence, and disability-adjusted life-years (DALYs) attributable to asthma and atopic dermatitis by sex, age, and year across 204 countries and territories between 1990 and 2021 (appendix pp 4–14). We followed the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) statement (appendix pp 13–14).[10] Detailed methodology for the GBD study has been reported elsewhere.[11]

Case definition and input data

Asthma, which corresponds to ICD-10 codes J45 and J46 and ICD-9 code 493, is a chronic lung disease characterised by bronchospasms, which are typically triggered by allergic reactions or hypersensitivity, leading to breathing difficulties. In GBD 2021, the reference case definition for asthma is a physician diagnosis and wheezing within the past year, although either physician diagnosis alone or recent wheezing alone serves as an alternative case definition. Key data sources for GBD 2021, including Wave 7 of the English Longitudinal Study of Ageing (ELSA) and the International Study of Asthma and Allergies in Childhood (ISAAC), used definitions aligned with the GBD reference definition for asthma.

Atopic dermatitis, corresponding to ICD-10 code L20, manifests as chronic skin inflammation, immune dysregulation, and high serum IgE. According to GBD 2021, physical exams are the reference standard for atopic dermatitis, with self-reports and non-physical exams as alternatives. Data derived from general dermatitis questionnaires without precise atopic dermatitis criteria were excluded from the GBD model to maintain specificity. Further details regarding case definitions and input data can be found in the appendix (pp 15–24).

Data processing and disease modelling

The data sources included mainly population representative surveys, limited prevalence investigations summarised through a systematic review, survey data, health service visits, medical claims information, and surveillance data (appendix pp 15–24). To account for the higher prevalence of asthma in young males and the shift towards higher prevalence in females after puberty,[12] asthma data reported for both sexes combined were separated by sex, using meta-regression—Bayesian, regularised, trimmed (MR-BRT)—and a cubic spline on age. After that, data with alternative case definitions or study designs were adjusted with MR-BRT.

The severity of asthma and atopic dermatitis was derived from the US Medical Expenditure Panel Surveys (MEPS).[13] The participants recruited annually in the MEPS reported the reasons for their health-care visits using ICD-9 codes and filled out a 12-item Short Form (SF-12) questionnaire twice over the 2-year follow-up. Based on the results of MEPS, the disability weight value, which was indirectly reported on SF-12, was calculated to estimate the contribution of asthma and atopic dermatitis to disability by controlling for any comorbid conditions. DALYs were computed as the sum of years of life lost and years lived with disability (appendix pp 8–9). To compare trends in age-standardised prevalence changes before (2010–19) and during (2019–21) the COVID-19 pandemic, we calculated average annual percentage change (AAPC) as a measure that condenses the annual percentage changes over multiple years into a single representative value (appendix pp 58–59).

See Online for appendix

All calculations accounted for uncertainty by generating 500 values for each estimate of prevalence, incidence, deaths, and DALYs (presented as counts [rounded to three significant figures] and age-standardised rates per 100 000 population [rounded to one decimal place]). These values were then aggregated across causes and locations for each of the 500 calculations at every intermediate step. The 95% uncertainty interval (UI) is defined by the 2·5th and 97·5th percentiles.

Association between SDI and the prevalence of asthma and atopic dermatitis

The SDI is a composite measure that reflects the social and economic conditions affecting health outcomes in each region.[14,15] Essentially, it is calculated as the geometric mean of three indices, each ranging from 0 to 1: the total fertility rate among females younger than 25 years, the average educational attainment of individuals aged 15 years and older, and the lagged distributive income per capita.[14]

We examined the association between the national SDI and the age-standardised prevalence and DALY rates for asthma and atopic dermatitis in 2021.[16] All analyses were conducted with Python (version 3.11.4).

Estimating asthma risk factors in the GBD 2021 study

Because GBD 2021 did not identify any modifiable risk factors for atopic dermatitis, our assessment of risk-attributable burden focused solely on estimating the risk factors contributing to asthma DALYs. GBD 2021 included four potential risk factors for asthma-related DALYs: high BMI, nitrogen dioxide pollution, occupational asthmagens, and smoking.[17] These risk factors were selected on the basis of strong evidence of association and assessed according to World Cancer Research Fund standards.[18] Although other risk factors were present in GBD 2019, nitrogen dioxide pollution was newly included in 2021 on the basis of expert consensus for its potential effect on the disease burden, sufficient data, and robust estimation methods.[17] A comprehensive review of previous studies was conducted, and the risks and outcomes were integrated to assess the levels of each risk factor using a risk assessment framework. Subsequently, relative risks

were estimated based on exposure and meta-regression assumptions, and the DisMod-MR 2.1 model was used to calculate exposure distributions of risk factors by age, sex, location, and year. The four risk factors for asthma are extensively detailed in the appendix (pp 25–52).

Forecasting relative risk

Relative risks serve as covariates in incidence models and are derived from a summary exposure value (SEV), which compares excessive risk-exposure levels between high-risk groups and the general population.[19] The SEV range is defined as 0–1, with 0 indicating no risk to the population (or no protection against a protective factor), and 1 indicating that the entire population is exposed to maximum risk. To predict SEVs from 2022 to 2050, we calculated the annual rate of change in logit SEVs by location, age, sex, and previous year.

We used similar methods to predict cumulative cigarette exposure (10 pack-years)[20] and indoor air pollution (all cooking fuels).[21] The methodologies used in previous GBD prediction studies for cause-specific mortality rates closely resemble those used in this study. Further details, including the process for selecting predictive variables, can be found in the appendix (pp 53–55).[11,17]

Forecasting asthma and atopic dermatitis prevalence to the year 2050

In asthma, four risk factors were calculated within the GBD framework. To predict the combined effect of these risk factors, we used the predicted SEV for each risk factor to calculate a risk factor scalar associated with asthma.[22] To estimate the population attributable fractions (PAFs) for each risk factor, we used past and forecasted SEVs from 1990 to 2050 and performed regression analysis based on the GBD 2021 asthma risk factors.[23] The scalar calculation was done as follows:[19]

$$\text{Scalar}=\frac{1}{1-\text{PAF}}$$

However, GBD 2021 did not identify specific risk factors for atopic dermatitis, so the same process was not applied.[24]

To forecast the prevalence of asthma not attributable to GBD risk factors, we divided the total prevalence by the risk factor scalar. To incorporate additional risk factors into our prediction model, we selected covariates from the GBD data, specifically predicted cumulative cigarette exposure (10 pack-years)[20] and indoor air pollution (all cooking fuels),[21] and included them as fixed coefficients over time (appendix pp 55–56). By contrast, we forecasted the prevalence for atopic dermatitis based on the total prevalence since no risk factors were identified in GBD 2021. Thus, the SDI was selected as a covariate.[24,25]

Sex-specific models were used for each disease to predict the logit-transformed prevalence through linear regression analysis.[11,17,26] The prediction models for each disease are as follows:

$$\begin{aligned}\text{Logit}(\text{asthma prevalence}) &= \alpha+\beta_1\times\text{culmulative cigarette exposure}+\beta_2\times\text{indoor air pollution}+\varepsilon\\ \text{Logit}(\text{atopic dermatitis prevalence}) &= \alpha_{l,a,s}+\beta_1\times\text{SDI}+\varepsilon\end{aligned}$$

In these models, the term logit (asthma prevalence) and logit (atopic dermatitis prevalence) represent the forecasted logit-transformed prevalence. In the asthma model, the parameter α represents the intercept, β_1 is the coefficient for the prevalence of predicted cumulative cigarette exposure (10 pack-years),[20] and β_2 is the coefficient for the prevalence of indoor air pollution (all cooking fuels).[21] In the atopic dermatitis model, the location-age-sex-specific random intercept, $\alpha_{l,a,s}$, represents the random effect, whereas the SDI coefficient indicates the fixed effect. The error term in both models is represented by ε.[24,27]

Final prevalence forecasts

To determine the final forecasted prevalence of asthma, the projected prevalence that was not attributable to GBD risk factors was multiplied by the risk factor scalar.[19] Subsequently, the anticipated number of cases in each geographical region was calculated by multiplying the forecasted prevalence with population estimates derived from GBD demographic data.[26]

To ensure consistency between the model-derived prevalence estimates and the observed GBD prevalence estimates, adjustments were made to the intercept for each disease. Specifically, the difference between the model's projected prevalence for the base year (2021) and the GBD prevalence for the same year was calculated and deducted from all forecasted values extending until 2050.[24,27] This adjustment aimed to minimise systematic biases and align the model's projections with observed estimate trends. We validated our forecast model (2021–50) by using data from 1990 to 2010 to project estimates for 2010–21 and comparing these projections with the corresponding GBD estimates. Root mean square errors were used to evaluate the model's accuracy (appendix p 60).[19]

Decomposition analysis

The Das Gupta decomposition analysis was conducted for asthma and atopic dermatitis to determine the relative contributions of population growth, population ageing, and changes in prevalence rate from 2021 to 2050 (appendix p 57).[24] This involves algebraically decomposing the standardised effects of each contributing factor to summarise the contributions of various factors to the observed changes.[27]

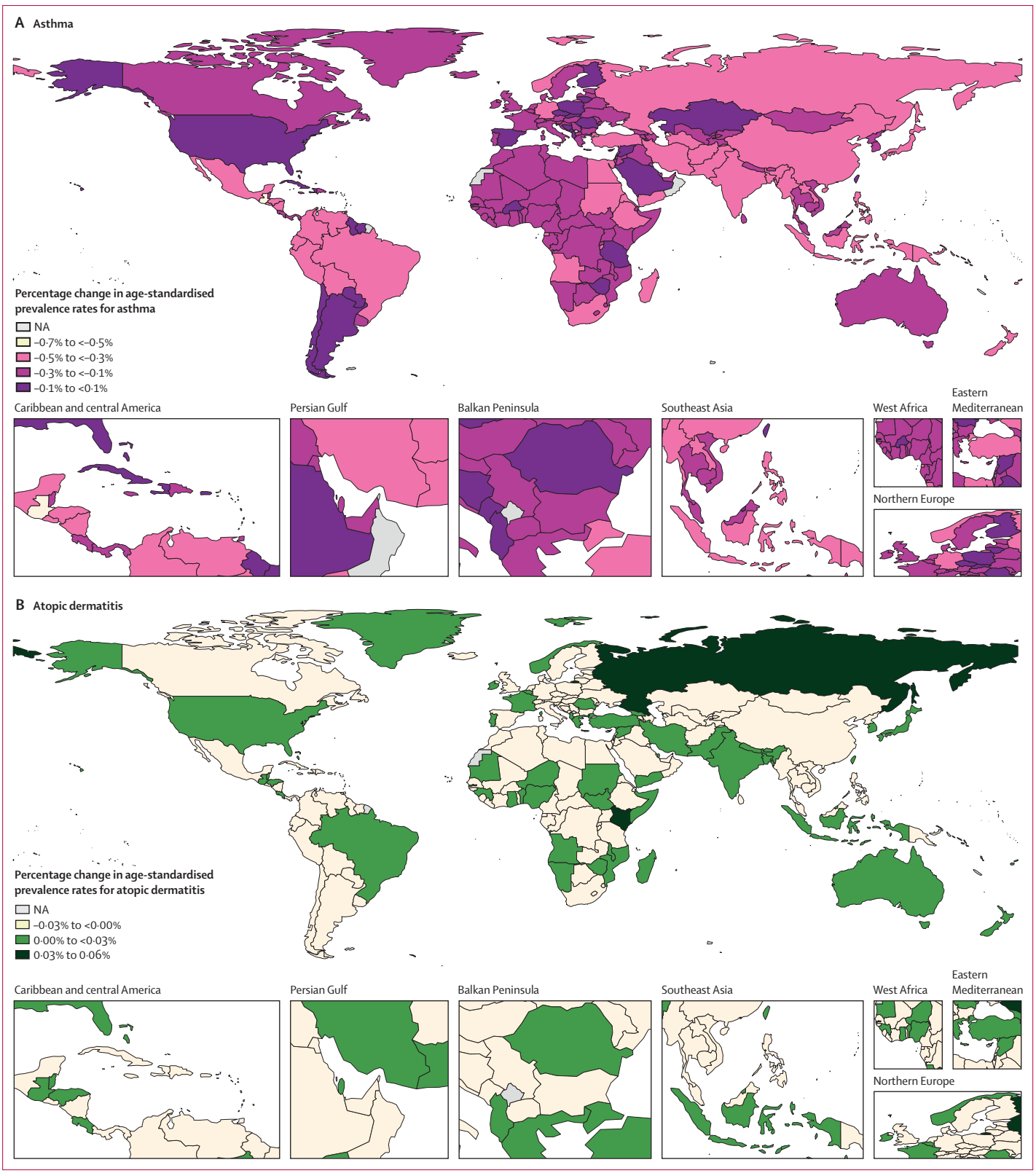

Figure 1: **Percentage change in age-standardised prevalence rates for asthma (A) and atopic dermatitis (B) from 1990 to 2021**
NA=not available.

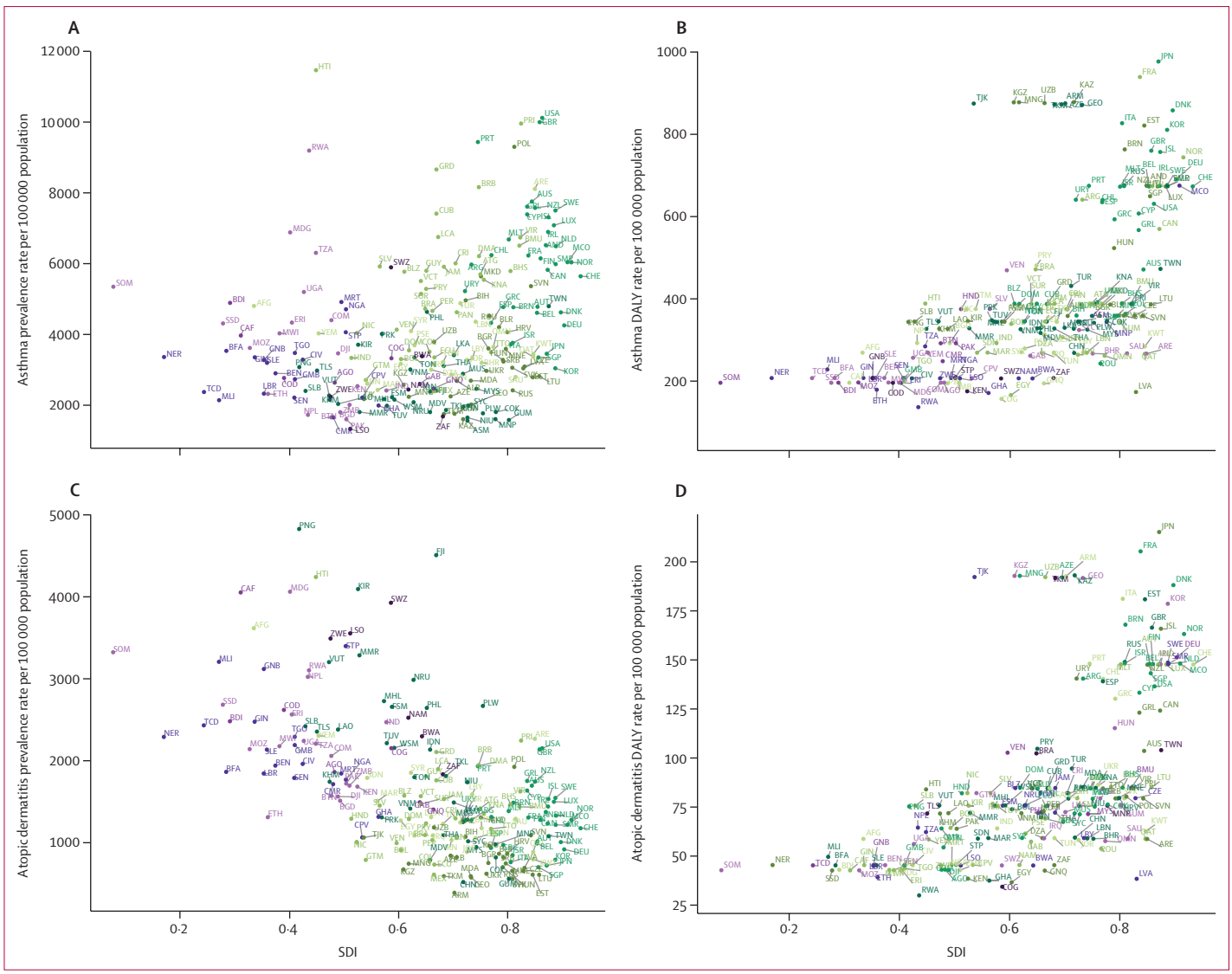

Figure 2: **Age-standardised prevalence and DALY rates of asthma and atopic dermatitis and the SDI by country in 2021**
(A) Asthma age-standardised prevalence rate by SDI. (B) Asthma age-standardised DALY rate by SDI. (C) Atopic dermatitis age-standardised prevalence rate by SDI. (D) Atopic dermatitis age-standardised DALY rate by SDI. DALY=disability-adjusted life-year. SDI=Socio-demographic Index. Definitions for country abbreviations are given in the appendix (pp 9–13).

Role of the funding source

The funder of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Results

In 2021, there were an estimated 260 million (95% UI 227–298) individuals of all ages with asthma globally, representing a decrease of 9·3% from 287 million (250–331) in 1990. However, the number of prevalent cases has risen since 2005 (238 million [209–272]). The global age-standardised prevalence rate consistently decreased by 40·0% from 5568·3 (4899·6–6349·8) per 100 000 in 1990 to 3340·1 (2905·2–3832·2) per 100 000 in 2021 (figure 1A; appendix pp 61–73, 158). Total DALYs decreased from 22·9 million (18·3–28·8) in 1990 to 21·4 million (17·0–26·9) in 2021. The age-standardised DALY rate was 264·6 (208·3–333·4) per 100 000 in 2021, representing a 44·5% decrease from the estimate of 476·5 (386·6–587·8) per 100 000 in 1990 (appendix pp 100–112).

Unlike asthma, the crude number of prevalent atopic dermatitis cases showed a marked increase from 1990 to 2021. In 2021, an estimated 129 million (95% UI 124–134) individuals were affected worldwide, marking a 20·0% increase from 107 million (103–112) in 1990 (figure 1B; appendix pp 61–73, 157). However, the global age-standardised prevalence rate mirrored the trend of asthma, decreasing by 8·3% from 1885·4 (1809·0–1962·3) per 100 000 in 1990 to 1728·5 (1658·5–1798·6) per 100 000 in 2021. Although the global age-standardised prevalence

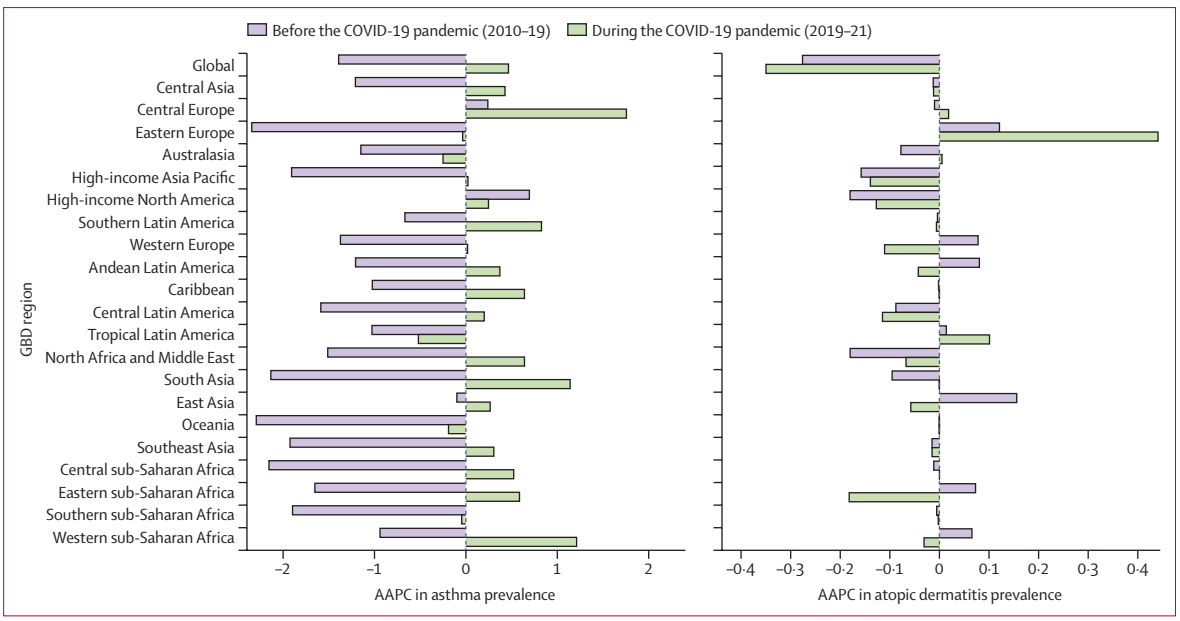

Figure 3: **AAPC in asthma (A) and atopic dermatitis (B) age-standardised prevalence before and during the COVID-19 pandemic by GBD region**
AAPC=average annual percentage change. GBD=Global Burden of Diseases, Injuries, and Risk Factors Study.

rate declined from 1990 to 2021, 42 (20·6%) of 204 countries and territories showed an increase. Total DALYs also increased by 19·7%, from 4·70 million (2·42–7·83) in 1990 to 5·62 million (2·89–9·37) in 2021, whereas the age-standardised DALY rate decreased from 82·1 (42·4–136·7) per 100 000 in 1990 to 75·5 (38·8–125·6) per 100 000 in 2021 (appendix pp 158–159). We present the incidence and death estimates of asthma and atopic dermatitis in the appendix (pp 160–162).

Age-standardised asthma prevalence rates appeared to increase with higher SDI in 2021; however, Rwanda (9222·7 [95% UI 8050·6–10 486·6] per 100 000) and Haiti (11 503·7 [10 476·2–12 510·4] per 100 000) showed disproportionately high prevalence rates compared with other countries with similar SDI (figure 2A). By contrast, age-standardised DALY rates for asthma appeared to decrease with SDI (figure 2B). For atopic dermatitis, the age-standardised prevalence and DALY rates were positively associated with SDI, with higher rates observed in countries with greater SDI (figure 2C, D).

Considering this clear association between disease estimates and SDI, we also present findings on age-standardised prevalence and DALY rates across the region. The asthma age-standardised prevalence rate in 2021 ranged from 2264·2 (95% UI 1980·3–2598·6) per 100 000 in south Asia (appendix pp 61–73) to 6871·1 (5929·8–7925·7) per 100 000 in the high-income GBD super-region. Notably, the pattern of DALY burden due to asthma reversed; south Asia had the highest age-standardised DALY rates of 465·0 (357·2–648·9) per 100 000, and the lowest DALY rates were in central Europe, eastern Europe, and the central Asia super-region, with a rate of 156·3 (107·7–220·8) per 100 000 (appendix pp 100–112). From 1990 to 2021, changes in the age-standardised DALY rate ranged from a 35·2% decrease in the high-income super-region to a 55·0% decrease in the south Asia super-region (appendix pp 100–112). In 2021, the age-standardised atopic dermatitis prevalence rate ranged from 1035·3 (989·0–1080·3) per 100 000 in the sub-Saharan Africa region to 3552·5 (3407·2–3706·1) per 100 000 in the high-income super-region. The lowest age-standardised DALY rate was in the sub-Saharan Africa region (45·2 [23·3–75·8] per 100 000), whereas the highest was in the high-income super-region (155·0 [79·9–257·7] per 100 000). Between 1990 and 2021, changes in the age-standardised prevalence rate ranged from a decrease of 3·7% (2·9–4·8) in north Africa and the Middle East to an increase of 9·3% (8·3–10·3) in central Europe, eastern Europe, and central Asia (appendix pp 61–73). We provide regional and country-level asthma and atopic dermatitis estimates for 2021 (appendix pp 61–138).

The age-specific and sex-specific burden of asthma and atopic dermatitis in 2021 is described in the appendix (pp 163–164). We replicated the findings from previous studies, which showed similar age-specific asthma prevalence patterns for both sexes. Asthma prevalence peaked at ages 5–9 years, declined from ages 25 years to 69 years, then decreased again in older ages. However, from ages 25 years to 69 years, the prevalence rate increased with age. Males aged 0–14 years had higher prevalence rates than females of the same age range, but this reversed at older ages. The age-specific prevalence of atopic dermatitis mirrored asthma, with a higher burden in children and a steep decline after that. Females had higher atopic dermatitis age-specific prevalence rates across all ages than males.

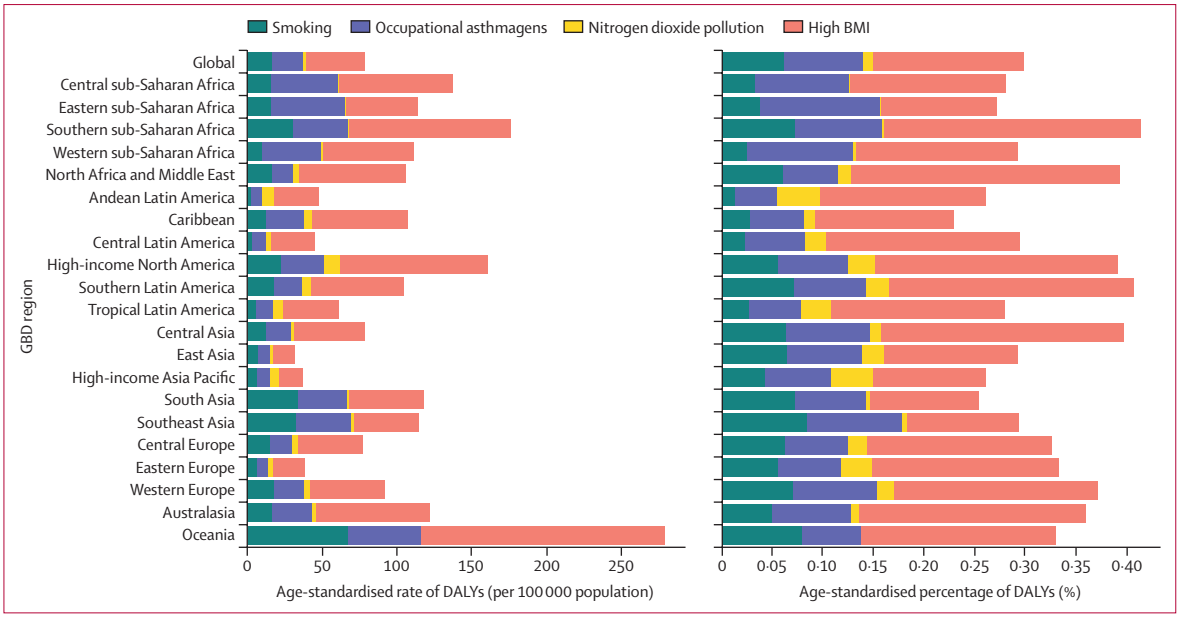

Figure 4: **Age-standardised DALY rate (A) and percentage (B) for asthma in 2021, attributed to four risk factors (smoking, occupational asthmagens, nitrogen dioxide pollution, and high BMI) by GBD region**
DALYs=disability-adjusted life-years. GBD=Global Burden of Diseases, Injuries, and Risk Factors Study.

Figure 3 presents asthma and atopic dermatitis prevalence change during the COVID-19 pandemic, with AAPC (appendix pp 58–59). During the pandemic, there was a stagnation of the asthma age-standardised prevalence rate decline globally (AAPC pre-pandemic –1·39% [95% UI –2·07 to –0·71]; AAPC during the pandemic 0·47% [–1·86 to 2·79]; p=0·020). This was true in all regions except the Caribbean, central and western Europe, central and east Asia, high-income Asia Pacific, high-income North America, and tropical Latin America. However, the global atopic dermatitis age-standardised prevalence rate remained consistent (AAPC pre-pandemic –0·28% [–0·33 to –0·22]; AAPC during the pandemic –0·35% [–0·78 to 0·08]; p=0·20). This was consistent in all regions except central sub-Saharan Africa, southern sub-Saharan Africa, eastern Europe, north Africa and the Middle East, and tropical Latin America (appendix p 139). We provide the change in DALY, incidence, and death estimates during the pandemic in the appendix (pp 140–142, 165–167).

In 2021, the age-standardised DALY rate of asthma attributed to all estimated risk factors globally was 70·2 (95% UI 48·4–95·9) per 100 000, which accounted for 26·6% of the total age-standardised DALY rate of asthma (figure 4; appendix pp 168–169). High BMI contributed most to the DALY burden (39·4 [19·6–60·2] per 100 000), followed by occupational asthmagens (20·8 [16·7–26·5] per 100 000) and smoking (16·2 [1·9–31·7] per 100 000). Among 21 GBD regions, Oceania had the highest age-standardised DALY rate attributable to BMI (162·8 [74·0–285·6] per 100 000), and eastern sub-Saharan Africa had the highest DALY rate attributable to occupational asthmagens (49·8 [37·7–67·2] per 100 000).

We observed a temporal trend in asthma burden attributable to four factors between 1990 and 2021 across five SDI settings (figure 5; appendix pp 170–171). The DALY rate attributable to smoking and occupational asthmagens consistently decreased in all five SDI settings. Nevertheless, it is noteworthy that in low-middle and low-SDI settings, smoking and occupational asthmagens, respectively, made the highest contributions to the DALY rate compared with other SDI groups over the past three decades. Although the age-standardised DALY rate attributable to nitrogen dioxide pollution was lower than that for other risk factors, its impact was relatively high in high-SDI settings. The asthma DALY rate attributable to high BMI was particularly high in high-SDI, low-SDI, and low-middle-SDI settings. However, the temporal trend of high BMI varied among these three SDI settings: high SDI has the U-curve trend, reaching its lowest point in 2005 (76·7 [95% UI 36·7–121·2] per 100 000 in 1990; 55·5 [27·4–86·5] per 100 000 in 2005; 62·1 [30·6–95·2] per 100 000 in 2021); low SDI showed a stable trend (59·0 [27·0–93·1] per 100 000 in 1990; 58·3 [26·5–96·8] per 100 000 in 2021); and low-middle SDI displayed a slight increase in the DALY rate (52·9 [24·3–82·8] per 100 000 in 1990; 55·5 [24·5–88·2] per 100 000 in 2021).

Based on forecasted population estimates, 275 million (95% UI 224 to 330) individuals worldwide are expected to have asthma in 2050, representing a 5·5% increase from 2021 (figure 6; appendix pp 143–148). Of the total asthma cases in 2050, 146 million (120 to 173) are expected to be female (53·1%; appendix pp 149–154). While western sub-Saharan Africa showed the largest increase

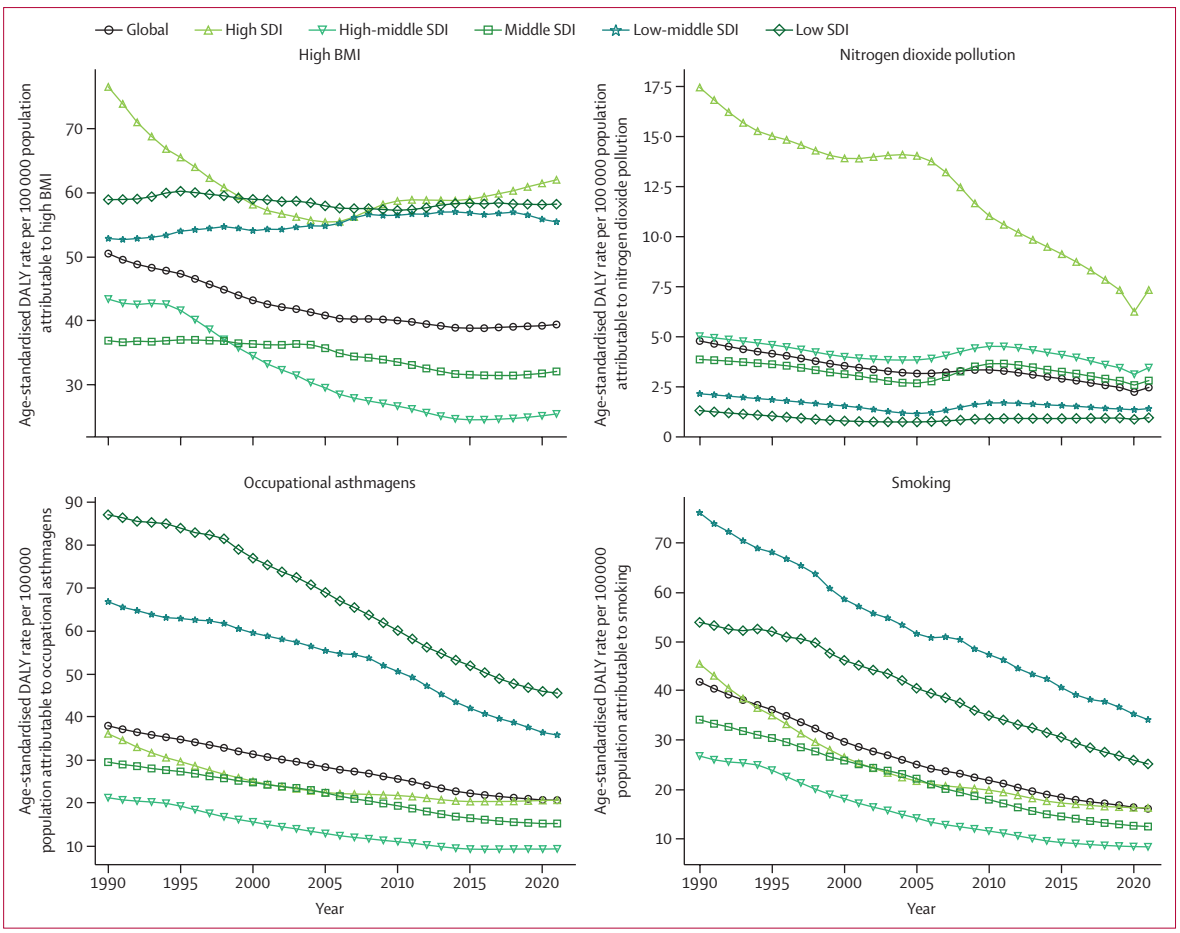

Figure 5: **Trend in age-standardised DALY rates attributable to four risk factors for asthma by SDI level from 1990 to 2021**
DALY=disability-adjusted life-year. SDI=Socio-demographic Index.

in case counts, eight GBD regions showed a marked decrease, pronounced in high-income Asia Pacific, with a 67·1% decrease. According to our decomposition analysis, this forecasted change was driven primarily by population growth globally and across 14 regions (figure 6; appendix pp 155–156). Population ageing showed the greatest contribution in some regions, including high-income Asia Pacific, eastern Europe, and central Europe. Consequently, the age-standardised asthma prevalence rate is expected to remain stable (–23·2% [–44·4 to 5·3]), resulting in a prevalence rate of 2566·7 (2131·9 to 3058·9) per 100 000 in 2050.

In 2050, 148 million (95% UI 140 to 158) people are expected to live with atopic dermatitis, reflecting a 15·3% increase from 2021. Among them, 85 million (80 to 90) cases will be female (57·3%). Central Europe, high-income Asia Pacific, east Asia, and eastern Europe showed a decrease in atopic dermatitis case counts. The age-standardised atopic dermatitis prevalence rate in 2050 is projected to be 1704·5 [1634·5 to 1774·6] per 100 000, indicating a minimal change from 2021 (–1·4% [–9·1 to 7·0]). Population growth was the primary contributor to this atopic dermatitis forecast globally and in eight regions, including tropical Latin America, Andean Latin America, north Africa and the Middle East, central Latin America, central sub-Saharan Africa, southeast Asia, western sub-Saharan Africa, and eastern sub-Saharan Africa.

Discussion

Based on the systematic analysis done by the GBD 2021, this study provides up-to-date insights into the global, regional, and national burden of asthma and atopic dermatitis from 1990 to 2021, and forecasted estimates of disease burden to 2050 for the first time. In 2021, an estimated 260 million (95% UI 227–298) individuals worldwide had asthma and 129 million (124–134) had atopic dermatitis. The number of prevalent cases of asthma and atopic dermatitis has risen in the 21st century, but the age-standardised prevalence rate has decreased. This trend mirrors worldwide ageing trends, demographic changes, and increased exposure to environmental and lifestyle risk factors.

The two conditions showed epidemiological differences. First, the age-standardised asthma

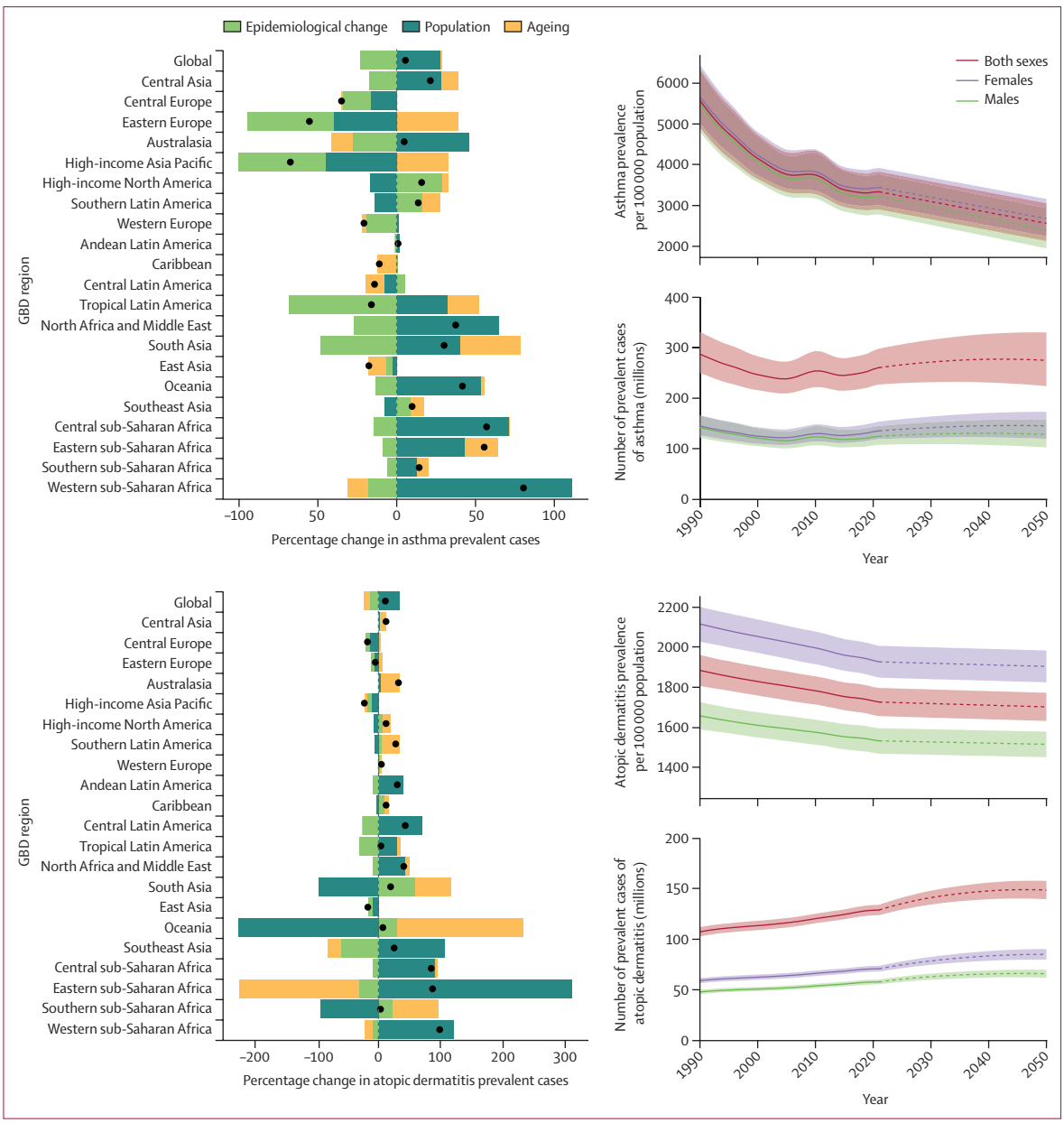

Figure 6: **Decomposition of projected change in the number of prevalent asthma and atopic dermatitis cases between 2021 and 2050**
Each dot represents the total percentage change from 2021 to 2050. Shaded areas indicate 95% uncertainty intervals. The dotted part of the line indicates the projected change from 2021 to 2050.

prevalence rate was associated with SDI, whereas its DALY rate was inversely associated with SDI. This finding suggests that although asthma prevalence is higher in high-SDI settings, inequality in access to adequate diagnosis and intervention across the countries resulted in the inverse association between the age-standardised DALY rate and SDI. Meanwhile, higher age-standardised atopic dermatitis prevalence and DALY rates were both associated with higher SDI. Given that atopic dermatitis is unlikely to lead to deaths, the prevalence and DALY rates might exhibit an overlapping pattern, where higher prevalence and DALY rates are observed in higher-SDI settings. Second, from an age-specific perspective, both diseases appear to reach the highest number of cases in early childhood, but the prevalence rate continues to rise in later adulthood. However, sex-specific prevalence showed a difference: whereas a higher preponderance of asthma in male children shifted to higher prevalence rates in female adults, females had a higher atopic dermatitis burden than males across the entire lifespan. Third, COVID-19 pandemic-related effects are shown only in the asthma

burden worldwide: the decrease in asthma prevalence rates stagnated during the pandemic.

Modifiable risk factors were responsible for about 30% of the global asthma burden, underscoring the potential impact of public health initiatives to reduce the burden by modifying these risk factors. Among risk factors, high BMI was the greatest contributor to global asthma burden, and its contribution was particularly pronounced in high-SDI settings. By contrast, age-standardised DALY rates of asthma attributable to smoking and occupational asthmagens were highest in low-resource countries, suggesting the need for tailored prevention and intervention approaches by policy makers in accordance with the specific SDI settings.

In 2050, global cases are expected to rise to 275 million (95% UI 224–330) for asthma (a 5·5% increase from 2021) and 148 million (140–158) for atopic dermatitis (a 15·3% increase from 2021), primarily driven by population growth. Age-standardised prevalence rates are expected to decrease for both conditions.

In the past decade, the absolute number of asthma and atopic dermatitis cases has increased worldwide; however, age-standardised measures have continuously decreased. This trend is likely to persist until 2050, primarily driven by the growing population. Despite the decline in age-standardised estimates, the overall burden of asthma and atopic dermatitis remains substantial, shaped by a complex interplay of behavioural, environmental, climatic, and socioeconomic factors. For example, our findings revealed the growing proportion of asthma DALY burden attributable to high BMI between 1990 and 2021. With a global decline in smoking prevalence,[28] obesity became an emerging risk factor,[29] and it is likely to contribute further to the increasing number of asthma cases.

In the case of atopic dermatitis, risk factors vary along a rural–urban gradient,[30] with urbanisation introducing substantial challenges. Factors such as air pollution, dietary changes, and psychological stress—by-products of westernisation—are multifactorial contributors to increased atopic dermatitis risk.[30] Climate change might also lead to changes in humidity and allergen distribution, further aggravating the risk of atopic dermatitis in susceptible populations.[31]

Although asthma and atopic dermatitis are often overlooked as childhood conditions, age-specific estimates showed an increase throughout adulthood in this study, which aligns with a previous study.[32] Asthma and atopic dermatitis in older adults have been less investigated and reported in the literature; however, the burden of these diseases in adulthood is more common than previously thought.[33,34] They have distinctive characteristics compared with childhood conditions.[34] For example, immunosenescence (the term for ageing-related impaired immune function), barrier dysfunction, and changes in sex hormones have important roles in the development, persistence, and even exacerbation of allergic conditions in late adulthood.[35] This suggests that asthma and atopic dermatitis will remain important clinical conditions in ageing societies. However, according to our decomposition analysis, population growth has a more substantial role in the projected increase in overall case counts from 2021 to 2050. This aligns with the decrease in age-standardised prevalence rates despite the increase in overall case numbers.

Moreover, we replicated the findings of a previous study, indicating that boys initially carry a more significant burden of asthma, which later reverses post-puberty, while females exhibit a higher burden of atopic dermatitis throughout their lifespan.[8] Sex differences in asthma burden are well established, associated with sex hormone fluctuations during puberty in females and differences in lung development, particularly in terms of dysanaptic growth, in which boys typically experience a greater mismatch between airway size and lung volume than girls.[12] However, sex disparity in atopic dermatitis burden is still controversial;[36,37] higher atopic dermatitis burden in males observed in some studies might be associated with surveillance bias[38] and often depends on the case definition. Furthermore, hormonal changes in females during puberty and menopause might also affect the incidence and severity of atopic dermatitis, complicating the understanding of sex differences in this condition.[39]

We observed a clear association between SDI and asthma and atopic dermatitis burden. Higher-SDI countries showed greater asthma and atopic dermatitis age-standardised prevalence rates; however, the age-standardised DALY rate showed contrasting results. Age-standardised DALY rates due to asthma were estimated to be higher in lower-SDI settings, whereas higher DALY burden due to atopic dermatitis was associated with higher-SDI settings. Considering that the DALY measure reflects the burden of severe conditions, including disability and deaths, these findings indicate that patients with asthma in low-resource countries are more likely to have worse outcomes, probably attributable to limited access to health care and socioeconomic factors (eg, income and education).[40] By contrast, because atopic dermatitis typically does not result in mortality, the high prevalence in affluent countries leads to a substantial DALY burden.

Importantly, during the COVID-19 pandemic, there was a significant difference in asthma prevalence and incidence rates, but not in the rates for atopic dermatitis: we found that the decline in asthma burden stagnated. Several previous studies have suggested an association between respiratory virus infection, including SARS-CoV-2, and the onset or exacerbation of asthma.[41,42] It is known that respiratory viral infections probably disrupt epithelial barrier integrity and produce pro-inflammatory cytokines, potentially leading to the development or exacerbation of asthma;[43] however, the specific underlying pathophysiology of SARS-CoV-2 requires further examination. Apart from the direct interaction between

respiratory conditions, a combination of psychological stress, changes in physical activity, and increased indoor time might also contribute to this marked change. However, the lack of a significant change in atopic dermatitis prevalence during the pandemic might be attributable to the chronic nature of the condition and its lesser dependence on environmental triggers compared with asthma. Nevertheless, the psychological stress and lifestyle changes associated with the pandemic might still influence atopic dermatitis management and quality of life for affected individuals.

From 1990 to 2021, a decrease in the burden of asthma and atopic dermatitis was not realised, and the absolute burden is estimated to significantly increase based on the forecast for 2050. For asthma, substantial variation in the contribution of modifiable risk factors to asthma burden across the regions and levels of SDI could provide valuable insights for tailoring prevention and intervention strategies. For example, the already significant and rising contribution of obesity to the disease burden in high-SDI settings was observed in this study. Some clinical trial studies reported that weight loss could improve airway hyper-responsiveness and asthma control.[44,45] Therefore, lifestyle weight loss intervention in patients with obesity and asthma and careful monitoring of asthma among the obese population might help to reduce the asthma burden in affluent countries. By contrast, occupational asthmagens and smoking showed a higher contribution to asthma burden in limited-resource settings than in high-income countries. Primary preventive initiatives should include the control of workplace exposures and educational and managerial refinements to minimise the contribution of occupational asthmagens to the asthma burden.[46] Reducing the asthma burden attributable to smoking requires a multifaceted approach that encompasses raising public awareness through education campaigns, supporting individuals with nicotine addiction, and increasing cigarette pricing to reduce expenditures on tobacco, leading to smoking cessation.[40,47]

For atopic dermatitis, despite the decreasing age-standardised prevalence rate globally, of 204 countries and territories, 42 had an upward trend. These are primarily in low-SDI countries, addressing the major challenges in atopic dermatitis management in this setting,[48] such as a scarcity of specialists, limited health-care systems, and the cost of atopic dermatitis treatment. Thus, improving primary care physician training and affordability of care might reduce the disproportionate disease burden in low-resource settings. Overall, global-scale and regional-scale estimates of asthma and atopic dermatitis are essential for adequate policy making to implement robust management strategies. Therefore, urgent collaborative efforts are needed to collect asthma and atopic dermatitis burden data in a standardised manner that is globally generalisable.

This is the latest study to systematically estimate the burden of asthma and atopic dermatitis across the globe and throughout the lifespan, and the first to provide forecasted estimates of asthma and atopic dermatitis disease burden, using GBD 2021. However, several limitations of the study should be addressed. First, the definitions of asthma and atopic dermatitis were primarily based on physician diagnosis and related symptoms; therefore, the heterogeneity of diagnostic stringency across the globe might be overlooked. As a result, the number of people living with asthma and atopic dermatitis might be over-estimated or under-estimated substantially depending on the location.[49] Second, we acknowledge the possibility of under-reporting of the disease burden. This critical limitation arises from the reference case definition of asthma, which relies on a physician's diagnosis and wheezing in the past year. While this approach helps to standardise case identification and is commonly used in multinational studies, including ISAAC,[50] it might not fully capture asymptomatic asthma cases, especially in adults.[51] These cases often stem from modifiable risk factors such as BMI, occupational exposures, smoking, and air pollution. Due to the wide range of atopic dermatitis severity, we also acknowledge the high possibility of under-reporting of mild or asymptomatic atopic dermatitis. Future research expanding beyond symptomatic definitions might be valuable in addressing this gap. Third, estimates for the atopic dermatitis disease burden in GBD 2021 were limited by the absence of available risk factor data, restricting our ability to further estimate risk factors for atopic dermatitis. Fourth, although some evidence suggests a possible association between environmental triggers, such as climate change and global warming, and asthma or atopic dermatitis, these factors were not included in GBD 2021. Increasing temperatures and extreme weather events contribute to heightened air pollution, extended pollen seasons, and increased allergen concentration, all of which exacerbate asthma and atopic dermatitis symptoms and lead to more frequent hospitalisations.[52,53] In addition, despite the role of respiratory infections in the onset and exacerbation of asthma,[32] incorporating infections as a risk factor was challenging. The GBD 2021 framework includes only metabolic, behavioural, occupational, and environmental risk factors. Fifth, although we found that the decline in asthma burden stagnated in this study, we could not quantify the direct impact of the COVID-19 pandemic on the disease burden.[54] Furthermore, given the impact of the COVID-19 pandemic on data collection and reporting, this study relied on estimates modelled to account for potential disruptions and gaps. However, despite efforts to adjust for these challenges, residual uncertainty in estimates from 2019 to 2021 might affect interpretations of disease trends during this period.[55] Sixth, our projections for 2050 are based on assumptions that might fail to capture all possible future changes in risk

factors and environmental conditions. Seventh, allergic disorders include a wide range of clinical conditions (eg, food allergy and allergic rhinitis); however, the current study could not extensively assess their burdens due to insufficient data available on the prevalence or incidence of these diseases. Eighth, the large heterogeneity of data collection, temporal availability of data, and the quality and completeness of data are some of the inherent limitations of GBD methodology.[11] Hence, our findings should be interpreted cautiously, and future studies must address other allergic conditions and associated risk factors comprehensively. Nonetheless, this study has inherent strengths and includes novel features. Despite the potential for under-estimation of the disease burden, the global estimate of 260 million asthma cases and 129 million atopic dermatitis cases already represents a considerable load. Therefore, there is a pivotal focus on understanding its impact globally, regionally, and nationally and estimating its future contribution.

Despite a global increase in the total case counts of asthma and atopic dermatitis in recent years, their age-standardised rates have declined from 1990 to 2021, and these rates are expected to remain stable until 2050. In addition, high BMI contributed most to the asthma DALY burden globally and in high-SDI settings, whereas the contribution of occupational asthmagens was higher in low-SDI settings. The evidence from this study indicates that a notable portion of the global asthma burden could be managed through collaborative efforts to address modifiable risk factors. We also found that the decline in asthma prevalence stagnated during the COVID-19 pandemic, highlighting the increasing importance of management and surveillance. This study will help to effectively target the burden of asthma and atopic dermatitis at global, national, and regional levels.

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Please see the appendix (pp 172–175) for more detailed information about individual author contributions to the research, divided into the following categories: providing data or critical feedback on data sources; developing methods or computational machinery; providing critical feedback on methods or results; drafting the manuscript or revising it critically for important intellectual content; and managing the estimation or publications process. Members of the core research team from the Institute for Health Metrics and Evaluation (IHME) for this topic area had full access to the underlying data used to generate estimates presented in this study. All other authors had access to and reviewed estimates as part of GBD and the research evaluation process, which includes additional stages of internal IHME and external formal collaborator review. S I Hay and D K Yon accessed and verified the underlying data reported in this study. All authors had full access to the study data and had final responsibility for the decision to submit for publication.

Declaration of interests

M L Bell reports grants or contracts from US EPA, National Institutes of Health (NIH), Hutchinson Postdoctoral Fellowship, Health Effects Institute, Yale Women Faculty Forum, Robert Wood Johnson Foundation, Yale Institute for Biospheric Studies, and Wellcome Trust Foundation; consulting fees from Clinique and ToxiMap; payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events from Colorado School of Public Health, Duke University, University of Texas, Data4Justice, Korea University, University of Pennsylvania, Brown University, Northeastern University, IOP Publishing, NIH, Health Canada, EHS, PAC-10, UKRI, AXA Research Fund Fellowship, Harvard University, University of Montana, and SciQuest; support for attending meetings or travel from Colorado School of Public Health, University of Texas, Duke University, Harvard University, *American Journal of Public Health*, Columbia University, Harvard University, CMAS Conference, and Nature Conference; leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid with Fifth National Climate Assessment, *Lancet* Countdown, US EPA Clean Air Scientific Advisory Committee (CASAC), Johns Hopkins EHE Advisory Board, Harvard external advisory committee for training grant, WHO Global Air Pollution and Health Technical Advisory Group, and the National Academies Panels and Committees, outside the submitted work. T C Ekundayo reports grants or contracts from PDF Research

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Data sharing

The findings from this study were produced using data available in public online repositories or in the published literature, data that are publicly available on request from the data provider, and data that are not publicly available due to restrictions by the data provider and which were used under licence for the current study. Details on data sources can be found on the Global Health Data Exchange website, including information about the data provider and links to where the data can be accessed or requested (where available). To download the data used in these analyses, please visit the Global Health Data Exchange GBD 2021 Sources Tool.

For the **Global Health Data Exchange website** see https://ghdx.healthdata.org/

For the **Global Health Data Exchange GBD 2021 Sources Tool** see https://ghdx.healthdata.org/gbd-2021/sources

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References

1 Pinart M, Benet M, Annesi-Maesano I, et al. Comorbidity of eczema, rhinitis, and asthma in IgE-sensitised and non-IgE-sensitised children in MeDALL: a population-based cohort study. *Lancet Respir Med* 2014; **2:** 131–40.
2 Guilbert TW, Morgan WJ, Zeiger RS, et al. Atopic characteristics of children with recurrent wheezing at high risk for the development of childhood asthma. *J Allergy Clin Immunol* 2004; **114:** 1282–87.
3 Dunn RM, Busse PJ, Wechsler ME. Asthma in the elderly and late-onset adult asthma. *Allergy* 2018; **73:** 284–94.
4 Abuabara K, Langan SM. Atopic dermatitis across the life course. *Br J Dermatol* 2023; **188:** 709–17.
5 Barbarot S, Auziere S, Gadkari A, et al. Epidemiology of atopic dermatitis in adults: results from an international survey. *Allergy* 2018; **73:** 1284–93.
6 Shin YH, Lee SW, Yon DK. Single inhaler as maintenance and reliever therapy (SMART) in childhood asthma in 2021: the paradigm shift in the inhaled corticosteroids reliever therapy era. *J Allergy Clin Immunol Pract* 2021; **9:** 3819–20.
7 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.
8 Shin YH, Hwang J, Kwon R, 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.
9 Beggs PJ, Clot B, Sofiev M, Johnston FH. Climate change, airborne allergens, and three translational mitigation approaches. *EBioMedicine* 2023; **93:** 104478.
10 Stevens GA, Alkema L, Black RE, et al. Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER statement. *Lancet* 2016; **388:** e19–23.
11 GBD 2021 Causes of Death Collaborators. 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.
12 Chowdhury NU, Guntur VP, Newcomb DC, Wechsler ME. Sex and gender in asthma. *Eur Respir Rev* 2021; **30:** 210067.
13 Agency for Healthcare Research and Quality. Medical Expenditure Panel Survey. 2016. https://www.meps.ahrq.gov/mepsweb/ (accessed Feb 17, 2025).
14 GBD 2017 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1789–858.
15 Institute for Health Metrics and Evaluation. Global Burden of Disease Study 2021 (GBD 2021) Socio-Demographic Index (SDI) 1950–2021. 2024. https://ghdx.healthdata.org/record/global-burden-disease-study-2021-gbd-2021-socio-demographic-index-sdi-1950%E2%80%932021 (accessed Feb 17, 2025).

16 Hahn JW, Woo S, Park J, et al. Global, regional, and national trends in liver disease-related mortality across 112 countries from 1990 to 2021, with projections to 2050: comprehensive analysis of the WHO Mortality Database. *J Korean Med Sci* 2024; **39:** e292.

17 GBD 2021 Risk Factors Collaborators. 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.

18 Clinton SK, Giovannucci EL, Hursting SD. The World Cancer Research Fund/American Institute for Cancer Research Third Expert Report on Diet, Nutrition, Physical Activity, and Cancer: impact and future directions. *J Nutr* 2020; **150:** 663–71.

19 GBD 2019 Dementia Forecasting Collaborators. Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the Global Burden of Disease Study 2019. *Lancet Public Health* 2022; **7:** e105–25.

20 Turek EM, Cox MJ, Hunter M, et al. Airway microbial communities, smoking and asthma in a general population sample. *EBioMedicine* 2021; **71:** 103538.

21 Tiotiu AI, Novakova P, Nedeva D, et al. Impact of air pollution on asthma outcomes. *Int J Environ Res Public Health* 2020; **17:** 6212.

22 GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1223–49.

23 Mukadam N, Sommerlad A, Huntley J, Livingston G. Population attributable fractions for risk factors for dementia in low-income and middle-income countries: an analysis using cross-sectional survey data. *Lancet Glob Health* 2019; **7:** e596–603.

24 GBD 2021 Neck Pain Collaborators. Global, regional, and national burden of neck pain, 1990–2020, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. *Lancet Rheumatol* 2024; **6:** e142–55.

25 2019 Demographics Collaborators. Global age-sex-specific fertility, mortality, healthy life expectancy (HALE), and population estimates in 204 countries and territories, 1950–2019: a comprehensive demographic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1160–203.

26 Vollset SE, Goren E, Yuan C-W, et al. Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study. *Lancet* 2020; **396:** 1285–306.

27 GBD 2021 Osteoarthritis Collaborators. Global, regional, and national burden of osteoarthritis, 1990–2020 and projections to 2050: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet Rheumatol* 2023; **5:** e508–22.

28 GBD 2019 Tobacco Collaborators. Spatial, temporal, and demographic patterns in prevalence of smoking tobacco use and attributable disease burden in 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. *Lancet* 2021; **397:** 2337–60.

29 Chong B, Jayabaskaran J, Kong G, et al. Trends and predictions of malnutrition and obesity in 204 countries and territories: an analysis of the Global Burden of Disease Study 2019. *EClinicalMedicine* 2023; **57:** 101850.

30 Mohn CH, Blix HS, Halvorsen JA, Nafstad P, Valberg M, Lagerløv P. Incidence trends of atopic dermatitis in infancy and early childhood in a nationwide prescription registry study in Norway. *JAMA Network Open* 2018; **1:** e184145.

31 Wang S-P, Stefanovic N, Orfali RL, et al. Impact of climate change on atopic dermatitis: a review by the International Eczema Council. *Allergy* 2024; **79:** 1455–69.

32 Melén E, Zar HJ, Siroux V, et al. Asthma inception: epidemiologic risk factors and natural history across the life course. *Am J Respir Crit Care Med* 2024; **210:** 737–54.

33 Margolis JS, Abuabara K, Bilker W, Hoffstad O, Margolis DJ. Persistence of mild to moderate atopic dermatitis. *JAMA Dermatol* 2014; **150:** 593–600.

34 Baan EJ, de Roos EW, Engelkes M, et al. Characterization of asthma by age of onset: a multi-database cohort study. *J Allergy Clin Immunol Pract* 2022; **10:** 1825–34.e8.

35 Zhou L, Leonard A, Pavel AB, et al. Age-specific changes in the molecular phenotype of patients with moderate-to-severe atopic dermatitis. *J Allergy Clin Immunol* 2019; **144:** 144–56.

36 Bylund S, Kobyletzki LB, Svalstedt M, Svensson Å. Prevalence and incidence of atopic dermatitis: a systematic review. *Acta Derm Venereol* 2020; **100:** adv00160.

37 Johansson EK, Bergström A, Kull I, et al. Prevalence and characteristics of atopic dermatitis among young adult females and males—report from the Swedish population-based study BAMSE. *J Eur Acad Dermatol Venereol* 2022; **36:** 698–704.

38 Maziak W, Behrens T, Brasky TM, et al. Are asthma and allergies in children and adolescents increasing? Results from ISAAC phase I and phase III surveys in Münster, Germany. *Allergy* 2003; **58:** 572–79.

39 Ständer S. Atopic Dermatitis. *N Engl J Med* 2021; **384:** 1136–43.

40 Mortimer K, Reddel HK, Pitrez PM, Bateman ED. Asthma management in low and middle income countries: case for change. *Eur Respir J* 2022; **60:** 2103179.

41 Kim BG, Lee H, Yeom SW, et al. Increased risk of new-onset asthma after COVID-19: a nationwide population-based cohort study. *J Allergy Clin Immunol Pract* 2024; **12:** 120–32.e5.

42 Oh J, Lee M, Kim M, 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.

43 Novak N, Cabanillas B. Viruses and asthma: the role of common respiratory viruses in asthma and its potential meaning for SARS-CoV-2. *Immunology* 2020; **161:** 83–93.

44 Pakhale S, Baron J, Dent R, Vandemheen K, Aaron SD. Effects of weight loss on airway responsiveness in obese adults with asthma: does weight loss lead to reversibility of asthma? *Chest* 2015; **147:** 1582–90.

45 Ma J, Strub P, Xiao L, et al. Behavioral weight loss and physical activity intervention in obese adults with asthma. A randomized trial. *Ann Am Thorac Soc* 2015; **12:** 1–11.

46 Cullinan P, Tarlo S, Nemery B. The prevention of occupational asthma. *Eur Respir J* 2003; **22:** 853–60.

47 Theilmann M, Lemp JM, Winkler V, et al. Patterns of tobacco use in low and middle income countries by tobacco product and sociodemographic characteristics: nationally representative survey data from 82 countries. *BMJ* 2022; **378:** e067582.

48 Lopez Carrera YI, Al Hammadi A, Huang YH, Llamado LJ, Mahgoub E, Tallman AM. Epidemiology, diagnosis, and treatment of atopic dermatitis in the developing countries of Asia, Africa, Latin America, and the Middle East: a review. *Dermatol Ther* 2019; **9:** 685–705.

49 O'Carroll O, Mcgowan A, Gough C, Shah W, Burke C. The validity of physician-diagnosed asthma. *Eur Respir J* 2019; **54** (suppl 63)**:** PA780 (abstr).

50 Asher MI, Montefort S, Björkstén B, et al. Worldwide time trends in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and eczema in childhood: ISAAC Phases One and Three repeat multicountry cross-sectional surveys. *Lancet* 2006; **368:** 733–43.

51 Yang JM, Koh HY, Moon SY, et al. Allergic disorders and susceptibility to and severity of COVID-19: a nationwide cohort study. *J Allergy Clin Immunol* 2020; **146:** 790–98.

52 Makrufardi F, Manullang A, Rusmawatiningtyas D, Chung KF, Lin SC, Chuang HC. Extreme weather and asthma: a systematic review and meta-analysis. *Eur Respir Rev* 2023; **32:** 230019.

53 D'Amato G, Holgate ST, Pawankar R, et al. Meteorological conditions, climate change, new emerging factors, and asthma and related allergic disorders. A statement of the World Allergy Organization. *World Allergy Organ J* 2015; **8:** 25.

54 GBD 2021 Tuberculosis Collaborators. Global, regional, and national age-specific progress towards the 2020 milestones of the WHO End TB Strategy: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet Infect Dis* 2024; **24:** 698–725.

55 GBD 2021 Demographics Collaborators. Global age-sex-specific mortality, life expectancy, and population estimates in 204 countries and territories and 811 subnational locations, 1950–2021, and the impact of the COVID-19 pandemic: a comprehensive demographic analysis for the Global Burden of Disease Study 2021. *Lancet* 2024; **403:** 1989–2056.