Published in final edited form as:

Allergy. 2023 August ; 78(8): 2232–2254. doi:10.1111/all.15807.

[*]**Corresponding authors:** Jae II Shin, MD, PhD, Department of Pediatrics, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, South Korea, Phone: +82-2-2228-2050, Fax: +82-2-393-9118, shinji@yuhs.ac Dong Keon Yon, MD, FACAAI, Department of Pediatrics, Kyung Hee University College of Medicine, 23 Kyungheedae-ro, Dongdaemun-gu, Seoul, 02447, South Korea, Phone: +82-2-6935-2476, Fax: +82-504-478-0201, yonkkang@gmail.com.

[*]Youn Ho Shin, Jimin Hwang, Rosie Kwon, Seung Won Lee, and Min Seo Kim contributed equally to this work as first authors.

[#]Jae II Shin and Dong Keon Yon contributed equally to this work as corresponding authors

Contributors

Please see appendix 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. Youn Ho Shin, Jimin Hwang, Rosie Kwon, Seung Won Lee, and Min Seo Kim contributed equally to this work as first authors. Jae II Shin and Dong Keon Yon contributed equally to this work as corresponding authors. Dong Keon Yon is a senior author.

Conflicts of interest

E M Abrams reports leadership or fiduciary role in other board, society, committee or advocacy group, unpaid, as President of the Allergy Section, Canadian Pediatric Society, and as Chair of the Food Allergy/Anaphylaxis Section, Canadian Society of Allergy and Clinical Immunology; other financial or non-financial interests in the Public Health Agency of Canada (PHAC) as their employee. The views expressed in this manuscript are not necessarily representative of PHAC; all outside the submitted work. A Agrawal reports leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid, with the International Clinical Epidemiology Network as a board member, outside the submitted work. N Bayileyegn reports a planned patent for surgical instruments to be used in low resources settings (Jan 2024); participation on a Data Safety Monitoring Board or Advisory Board as hospital lead for HIPPO and supervision of surgical data quality; leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid, as surgical unit head at the hospital department of surgery Jimma University; all outside the submitted work. A Bikov reports grants or contracts form the Northwest Lung Charity and Manchester NIHR Biomedical Research Centre outside the submitted work. A Carungo reports consulting fees from AbbVie as personal payments; payment or honoraria for educational events from Janssen-Cilag, Almirall, Novartis, Eli Lilly, Leo Pharma, and Amgen, all as personal payments; all outside the submitted work. J S K Chan reports grants or contracts from the Observational and Pragmatic Research Institute as their employee, outside the submitted work. X Dai reports support for the present work from UW and IHME as salary payments. T Fukumoto reports payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events from AbbVie, Eli Lilly, Sanofi, Pfizer, and Maruho, all outside the submitted work. R F Gillum reports other financial or non-financial interest in Annals of Epidemiology as the Associate Editor, and in the Journal of the National Medical Association as a member of the editorial board, all outside the submitted work. V K Gupta reports grants or contracts from National Health and Medical Research Council (NHMRC), Australia outside the submitted work. N E Ismail reports leadership or fiduciary role in other board, society, committee or advocacy group, unpaid, as Bursar for the Malaysian Academy of Pharmacy, outside the submitted work. B Kaambwa reports leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid, with PloS One, PharmacoEconomics Open, and International Journal of Environmental Research and Public Health as a member of their editorial boards, all outside the submitted work. I M Karaye reports support for attending meetings and/or travel from Hofstra University, Hempstead, New York, for the American Public Health Association Meeting 2022, and the American College of Epidemiology Meeting 2022, all outside the submitted work. P Kolkhir reports consulting fees from ValenzaBio; payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events from Novartis and Roche; leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid, with EAACI Dermatology Section as a board member; all outside the submitted work. K Krishan reports non-financial support from UGC Centre of Advanced Study, CAS II, Department of Anthropology, Panjab University, Chandigarh, India, outside the submitted work. M-C Li reports support for the present manuscript from National Science and Technology Council, Taiwan through research funding (NSTC 111–2410-H-003–100-SSS). G L L Lopes reports grants or contracts from Fundação para a Ciência e Tecnologia (FCT), under the Scientific Employment Stimulus–Individual Call (CEECIND/01768/2021), outside the submitted work. J R Medina reports support for attending meetings and/or travel from SPARK Consortium to attend the Introduction to Mathematical Modeling for Infectious Diseases in Bali, Indonesia, March 6 – 12, 2023, outside the submitted work. A-F Mentis reports grants or contracts from 'MilkSafe: A novel pipeline to enrich formula milk using omics technologies', a research co financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH - CREATE - INNOVATE (project code: T2EDK-02222), as well as from ELIDEK (Hellenic Foundation for Research and Innovation, MIMS-860); payment for expert testimony as a peer-reviewer for Fondazione Cariplo, Italy; leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid, by serving as Editorial Board Member for "Systematic Reviews" journal, for "Annals of Epidemiology" journal, and as Associate Editor for "Translational Psychiatry"; stocks in a family winery; and other financial or non-financial interests as a scientific officer with the BGI Group; all outside the submitted work. S Mohammed reports support for the present manuscript from the Bill and Melinda Gates Foundation. L Monasta reports support for the present manuscript from Italian Ministry of Health through a contribution given to the Institute for Maternal and Child Health IRCCS Burlo Garofolo, Trieste, Italy (RC 34/2017). D Munblit reports grants or contracts from the European Cooperation in Science and Technology (COST) as payments made to their institution for the Core Outcome Measures for Food Allergy (COMFA) consortium; support for attending meetings and/or travel from European Cooperation in Science and Technology (COST) as personal payments; all outside the submitted work. T P Ng reports support from the present manuscript from Agency for Science, Technology and Research and National Medical Research Council as grant funding; payment or honoraria for lectures, presentations, speakers bureaus, manuscript

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

Youn Ho Shin,
Jimin Hwang[1,2,*], **Rosie Kwon**[3,4,*], **Seung Won Lee**[5,*], **Min Seo Kim**[6,*], **GBD 2019 Allergic Disorders Collaborators**[7,8,*], **Jae Il Shin**[462,#], **Dong Keon Yon**[5,463,#]

[1]Department of Pediatrics, CHA University, Seoul, South Korea

[2]Department of Pediatrics, CHA Gangnam Medical Center, Seoul, South Korea

[3]Department of Epidemiology, Johns Hopkins University, Baltimore, MD, USA

[4]Department of Pediatrics, Yonsei University, Seoul, South Korea

[5]Center for Digital Health, Kyung Hee University Medical Center, Kyung Hee University College of Medicine, Seoul, South Korea

[6]Department of Precision Medicine, Sungkyunkwan University, Suwon, South Korea

[7]Department of Genomics and Digital Health, Samsung Advanced Institute for Health Sciences & Technology (SAIHST), Seoul, South Korea

[8]Public Health Center, Ministry of Health and Welfare, Wando, South Korea

[462]Department of Pediatrics, Yonsei University College of Medicine, Seoul, South Korea

[463]Department of Pediatrics, Kyung Hee University College of Medicine, Seoul, South Korea

writing or educational events from Singapore Institute of Technology, Singapore Nanyang Technological University, Singapore; all outside the submitted work. A Sheikh reports grants or contracts from HDRUK through a research infrastructure grant, outside the submitted work. C Simpson reports research grants to their institution from MBIE (NZ), HRC (NZ), Ministry of Health (NZ), MRC (UK), HDRUK, and CSO (UK), all outside the submitted work. J A Singh reports consulting fees from Crealta/Horizon, Medisys, Fidia, PK Med, Two Labs Inc., Adept Field Solutions, Clinical Care Options, Clearview Healthcare Partners, Putnam Associates, Focus Forward, Navigant Consulting, Spherix, MedIQ, Jupiter Life Science, UBM, Trio Health, Medscape, WebMD, and Practice Point Communications, the National Institutes of Health, and the American College of Rheumatology; payment or honoraria for speakers' bureaus from Simply Speaking; support for attending meetings or travel from the steering committee of OMERACT; participation on a Data Safety Monitoring Board or Advisory Board with the US Food and Drug Administration Arthritis Advisory Committee; leadership or fiduciary role in board, society, committee or advocacy group, paid or unpaid, with OMERACT as a steering committee member, with the Veterans Affairs Rheumatology Field Advisory Committee as Chair (unpaid), and with the UAB Cochrane Musculoskeletal Group Satellite Center on Network Meta-analysis and editor and director (unpaid); stock or stock options in TPT Global Tech, Vaxart Pharmaceuticals, Aytu BioPharma, Adaptimmune Therapeutics, GeoVax Labs, Pieris Pharmaceuticals, Enzolytics, Seres Therapeutics, Tonix Pharmaceuticals and Charlotte's Web Holdings, and previously owned stock options in Amarin, Viking, and Moderna Pharmaceuticals; all outside the submitted work. E Upadhyay reports patents planned, issued or pending for a system and method of reusable filters for anti-pollution mask (published), a system and method for electricity generation through crop stubble by using microbial fuel cells (published), a system for disposed personal protection equipment (PPE) into biofuel through pyrolysis and method (published), and a novel herbal pharmaceutical aid for formulation of gel and method thereof (filed); leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid, Indian Meteorological Society, Jaipur Chapter, as joint secretary; all outside the submitted work. J F M van Boven reports grants or contracts from Aardex, AstraZeneca, Chiesi, European Commission COST Action 19132 "ENABLE", Novartis, Pill Connect, Pfizer, and Trudell Medical, all as payments made to their institution; consulting fees from AstraZeneca, Chiesi, GSK, Novartis, Teva, and Vertex as payments made to their institution; all outside the submitted work.

Summary

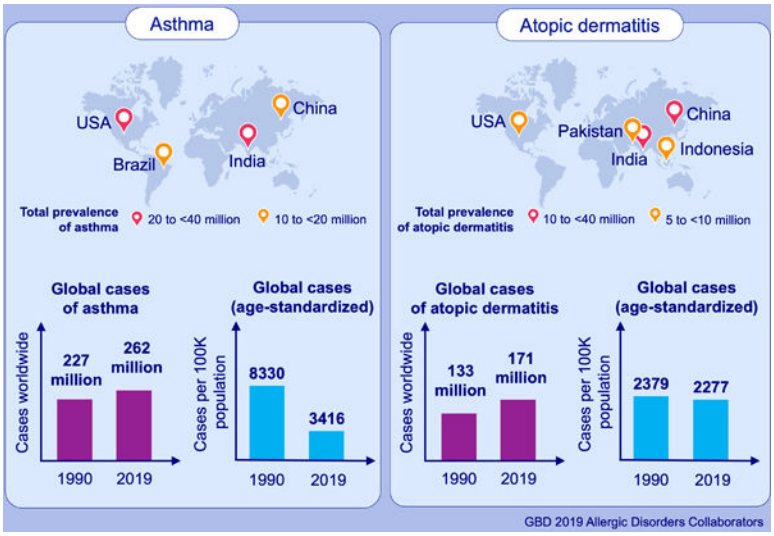
Background: Asthma and atopic dermatitis (AD) are chronic allergic conditions, along with allergic rhinitis and food allergy and cause high morbidity and mortality both in children and adults. This study aims to evaluate the global, regional, national and temporal trends of the burden of asthma and AD from 1990 to 2019 and analyze their associations with geographic, demographic, social, and clinical factors.

Methods: Using data from the Global Burden of Diseases (GBD), Injuries, and Risk Factors Study 2019, we assessed the age-standardized prevalence, incidence, mortality, and disability-adjusted life years (DALYs) of both asthma and AD from 1990 to 2019, stratified by geographic region, age, sex, and socio-demographic index (SDI). DALYs were calculated as the sum of years lived with disability and years of life lost to premature mortality. Additionally, the disease burden of asthma attributable to high body mass index, occupational asthmagens, and smoking was described.

Results: In 2019, there were a total of 262 million [95% UI: 224–309 million] cases of asthma and 171 million [95% UI: 165–178 million] total cases of AD globally; age-standardized prevalence rates were 3,416 [95% UI: 2,899–4,066] and 2,277 [95% UI: 2,192–2,369] per 100,000 population for asthma and AD, respectively, a 24.1% [95% UI: −27.2 to −20.8] decrease for asthma and a 4.3% [95% UI: 3.8–4.8] decrease for AD compared to baseline in 1990. Both asthma and AD had similar trends according to age, with age-specific prevalence rates peaking at age 5–9 years and rising again in adulthood. The prevalence and incidence of asthma and AD were both higher for individuals with higher SDI; however, mortality and DALYs rates of individuals with asthma had a reverse trend, with higher mortality and DALYs rates in those in the lower SDI quintiles. Of the three risk factors, high body mass index contributed to the highest DALYs and deaths due to asthma, accounting for a total of 3.65 million [95% UI: 2.14–5.60 million] asthma DALYs and 75,377 [95% UI: 40,615–122,841] asthma deaths.

Conclusions: Asthma and AD continue to cause significant morbidity worldwide, having increased in total prevalence and incidence cases worldwide, but having decreased in age-standardized prevalence rates from 1990 to 2019. Although both are more frequent at younger ages and more prevalent in high-SDI countries, each condition has distinct temporal and regional characteristics. Understanding the temporospatial trends in the disease burden of asthma and AD could guide future policies and interventions to better manage these diseases worldwide and achieve equity in prevention, diagnosis and treatment.

Graphical Abstract



Using data from the GBD 2019 study, we assessed the total cases and age-standardized prevalence of both asthma and atopic dermatitis in 204 countries and territories from 1990 to 2019.

In 2019, there were a total of 262 million [95% UI: 224–309 million] cases of asthma and 171 million [95% UI: 165–178 million] total cases of AD globally; age-standardized prevalence rates were 3,416 [95% UI: 2,899–4,066] and 2,277 [95% UI: 2,192–2,369] per 100,000 population for asthma and atopic dermatitis, respectively, a 24.1% [95% UI: −27.2 to −20.8] decrease for asthma and a 4.3% [95% UI: 3.8–4.8] decrease for atopic dermatitis compared to baseline in 1990.

Asthma and atopic dermatitis continue to cause significant morbidity worldwide, having increased in total prevalence and incidence cases worldwide, but having decreased in age-standardized prevalence rates from 1990 to 2019.

Keywords

Asthma; atopic dermatitis; disability-adjusted life years; epidemiology; eczema; global burden; mortality

Introduction

Although allergic disorders such as asthma and atopic dermatitis (AD) are frequently dismissed as diseases of childhood, they are chronic diseases that can cause significant morbidity having long-term effects even into adulthood[1,2]. The prevalence of physician-diagnosed allergic diseases has increased significantly over time, currently affecting approximately 10% to 30% of the global population[3–5]. These diseases, including asthma and AD, lead to substantial direct healthcare costs, as well as indirect costs due to their impact on quality of life, work, school, and productivity[6].

Asthma and AD were once characterized as frequent diseases in high-income countries, with affluent countries reporting higher prevalence rates and the “hygiene hypothesis” suggesting that transfer of early childhood infections between siblings is associated with protection

against allergies later in life[7]. However, the hypothesis that unhygienic conditions protect individuals against allergic illness has been criticized and expanded to encompass a complex interplay between genetic predisposition and the range of environmental exposures[8]. On an individual level, lower socioeconomic status has been associated with higher disease burden – increased severity and poorer control of asthma and AD[9]; racial and ethnic disparities also exist[9,10]. Health inequalities regarding these diseases have been further accentuated recently, as novel and targeted treatment options, such as biologics, have been gaining popularity. In this regard, numerous reports have called attention to disparities in access and efficacy of these emerging options[11]. Allergic diseases such as both asthma and AD are now recognized as major public health problems that greatly impact low-and-middle income countries as well as high-income countries[9,10]. Therefore, it is important to provide more precise epidemiological evidence that integrates data from around the world and across sociodemographic levels.

Further, it is critical at this time to comprehensively analyze data to represents a global picture regarding the disease burden and time trends of allergic diseases (i.e., asthma and AD). There have been isolated studies detailing with the global prevalence and disease burden of asthma and AD using the Global Burden of Disease (GBD) 2017[12,13], but there has not yet been an up-to-date study encompassing asthma and AD utilizing the recently released dataset from 2019. Moving forward from scattered systematic reviews regarding the global distribution of these allergic diseases[14], the present study aims to provide a bird's eyeview of the global distribution of asthma and AD by analyzing data from the GBD study from 1990 to 2019 and discussing temporospatial trends in association with country-level socioeconomic development to aid future public health interventions.

METHODS

Overview

Data utilized in this paper were obtained from the GBD 2019 Results Database which provides data on health loss from hundreds of diseases, injuries, and risk factors, from 204 countries and territories from 1990 to 2019. Our analysis was performed as part of the GBD Collaborator Network and complied with the Guidelines for Accurate and Transparent Health Estimates Reporting (Supplementary Method). A comprehensive methodology for the estimation models has been published elsewhere.[15,16]

Case Definition

In the GBD 2019 list of causes, asthma corresponds to the International Classification of Disease 10th revision (ICD-10) codes J45 and J46 and ICD-9 code 493.[13,17,18] Asthma was defined as a chronic lung disease involving bronchospasm and shortness of breath due to allergic reactions or hypersensitivity, adjudicated by physician diagnosis and wheezing in the past year. However, studies that are not population-based, such as hospital or clinic-based studies, or studies that do not provide primary data on epidemiological parameters, such as commentary pieces, and studies with a sample size of less than 150, are not included. We also added new data for Wave 7 of the English Longitudinal Study of Ageing (ELSA). Surveys carried out as part of the International Study of Asthma and Allergies

in Childhood (ISAAC) collaboration are the most important source of prevalence data in children.[15,16,19] AD, consistent with ICD-10 code L20 and ICD-9 code L691, was defined as relapsing dermatitis, either localized or widespread, associated with pruritus, elevated serum immunoglobulin E, and immune dysregulation.[1,12] However, the potential variation in the accuracy of physician diagnosis and symptom data across regions and differences in healthcare access, diagnostic criteria, and medical knowledge may result in under- or over-diagnosis of diseases. Cases were selected through a literature review with a physical exam and claim data and then further stratified into three severity levels with different disability weights according to physical deformity and pain/itch.

Data acquisition and processing

The main data inputs for assessing the prevalence of asthma and AD were population representative surveys, limited prevalence investigations in the literature described by a systematic review of the literature, health service visits, surveillance data, survey data, and medical claims information. Estimates for prevalence, incidence, and disease burden were modeled through three main standardized tools, namely, (1) Cause of Death Ensemble model, an optimized tool for assessing the cause of death by collecting an ensemble of different modeling methods with varying choices of covariates for high predictive validity; (2) Spatiotemporal Gaussian Process Regression, a model for analyzing and comparing temporal and regional estimates between different groups; and (3) Disease Modeling-Meta regression 2.1, a Bayesian meta-regression tool, utilized to provide consistency between epidemiological parameters including prevalence, incidence, remission, and mortality by adjusting variations of heterogeneous datasets from various modeling methods[15]. The Comprehensive R Archive Network (version4.2.1; r-project.org, R Foundation, Vienna, Austria) was used to generate all tables and figures.

Estimators of disease burden

For this study, we obtained the publication estimates of prevalence, incidence, mortality, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs) for asthma and AD, respectively, for each 5-year age group, sex, year, and location from GBD 2019. Briefly, age-standardized rates per 100,000 population were computed by the direct method to the GBD population standard[13]. YLLs were defined as the product of the number of deaths and the remaining life expectancy per age group, as per the GBD standard life table; YLDs were calculated as the product of the prevalence estimate and disability weights for that specific condition, in this case asthma and AD. DALYs were computed by the summation of YLLs and YLDs, representing the health loss due to a specific cause; in this case, asthma and AD. Estimates for disease burden were reported with 95% uncertainty intervals (UIs), defined as the 25^{th} and 75^{th} values of 1,000 samples drawn for each variable. A detailed description of the methods can be found in the literature[20].

Socio-demographic index

The development status of each country was graded based on the socio-demographic index (SDI) as defined in the GBD study in 2017, which is a composite score from 0 to 1 based on the total fertility under age 25 years, average education in those over age 15 years, and lag-distributed income per person[15,20]. In our analysis, we classified countries into quintiles

of ranked SDI values as low, low-middle, middle, high-middle, and high SDI as obtained from the GBD 2019 data.

Risk factors

DALYs and deaths for asthma attributable to three risk factors: namely, high body mass index (BMI), occupational asthmagens, and smoking, as classified in GBD 2019[15,20,21], were obtained and further stratified by region and sex. Initially, we utilized a framework for risk assessment to determine the level of attribution of each risk factor, by conducting a comprehensive review of prior studies and incorporating pairs of risk and outcomes. Subsequently, we estimated the relative risk in relation to exposure and meta-regression assumptions, and computed the distribution of exposure for each risk factor by age, sex, location, and year using Bayesian meta-regression modeling (DisMod-MR 2.1).[21,22] Thirdly, we established the theoretical minimum risk exposure level and assessed the population attributable fraction and attributable burden. Lastly, we combined various risk factors through other factors. A high BMI was defined as a BMI over 25.0 kg/m^2 for adults, which is considered overweight or obese, and as being overweight or obese for children (ages 1–19) on International Obesity Task Force standards. Occupational asthmagens were defined as airborne substances that cause asthma, such as dust, chemicals, and fumes, and smoking was defined as current or past smoking status.[21] Attributable risk factors for AD could not be evaluated from the current GBD database at this time.

Results

Global and regional burden of asthma

The age-standardized rates of asthma are mapped at the country level in Figure 1. Globally, the total number of patients with asthma increased slightly from 227 million [95% UI: 195–270 million] in 1990 to 262 million [95% UI: 224–309 million] in 2019, or an increase of 15.4%. However, age-standardized prevalence rates had a 24.1% [20.8–27.2] decrease, from 4,497 [3,914–5,224] per 100,000 population in 1990 to 3,416 [2,899–4,066] per 100,000 population in 2019. Incidence rates of asthma showed similar trends, with total incidence cases having increased from 32.2 million [25.8–40.5] to 37.0 million [29.6–45.9], whereas age-standardized incidence rates having decreased from 580.1 per 100,000 population [474.7–715.0] to 504.3 per 100,000 population [400.6–633.3] in 1990 and 2019, respectively (Figure S1 to S10 and Table S1 to S4). The incidence and prevalence of asthma are significant in several countries, with India and the United States of America having the highest number of cases. According to the study, India has 4,533,397 cases of asthma incidence and 34,305,973 cases of asthma prevalence, while the United States of America has 4,143,124 cases of asthma incidence and 33,954,467 cases of asthma prevalence. China, Brazil, and Nigeria are also among the top countries with high asthma incidence and prevalence (Table S5).

Trends in burden of asthma and AD separately by demographic factors

Asthma accounted for a total of 0.461 million [0.367–0.559] deaths in 2019, resulting in an age-standardized mortality rate of 5.8 per 100,000 population; this was a 51.3% decrease from 11.9 per 100,000 population in 1990. The total number of DALYs and

age-standardized DALYs rates due to asthma decreased from 1990 to 2019 (Figure 2). In particular, age-standardized DALYs rates underwent a steep decrease of 42.5% [−48.5 to −36.6] from 1990 and 2019, with DALYs rates of 476.3 per 100,000 population [378.5–579.6] in 1990 to 273.6 [216.7–343.4] per 100,000 population in 2019.

High-income North America and Australasia regions had the highest and second-highest age-standardized prevalence of asthma at 9,848 [8,624–11,312] and 8,393 [6,909–10,347] per 100,000 population in 2019, respectively. Notably, the high-income North America region had a 9.6% [1.2–19.2] increase from 1990, with the United States contributing most of the increase at 10.9% [2.0–21.4] from 1990 to 2019; Australasia, had a 30.6% [−40.6 to −18.5] decrease from its rate in 1990, a finding consistent with most regions and the global trend.

East, Central, and South Asia were the regions with the lowest age-standardized prevalence of asthma, at 2,026 [1,577–2,631], 2,277 [1,883–2,788], and 2,443 [2,030–2,910] per 100,000 population, respectively, in 2019. The lowest age-standardized prevalence rates of asthma were reported in Nepal and Bangladesh, at 1,073 [932–1,215] and 1,391 [1,217–1,574] per 100,000 population.

DALYs rates showed a somewhat different regional trend, with Oceania reporting the highest DALYs rates of 1,102 [864–1431] per 100,000 population, and East Asia reporting the lowest DALYs rates of 106.4 [75.3–152.1] per 100,000 population.

In most countries, age-standardized DALYs rates had a precipitous decrease over time, the drop in DALYs rates being as large as 72.3% [60.8–79.2] in the Republic of Korea; the only exceptions were Montenegro, the U.S., and Paraguay, with 6.7% [−1.3–15.9], 4.4% [−3.4–12.9], and 3.1% [7.8–13.7] increase in DALYs from 1990 to 2019, respectively.

Global and regional burden of AD

In 2019, the number of cases of AD worldwide was 171 million [165–178], which represents an increase of 28.6% from 133 million [128–138] cases in 1990; in contrast, the global age-standardized rates of AD had a slight decrease of −4.3% [−4.8 to −3.8] to 2,277 [2,193–2,369] per 100,000 population in 2019 (Figure 1). Similar to asthma, total incidence cases rose approximately 27.1% from 19.2 million [18.3–20.2] in 1990 to 24.4 million [23.3–25.6] in 2019, but age-standardized incidence rates dropped slightly (−4.2% [−4.8 to −3.6] change).

As no deaths were directly attributable to AD, DALYs for AD were the same as the YLDs. DALYs rates due to AD showed the same trend as prevalence and incidence; the total number of DALYs rose steeply from 5.827 million [3.090–9.784] in 1990 to 7.480 million [3.987–12.580] in 2019, age-standardized rates had a slight drop of 4.1% [−4.8 to −3.5] to 99.7 per 100,000 population.

Based on the 2019 GBD data, the significant contributors to the incidence/prevalence of AD are China (with 5,837,355 incident cases and 35,583,695 prevalent cases), followed by India (with 3,739,094 incident cases and 25,923,780 prevalent cases), Indonesia (with 1,437,343 incident cases and 9,679,480 prevalent cases), the United States of America (with

888,977 incident cases and 8,610,796 prevalent cases), and Pakistan (with 782,596 incident cases and 4,972,106 prevalent cases) (Table S5). The prevalence rates of AD did not vary as drastically between regions as those of asthma, but there were still some regional trends. The highest prevalence rates of AD were reported in the high-income Asia Pacific region at 4,876 [4,639–5,113] per 100,000 population and Central Asia at 4,678 [4,210–5,192] per 100,000 population; the lowest prevalence rates of AD were reported in African countries, including Central, Eastern, Southern, and Western Sub-Saharan Africa, with 1,081 [1,009–1,162], 1,082 [1,035–1,132], 1,083 [1,027–1,140], and 1,102 [1,054–1,149] per 100,000 population, respectively (Table S5). In most regions, prevalence rates of AD remained stable from 1990 to 2019; the steepest increase was seen in Kenya at merely 5.3% [2.0–8.2], and the largest drop was seen in the Maldives at a similar percentage of 6.6% [−7.2 to −6.0] (Table S5). The DALYs rates of AD had a similar regional distribution with prevalence rates of AD, with the highest DALYs rates in the high-income Asia Pacific region and lowest DALYs rates in the Sub-Saharan Africa (Figure S11 to S18 and Table S5 to S8).

Trends according to demographic factors

Consistently from 1990 to 2019, the total number of incident cases and age-standardized incidence rates of asthma were similar between females and males, whereas those of AD were substantially higher in females than males (Figure 3A). Both total incidence and incidence rates of asthma down-trended slightly from 1990 to 2005, then increased from 2005 to 2019, drawing a slight V-shape over time. In contrast, the total incidence of AD increased steadily from 1990 to 2019, while age-standardized rates decreased slightly over the same period. Time trends were similar in both sexes (Figure 3B).

Regarding stratification by age, in 2019, the total number of prevalence cases peaked at ages 5–9 years, down-trended to reach a plateau at ages 25–69 years, and then decreased in the older age groups (Figure 4A). In contrast, the age-specific prevalence rate of asthma had an N-shaped distribution, with prevalence rates peaking in ages 5–9 years, reaching the lowest at ages 25–29 years, then increasing continuously in the following groups. Total age-specific prevalence cases and prevalence rates of asthma were higher for males up to the 15–19 age group; afterwards, the trend reversed with higher prevalence in females.

Total cases of AD according to age groups showed similar trends as that of asthma, having a distribution heavily skewed in infancy and early childhood with a high peak in the 5–9 age group and a steep decrease thereafter (Figure 4B). Age-specific prevalence of AD was characterized by an earlier peak in the 1–4 and 5–9 years age groups and a later trough at ages 35–44 years. For AD, both age-specific prevalence rates and total number of prevalence cases were higher for females in all age groups, with the difference almost two-fold in young adulthood (ages 25–45 years; Figure 4B).

Burden of asthma and AD separately in accordance with SDI

Age-standardized DALYs rates of asthma decreased steadily from 1990 to 2005 across all SDI quintiles, with the exception of the high SDI quintile, for which the DALYs rates increased slightly since 2005 (Figure 5). Higher SDI levels tended to have lower DALYs rates, with high, high-middle, and middle SDI quintiles having substantially lower

DALYs rates than low and low-middle quintiles consistently over the study period, and with the low SDI quintile having the highest, and the high-middle quintile having the lowest DALYs rates from 1990 to 2019 (553.9 [434.7–726.8] and 158.3 [114.0–220.2] per 100,000 population, respectively, in 2019). On the other hand, the high SDI quintile had the highest age-standardized prevalence, incidence, and YLDs rates of asthma across the study period, compared to lower SDI quintiles. The highest SDI quintile had a prevalence rate of 6,855 [5,877–8,058] per 100,000 population; at the same time, the high and high-middle SDI quintiles experienced the largest decrease in asthma prevalence of 17.7% [−20.9 – −14.2] and 26.8% [−32.1 – −22.2], respectively, over the study period. Although the mortality rate decreased for all SDI quintiles over the study period, lower SDI quintiles having substantially higher DALYs and higher mortality.

Age-standardized DALYs rates of AD were largely stable from 1990 to 2019 in all SDI levels (Figure S9), and we characterized the relationship between DALYs and SDI in AD as being reversed. Higher SDI levels had higher DALYs rates of AD throughout 1990–2019, with the high SDI quintile having more than double the DALYs rates of the low SDI quintile (155.5 [83.5–262.0] and 59.7 [32.0–100.1] per 100,000 population, respectively, in 2019). This trend was replicated in prevalence and incidence rates of AD; the high SDI quintile had the highest prevalence rate of 3,540 [3,376–3,685] per 100,000 population, whereas the low SDI quintile had the lowest prevalence rate of 1,359 [1,301–1,424] per 100,000 population in 2019.

Burden of asthma attributable to risk factors

Asthma-related DALYs and deaths attributable to three risk factors: namely, body mass index (BMI), occupational asthmagens, and smoking, as classified in GBD 2019, were collected and further stratified by region (Figure 6A) and sex (Figure 6B). At this time, the current GBD database was not used to evaluate attributable risk factors for AD.

Globally, high BMI contributed to the most DALYs and deaths due to asthma in 2019, followed by smoking and occupational asthmagens, with a total of 3.65 million [2.14–5.60], 2.12 million [1.13–3.01], and 1.90 million [1.51–2.33] asthma DALYs, and total 75,377 [40,615–122,841], 54,849 [29,149–78,006] and 34,395 [27,828–42,614] deaths attributable to each risk factor, respectively (Figure S19 to S28). In both men and women, South Asia had the highest number of asthma DALYs attributable to all three risk factors (0.910 million [0.447–1.587] for high BMI, 0.622 million [0.475–0.818] for occupational asthmagens, and 0.689 million [0.333–1.044] for smoking), mirroring the number of total DALYs due to asthma. South Asia was followed by the North Africa and the Middle East, high-income North America, and Southeast Asia, for highest asthma DALYs due to high BMI; the trend was slightly different for occupational asthmagens and smoking, for which the second and third-highest asthma DALYs occurred in Southeast Asia and Eastern Sub-Saharan Africa for occupational asthmagens, and Southeast Asia and East Asia for smoking, respectively.

Consistent with the high absolute numbers of attributable DALYs, high BMI accounted for nearly 30% of asthma DALYs in the North Africa and Middle East (27.9% [18.3–38.8]) and Southern Sub-Saharan Africa (27.7% [18.3–38.0]), but only 9.6% [5.0–6.6] in the high-income Asia Pacific. In most regions, females had a higher proportion of asthma DALYs

attributable to high BMI, with the exception of the high-income Asia Pacific and East Asia regions. These two regions also had the lowest percentages of DALYs due to high BMI.

Eastern, Western, and Central Sub-Saharan Africa had a substantially higher percentage of asthma DALYs due to occupational asthmagens compared to other regions, which were 13.3% [11.8–14.8], 11.9% [10.5–13.3], and 10.8% [9.0–12.4], respectively. Further, the percentage of asthma DALYs attributable to occupational asthmagens were higher in males than in females in all regions.

The highest asthma DALYs attributable to smoking occurred in Central Europe (12.7% [7.2–17.8]) and Western Europe (12.2% [6.7–17.0]), and the lowest in Andean Latin America (1.3% [0.5–2.1]). Notably, the percentage of DALYs attributable to smoking was substantially higher in males in most regions with the exception of high-income North America, Southern Latin America, and Australasia; these countries had some of the highest proportions of DALYs due to smoking in females nearing 10%.

Discussion

Asthma and AD increased in total prevalence and incidence worldwide; however, age-standardized prevalence rates decreased from 1990 to 2019. The increase in total prevalence and incidence could be largely due to population growth, rather than an actual increase in the proportion of individuals affected by these conditions. It could also suggest that improvements in healthcare and public health measures may have had some effect on reducing the burden of asthma and AD. Both conditions seem to peak in terms of incidence at ages 5–9 years, however prevalence continues to increase in later adulthood. These diseases tend to have a higher prevalence in countries with higher SDI, but for asthma, lower SDI was associated with higher mortality and DALYs rates; further, disease burden varied substantially across geographic regions. Further epidemiologic studies of asthma and AD spanning the globe are warranted to inform actions targeting the decrease of disease burden, equity in prevention, diagnosis and treatment regarding these allergic diseases.

Asthma and AD are atopic diseases that can affect individuals throughout their life course and have major repercussions both on population health and on the global economy. However, reflecting heightened awareness from early in life, improved diagnostic capacity, and perceptions that affluent populations are prone to allergic diseases, mounting studies have focused on high-income countries, such as the United Kingdom, the European Union countries, and the U.S.[13,23–25]. Furthermore, as these diseases have been considered as pediatric conditions, most studies have leaned towards children[26]. To provide a global bird’s eyeview regarding the true public health impact of these diseases across the lifespan, we investigated the most up-to-date data from the GBD 2019 study to describe the global prevalence, incidence, and disease burden of asthma and AD and analyzed their associations with geographic region, demographic characteristics, SDI, and risk factors.

In 2019, there were 262 million [224–309] total cases (2.4%) of asthma globally across all ages, the percentage less than other studies from the World Health Survey (4.3% in adults), Global Asthma Network (10.4% in adolescents and 9.9% in children), and the

International Study of Asthma and Allergies in Childhood (13.7% in age 13–14 years and 11.6% in age 6–7 years)[27–29]. This discrepancy could be explained by differences in included countries and age groups, especially considering the significant variation in asthma prevalence between countries and along the life course evident in the GBD data and in the other worldwide studies. While the total number of patients with asthma increased, age-standardized prevalence rates had a large decrease of 24.1% globally, with incident cases and incidence rates mirroring the same trend, which suggests that the increase in number was in part due to population expansion. Likewise, the prevalence rate of asthma decreased in most regions. However, few regions, such as the United States, had a rise in asthma prevalence; this increase could be attributed to increased awareness and diagnostic availability of asthma due to public health campaigns such as the National Asthma Education and Prevention Program and, in part, due to overdiagnosis[30].

The disease burden of asthma is represented by age-standardized DALYs rates and its mortality rates also underwent a steep decrease of 42.5% and 51.3% from 1990 to 2019, respectively. This could reflect the establishment of cornerstone guidelines (e.g., the National Heart, Lung, and Blood Institute guidelines, first issued in 1991, and the Global Initiative for Asthma guidelines, first published in 1995), heightened awareness and better management of asthma globally, and the development and popularization of different treatment options[31,32]. For example, the decrease in asthma DALYs was especially precipitous in some countries, reaching 72.3% in the Republic of Korea; this could reflect various initiatives and cohorts that took place since the early 2000s, such as the Cohort for Reality and Evolution of Adult Asthma, the Korea Asthma Allergy Foundation, and the Seoul Atopy-Asthma-friendly School Project[33]. However, as there are still existed wide variations in DALYs and mortality rates around the globe and within regions, it is critical to continue efforts for better prevention and control of asthma, especially in under-resourced settings[9].

For AD, there were 171 million total cases globally, approximately 2.23% of the population. Although the absolute number of prevalence and incident cases rose from 1990 to 2019, age-standardized prevalence and incidence rates remained relatively stable over time, undergoing only a slight drop of 4.3% and 4.2%, respectively. Between regions, the prevalence and DALYs rates of AD did not vary as drastically between countries and regions as those of asthma; however, the highest prevalence and DALYs rates were reported in the high-income Pacific region, and the lowest rates were reported in the Sub-Saharan Africa regions. The low reported disease burden in African countries may be partly ascribed to differences in diet and environment, but may also be a result of under-reporting, especially as AD prevalence has recently been increasing in these low-and-middle income countries[34]. Therefore, additional epidemiologic studies should be conducted to delineate complex factors associated with the changes in different parts of the world and efforts to boost awareness and diagnostic capability in under-resourced settings should be continued.

Consistent with the literature and common perceptions, this study found that both asthma and AD peaked at younger ages, typically ages 5–9 years[28,31]; however, we also found that age-standardized rates increased past adulthood well into older ages. In older populations, asthma and AD may be difficult to diagnose and treat due to their traditional misconceptions

as “pediatric diseases”, different clinical presentations (i.e., phenotypes) and functional characteristics. Moreover, with the presence of multiple comorbidities associated with aging, physicians should be vigilant in recognition of these conditions and their multi-dimensional management in older adults[35].

Higher SDI levels tended to have a higher prevalence of asthma and AD, as reported in previous international studies[26,28,36]. Notably, however, mortality and DALYs rates had the reverse trend, with lower SDI was associated with higher mortality in all timeframes. Low-resource settings have been associated with worse outcomes of asthma, mediated by socioeconomic factors including income and education, environmental allergens or pollutants, psychosocial stressors, and lack of access to healthcare[9,37]. Likewise, many inner-city populations in low- and middle-income countries have a very high prevalence of asthma, but limited access to and affordability for essential medications for persistent asthma[38]; under-treatment in these countries causes significant morbidity and mortality[39]. Further, the high incidence of acute respiratory infections in low- and middle-income countries can lead to asthma exacerbations as well as under-diagnosis and thus under-treatment of asthma, leading to a relatively lower reported prevalence and higher morbidity[40]. These trends suggest a large potential for global and community initiatives to improve asthma outcomes in low-resource populations[37,41].

The trends in asthma prevalence and DALYs due to high BMI, occupational asthmagens, and smoking vary across countries and regions due to various factors such as differences in lifestyle, environmental exposures, and healthcare infrastructure. South Asia had the highest number of asthma DALYs attributable to all three risk factors, followed by North Africa and the Middle East, high-income North America, and Southeast Asia for high BMI. The high rates of obesity in South Asia may be related to factors such as a sedentary lifestyle, unhealthy diet, and genetic factors. However, the trend was slightly different for occupational asthmagens and smoking, with the second and third-highest asthma DALYs occurring in Southeast Asia and Eastern Sub-Saharan Africa for occupational asthmagens and Southeast Asia and East Asia for smoking, respectively. The high burden of occupational asthmagens in Southeast Asia and Eastern Sub-Saharan Africa could be related to the higher rates of certain occupations such as farming and mining, which may expose workers to hazardous substances. The higher smoking-related asthma DALYs in Southeast Asia and East Asia may be related to the high prevalence of smoking in these regions, driven by cultural factors and the easy availability of tobacco products. Additionally, differences in healthcare access, quality, and healthcare-seeking behavior could also contribute to the regional variation in asthma DALYs. Further research can help explore the underlying causes of these trends and their implications for public health interventions.

Implication of the study

Up-to-date population-level estimates on these frequent respiratory and skin conditions is crucial for efficient policy making with the aim of advancing access to health-care and scaling of vigorous prevention strategies. This study warrants greater standardization in data collection regarding case definitions and severity distributions of asthma and AD. We call for further and revised population measurements of asthma and AD to better quantify

the size of the problem and to better guide progress towards achievement of the 2030 health-related Sustainable Development Goals.

Strengths and limitations of the study

The present study was the first to systematically assess the disease burden of asthma and AD across regions and throughout the lifespan using the most recently released GBD data. However, there are some limitations to our study. First, the definition of asthma and AD were made mainly through physician diagnosis and symptom data, the stringency of which could have been heterogeneous across regions depending on local practices and terminology. For example, different countries using different terms to describe symptoms of asthma or AD, leading to inconsistencies in the diagnosis and resulting prevalence estimates. Furthermore, regional differences in under- or over-diagnosis of asthma could also contribute to discrepancies in prevalence statistics. Second, the case definition used in this study, requiring asthma to be due to “allergic reactions or hypersensitivity” and “wheezing” in the last year, may not capture all cases of asthma. As asthma is a heterogeneous disease that includes non-allergic phenotypes, this impact on generalizability should be considered. Additionally, the requirement of wheezing in the last year may exclude individuals with asthma who are on controlled medications and have no symptoms. This could explain the observed fall in asthma prevalence over time, as increasing access to asthma medication over the last decades has likely led to improved asthma control and a higher proportion of asymptomatic individuals who would not be captured by our definition. Third, while chronic allergic conditions encompass a variety of diseases including asthma, AD, allergic rhinitis, and food allergy, the GBD study data were unable to model these conditions comprehensively. This is due to the fact that some countries may not have had sufficient data available to accurately estimate the prevalence of these conditions, especially in cases where the disease is relatively rare or where there is a lack of clear disease codes to define cases. As a result, the analysis presented in this study was limited to asthma and AD. While this represents an important contribution to understanding the global burden of these diseases, it is important to recognize that other chronic allergic conditions may also significantly impact global health and should be the focus of future research efforts. Fourth, the attributable risk factors of AD were not evaluated from the current GBD database. Fifth, as this study was driven by data from the GBD study, it includes the limitations of the GBD dataset, mainly, that some regions had low availability and quality of data, for which statistics had to rely on predictive covariates. Sixth, the study primarily is based on GBD 2019 Results Database which relies on representative surveys, medical claims information etc. and may not take into account chronic cases that never make it to the clinics and go unreported. In low-income countries such as Sub-Saharan regions, it is likely that many people will resort to home-based treatments. Seventh, there may be the influence of non-modifiable factors on the results. Eighth, available data for AD has limitations; therefore, we were not able to do further analyses with AD data. Ninth, there are data under-reporting in low- and mid-income countries, which may bias the actual data interpretation. For example, illiteracy, lack of access to physician for all populations, economic issues, etc. may prevent people of deprived African areas to report the actual burden of asthma and AD in these regions. Tenth, as we compared country-level aggregate data, the trends and associations we found are subject to ecological bias. Eleventh, we were unable to consider the role of ethnicity in the burden

of asthma and AD. As the GBD study was obtained from various countries with different forms of resources, the heterogeneity of the data sources prevented us from considering racial factors in our analysis which can play a critical role in influencing health outcomes and disease burden. Lastly, we could only assess the attributable risk for asthma on three risk factors (high BMI, occupational asthmagens, and smoking); more research is necessary to investigate associations with different demographic and clinical factors, and also for AD. Therefore, caution should be taken when interpreting the trends in asthma prevalence and burden presented in this study, and further research is needed to investigate the potential impact of changes in asthma management and control on the observed trends.

Conclusion

In summary, asthma and AD are both allergic diseases that have increased in total burden worldwide but have decreased in age-standardized prevalence rates from 1990 to 2019. Although both are more frequent at younger ages and prevalent in high-SDI countries, each condition has distinct temporal and regional trends. In addition, Eastern, Western, and Central Sub-Saharan Africa had a substantially higher percentage of asthma DALYs due to occupational asthmagens compared to other regions. This study will help assess regional and temporal trends regarding the distribution and disease burden of asthma and AD, and guide interventions to better manage these diseases worldwide as well as to attain equity in prevention, diagnosis and treatment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgement

We would like to express our deepest gratitude to Hyeon Jin Kim, Han Gyeol Lee, Ho Hyeok Chang, and Sungchul Choi for helping data acquisition and making tables and figures. R Adha acknowledges support from the Department of Statistics, National Chengchi University, Taiwan. Ali Ahmed acknowledges support from Monash University, Malaysia. S M Alif acknowledges support from Monash University and the ASPREE team. A Badawi is supported by the Public Health Agency of Canada. A Bikov acknowledges support from Manchester NIHR BRC. J Car acknowledges support from the Centre for Population Health Sciences and NTU Singapore university's support. G Damiani acknowledges support from the the Italian Center of Precisione Medicine and Chronic Inflammation. A Fatehizadeh acknowledges support from the Department of Environmental Health Engineering of Isfahan University of Medical Sciences, Isfahan, Iran. V K Gupta acknowledges funding support from National Health and Medical Research Council (NHMRC), Australia. S Hussain Salman Hussain was supported from Operational Programme Research, Development and Education Project, Postdoc2MUNI (No.CZ.02.2.69/0.0/0.0/18_053/0016952). B-F Hwang was partially supported by China Medical University, Taiwan (CMU111-MF-55). N E Ismail acknowledges AIMST University, Malaysia, for encouraging research affairs. N Joseph acknowledges the Department of Community Medicine, Kasturba Medical College, Mangalore, Manipal Academy of Higher Education, Manipal, India for their encouragement and support. K Latief acknowledges funding from Taipei Medical University for Doctoral Education during the conduct of this review. M-C Li was supported by the National Science and Technology Council, Taiwan (NSTC 111–2410-H-003–100-SSS). G Liu acknowledges support from the CREATE Hope Scientific Fellowship from Lung Foundation Australia. G Lopes was supported by national funds through the Fundação para a Ciência e Tecnologia (FCT) under the Scientific Employment Stimulus–Individual Call (CEECIND/01768/2021). L Monasta received support from the Italian Ministry of Health (Ricerca Corrente 34/2017), payments made to the Institute for Maternal and Child Health IRCCS Burlo Garofolo. T P Ng acknowledges support from the following: Geylang East Home for the Aged, Presbyterian Community Services, St Luke's Eldercare Services, Thye Hua Kwan Moral Society (Moral Neighbourhood Links), Yuhua Neighbourhood Link, Henderson Senior Citizens Home, NTUC Eldercare Co-op Ltd, Thong Kheng Seniors Activity Centre (Queenstown Centre) and Redhill Moral Seniors Activity Centre. J R Padubidri acknowledges Manipal Academy of Higher Education, Manipal and Kasturba Medical College, Mangalore for their support to this collaborative research. E M M Redwan acknowledges support from

King Abdulaziz University (DSR), Jeddah, King Abdulaziz City for Science & Technology (KACSAT), Saudi Arabia, Science & Technology Development Fund (STDF), US-Egypt Science & Technology Joint Fund, and The Academy of Scientific Research & Technology (ASRT), Egypt. U Saeed acknowledges the International Center of Medical Sciences Research (ICMSR), Islamabad (44000) Pakistan. A M Samy acknowledges the support from Ain Shams University and the Egyptian Fulbright Mission Program. A Sheikh acknowledges support from HDRUK. J F M van Boven acknowledges his employer, the University Medical Center Groningen, University of Groningen, The Netherlands, for their support. C Yu acknowledges support from the National Natural Science Foundation of China (Grant No. 82173626) H J Zar acknowledges support from the the SA-Medical Research Council.

Role of the funding source

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

Funding

This study was funded by the Bill and Melinda Gates Foundation, Australian National Health and Medical Research Council, and Queensland Department of Health, Australia and National Research Foundation of Korea (NRF) grant funded by the Korea government (NRF-2021R1I1A2059735). The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. All authors had full access to the study data and had final responsibility for the decision to submit for publication.

GBD 2019 Allergic Disorders Collaborators

Youn Ho Shin,[1,2*] Jimin Hwang,[3,4*] Rosie Kwon,[5*] Seung Won Lee,[6*] Min Seo Kim,[7,8*] Yohannes Habtegiorgis Abate,[9] Mohsen Abbasi-Kangevari,[10] Zeinab Abbasi-Kangevari,[11,10] Michael Abdelmasseh,[12] Deldar Morad Abdulah,[13] Richard Gyan Aboagye,[14] Hassan Abolhassani,[15,16] Elissa M Abrams,[17,18] Yonas Derso Abtew,[19] Eman Abu-Gharbieh,[20] Denberu Eshetie Adane Adane,[21] Tigist Demssew Adane,[22,22] Isaac Yeboah Addo,[23,24] Rishan Adha,[25] Amin Adibi,[26] Qorinah Estiningtyas Sakilah Adnani,[27] Anurag Agrawal,[28,29] Sohail Ahmad,[30] Ali Ahmadi,[31,32] Ali Ahmed,[33,34] Ayman Ahmed,[35,36] Sayer Al-Azzam,[37] Fadwa Alhalaiqa Naji Alhalaiqa,[38,39] Sheikh Mohammad Alif,[40] Vahid Alipour,[41,42] Zaid Altaany,[43] Khalid A Altirkawi,[44] Nelson Alvis-Guzman,[45,46] Hany Aly,[47] Adnan Ansar,[48,49] Judie Arulappan,[50] Mohammad Asghari-Jafarabadi,[51,52] Tahira Ashraf,[53] Seyyed Shamsadin Athari,[54] Daniel Atlaw,[55] Avinash Aujayeb,[56] Sina Azadnajafabad,[10] Mahsa Babaei,[57,58] Hassan Babamohamadi,[59] Alaa Badawi,[60,61] Nayereh Baghcheghi,[62] Sara Bagherieh,[63] Khuloud Bajbouj,[64] Maciej Banach,[65,66] Mainak Bardhan,[67,68] Francesco Barone-Adesi,[69] Amadou Barrow,[70,71] Azadeh Bashiri,[72] Nebiyou Simegnew Bayileyegn,[73] Isabela M Bensenor,[74] Alemshet Yirga Berhie,[75] Kebede A Beyene,[76,77] Akshaya Srikanth Bhagavathula,[78] Pankaj Bhardwaj,[79,80] Ajay Nagesh Bhat,[81] Vijayalakshmi S Bhojaraja,[82] Ali Bijani,[83] Andras Bikov,[84,85] Jiao Cai,[86] Paulo Camargos,[87] Josip Car,[88,89] Sinclair Carr,[90] Andrea Carugno,[91] Promit Ananyo Chakraborty,[92] Jeffrey Shi Kai Chan,[93] Periklis Charalampous,[94] Mohammadreza Chashmyazdan,[95] Vijay Kumar Chattu,[96,97] Mohiuddin Ahsanul Kabir Chowdhury,[98,99] Dinh-Toi Chu,[100] Barbara Corso,[101] Natália Cruz-Martins,[102,103] Omid Dadras,[104,105] Xiaochen Dai,[90,106] Giovanni Damiani,[107,108] Lalit Dandona,[109,90,110] Rakhi Dandona,[109,90,106] Dessalegn Demeke,[111] Biniyam Demisse,[112] Daniel Diaz,[113,114] Mengistie Diress,[115] Deepa Dongarwar,[116] Michael Ekholuenetale,[117,118] Temitope Cyrus Ekundayo,[119] Muhammed Elhadi,[120] Omar Abdelsadek Abdou Elmeligy,[121,122] Habtamu Esubalew,[123] Farshid Etaee,[124] Azin Etemadimanesh,[125] Adeniyi Francis Fagbamigbe,[117,126] Ildar Ravisovich Fakhradiyev,[127] Ali Fatehizadeh,[128] Syeda Anum Fatima Fatima,[129,130] Xiaoqi Feng,[131,132] Mohammad Fereidouni,[133,134] Nuno Ferreira,[135]

Getahun Fetensa,[136] Florian Fischer,[137] Masoud Foroutan,[138,139] Takeshi Fukumoto,[140] Abduzhappar Gaipov,[141] Yibeltal Yismaw Gela,[142] Abera Getachew Obsa,[143] Fataneh Ghadirian,[144] Seyyed-Hadi Ghamari,[10,11] Sherief Ghozy,[145] Richard F Gillum,[146,147] Abraham Tamirat Gizaw,[148] Admasu Belay AB Gizaw,[149] Mohamad Goldust,[150] Mahaveer Golechha,[151] Pouya Goleij,[152] Sapna Gupta,[153] Vivek Kumar Gupta,[154] Arvin Haj-Mirzaian,[155,156] Rabih Halwani,[20,157] Samer Hamidi,[158] Md Abdul Hannan,[159,160] Ahmed I Hasaballah,[161] Hamidreza Hasani,[162] Abdiwahab Hashi,[163] Mohammed Bheser Hassen,[90,164] Behzad Heibati,[165] Golnaz Heidari,[166] Mohammad Heidari,[167] Mahsa Heidari-Foroozan,[168,169] Ramesh Holla,[170] Nobuyuki Horita,[171,172] Md Shakhaoat Hossain,[173] Salman Hussain,[174,175] Bing-Fang Hwang,[176] Irena M Ilic,[177] Milena D Ilic,[178] Rana Irilouzadian,[179,169] Nahlah Elkudssiah Ismail,[180] Zhanat Bakhitovna IZB Ispayeva,[181] Chidozie C D Iwu,[182] Linda Merin J,[183] Maziar Jajarmi,[184] Elham Jamshidi,[185,186] Manthan Dilipkumar Janodia,[187] Shubha Jayaram,[188] Rime Jebai,[189] Jost B Jonas,[190,191] Nitin Joseph,[192] Billingsley Kaambwa,[193,194] Zubair Kabir,[195] Feroze Kaliyadan,[196] Himal Kandel,[197,198] Rami S Kantar,[199,200] Ibraheem M Karaye,[201] Hanie Karimi,[202] Harkiran Kaur,[109] Leila Keikavoosi-Arani,[203] Mohammad Keykhaei,[10,204] Yousef Saleh Khader,[205] Himanshu Khajuria,[206] Imteyaz A Khan,[207] Maseer Khan,[208] Moien AB Khan,[209,210] Saval Khanal,[211] Moawiah Mohammad Khatatbeh,[212] Jagdish Khubchandani,[213] Biruk Getahun Kibret,[214] Adnan Kisa,[215,216] Sezer Kisa,[217] Pavel Kolkhir,[218,219] Farzad Kompani,[220] Hamid Reza Koohestani,[221] Oleksii Korzh,[222] Parvaiz A Koul,[223] Ai Koyanagi,[224,225] Kewal Krishan,[226] Claudia E Kuehni,[227,228] G Anil Kumar,[109] Om P Kurmi,[229,230] L V Simhachalam Kutikuppala,[231] Ambily Kuttikkattu,[232] Judit Lám,[233,234] Bagher Larijani,[235] Kamaluddin Latief,[236,237] Paolo Lauriola,[238] Thao Thi Thu Le,[239] Yo Han Lee,[240] Jacopo Lenzi,[241] Ming-Chieh Li,[242] Shanshan Li,[40] Virendra S Ligade,[243] Stephen S Lim,[90,106] Gang Liu,[244,245] Wei Liu,[86] Xuefeng Liu,[246,247] Chun-Han Lo,[248] Graciliana Lopes,[249] Soundarya Mahalingam,[250] Sandeep B Maharaj,[251,252] Mansour Adam Mahmoud,[253] Azeem Majeed,[89] Mohammad-Reza Malekpour,[10] Ahmad Azam Malik,[254,255] Tauqeer Hussain Mallhi,[256] Deborah Carvalho Malta,[257] Abdullah A Mamun,[258] Seyedeh Zahra Masoumi,[259] Andrea Maugeri,[260] John Robert Carabeo Medina,[261,262] Ritesh G Menezes,[263] George A Mensah,[264,265] Alexios-Fotios A Mentis,[266] Tomislav Mestrovic,[267,90] Irmina Maria Michalek,[268,269] Le Huu Nhat Minh,[270,271] Erkin M Mirrakhimov,[272,273] Awoke Misganaw,[106,274] Manish Mishra,[275] Shafiu Mohammed,[276,277] Ali H Mokdad,[90,106] Sara Momtazmanesh,[278,10] Lorenzo Monasta,[279] Md Moniruzzaman,[280] Temesgen Mulugeta,[281] Daniel Munblit,[282,283] Efrén Murillo-Zamora,[284,285] Ghulam Mustafa,[286,287] Tapas Sadasivan Nair,[288] Vinay Nangia,[289] Sreenivas Narasimha Swamy,[290] Hasan Nassereldine,[90] Zuhair S Natto,[291,292] Biswa Prakash Nayak,[206] Javad Nazari,[293] Tze Pin Ng,[294,295] Dang H Nguyen,[296] Van Thanh Nguyen,[297] Robina Khan Niazi,[298] Hasti Nouraei,[299] Ogochukwu Janet Nzoputam,[300,301] Bogdan Oancea,[302] Rahman Md Obaidur,[303,304] Hassan Okati-Aliabad,[305] Osaretin Christabel Okonji,[306] Patrick Godwin Okwute,[307,308] Andrew T Olagunju,[309,310] Isaac Iyinoluwa Olufadewa,[311,118] Hans Orru,[312,313] Mahesh P A,[314] Jagadish Rao Padubidri,[315] Anamika Pandey,[109] Shahina Pardhan,[316] Eun-Kee Park,[317] Jay Patel,[318,319] Shankargouda Patil,[320,321] Venkata Suresh Patthipati,[322,323] Uttam Paudel,[324,325] Marcos Pereira,[326] Renato B Pereira,[327] Ionela-Roxana Petcu,[328] Indrashis Podder,[329] Vivek Podder,[330,331] Arash Pour Mohammad,[332] Ibrahim Qattea,[333] Navid Rabiee,[334,335] Mehran Rahimi,[336]

Mosiur Rahman,[337] Muhammad Aziz Rahman,[338,48] Amir Masoud Rahmani,[339] Shayan Rahmani,[169,10] Vahid Rahmanian,[340] Prashant Rajput,[341] Pradhum Ram,[342] Premkumar Ramasubramani,[343] Indu Ramachandra Rao,[344] Ahmed Mustafa Rashid,[345] Zubair Ahmed Ratan,[346,347] Nakul Ravikumar,[348] Salman Rawaf,[89,349] Lal Rawal,[350] Elrashdy Moustafa Mohamed Redwan,[351,352] Aavishkar Raj Regmi,[353] Nazila Rezaei,[10] Negar Rezaei,[10,235] Nima Rezaei,[15,354] Saeid Rezaei,[355,356] Mohsen Rezaeian,[357] Jefferson Antonio Buendia Rodriguez,[358] Leonardo Roever,[359] Esperanza Romero-Rodríguez,[360] Luca Ronfani,[279] Aly M A Saad,[361] Basema Saddik,[362] Umar Saeed,[363,364] Dominic Sagoe,[365] Fatemeh Saheb Sharif-Askari,[366] Amirhossein Sahebkar,[367,368] Harihar Sahoo,[369] Mirza Rizwan Sajid,[370] Joseph W Sakshaug,[371,372] Saina Salahi,[373] Sana Salehi,[374] Abdallah M Samy,[375,376] Milena M Santric-Milicevic,[177,377] Made Ary Sarasmita,[378,379] Maryam Sarkhosh,[380,381] Ganesh Kumar Saya,[382] Subramanian Senthilkumaran,[383] Humaira Shah,[384] Masood Ali Shaikh,[385] Mohd Shanawaz,[386] Aziz Sheikh,[387,388] Shashank Shekhar,[389] Mika Shigematsu,[390] Parnian Shobeiri,[391,392] Seyed Afshin Shorofi,[393,394] Migbar Mekonnen Sibhat,[395] Colin R Simpson,[396,397] Jasvinder A Singh,[398,399] Paramdeep Singh,[400] Surjit Singh,[401] Virendra Singh,[402] Md Shahjahan Siraj,[403] Anna Aleksandrovna Skryabina,[404] Yonatan Solomon,[405] Suhang Song,[406] Sergey Soshnikov,[407,408] Ireneous N Soyiri,[409] Paschalis Steiropoulos,[410] Mindy D Szeto,[411] Iman M Talaat,[20,412] Jacques JL Lukenze Tamuzi,[413,414] Ker-Kan Tan,[415] Nathan Y Tat,[416,417] Mohamad-Hani Temsah,[44] Dufera Rikitu Terefa,[418,419] Riki Tesler,[420] Pugazhenthan Thangaraju,[421] Jansje Henny Vera Ticoalu,[422] Tala Tillawi,[423] Mai Thi Ngoc Tran,[424,425] Biruk Shalmeno Tusa,[426] Irfan Ullah,[427] Saif Ullah,[428] Sana Ullah,[429,430] Era Upadhyay,[431] Seyed Mohammad Vahabi,[432] Job F M van Boven,[433] Tommi Juhani Vasankari,[434,435] Georgios-Ioannis Verras,[436,437] Rafael José Vieira,[438,439] Francesco S Violante,[440,441] Theo Vos,[90,106] Ronny Westerman,[442] Nuwan Darshana Wickramasinghe,[443] Hywel C Williams,[444] Dereje Y Yada,[90] Yazachew Yismaw,[445,446] Naohiro Yonemoto,[447,448] Chuanhua Yu,[449] Ismaeel Yunusa,[450] Mazyar Zahir,[451] Heather J Zar,[452,453] Iman Zare,[454] Mikhail Sergeevich Zastrozhin,[455,456] Mohammad A Zeineddine,[457] Getachew Assefa Zenebe,[458] Zhi-Jiang Zhang,[459] Hanqing Zhao,[460] Mohammad Zoladl,[461] Jae II Shin,[462] Dong Keon Yon.[5,463]

GBD 2019 Allergic Disorders Collaborators Affiliations

[1]Department of Pediatrics, CHA University, Seoul, South Korea; [2]Department of Pediatrics, CHA Gangnam Medical Center, Seoul, South Korea; [3]Department of Epidemiology, Johns Hopkins University, Baltimore, MD, USA; [4]Department of Pediatrics, Yonsei University, Seoul, South Korea; [5]Center for Digital Health, Kyung Hee University Medical Center, Kyung Hee University College of Medicine, Seoul, South Korea; [6]Department of Precision Medicine, Sungkyunkwan University, Suwon, South Korea; [7]Department of Genomics and Digital Health, Samsung Advanced Institute for Health Sciences & Technology (SAIHST), Seoul, South Korea; [8]Public Health Center, Ministry of Health and Welfare, Wando, South Korea; [9]Clinical Governance and Quality Improvement, Aleta Wondo Hospital, Aleta Wondo, Ethiopia; [10]Non-communicable Diseases Research Center, Tehran University of Medical Sciences, Tehran, Iran; [11]Social Determinants of Health Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [12]Department of Surgery, Marshall University, Huntington, WV, USA; [13]Community and Maternity

Nursing Unit, University of Duhok, Duhok, Iraq; [14]Department of Family and Community Health, University of Health and Allied Sciences, Ho, Ghana; [15]Research Center for Immunodeficiencies, Tehran University of Medical Sciences, Tehran, Iran; [16]Department of Biosciences and Nutrition, Karolinska University Hospital, Huddinge, Sweden; [17]Section of Allergy and Clinical Immunology, University of Manitoba, Winnipeg, MB, Canada; [18]Department of Pediatrics, University of British Columbia, Vancouver, BC, Canada; [19]Department of Biomedical Science, Arba Minch University, Arba Minch, Ethiopia; [20]Clinical Sciences Department, University of Sharjah, Sharjah, United Arab Emirates; [21]Depatment of Anesthesia and critical care, Debre Tabor University, Debre Tabor, Ethiopia; [22]Department of Clinical and Psychosocial Epidemiology, University of Groningen, Groningen, Netherlands; [23]Centre for Social Research in Health, University of New South Wales, Sydney, NSW, Australia; [24]Quality and Systems Performance Unit, Cancer Institute NSW, Sydney, NSW, Australia; [25]Department of Business Administration, Muhammadiyah University of Mataram, Mataram, Indonesia; [26]Department of Pharmaceutical Sciences, University of British Columbia, Vancouver, BC, Canada; [27]Faculty of Medicine, Universitas Padjadjaran (Padjadjaran University), Bandung, Indonesia; [28]Trivedi School of Biosciences, Ashoka University, Sonipat, India; [29]Section of General Internal Medicine, Baylor College of Medicine, Houston, TX, USA; [30]Faculty of Pharmacy, MAHSA University, Kuala Langat, Malaysia; [31]Department of Epidemiology and Biostatistics, Shahrekord University of Medical Sciences, Shahrekord, Iran; [32]Department of Epidemiology, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [33]School of Pharmacy, Monash University, Bandar Sunway, Malaysia; [34]Department of Pharmacy, Quaid I Azam University Islamabad, Islamabad, Pakistan; [35]Institute of Endemic Diseases, University of Khartoum, Khartoum, Sudan; [36]Swiss Tropical and Public Health Institute, University of Basel, Basel, Switzerland; [37]Department of Clinical Pharmacy, Jordan University of Science and Technology, Irbid, Jordan; [38]Faculty of Nursing, Philadelphia University, Amman, Jordan; [39]Psychological Sciences Association, Amman, Jordan; [40]School of Public Health and Preventive Medicine, Monash University, Melbourne, VIC, Australia; [41]Health Management and Economics Research Center, Iran University of Medical Sciences, Tehran, Iran; [42]Department of Health Economics, Iran University of Medical Sciences, Tehran, Iran; [43]Departent of Basic sciences, Yarmouk Univeristy, Irbid, Jordan; [44]Pediatric Intensive Care Unit, King Saud University, Riyadh, Saudi Arabia; [45]Research Group in Hospital Management and Health Policies, Universidad de la Costa (University of the Coast), Barranquilla, Colombia; [46]Research Group in Health Economics, University of Cartagena, Cartagena, Colombia; [47]Pediatrics Department, Cleveland Clinic, Cleveland, OH, USA; [48]School of Nursing and Midwifery, La Trobe University, Melbourne, VIC, Australia; [49]Special Interest Group International Health, Public Health Association of Australia, Canberra, ACT, Australia; [50]Department of Maternal and Child Health, Sultan Qaboos University, Muscat, Oman; [51]Cabrini Research, Cabrini Health, Melbourne, VIC, Australia; [52]School of Public Health and Preventative Medicine, Monash University, Melbourne, VIC, Australia; [53]University Institute of Radiological Sciences and Medical Imaging Technology, The University of Lahore, Lahore, Pakistan; [54]Department of Immunology, Zanjan University of Medical Sciences, Zanjan, Iran; [55]Department of Biomedical Science, Madda Walabu University, Bale Robe, Ethiopia; [56]Northumbria HealthCare NHS Foundation Trust, National Health Service (NHS) Scotland, Newcastle upon Tyne, UK;

[57]Neurosicence Institute, Tehran University of Medical Sciences, Tehran, Iran; [58]School of Medicine, Stanford University, Palo Alto, CA, USA; [59]Department of Nursing, Semnan University of Medical Sciences and Health Services, Semnan, Iran; [60]Public Health Risk Sciences Division, Public Health Agency of Canada, Toronto, ON, Canada; [61]Department of Nutritional Sciences, University of Toronto, Toronto, ON, Canada; [62]Department of Nursing, Saveh University of Medical Sciences, Saveh, Iran; [63]School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran; [64]Basic Medical Sciences, University of Sharjah, Sharjah, United Arab Emirates; [65]Department of Hypertension, Medical University of Lodz, Lodz, Poland; [66]Polish Mothers' Memorial Hospital Research Institute, Lodz, Poland; [67]Molecular Microbiology and Bacteriology, National Institute of Cholera and Enteric Diseases, Kolkata, India; [68]Molecular Microbiology, Indian Council of Medical Research, New Delhi, India; [69]Department of Translational Medicine, University of Eastern Piedmont, Novara, Italy; [70]Department of Public & Environmental Health, University of The Gambia, Brikama, The Gambia; [71]Epidemiology and Disease Control Unit, Ministry of Health, Kotu, The Gambia; [72]Health Information Management, Shiraz University of Medical Sciences, Shiraz, Iran; [73]Department of Surgery, Jimma University, Jimma, Ethiopia; [74]Department of Internal Medicine, University of São Paulo, São Paulo, Brazil; [75]School of Health Science, Bahir Dar University, Bahir Dar, Ethiopia; [76]School of Pharmacy, University of Auckland, Auckland, New Zealand; [77]Department of Pharmaceutical and Administrative Sciences, University of Health Sciences and Pharmacy in St. Louis, St louis, MO, USA; [78]Department of Health, Human Performance and Recreation, University of Arkansas, Fayetteville, AR, USA; [79]Department of Community Medicine and Family Medicine, All India Institute of Medical Sciences, Jodhpur, India; [80]School of Public Health, All India Institute of Medical Sciences, Jodhpur, India; [81]Department of General Medicine, Manipal Academy of Higher Education, Mangalore, India; [82]Department of Anatomy, Royal College of Surgeons in Ireland Medical University of Bahrain, Busaiteen, Bahrain; [83]Social Determinants of Health Research Center, Babol University of Medical Sciences, Babol, Iran; [84]Division of Infection, Immunity and Respiratory Medicine, University of Manchester, Manchester, UK; [85]Department of Pulmonology, Semmelweis University, Budapest, Hungary; [86]Institute for Health and Environment, Chongqing University of Science and Technology, Chongqing, China; [87]Department of Pediatrics, Federal University of Minas Gerais, Belo Horizonte, Brazil; [88]Centre for Population Health Sciences, Nanyang Technological University, Singapore, Singapore; [89]Department of Primary Care and Public Health, Imperial College London, London, UK; [90]Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA, USA; [91]Dermatology Unit, Azienda Socio Sanitaria Territoriale Papa Giovanni XXIII (Territorial Healthcare Company Pope John XXIII), Bergamo, Italy; [92]School of Population and Public Health, University of British Columbia, Vancouver, BC, Canada; [93]Heart Failure and Structural Heart Disease Unit, Cardiovascular Analytics Group, Hong Kong, China; [94]Department of Public Health, Erasmus University Medical Center, Rotterdam, Netherlands; [95]Medical Library and Information Science, Kerman University of Medical Sciences, Kerman, Iran; [96]Department of Community Medicine, Datta Meghe Institute of Medical Sciences, Sawangi, India; [97]Saveetha Medical College and Hospitals, Saveetha University, Chennai, India; [98]Department of Public Health, Asian University for Women, Chittagong, Bangladesh; [99]James P Grant School of Public Health, BRAC University,

Dhaka, Bangladesh; [100]Center for Biomedicine and Community Health, VNU-International School, Hanoi, Viet Nam; [101]Institute of Neuroscience, National Research Council, Pisa, Italy; [102]Therapeutic and Diagnostic Technologies, Cooperativa de Ensino Superior Politécnico e Universitário (Polytechnic and University Higher Education Cooperative), Gandra, Portugal; [103]Institute for Research and Innovation in Health, University of Porto, Porto, Portugal; [104]Section Global Health and Rehabilitation, Western Norway University of Applied Sciences, Bergen, Norway; [105]Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway; [106]Department of Health Metrics Sciences, School of Medicine, University of Washington, Seattle, WA, USA; [107]IRCCS Istituto Ortopedico Galeazzi (Galeazzi Orthopedic Institute IRCCS), University of Milan, Milan, Italy; [108]Department of Dermatology, Case Western Reserve University, Cleveland, OH, USA; [109]Public Health Foundation of India, Gurugram, India; [110]Indian Council of Medical Research, New Delhi, India; [111]Department of Physiology, Bahir Dar University, Bahir Dar, Ethiopia; [112]Department of Nursing, Arba Minch University, Arba Minch, Ethiopia; [113]Center of Complexity Sciences, National Autonomous University of Mexico, Mexico City, Mexico; [114]Faculty of Veterinary Medicine and Zootechnics, Autonomous University of Sinaloa, Culiacán Rosales, Mexico; [115]Department of Human Physiology, University of Gondar, Gondar, Ethiopia; [116]Health Science Center, University of Texas, Houston, TX, USA; [117]Department of Epidemiology and Medical Statistics, University of Ibadan, Ibadan, Nigeria; [118]Faculty of Public Health, University of Ibadan, Ibadan, Nigeria; [119]Department of Biological Sciences, University of Medical Sciences Ondo, Ondo, Nigeria; [120]Faculty of Medicine, University of Tripoli, Tripoli, Libya; [121]Pediatric Dentistry Department, King Abdulaziz University, Jeddah, Saudi Arabia; [122]Pediatric Dentistry and Dental Public Health Department, Alexandria University, Alexandria, Egypt; [123]Department of Public Health, Arba Minch University, Arba Minch, Ethiopia; [124]Internal Medicine, Yale University, New Haven, CT, USA; [125]Department of Pathology, Tehran University of Medical Sciences, Tehran, Iran; [126]Institute of Applied Health Sciences, University of Aberdeen, Aberdeen, UK; [127]Head of the Laboratory of Experimental Medicine, Kazakh National Medical University, Almaty, Kazakhstan; [128]Department of Environmental Health Engineering, Isfahan University of Medical Sciences, Isfahan, Iran; [129]Department of community medicine and global health, University of Oslo, Oslo, Norway; [130]Department of Bacteriology, Norwegian Institute of Public Health, Oslo, Norway; [131]School of Population Health, University of New South Wales, Sydney, NSW, Australia; [132]National Institute of Environmental Health, Chinese Center for Disease Control and Prevention, Beijing, China; [133]Department of Molecular Medicine, Birjand University of Medical Sciences, Birjand, Iran; [134]Cellular and Molecular Research Center, Birjand University of Medical Sciences, Birjand, Iran; [135]Department of Social Sciences, University of Nicosia, Nicosia, Cyprus; [136]Department of Nursing, Wollega University, Nekemte, Ethiopia; [137]Institute of Public Health, Charité Universitätsmedizin Berlin (Charité Medical University Berlin), Berlin, Germany; [138]Department of Medical Parasitology, Abadan University of Medical Sciences, Abadan, Iran; [139]Faculty of Medicine, Abadan University of Medical Sciences, Abadan, Iran; [140]Department of Dermatology, Kobe University, Kobe, Japan; [141]Department of Medicine, Nazarbayev University School of Medicine, Nur-Sultan, Kazakhstan; [142]Human Physiology, University of Gondar, Gondar, Ethiopia; [143]School of Psychology, Addis Ababa University, Addis Ababa, Ethiopia;

[144]Psychiatric Nursing and Management Department, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [145]Department of Radiology, Mayo Clinic, Rochester, MN, USA; [146]Division of General Internal Medicine, Howard University, Washington, DC, USA; [147]Department of Community and Family Medicine, Howard University, Washington, DC, USA; [148]Department of Health, Behavior and Society, Jimma University, Jimma, Ethiopia; [149]Department of Nursing, Jimma University, Jimma, Ethiopia; [150]Department of Dermatology, Yale University, New Haven, CT, USA; [151]Health Systems and Policy Research, Indian Institute of Public Health, Gandhinagar, India; [152]Department of Genetics, Sana Institute of Higher Education, Sari, Iran; [153]Toxicology Department, Shriram Institute for Industrial Research, Delhi, Delhi, India; [154]Faculty of Medicine Health and Human Sciences, Macquarie University, Sydney, NSW, Australia; [155]Department of Pharmacology, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [156]Obesity Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [157]College of Medicine, University of Sharjah, Sharjah, United Arab Emirates; [158]School of Health and Environmental Studies, Hamdan Bin Mohammed Smart University, Dubai, United Arab Emirates; [159]Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh, Bangladesh; [160]Department of Anatomy, Dongguk University, Gyeongju, South Korea; [161]Department of Zoology and Entomology, Al Azhar University, Cairo, Egypt; [162]Department of Ophthalmology, Iran University of Medical Sciences, Karaj, Iran; [163]Department of Public Health, Jigjiga University, Jigjiga, Ethiopia; [164]National Data Management Center for Health (NDMC), Ethiopian Public Health Institute, Addis Ababa, Ethiopia; [165]Department of Research, Cancer Registry of Norway, Oslo, Norway; [166]Independent Consultant, Santa Clara, CA, USA; [167]Community-Oriented Nursing Midwifery Research Center, Shahrekord University of Medical Sciences, Shahrekord, Iran; [168]Department of Epidemiology, Non-Communicable Diseases Research Center (NCDRC), Tehran, Iran; [169]School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [170]Kasturba Medical College, Mangalore, Manipal Academy of Higher Education, Manipal, India; [171]Department of Pulmonology, Yokohama City University, Yokohama, Japan; [172]National Human Genome Research Institute (NHGRI), National Institutes of Health, Bethesda, MD, USA; [173]Department of Public Health and Informatics, Jahangirnagar University, Dhaka, Bangladesh; [174]Czech National Centre for Evidence-Based Healthcare and Knowledge Translation, Masaryk University, Brno, Czech Republic; [175]Institute of Biostatistics and Analyses, Masaryk University, Brno, Czech Republic; [176]Department of Occupational Safety and Health, China Medical University, Taichung, Taiwan; [177]Faculty of Medicine, University of Belgrade, Belgrade, Serbia; [178]Department of Epidemiology, University of Kragujevac, Kragujevac, Serbia; [179]Burn Research Center, Iran University of Medical Sciences, Tehran, Iran; [180]Department of Clinical Pharmacy, MAHSA University, Bandar Saujana Putra, Malaysia; [181]Department of Allergology, Kazakh National Medical University, Almaty, Kazakhstan; [182]School of Health Systems and Public Health, University of Pretoria, Pretoria, South Africa; [183]Department of Orthodontics & Dentofacial Orthopedics, Dr. D. Y. Patil University, Pune, India; [184]Department of Pathobiology, Shahid Bahonar University of Kerman, Kerman, Iran; [185]Functional Neurosurgery Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [186]Division of Pulmonary Medicine, Lausanne University Hospital (CHUV), Lausanne, Switzerland; [187]Manipal College of Pharmaceutical Sciences, Manipal Academy

of Higher Education, Manipal, India; [188]Department of Biochemistry, Government Medical College, Mysuru, India; [189]Department of Epidemiology, Florida International University, Miami, FL, USA; [190]Institute of Molecular and Clinical Ophthalmology Basel, Basel, Switzerland; [191]Department of Ophthalmology, Heidelberg University, Mannheim, Germany; [192]Department of Community Medicine, Manipal Academy of Higher Education, Mangalore, India; [193]Health Economics Unit, Flinders University, Adelaide, SA, Australia; [194]College of Medicine and Public Health, Flinders University, Adelaide, SA, Australia; [195]School of Public Health, University College Cork, Cork, Ireland; [196]Dermatology Department, King Faisal University, Hofuf, Saudi Arabia; [197]Save Sight Institute, University of Sydney, Sydney, NSW, Australia; [198]Sydney Eye Hospital, South Eastern Sydney Local Health District, Sydney, NSW, Australia; [199]The Hansjörg Wyss Department of Plastic and Reconstructive Surgery, Nab'a Al-Hayat Foundation for Medical Sciences and Health Care, New York, NY, USA; [200]Cleft Lip and Palate Surgery, Global Smile Foundation, Norwood, MA, USA; [201]School of Health Professions and Human Services, Hofstra University, Hempstead, NY, USA; [202]Medical School, Tehran University of Medical Sciences, Tehran, Iran; [203]Department of Healthcare Services Management, Alborz University of Medical Sciences, Karaj, Iran; [204]Students' Scientific Research Center (SSRC), Tehran University of Medical Sciences, Tehran, Iran; [205]Department of Public Health, Jordan University of Science and Technology, Irbid, Jordan; [206]Amity Institute of Forensic Sciences, Amity University, Noida, India; [207]Department of Pediatrics, Rutgers University, New Brunswick, NJ, USA; [208]Epidemiology Department, Jazan University, Jazan, Saudi Arabia; [209]Family Medicine Department, United Arab Emirates University, Al Ain, United Arab Emirates; [210]Primary Care Department, NHS North West London, London, UK; [211]Warwick Medical School, University of Warwick, Coventry, UK; [212]Basic Medical Sciences, Yarmouk University, Irbid, Jordan; [213]Department of Public Health, New Mexico State University, Las Cruces, NM, USA; [214]Department of Medical Physiology, Bahir Dar University, Bahir Dar, Ethiopia; [215]School of Health Sciences, Kristiania University College, Oslo, Norway; [216]Department of International Health and Sustainable Development, Tulane University, New Orleans, LA, USA; [217]Department of Nursing and Health Promotion, Oslo Metropolitan University, Oslo, Norway; [218]Institute for Allergology, Charité Medical University Berlin, Berlin, Germany; [219]Division of Immune-mediated Skin Diseases, First Moscow State Medical University (Sechenov University), Moscow, Russia; [220]Children's Medical Center, Tehran University of Medical Sciences, Tehran, Iran; [221]Social Determinants of Health Research Center, Saveh University of Medical Sciences, Saveh, Iran; [222]Department of General Practice, Kharkiv Medical Academy of Postgraduate Education, Kharkiv, Ukraine; [223]Department of Internal and Pulmonary Medicine, Sheri Kashmir Institute of Medical Sciences, Srinagar, India; [224]Biomedical Research Networking Center for Mental Health Network (CIBERSAM), San Juan de Dios Sanitary Park, Sant Boi de Llobregat, Spain; [225]Catalan Institution for Research and Advanced Studies (ICREA), Barcelona, Spain; [226]Department of Anthropology, Panjab University, Chandigarh, India; [227]Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland; [228]University Children's Hospital, University of Bern, Bern, Switzerland; [229]Faculty of Health and Life Sciences, Coventry University, Coventry, UK; [230]Department of Medicine, McMaster University, Hamilton, ON, Canada; [231]General Surgery, Dr NTR University of Health Sciences, Vijayawada, India; [232]Department of Nephrology, Pushpagiri Institute of

Medical Sciences and Research Centre, Thiruvalla, India; [233]Health Services Management Training Centre, Semmelweis University, Budapest, Hungary; [234]NEVES Society for Patient Safety, NEVES Society for Patient Safety, Budapest, Hungary; [235]Endocrinology and Metabolism Research Institute, Tehran University of Medical Sciences, Tehran, Iran; [236]Centre for Family Welfare, University of Indonesia, Depok, Indonesia; [237]Global Health and Health Security, Taipei Medical University, Taipei, Taiwan; [238]International Society Doctors for the Environment, Arezzo, Italy; [239]University of Medicine and Pharmacy at Ho Chi Minh City, University of Medicine and Pharmacy at Ho Chi Minh City, Ho Chi Minh City, Viet Nam; [240]Department of Preventive Medicine, Korea University, Seoul, South Korea; [241]Department of Biomedical and Neuromotor Sciences, University of Bologna, Bologna, Italy; [242]Department of Health Promotion and Health Education, National Taiwan Normal University, Taipei, Taiwan; [243]Department of Pharmacy Management, Manipal Academy of Higher Education, Manipal, India; [244]School of Life Sciences, University of Technology Sydney, Ultimo, NSW, Australia; [245]Centre for Inflammation, Centenary Institute, Camperdown, NSW, Australia; [246]Lerner Research Institute, Cleveland Clinic, Cleveland, OH, USA; [247]Department of Quantitative Health Science, Case Western Reserve University, Cleveland, OH, USA; [248]Department of Internal Medicine, Kirk Kerkorian School of Medicine at UNLV, Las Vegas, NV, USA; [249]Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Matosinhos, Portugal; [250]Department of Pediatrics, Manipal Academy of Higher Education, Mangalore, India; [251]School of Pharmacy, University of the West Indies, St. Augustine, Trinidad and Tobago; [252]Planetary Health Alliance, Boston, MA, USA; [253]Department of Clinical and Hospital Pharmacy, Taibah University, Al-Madinah Al-Munawarrah, Saudi Arabia; [254]Rabigh Faculty of Medicine, King Abdulaziz University, Jeddah, Saudi Arabia; [255]University Institute of Public Health, The University of Lahore, Lahore, Pakistan; [256]Department of Clinical Pharmacy, Jouf University, Sakaka, Saudi Arabia; [257]Department of Maternal and Child Nursing and Public Health, Federal University of Minas Gerais, Belo Horizonte, Brazil; [258]Institute for Social Science Research, The University of Queensland, Indooroopilly, QLD, Australia; [259]Department of Midwifery, Hamadan University of Medical Sciences, Hamadan, Iran; [260]Department GF Ingrassia, University of Catania, Catania, Italy; [261]Department of Epidemiology and Biostatistics, University of the Philippines Manila, Manila, Philippines; [262]Department of Global Health, University of the Ryukyus, Nishihara, Japan; [263]Forensic Medicine Division, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia; [264]Center for Translation Research and Implementation Science, National Institutes of Health, Bethesda, MD, USA; [265]Department of Medicine, University of Cape Town, Cape Town, South Africa; [266]International Dx Department, BGI Genomics, Copenhagen, Denmark; [267]University Centre Varazdin, University North, Varazdin, Croatia; [268]Polish National Cancer Registry, Maria Sklodowska-Curie National Research Institute of Oncology, Warsaw, Poland; [269]Department of Pathology, Maria Sklodowska-Curie National Research Institute of Oncology, Warsaw, Poland; [270]College of Medicine, Taipei Medical University, Taipei, Taiwan; [271]Research Center for Artificial Intelligence in Medicine, Taipei Medical University, Taipei, Taiwan; [272]Internal Medicine Programme, Kyrgyz State Medical Academy, Bishkek, Kyrgyzstan; [273]Department of Atherosclerosis and Coronary Heart Disease, National Center of Cardiology and Internal Disease, Bishkek, Kyrgyzstan; [274]National Data Management Center for Health, Ethiopian

Public Health Institute, Addis Ababa, Ethiopia; [275]Department of Biomedical Sciences, Mercer University School of Medicine, Macon, GA, USA; [276]Health Systems and Policy Research Unit, Ahmadu Bello University, Zaria, Nigeria; [277]Department of Health Care Management, Technical University of Berlin, Berlin, Germany; [278]School of Medicine, Tehran University of Medical Sciences, Tehran, Iran; [279]Clinical Epidemiology and Public Health Research Unit, Burlo Garofolo Institute for Maternal and Child Health, Trieste, Italy; [280]Mater Research Institute, The University of Queensland, Brisbane, QLD, Australia; [281]Department of Clinical Pharmacy, Jimma University, Jimma, Ethiopia; [282]Department of Paediatrics and Paediatric Infectious Diseases, I.M. Sechenov First Moscow State Medical University, Moscow, Russia; [283]National Heart & Lung Institute, Imperial College London, London, UK; [284]Clinical Epidemiology Research Unit, Mexican Institute of Social Security, Villa de Alvarez, Mexico; [285]Postgraduate in Medical Sciences, Universidad de Colima, Colima, Mexico; [286]Department of Pediatrics, Shaqra University, Shaqra, Saudi Arabia; [287]Department of Pediatrics & Pediatric Pulmonology, Institute of Mother & Child Care, Multan, Pakistan; [288]Health Workforce Department, World Health Organisation, Geneva, Switzerland; [289]Suraj Eye Institute, Nagpur, India; [290]Mysore Medical College and Research Institute, Government Medical College, Mysore, India; [291]Department of Dental Public Health, King Abdulaziz University, Jeddah, Saudi Arabia; [292]Department of Health Policy and Oral Epidemiology, Harvard University, Boston, MA, USA; [293]Department of Pediatrics, Arak University of Medical Sciences, Arak, Iran; [294]Department of Psychological Medicine, National University of Singapore, Singapore, Singapore; [295]Geriatric Education and Research Institute, Geriatric Education and Research Institute, Singapore, Singapore; [296]Department of Biomedical Engineering, University of South Florida, Tampa, FL, USA; [297]Department of General Medicine, University of Medicine and Pharmacy at Ho Chi Minh City, Ho Chi Minh City, Viet Nam; [298]International Islamic University Islamabad, Islamabad, Pakistan; [299]Department of Medical Mycology and Parasitology, Shiraz University of Medical Sciences, Shiraz, Iran; [300]Department of Physiology, University of Benin, Edo, Nigeria; [301]Department of Physiology, Benson Idahosa University, Benin City, Nigeria; [302]Department of Applied Economics and Quantitative Analysis, University of Bucharest, Bucharest, Romania; [303]National Institute of Infectious Diseases, Center for Surveillance, Immunization, and Epidemiologic Research, Tokyo, Japan; [304]Center for Evidence-Based Medicine and Clinical Research, Dhaka, Bangladesh; [305]Health Promotion Research Center, Zahedan University of Medical Sciences, Zahedan, Iran; [306]School of Pharmacy, University of the Western Cape, Cape Town, South Africa; [307]Department of Medical Physiology, Babcock University, Ilisan-Remo, Nigeria; [308]Department of Medical Physiology, University of Lagos, Lagos, Nigeria; [309]Department of Psychiatry and Behavioural Neurosciences, McMaster University, Hamilton, ON, Canada; [310]Department of Psychiatry, University of Lagos, Lagos, Nigeria; [311]Slum and Rural Health Initiative Research Academy, Slum and Rural Health Initiative, Ibadan, Nigeria; [312]Institute of Family Medicine and Public Health, University of Tartu, Tartu, Estonia; [313]Section of Sustainable Health, Umeå University, Umea, Sweden; [314]Department of Respiratory Medicine, Jagadguru Sri Shivarathreeswara Academy of Health Education and Research, Mysore, India; [315]Department of Forensic Medicine and Toxicology, Manipal Academy of Higher Education, Mangalore, India; [316]Vision and Eye Research Institute, Anglia Ruskin University, Cambridge, UK;

[317]Department of Medical Humanities and Social Medicine, Kosin University, Busan, South Korea; [318]Global Health Governance Programme, University of Edinburgh, Edinburgh, UK; [319]School of Dentistry, University of Leeds, Leeds, UK; [320]College of Dental Medicine, Roseman University of Health Sciences, South Jordan, UT, USA; [321]Centre of Molecular Medicine and Diagnostics (COMManD), Saveetha University, Chennai, India; [322]Department of Internal Medicine, Advent Health, Palm Coast, FL, USA; [323]Hospital Medicine, Sound Physicians, Palm Coast, FL, USA; [324]Research Section, Nepal Health Research Council, Kathmandu, Nepal; [325]Faculty of Humanities and Social Sciences, Tribhuvan University, Kathmandu, Nepal; [326]Institute of Collective Health, Federal University of Bahia, Salvador, Brazil; [327]Department of Chemistry, University of Porto, Porto, Portugal; [328]Department of Statistics and Econometrics, Bucharest University of Economic Studies, Bucharest, Romania; [329]Department of Dermatology, College of Medicine and Sagore Dutta Hospital, Kolkata, India; [330]Medical College, Tairunnessa Memorial Medical College and Hospital, Gazipur, Bangladesh; [331]School of Public Health, University of Adelaide, Adelaide, SA, Australia; [332]School of medicine, Iran University of Medical Sciences, Tehran, Iran; [333]Department of Neonatology, Case Western Reserve University, Cleveland, OH, USA; [334]School of Engineering, Macquarie University, Sydney, NSW, Australia; [335]Pohang University of Science and Technology, Pohang, South Korea; [336]Cardiovascular Research Center, Tabriz University of Medical Sciences, Tabriz, Iran; [337]Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi, Bangladesh; [338]School of Nursing and Healthcare Professions, Federation University Australia, Berwick, VIC, Australia; [339]Future Technology Research Center, National Yunlin University of Science and Technology, Yunlin, Taiwan; [340]Department of Public Health, Torbat Jam Faculty of Medical Sciences, Torbat Jam, Iran; [341]Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi, India; [342]Department of Cardiology, Emory University, Atlanta, GA, USA; [343]Department of Community Medicine, Mahatma Gandhi Medical College and Research Institute, Puducherry, India; [344]Department of Nephrology, Manipal Academy of Higher Education, Manipal, India; [345]Department of Medicine, Jinnah Sindh Medical University, Karachi, Pakistan; [346]Department of Biomedical Engineering, Khulna University of Engineering and Technology, Khulna, Bangladesh; [347]School of Health and Society, University of Wollongong, Wollongong, NSW, Australia; [348]Pulmonary Critical Care, University of Chicago, Chicago, IL, USA; [349]Academic Public Health England, Public Health England, London, UK; [350]School of Health, Medical and Applied Sciences, CQ University, Sydney, NSW, Australia; [351]Department Biological Sciences, King Abdulaziz University, Jeddah, Egypt; [352]Department of Protein Research, Research and Academic Institution, Alexandria, Egypt; [353]Kist Medicial College and Teaching Hospital, Tribhuvan University, Kathmandu, Nepal; [354]Network of Immunity in Infection, Malignancy and Autoimmunity (NIIMA), Universal Scientific Education and Research Network (USERN), Tehran, Iran; [355]The Five Senses Health Institute, Iran University of Medical Sciences, Tehran, Iran; [356]Eye and Skull Base Research Centers, Rassoul Akram Hospital, Tehran, Iran; [357]Department of Epidemiology and Biostatistics, Rafsanjan University of Medical Sciences, Rafsanjan, Iran; [358]Deparment of Pharmacology and Toxicology, University of Antioquia, Medellin, Colombia; [359]Department of Clinical Research, Federal University of Uberlândia, Uberlândia, Brazil; [360]Clinical and Epidemiological Research

in Primary Care (GICEAP), Maimonides Biomedical Research Institute of Cordoba (IMIBIC), Cordoba, Spain; [361]Cardiovascular Department, Zagazig University, Zagazig, Egypt; [362]Sharjah Institute for Medical Research, University of Sharjah, Sharjah, United Arab Emirates; [363]Multidisciplinary Laboratory Foundation University School of Health Sciences (FUSH), Foundation University, Islamabad, Pakistan; [364]International Center of Medical Sciences Research (ICMSR), Islamabad, Pakistan; [365]Department of Psychosocial Science, University of Bergen, Bergen, Norway; [366]Sharjah Institute of Medical Sciences, University of Sharjah, Sharjah, United Arab Emirates; [367]Applied Biomedical Research Center, Mashhad University of Medical Sciences, Mashhad, Iran; [368]Biotechnology Research Center, Mashhad University of Medical Sciences, Mashhad, Iran; [369]Department of Development Studies, International Institute for Population Sciences, Mumbai, India; [370]Department of Statistics, University of Gujrat, Gujrat, Pakistan; [371]Institute for Employment Research, University of Warwick, Coventry, UK; [372]Department of Statistics, Ludwig Maximilians University, Munich, Germany; [373]Medical Laboratory, Azad University of Medical Sciences, Tehran, Iran; [374]Mark and Mary Stevens Neuroimaging and Informatics Institute, University of Southern California, Los Angeles, CA, USA; [375]Department of Entomology, Ain Shams University, Cairo, Egypt; [376]Medical Ain Shams Research Institute (MARSI), Ain Shams University, Cairo, Egypt; [377]School of Public Health and Health Management, University of Belgrade, Belgrade, Serbia; [378]Pharmacy Study Program, Udayana University, Badung, Indonesia; [379]Department of Clinical Pharmacy, Taipei Medical University, Taipei, Taiwan; [380]Social Determinants of Health Research Center, Mashhad University of Medical Sciences, Mashhad, Iran; [381]Department of Environmental Health Engineering, Tehran University of Medical Sciences, Tehran, Iran; [382]Department of Preventive and Social Medicine, Jawaharlal Institute of Postgraduate Medical Education and Research, Puducherry, India; [383]Emergency Department, Manian Medical Centre, Erode, India; [384]Office of Research and Innovation (ORIC-KRSS), University of Management and Technology, Lahore, Pakistan; [385]Independent Consultant, Karachi, Pakistan; [386]Department of Health Education and Promotion, Jazan University, Jazan, Saudi Arabia; [387]Centre for Medical Informatics, University of Edinburgh, Edinburgh, UK; [388]Division of General Internal Medicine, Harvard University, Boston, MA, USA; [389]Department of Cardiovascular Medicine, Cleveland Clinic, Cleveland, OH, USA; [390]National Institute of Infectious Diseases, Tokyo, Japan; [391]Department of International Studies, Non-Communicable Diseases Research Center (NCDRC), Tehran, Iran; [392]Faculty of Medicine, Tehran University of Medical Sciences, Tehran, Iran; [393]Medical-Surgical Nursing, Mazandaran University of Medical Sciences, Sari, Iran; [394]Department of Nursing and Health Sciences, Flinders University, Adelaide, SA, Australia; [395]Department of Pediatrics and Child Health Nursing, Dilla University, Dilla, Ethiopia; [396]School of Health, Victoria University of Wellington, Wellington, New Zealand; [397]Usher Institute, University of Edinburgh, Edinburgh, UK; [398]School of Medicine, University of Alabama at Birmingham, Birmingham, AL, USA; [399]Medicine Service, US Department of Veterans Affairs (VA), Birmingham, AL, USA; [400]Department of Radiodiagnosis, All India Institute of Medical Sciences, Bathinda, India; [401]Department of Pharmacology, All India Institute of Medical Sciences, Jodhpur, India; [402]Department of Pulmonary Medicine, Asthma Bhawan, Jaipur, India; [403]Maternal and Child Health Division, International Centre for Diarrhoeal Disease Research Bangladesh, Dhaka, Bangladesh; [404]Department of Infectious

Diseases and Epidemiology, Pirogov Russian National Research Medical University, Moscow, Russia; [405]Department of Nursing, Dire Dawa University, Dire Dawa, Ethiopia; [406]Department of Health Policy and Management, University of Georgia College of Public Health, Athens, GA, USA; [407]Public Health Department, Bukhara State Medical Institute, Bukhara, Uzbekistan; [408]Laboratory of Public Health Indicators Analysis and Health Digitalization, Moscow Institute of Physics and Technology, Moscow, Russia; [409]Hull York Medical School, University of Hull, Hull City, UK; [410]Department of Medicine, Democritus University of Thrace, Alexandroupolis, Greece; [411]Department of Dermatology, University of Colorado, Aurora, CO, USA; [412]Pathology Department, Alexandria University, Alexandria, Egypt; [413]Department of Epidemiology, Stellenbosch University, Cape Town, South Africa; [414]Department of Medicine, Northlands Medical Group, Omuthiya, Namibia; [415]Department of Surgery, National University of Singapore, Singapore, Singapore; [416]Department of Economics, Rice University, Houston, TX, USA; [417]Research and Innovation, Enventure Medical Innovation, Houston, TX, USA; [418]Outpatient Department, Wollega University, Bedele town, Ethiopia; [419]Department of Public Health, Wollega University, Nekemte, Ethiopia; [420]Health Management Department, Ariel University, Ariel, Israel; [421]Department of Pharmacology, All India Institute of Medical Sciences, Raipur, India; [422]Faculty of Public Health, Universitas Sam Ratulangi, Manado, Indonesia; [423]Nuffield Department of Primary Care Health Sciences, Oxford University, Oxford, UK; [424]School of Public Health and Social Work, Queensland University of Technology, Brisbane, QLD, Australia; [425]Health Informatics Department, Hanoi Medical University, Ha Noi, Viet Nam; [426]Department of Epidemiology and Biostatistics, Haramaya University, Haramaya, Ethiopia; [427]Department of Life Sciences, University of Management and Technology, Lahore, Pakistan; [428]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Faisalabad, Pakistan; [429]Department of Zoology, University of Education, Lahore, Lahore, Pakistan; [430]Division of Science and Technology, University of Education, Lahore, Pakistan; [431]Amity Institute of Biotechnology, Amity University Rajasthan, Jaipur, India; [432]Faculty Of Medicine, Tehran University of Medical Sciences, Tehran, Iran; [433]University Medical Center Groningen, University of Groningen, Groningen, Netherlands; [434]UKK Institute, Tampere, Finland; [435]Faculty of Medicine and Health Technology, Tampere University, Tampere, Finland; [436]Department of Surgery, General University Hospital of Patras, Patras, Greece; [437]College of Medicine and Veterinary Medicine, University of Edinburgh, Edinburgh, UK; [438]Department of Community Medicine, University of Porto, Porto, Portugal; [439]Evidence-Based Decision Making, Research Synthesis and Health Technology, Center for Health Technology and Services Research (CINTESIS), Porto, Portugal; [440]Department of Medical and Surgical Sciences, University of Bologna, Bologna, Italy; [441]Occupational Health Unit, Sant'Orsola Malpighi Hospital, Bologna, Italy; [442]Competence Center of Mortality-Follow-Up of the German National Cohort, Federal Institute for Population Research, Wiesbaden, Germany; [443]Department of community Medicine, Rajarata University of Sri Lanka, Anuradhapura, Sri Lanka; [444]Centre of Evidence-Based Dermatology, University of Nottingham, Nottingham, England; [445]Department of Pharmacology, Bahir Dar University, Bahir Dar, Ethiopia; [446]Pharmacy Department, Alkan Health Science, Business and Technology College, Bahir Dar, Ethiopia; [447]Department of Neuropsychopharmacology, National Center of Neurology and Psychiatry, Kodaira, Japan; [448]Department of

Public Health, Juntendo University, Tokyo, Japan; [449]Department of Epidemiology and Biostatistics, Wuhan University, Wuhan, China; [450]Department of Clinical Pharmacy and Outcomes Sciences, University of South Carolina, Columbia, SC, USA; [451]Urology and Nephrology Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [452]Department of Paediatrics & Child Health, University of Cape Town, Cape Town, South Africa; [453]Unit on Child & Adolescent Health, Medical Research Council South Africa, Cape Town, South Africa; [454]Research and Development Department, Sina Medical Biochemistry Technologies, Shiraz, Iran; [455]Department of Bioengineering and Therapeutic Sciences, University of California San Francisco, San Francisco, CA, USA; [456]Addictology Department, Russian Medical Academy of Continuous Professional Education, Moscow, Russia; [457]GI Med Oncology, University of Texas, Houston, FL, USA; [458]Department of Public Health, Dilla University, Dilla, Ethiopia; [459]School of Medicine, Wuhan University, Wuhan, China; [460]College of Traditional Chinese Medicine, Hebei University, Baoding, China; [461]Department of Nursing, Yasuj University of Medical Sciences, Yasuj, Iran; [462] Department of Pediatrics, Yonsei University College of Medicine, Seoul, South Korea; [463] Department of Pediatrics, Kyung Hee University College of Medicine, Seoul, South Korea.

Abbreviations:

GBD	Global Burden Disease
UI	uncertainty interval

Abbreviations

AD	Atopic dermatitis
DALYs	Disability-adjusted life years
GBD	Global Burden of Diseases
ICD	International Classification of Disease
SDI	socio-demographic index
ISAAC	International Study of Asthma and Allergies in Childhood
QoL	quality of life
95% UI	95% uncertainty interval
YLDs	Years lived with disability
YLLs	Years of life lost.

REFERENCES

1. Yang JM, Koh HY, Moon SY, et al. Allergic disorders and susceptibility to and severity of COVID-19: A nationwide cohort study. The Journal of allergy and clinical immunology 2020;146(4):790–798. [PubMed: 32810517]

2. Lee SW, Shin YH, Shin JI, et al. Fracture incidence in children after developing atopic dermatitis: A Korean nationwide birth cohort study. Allergy 2023;78(3):871–875. [PubMed: 36353744]
3. Pearce N, Sunyer J, Cheng S, et al. Comparison of asthma prevalence in the ISAAC and the ECRHS. ISAAC Steering Committee and the European Community Respiratory Health Survey. International Study of Asthma and Allergies in Childhood. The European respiratory journal 2000;16(3):420–426. [PubMed: 11028654]
4. Alavinezhad A, Boskabady MH. The prevalence of asthma and related symptoms in Middle East countries. The clinical respiratory journal 2018;12(3):865–877. [PubMed: 28544458]
5. Koo MJ, Kwon R, Lee SW, et al. National trends in the prevalence of allergic diseases among Korean adolescents before and during COVID-19, 2009–2021: A serial analysis of the national representative study. Allergy 2022.
6. Yaghoubi M, Adibi A, Safari A, FitzGerald JM, Sadatsafavi M. The Projected Economic and Health Burden of Uncontrolled Asthma in the United States. American journal of respiratory and critical care medicine 2019;200(9):1102–1112. [PubMed: 31166782]
7. Strachan DP. Family size, infection and atopy: the first decade of the “hygiene hypothesis”. Thorax 2000;55 Suppl 1(Suppl 1):S2–10. [PubMed: 10943631]
8. Schaub B, Lauener R, von Mutius E. The many faces of the hygiene hypothesis. The Journal of allergy and clinical immunology 2006;117(5):969–977; quiz 978. [PubMed: 16675321]
9. Carroll K Socioeconomic status, race/ethnicity, and asthma in youth. American journal of respiratory and critical care medicine 2013;188(10):1180–1181. [PubMed: 24236582]
10. Martinez A, de la Rosa R, Mujahid M, Thakur N. Structural racism and its pathways to asthma and atopic dermatitis. The Journal of allergy and clinical immunology 2021;148(5):1112–1120. [PubMed: 34743832]
11. Inselman JW, Jeffery MM, Maddux JT, Shah ND, Rank MA. Trends and Disparities in Asthma Biologic Use in the United States. The journal of allergy and clinical immunology In practice. 2020;8(2):549–554.e541. [PubMed: 31472294]
12. Laughter MR, Maymone MBC, Mashayekhi S, et al. The global burden of atopic dermatitis: lessons from the Global Burden of Disease Study 1990–2017. The British journal of dermatology 2021;184(2):304–309. [PubMed: 33006135]
13. Collaborators GCRD. Prevalence and attributable health burden of chronic respiratory diseases, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet Respiratory medicine 2020;8(6):585–596. [PubMed: 32526187]
14. Lee HH, Patel KR, Singam V, Rastogi S, Silverberg JI. A systematic review and meta-analysis of the prevalence and phenotype of adult-onset atopic dermatitis. Journal of the American Academy of Dermatology 2019;80(6):1526–1532.e1527. [PubMed: 29864464]
15. Collaborators GD. 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 (London, England) 2020;396(10258):1160–1203. [PubMed: 33069325]
16. Smith L, Shin JI, Hwang SY, et al. Global Burden of Disease study at the World Health Organization: research methods for the most comprehensive global study of disease and underlying health policies. Life Cycle 2022;2:e8.
17. Woo A, Lee SW, Koh HY, Kim MA, Han MY, Yon DK. Incidence of cancer after asthma development: 2 independent population-based cohort studies. The Journal of allergy and clinical immunology 2021;147(1):135–143. [PubMed: 32417133]
18. Lee SW, Yon DK, James CC, et al. Short-term effects of multiple outdoor environmental factors on risk of asthma exacerbations: Age-stratified time-series analysis. The Journal of allergy and clinical immunology 2019;144(6):1542–1550.e1541. [PubMed: 31536730]
19. Vos T, Lim SS, Abbafati C, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet 2020;396(10258):1204–1222.
20. Collaborators GDaIIaP. 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 (London, England) 2018;392(10159):1789–1858. [PubMed: 30496104]

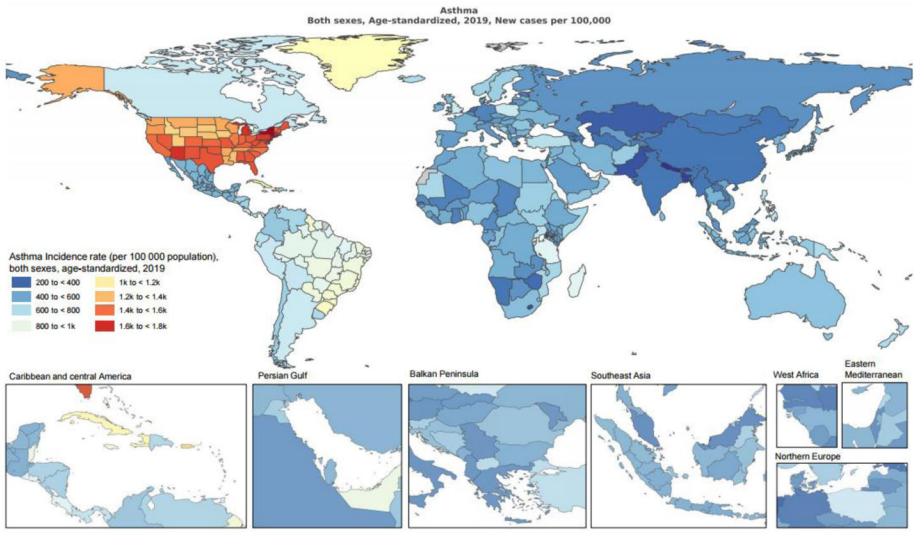
21. Murray CJL, Aravkin AY, Zheng P, et al. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet 2020;396(10258):1223–1249.
22. Collaborators GRF. Population-level risks of alcohol consumption by amount, geography, age, sex, and year: a systematic analysis for the Global Burden of Disease Study 2020. Lancet (London, England) 2022;400(10347):185–235. [PubMed: 35843246]
23. Barbarot S, Auziere S, Gadkari A, et al. Epidemiology of atopic dermatitis in adults: Results from an international survey. Allergy 2018;73(6):1284–1293. [PubMed: 29319189]
24. Enilari O, Sinha S. The Global Impact of Asthma in Adult Populations. Annals of global health 2019;85(1). [PubMed: 31225954]
25. Smirnova J, Montgomery S, Lindberg M, Svensson Å, von Kobyletzki L. Associations of self-reported atopic dermatitis with comorbid conditions in adults: a population-based cross-sectional study. BMC dermatology 2020;20(1):23. [PubMed: 33334332]
26. 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 (London, England) 2006;368(9537):733–743. [PubMed: 16935684]
27. Asher MI, García-Marcos L, Pearce NE, Strachan DP. Trends in worldwide asthma prevalence. The European respiratory journal 2020;56(6).
28. Asher MI, Rutter CE, Bissell K, et al. Worldwide trends in the burden of asthma symptoms in school-aged children: Global Asthma Network Phase I cross-sectional study. Lancet (London, England) 2021;398(10311):1569–1580. [PubMed: 34755626]
29. To T, Stanojevic S, Moores G, et al. Global asthma prevalence in adults: findings from the cross-sectional world health survey. BMC public health 2012;12:204. [PubMed: 22429515]
30. Aaron SD, Boulet LP, Reddel HK, Gershon AS. Underdiagnosis and Overdiagnosis of Asthma. American journal of respiratory and critical care medicine 2018;198(8):1012–1020. [PubMed: 29756989]
31. 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. The journal of allergy and clinical immunology In practice 2021;9(10):3819–3820. [PubMed: 34627538]
32. Cloutier MM, Baptist AP, Blake KV, et al. 2020 Focused Updates to the Asthma Management Guidelines: A Report from the National Asthma Education and Prevention Program Coordinating Committee Expert Panel Working Group. The Journal of allergy and clinical immunology 2020;146(6):1217–1270. [PubMed: 33280709]
33. Cho YM, Kim CB, Yeon KN, Lee ES, Kim K. Trends in the Prevalence of Childhood Asthma in Seoul Metropolitan City, Korea: The Seoul Atopy · Asthma-friendly School Project. Journal of preventive medicine and public health = Yebang Uihakhoe chi 2018;51(6):275–280. [PubMed: 30514057]
34. Williams H, Stewart A, von Mutius E, Cookson W, Anderson HR. Is eczema really on the increase worldwide? The Journal of allergy and clinical immunology 2008;121(4):947–954.e915. [PubMed: 18155278]
35. Gibson PG, McDonald VM, Marks GB. Asthma in older adults. Lancet (London, England) 2010;376(9743):803–813. [PubMed: 20816547]
36. Deckers IA, McLean S, Linssen S, Mommers M, van Schayck CP, Sheikh A. Investigating international time trends in the incidence and prevalence of atopic eczema 1990–2010: a systematic review of epidemiological studies. PloS one 2012;7(7):e39803. [PubMed: 22808063]
37. Cruz ÁA, Stelmach R, Ponte EV. Asthma prevalence and severity in low-resource communities. Current opinion in allergy and clinical immunology 2017;17(3):188–193. [PubMed: 28333691]
38. Cooper PJ, Rodrigues LC, Cruz AA, Barreto ML. Asthma in Latin America: a public heath challenge and research opportunity. Allergy 2009;64(1):5–17. [PubMed: 19076533]

39. Lenney W, Bush A, Fitzgerald DA, et al. Improving the global diagnosis and management of asthma in children. Thorax 2018;73(7):662–669.

40. Østergaard MS, Nantanda R, Tumwine JK, Aabenhus R. Childhood asthma in low income countries: an invisible killer? Primary care respiratory journal : journal of the General Practice Airways Group 2012;21(2):214–219.

41. Woods ER, Bhaumik U, Sommer SJ, et al. Community Asthma Initiative to Improve Health Outcomes and Reduce Disparities Among Children with Asthma. MMWR supplements 2016;65(1):11–20. [PubMed: 26916259]

(A)



(B)

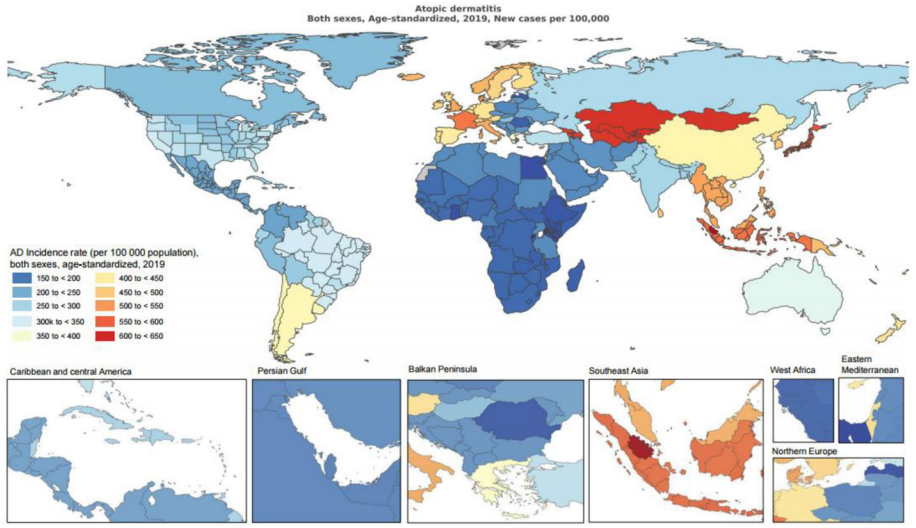


Figure 1.

Global distribution of the age-standardized prevalence rates of asthma (A) and atopic dermatitis (B). AD=atopic dermatitis.

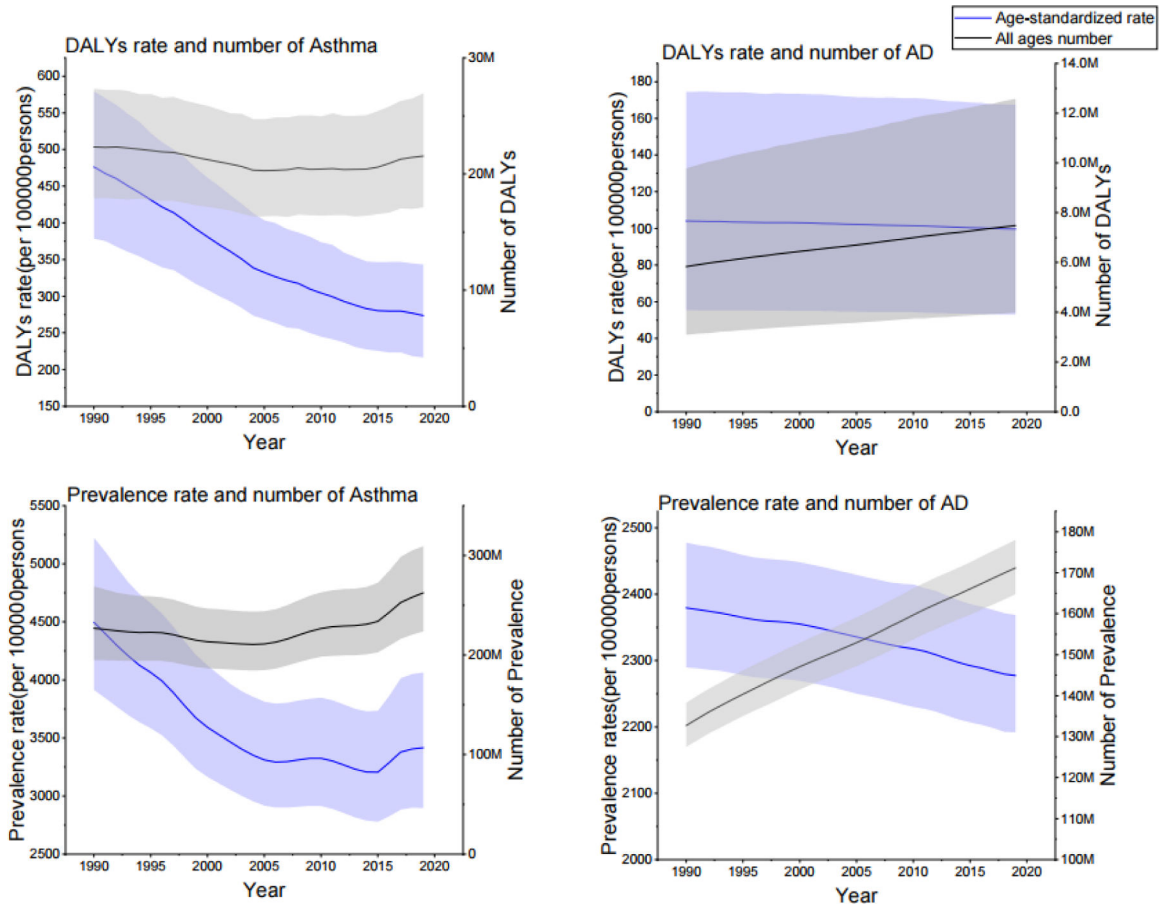


Figure 2.

Global prevalence and disability-adjusted life years of asthma and atopic dermatitis, 1990–2019. AD=atopic dermatitis. DALYs=disability-adjusted life years.

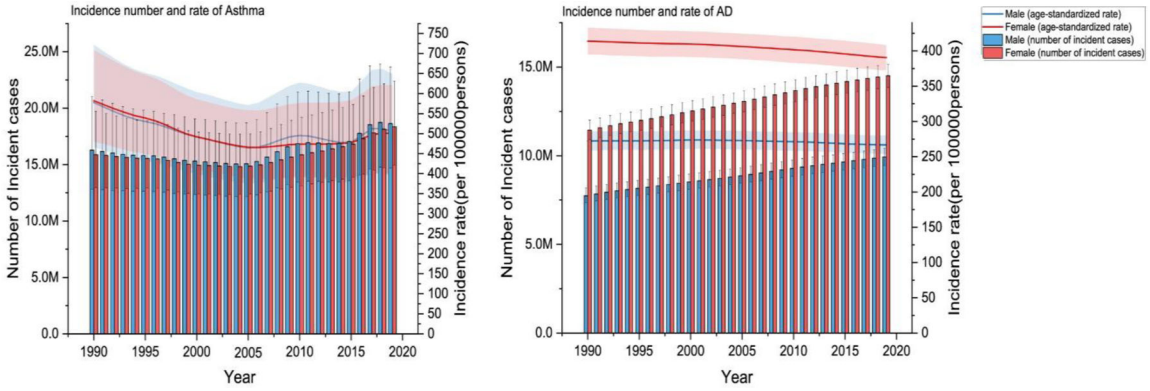


Figure 3.

Total number of incident cases and global incidence rates of asthma (left) and atopic dermatitis (right) by sex, 1990–2019.

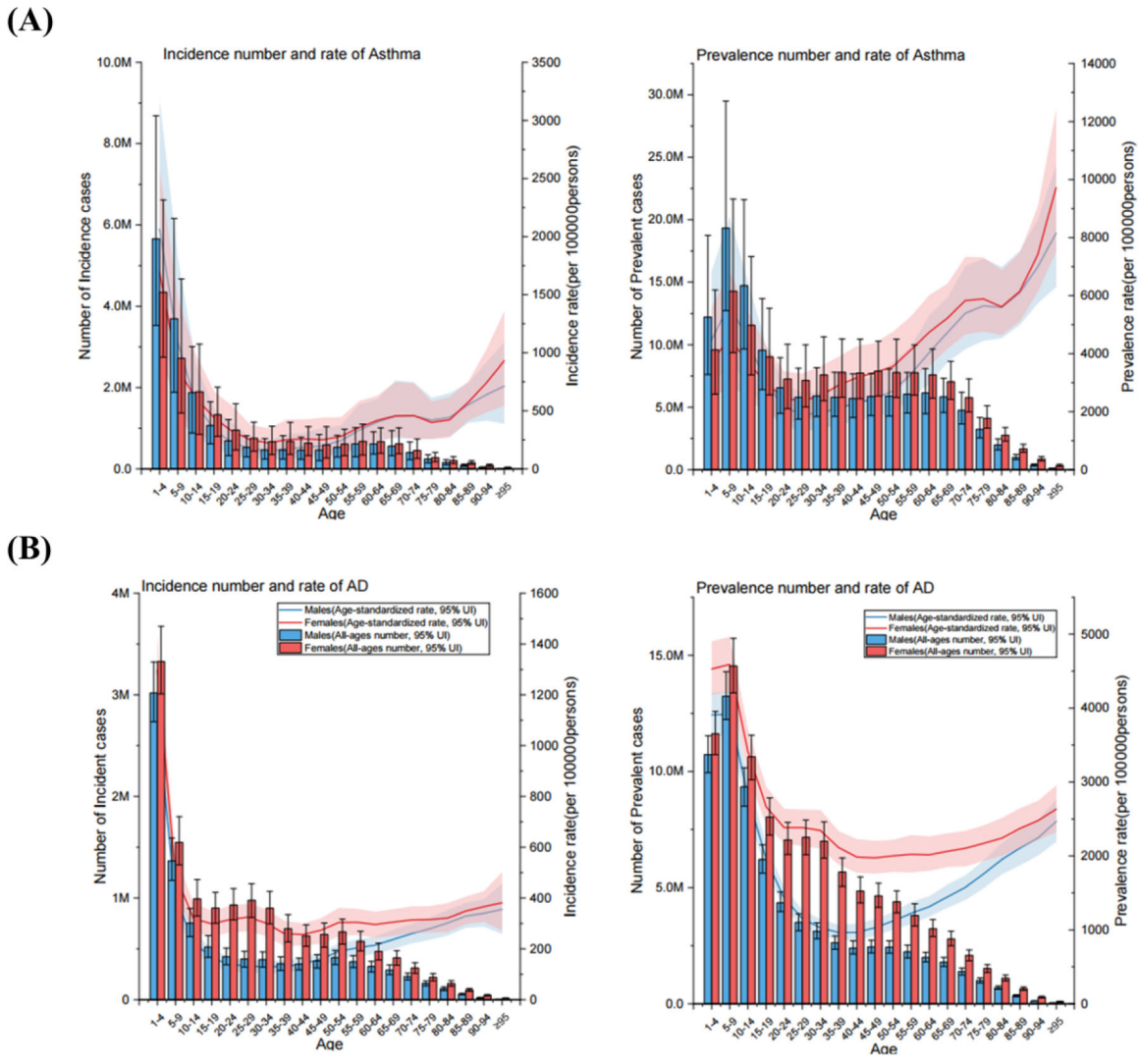


Figure 4.

Total number of prevalent cases and global prevalence rates of asthma (A) and atopic dermatitis (B) by age, 1990–2019.

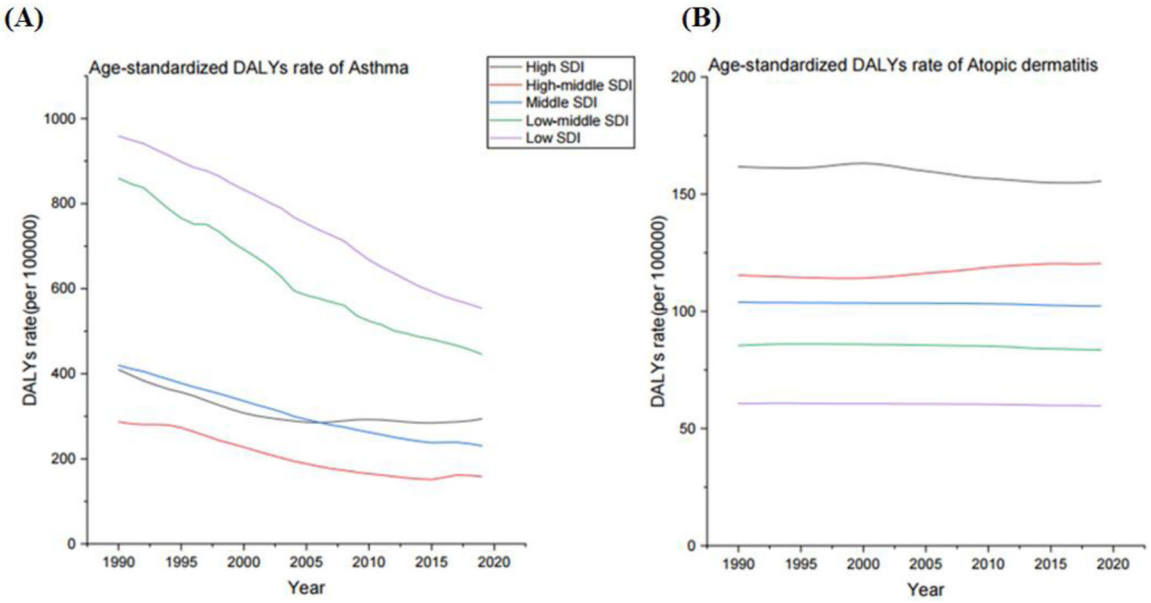
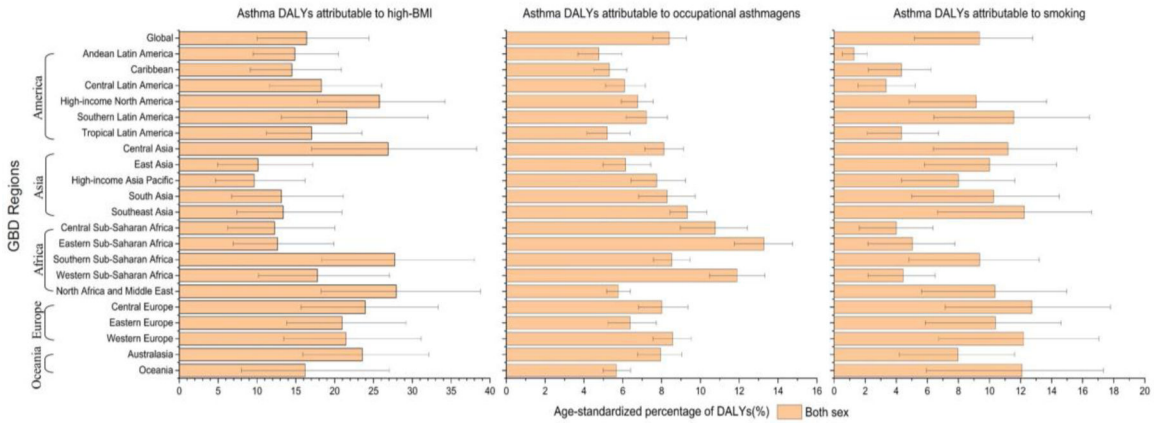


Figure 5.

Age-standardized DALYs rates of asthma (A) and atopic dermatitis (B) according to SDI, 1990–2019. DALYs, disability-adjusted life years; SDI, socio-demographic index.

(A)



(B)

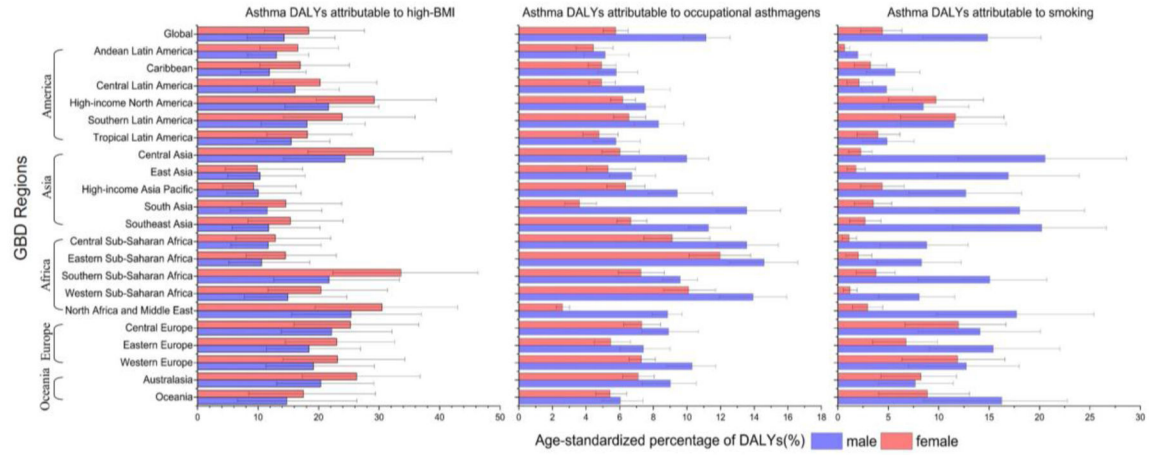


Figure 6.

Percentage of age-standardized DALYs rates of asthma attributable to high BMI, occupational asthmagens, and smoking by geographic region, total (A) and sex-stratified (B). BMI, body mass index; DALYs, disability-adjusted life years.