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Burden of diseases attributable to excess body weight in 204 countries and territories, 1990–2019

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Abstract

Background To investigate the global, regional, and national burden of the diseases attributable to excess body weight (EBW) from 1990 to 2019, stratified by age, sex, underlying cause, and sociodemographic index (SDI).

Methods Using the Comparative Risk Assessment approach of the Global Burden of Disease (GBD) study 2019, the burden of diseases attributable to EBW was reported for the period from 1990 to 2019. For adults, EBW was defined as a body mass index (BMI) exceeding 25 kg/m^2, while for children aged 1 to 19 years, EBW was determined according to the standards set by the International Obesity Taskforce. The burden was reported in terms of numbers, proportions, and age-standardised rates per 100,000, accompanied by corresponding 95% uncertainty intervals (UIs).

Results In 2019, there were an estimated 5.0 million deaths (95% UI: 3.2–7.1) and 160.3 million DALYs (106.0–218.9) attributable to EBW worldwide. The age-standardised DALY rate attributable to EBW increased by 18.0% (2.2–42.3) from 1990 to 2019, with notable regional variations. Southeast Asia and South Asia exhibited the highest age-standardised DALY rates. Conversely, the age-standardised death rate due to EBW showed no significant change, with an increase of 4.9% (-7.3 to 24.6) over the same period. Significant regional variations were again observed, particularly in Southeast Asia and South Asia, which recorded the highest age-standardised death rates. Moreover, a non-linear association was observed between the SDI and the regional age-standardised DALY rate of diseases attributable to EBW.

Conclusions The global burden of EBW has increased over the past three decades. This trend aligns with sociodemographic indices and is influenced by the physical activity levels and dietary habits of these populations.

Keywords Obesity, Overweight, Death, Mortality, Prevalence, Incidence, Disability-adjusted life-year

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What is already known about this subject?

- EBW results from a long-term positive energy balance, where energy intake exceeds energy expenditure, with contributing factors including genetics, age, and habitual behaviours.
- Overweight and obesity are linked to numerous health complications and pose a significant burden on individuals and societies, with EBW contributing to millions of deaths and disability-adjusted life years (DALYs) globally.

What are the new findings in your manuscript?

- In 2019, an estimated 5.0 million deaths (95% UI: 3.2–7.1) and 160.3 million DALYs (106.0–218.9) were attributable to EBW worldwide.
- The age-standardised DALY rate due to EBW increased by 18.0% (2.2–42.3) from 1990 to 2019.

How might your results change the direction of research or the focus of clinical practice?

- The substantial global burden of diseases attributable to EBW underscores the need for intensified research into effective prevention and intervention strategies targeting obesity and related health conditions.
- The findings can guide policymakers in allocating resources and designing targeted public health policies that address the socio-economic determinants of obesity, especially in high-risk regions.

Introduction

The terms "overweight" and "obesity", collectively referred to as excess body weight (EBW), indicate a body weight that is higher than what is considered normal or healthy for a person of a certain height, usually determined using the body mass index (BMI) [2]. A high BMI results from a long-term positive energy balance, where energy intake exceeds energy expenditure [2]. Furthermore, the interplay of many factors, including genetics, age and habitual behaviours, also contributes to an increase in BMI [2].

Research has shown that overweight and obesity are linked to numerous complications and impose a considerable burden on individuals and society globally [4]. In 2017, EBW was estimated to have contributed to 2.4 million deaths and 70.7 million disability-adjusted life years (DALYs) in females, and 2.3 million deaths and 77.0 million DALYs in males [4]. Furthermore, projections estimate that the economic cost of obesity could rise from 1.8% of gross domestic product (GDP) in 2019 to 3.6% by 2060 [5].

Given the numerous health issues attributable to EBW, it is important to provide a comprehensive overview of the burden across countries worldwide. Previous studies have evaluated the global burden of various diseases attributable to EBW, including non-communicable diseases [6], osteoarthritis [2], cancers [7, 8], type 2 diabetes [9], stroke [10], and asthma [11]. However, none of these studies have investigated the total burden attributable to EBW at the global level. Moreover, a previous study [4] reported the global burden of EBW using an earlier iteration of the Global Burden of Diseases (GBD) study, which now requires updating. This study aims to update the global burden of diseases attributable to EBW, providing essential data for policymakers and public health officials to design targeted interventions. Therefore, the present work employs the Comparative Risk Assessment approach from GBD 2019 to provide the most current and comprehensive information on the global, regional and national burden of EBW, stratified by age, sex, underlying cause, and SDI.

Methods

Overview

The Global Burden of Disease (GBD) project, which is administered by the Institute for Health Metrics and Evaluation (IHME), monitors the burden of diseases and injuries across the world. GBD 2019 monitored 87 risk factors in over 200 countries, seven super-regions, and 21 regions from 1990 to 2019 [12]. In GBD 2019, the Comparative Risk Assessment approach was used to calculate the burden of diseases due to EBW. A precise description of the methodology used in GBD 2019 to model the burden of disease attributable to EBW is available elsewhere [12–14]. The raw data can be obtained from the following websites: https://vizhub.healthdata.org/gbd-compare/ and http://ghdx.healthdata.org/gbd-results-tool).

Case definition and data sources

For adults (aged 20 years and above), EBW was defined as a BMI exceeding 25 kg/m^2, while for children aged 1 to 19 years, EBW were determined in accordance with the standards set by the International Obesity Taskforce [14]. Additional data were incorporated into GBD 2019 from sources included in the Global Health Data Exchange (GHDx) yearly update. In order to establish prevalence estimates of overweight and obesity, or mean BMI, a systematic review was conducted as a part of GBD 2017, as reported elsewhere [14]. This review included studies with nationally or sub-nationally representative figures. In summary, the systematic literature search was confined to articles published between January 1, 2016, and

December 31, 2016, with the aim of updating the literature search conducted for GBD 2015 [14]. The systematic literature search included only studies that provided data on the mean BMI or the prevalence of overweight or obesity. For those over 20 years old, overweight was defined as having a BMI of more than 25 kg/m2, while obesity was having a BMI that was higher than 30 kg/m2. For those aged 1 to 19 years, classifications of overweight or obesity followed the standards set by the International Obesity Taskforce [14]. Studies were excluded if they employed non-random sampling, focused on specific subpopulations, utilised alternative adiposity assessment methods, had fewer than 20 participants per age-sex group, were not published in English, or lacked sufficient information to meet any of the inclusion criteria [14]. Studies were also omitted if they used the World Health Organization (WHO) or country-specific thresholds to define childhood overweight or obesity.

The literature derived data included several key parameters: mean BMI, prevalence of overweight and obesity, along with corresponding measures of uncertainty and sample sizes for each parameter. These data were stratified by the most detailed age and sex groups. Furthermore, study level covariates were collected, encompassing microdata details such as measurement methods, urbanicity, representativeness, and location [14]. In addition, the extracted data included survey-design variables, such as the primary sampling unit, strata, and survey weights.

Data process and modelling

The approach employed by Ng and colleagues [15] was applied to separate all data that used age groups wider than five years or did not report separate figures for males and females. An assessment was conducted to identify any potential bias in self-reported data when compared to measured data. Given the absence of a clear bias direction for individuals aged 2 to 14 years, only measured data were included for this age range. For those aged 15 years and above, adjustments were made to self-reported data regarding the prevalence of overweight and obesity using sex-specific MR-BRT models, with the logit difference between measured and self-reported data fitted as a fixed effect at the super-region level. The adjustment for self-reported data and age-sex stratification in calculating overweight and obesity was achieved using spatiotemporal Gaussian process regression (ST-GPR) [14].

The covariates used in the random-effects model consisted of per capita energy consumption, per capita SDI, the number of two- or four-wheel vehicles per capita, and the proportion of the population engaged in agricultural work [14]. A nested hierarchical mixed-effects model was applied to determine the mean BMI for adults across different countries, age ranges, time periods and sexes. In addition, to estimate the BMI distribution for each country, year, age group, and sex, IHME employed the ensemble distribution approach, which involved 1000 draws of the estimated mean BMI, standard deviation, and ensemble weights [14].

Data on estimated relative risk

To identify and assess risk-outcome associations, a comprehensive review of published meta-analyses, pooled analyses, and systematic reviews was undertaken using the PubMed database [14]. The inclusion criteria required that the health outcome be a part of the GBD study, include at least one prospective cohort study, and have a statistically significant pooled effect size [14].

The Theoretical Minimum Risk Exposure Level (TMREL) for adult BMI represents the BMI level that minimises risk for individuals aged 20 and above. This level was determined based on the lowest risk of all-cause mortality observed in prospective cohort studies [14]. For children, the TMREL was defined as "normal weight" according to the standards set by the International Obesity Taskforce standards [14].

The relative risk associated with each five-unit change in BMI for different diseases was derived from meta-analyses or pooled analyses of prospective observational studies, when available. In cases where such data were not available, a dose–response meta-analysis utilising the two-step generalised least squares method for time trend estimation was employed. To quantify the disease burden linked to high BMI, population-attributable fractions (PAF) were calculated for each country, age group, sex, and year [14].

Estimation of the proportion of disease attributable to high BMI

The calculation of deaths and DALYs associated with high BMI involved multiplying the PAFs by the total number of deaths or DALYs reported in GBD 2019 for each country, age range, sex, year, and disease type. To evaluate a population's exposure to a risk factor, while considering both the extent of exposure across various risk levels and the impact on disease prevalence, IHME used the summary exposure value (SEV). The SEV ranges from 0% (indicating absence of elevated risk exposure) to 100% (representing the highest possible risk exposure) [12, 14]. Furthermore, 95% uncertainty intervals (UIs) were calculated for each estimate by running 1000 draws at each stage of the modelling process, with the UIs being the 25th and 975th values of the numerically ordered draws [16].

All estimates were standardised using the GBD standard population and were presented as numerical counts, proportions (PAFs), and age-standardised rates per 100,000, accompanied by 95% UIs. In addition to these analyses, the present study explored the relationship between the DALYs attributed to high BMI and the SDI. The SDI is a summary measure of a country's sociodemographic development and is comprised of the average income per person, educational attainment, and total fertility rate. The SDI ranges from 0 (least developed) to 1 (most developed). The GATHER Statement was used to guide the reporting of this study.

Results

Global level

In 2019, globally there were an estimated 5 million deaths (95% UI: 3.2 to 7.1) attributable to EBW, which represented 8.9% (5.7 to 12.5) of all disease-related deaths (Table 1). This estimate was comprised of 2.5 million (1.5 to 3.6) deaths among males and an equivalent 2.5 million (1.7 to 3.6) among females (Table S1). The overall age-standardised death rate in 2019 for all diseases attributable to EBW was 62.6 (39.9 to 89.1) per 100,000 population, which was not significantly different from the rate in 1990 (4.9% [-7.3 to 24.6]) (Table 1). In 2019, the estimated age-standardised death rates from all diseases attributable to EBW among males and females were 66.6 (39.8 to 97.2) and 58.1 (38.5 to 81.4), respectively (Table S1).

In 2019, EBW contributed to an estimated 160.3 million DALYs (106.0 to 218.9) and accounted for 6.3% (4.2 to 8.6) of all disease-related DALYs (Table 1). This burden was comprised of 82.8 (52.8 to 115.1) million DALYs in males and 77.4 (53.2 to 104.6) million DALYs in females (Table S2). In 2019, the overall age-standardised DALY rate of diseases attributable to EBW was 1932.5 (1276.6 to 2639.7) per 100,000 population, which was 28.0% (2.2 to 42.3) higher than in 1990 (Table 1). The overall age-standardised DALY rate of diseases attributable to EBW in 2019 was comprised of 2070.3 (1311.9 to 2888.8) among males and 1789.7 (1228.7 to 2417.1) among females (Table S2).

Regional level

In 2019, the total number of estimated deaths attributable to EBW were highest in East Asia (788,055 [344593 to 1348577]), South Asia (733,499 [435377 to 1063147]), and North Africa and Middle East (538,448 [369917 to 712329]). In contrast, the lowest numbers were found in Oceania (10,617 [6263 to 16311]), Australasia (22,338 [14173 to 312242]), and Central Sub-Saharan Africa (33,914 [18519 to 52564]) (Table 1). The proportion of all disease-related deaths (PAFs) that were attributable to EBW ranged from 3.7% to 17.4%. The North Africa and Middle East (17.4% [12.2 to 22.5]), Central Asia (17.1% [11.6 to 22.9]), and Eastern Europe (16.1% [10.7 to 21.9]) regions had the three highest PAFs, while the lowest were found in Eastern Sub-Saharan Africa (3.7% [2.2 to 5.4]), Western Sub-Saharan Africa (3.7% [2.3 to 5.2]), and Central Sub-Saharan Africa (3.9% [2.2 to 5.7]) (Table 1).

The age-standardised death rates for all diseases attributable to EBW in 2019 were highest in Central Asia (163.2 [107.7 to 223.6]), Oceania (139.1 [78.7 to 217.9]), and North Africa and Middle East (133.6 [90.0 to 179.0]). The lowest rates were observed in high-income Asia Pacific (14.7 [6.0 to 26.2]), Western Europe (39.5 [24.2 to 57.4]), and East Asia (40.3 [17.4 to 70.2]) (Table S3). There were only six GBD regions whose age-standardised death rates had increased since 1990, with the largest increases being observed in Southeast Asia (121.8% [56.0 to 301.0]), South Asia (113.4% [48.3 to 283.2]), and Western Sub-Saharan Africa (64.8% [26.1 to 149.8]) (Table 1). In addition, four GBD regions had decreases in the age-standardised death rates since 1990, with the largest decreases observed in high-income Asia Pacific (-41.0% [-48.1 to -25.0]), Australasia (-35.6% [-42.7 to -22.1]), and Western Europe (-34.8% [-40.2 to -26.4]) (Table 1). Figure S1 shows the number of deaths attributable to EBW from 1990 to 2019. Additionally, Figure S2 presents the age-standardised death rates of diseases attributable to EBW (per 100,000) in 2019, while Figure S3 illustrates the changes in these rates from 1990 to 2019.

In 2019, the total number of DALYs attributable to EBW were estimated to be the highest in South Asia (26,616,248 [16084057 to 37385029]), East Asia (25,604,542 [12117005 to 41896834]), and North Africa and Middle East (17,887,734 [12867706 to 23,131,993). The lowest number of DALYs were estimated in Oceania (419,945 [259662 to 615431]), Australasia (623,988 [416435 to 842581]), and Andean Latin America (1,185,179 [826956 to 1604803]) (Table 1). The proportion of DALYs that were attributable to EBW ranged from 1.8% to 13.6%. Central Europe (13.6% [9.6 to 17.7]), Eastern Europe (12.6% [8.7 to 16.7]) and Central Asia (12.0% [8.4 to 15.6]) had the three highest PAFs, while the lowest were found in Western Sub-Saharan Africa (1.8% [1.2 to 2.5]), Eastern Sub-Saharan Africa (2.0% [1.2 to 2.8]), and Central Sub-Saharan Africa (2.1% [1.2 to 3.0]) (Table 1).

In 2019, the age-standardised DALY rates of the diseases attributable to EBW (per 100,000) were highest in Oceania (4543.3 [2835.7 to 6902.6]), Central Asia (4303.6 [2988.6 to 5696.9]), and North Africa and Middle East (3777.2 [2692.6 to 4943.3]) regions. Conversely, the lowest rates were found in high-income Asia Pacific (576.3 [255.4 to 972.4]), East Asia (1226.2 [574.6 to 2015.6]), and Western Europe (1258.7 [793.5 to 1767.7]) (Table S4).

Table 1 Deaths and DALYs attributable to high body mass index in 2019 by GBD region

	Deaths (95% UI)				DALY (95% UI)			
	Counts (2019)	PAF (2019)	ASRs (2019)	% change in ASRs1990-2019	Counts (2019)	PAF (2019)	ASRs (2019)	% change in ASRs1990-2019
Global	5019360 (3223364 , 7110736)	8.9 (5.7 , 12.5)	62.6 (39.9 , 89.1)	4.9 (-7.3 , 24.6)	160265357 (105969034 , 218870439)	6.3 (4.2 , 8.6)	1932.5 (1276.6 , 2639.7)	18 (2.2 , 42.3)
High-income Asia Pacific	73120 (28472 , 136625)	4.2 (1.6 , 7.8)	14.7 (6 , 26.2)	-41 (-48.1 , -25)	2091826 (911107 , 3616817)	4.2 (1.8 , 7.1)	576.3 (255.4 , 972.4)	-26 (-35.1 , -5.3)
High-income North America	423730 (275550 , 570055)	13.1 (8.5 , 17.6)	65.6 (43.7 , 86.7)	-7.8 (-17 , 7.5)	13371872 (9227608 , 17294594)	11.1 (7.8 , 13.9)	2374.4 (1669.1 , 3051.6)	4.8 (-5.2 , 22.9)
Western Europe	405590 (242188 , 602633)	9.5 (5.7 , 14)	39.5 (24.2 , 57.4)	-34.8 (-40.2 , -26.4)	10088353 (6278366 , 14258435)	8 (5.1 , 11)	1258.7 (793.5 , 1767.7)	-23.4 (-30.6 , -12)
Australasia	22338 (14173 , 31242)	10.9 (6.9 , 15.2)	42.1 (27.1 , 58.4)	-35.6 (-42.7 , -22.1)	623988 (416435 , 842581)	8.3 (5.6 , 11)	1390.2 (948 , 1867.3)	-23.5 (-32.5 , -8.3)
Andean Latin America	36792 (23628 , 51483)	11.5 (7.7 , 15.4)	66.5 (42.5 , 93.3)	13 (-10.8 , 53.8)	1185179 (826956 , 1604803)	7.6 (5.3 , 9.8)	2050.4 (1426.7 , 2780.2)	12.9 (-7.6 , 46)
Tropical Latin America	182760 (127418 , 243771)	12.6 (8.8 , 16.8)	76.4 (53.2 , 102.6)	-8.8 (-22.1 , 17.2)	5972241 (4308187 , 7744330)	8.9 (6.5 , 11.5)	2409.7 (1731.4 , 3128.1)	-5.6 (-18.9 , 20.1)
Central Latin America	206605 (133942 , 285743)	14.4 (9.5 , 19.3)	88.5 (57 , 122.9)	16.9 (-0.6 , 42.3)	7120347 (4849320 , 9559927)	10.7 (7.4 , 13.8)	2918.4 (1979 , 3924.5)	21 (5.6 , 43.2)
Southern Latin America	53996 (33192 , 76847)	10.9 (6.8 , 15.5)	64.2 (39.7 , 90.8)	-9 (-21.5 , 17.7)	1527234 (983827 , 2091664)	8.4 (5.4 , 11.4)	1886.3 (1215.1 , 2574.7)	-2.5 (-15.7 , 25.7)
Caribbean	44096 (27954 , 62438)	11.6 (7.7 , 15.9)	84.8 (53.7 , 120.2)	6.7 (-10.6 , 31.8)	1455601 (981730 , 1964739)	8.7 (6 , 11.4)	2816.7 (1904.8 , 3796.9)	14.5 (-2.7 , 38.1)
Central Europe	213369 (141572 , 293255)	15.5 (10.5 , 21.2)	98.5 (66 , 134.9)	-25.6 (-35.2 , -13.4)	5524972 (3897786 , 7319591)	13.6 (9.6 , 17.7)	2771.1 (1976.6 , 3638)	-22 (-31 , -10.5)
Eastern Europe	439688 (288009 , 602882)	16.1 (10.7 , 21.9)	129 (85.1 , 176.1)	8 (-6.3 , 25.3)	11199973 (7613493 , 14923535)	12.6 (8.7 , 16.7)	3406.9 (2336.4 , 4514.5)	9.5(-3.8 , 26.5)
Central Asia	109112 (73663 , 146382)	17.1 (11.6 , 22.9)	163.2 (107.7 , 223.6)	37.3 (22.3 , 59.6)	3412227 (2388581 , 4453832)	12 (8.4 , 15.6)	4303.6 (2988.6 , 5696.9)	31.9 (17.6 , 52.5)
North Africa and Middle East	538448 (369917 , 712329)	17.4 (12.2 , 22.5)	133.6 (90 , 179)	5.1 (-9 , 25.9)	17887734 (12867706 , 23131993)	10.9 (7.9 , 13.9)	3777.2 (2692.6 , 4943.3)	8.3 (-6.5 , 28.8)
South Asia	733499 (435377 , 1063147)	6.1 (3.7 , 8.9)	52.8 (30.9 , 77.9)	113.4 (48.3 , 283.2)	26616248 (16084057 , 37385029)	4.3 (2.7 , 6.1)	1729.7 (1043.5 , 2440.6)	132.9 (61.8 , 306.8)
Southeast Asia	411963 (251454 , 591585)	9.4 (5.8 , 13.2)	66.5 (39.7 , 97.6)	121.8 (56 , 301)	14997502 (9547594 , 20899509)	7.6 (4.9 , 10.4)	2202 (1382.8 , 3086.5)	125.4 (61.6 , 293.7)
East Asia	788055 (344593 , 1348577)	7.1 (3.3 , 11.9)	40.3 (17.4 , 70.2)	33.7 (-3.2 , 161.3)	25604542 (12117005 , 41896834)	6.4 (3.2 , 10.3)	1226.2 (574.6 , 2015.6)	42.3 (1.8 , 186.9)
Oceania	10617 (6263 , 16311)	10.9 (6.8 , 15.6)	139.1 (78.7 , 217.9)	22.1 (-0.3 , 55.4)	419945 (259662 , 615431)	7.4 (4.7 , 10.3)	4643.3 (2835.7 , 6902.6)	25.5 (4.3 , 56)

Table 1 (continued)

	Deaths (95% UI)				DALY (95% UI)			
	Counts (2019)	PAF (2019)	ASRs (2019)	% change in ASRs1990-2019	Counts (2019)	PAF (2019)	ASRs (2019)	% change in ASRs1990-2019
Western Sub-Saharan Africa	127861 (80511 , 182457)	3.7 (2.3 , 5.2)	70.4 (43.1 , 102.2)	64.8 (26.1 , 149.8)	4471394 (2958805 , 6221599)	1.8 (1.2 , 2.5)	2033.7 (1313.9 , 2877.8)	64.5 (26 , 146.7)
Eastern Sub-Saharan Africa	94662 (55469 , 140091)	3.7 (2.2 , 5.4)	59.7 (33.8 , 91.9)	59.5 (19 , 161.2)	3351338 (2052302 , 4766230)	2 (1.2 , 2.8)	1727.1 (1031.2 , 2506.9)	57.8 (17.5 , 156.6)
Central Sub-Saharan Africa	33914 (18519 , 52564)	3.9 (2.2 , 5.7)	65.6 (34.4 , 103.8)	1.6 (-19.2 , 37.8)	1210479 (680622 , 1810676)	2.1 (1.2 , 3)	1921.7 (1069.8 , 2910.2)	5.2 (-16.3 , 41.9)
Southern Sub-Saharan Africa	69144 (52001 , 87063)	9.4 (7.1 , 11.8)	133.8 (99.4 , 171.5)	39.8 (25.2 , 58.4)	2132363 (1656714 , 2651186)	5.6 (4.3 , 6.9)	3593.2 (2763.1 , 4492.4)	27.9 (16.3 , 43.8)

DALY Disability adjusted life year, *GBD* Global Burden of Disease, *ASRs* Age-standardised rates

From 1990 to 2019, eight GBD regions experienced increases in the age-standardised DALY rates for all diseases attributable to EBW, with the largest increases being seen in South Asia (132.9% [61.8 to 306.8]), Southeast Asia (125.4% [61.6 to 293.7]), and Western Sub-Saharan Africa (64.5% [26.0 to 146.7]) (Table 1). Conversely, four GBD regions experienced decreases in the age-standardised DALY rates of diseases attributable to EBW over this period, with the largest decreases being seen in high-income Asia Pacific (-26.0% [-35.1 to -5.3]), Australasia (-23.5% [-32.5 to -8.3]), and Western Europe (-23.4% [-30.6 to -12.0]) (Table 1). Figure S4 shows the numbers of DALYs attributable to EBW from 1990 to 2019. In addition, Figure S5 presents the estimated age-standardised DALY rates of diseases attributable to EBW (per 100,000) in 2019, and Figure S6 illustrates the changes from 1990 to 2019. The contribution of EBW to each disease type varied by region. Cardiovascular diseases accounted for the highest number of deaths across all regions, while diabetes and kidney diseases were the second-largest contributors in most GBD regions. However, in some regions, such as East Asia and Eastern Europe, neoplasms were the second largest contributors to the number of deaths attributable to EBW (Fig. 1A). Similarly, in most regions, cardiovascular diseases were the leading contributors to the total number of DALYs attributable to EBW, followed by diabetes and kidney diseases as the second largest contributors (Fig. 1B).

National level

In 2019, the proportion of all disease-related deaths attributable to EBW varied substantially by country (from 1.1% to 31.7%). Fiji (31.7% [23.3 to 39]), the Cook Islands (27.2% [19.2 to 34.4]), and Bahrain (26.4% [19.3 to 32.4]) had the three highest PAFs. In contrast, the lowest PAFs were estimated in Somalia (1.1% [0.3 to 2.4]), Chad (1.7% [0.9 to 2.8]), and Niger (1.8% [1 to 2.8]) (Fig. 2A and Table S2).

The age-standardised death rate of diseases attributable to EBW in 2019 ranged from 12.7 to 319.1 per 100,000. In 2019, Fiji (319.1 [213.8 to 445.0]), Nauru (302.6 [192.9 to 428.9]), and Kiribati (284.1 [164.2 to 419.2]) had the three highest age-standardised death rates (per 100,000), while the lowest rates were found in Japan (12.7 [4.8 to 23.7]), the Republic of Korea (22.9 [10.4 to 37.6]), and Singapore (23.1 [12.8 to 35.2]) (Fig. 2B and Table S2). The largest increases in the age-standardised death rates between 1990 and 2019 were found in Equatorial Guinea (208.1% [60.4 to 863.4]), Mozambique (180.4% [67.4 to 634.0]), and Ghana (176.6% [81.5 to 437.2]). In contrast, the Republic of Korea (-52.5% [-61.4 to -25.6]), Luxembourg (-50.0% [-57.2 to -70.7]), and Bermuda (-48.8% [-57.2 to -36.7]) had the largest decreases over this period (Table S2).

The proportion of DALYs attributable to EBW in 2019 also varied considerably by country, ranging from 0.6% to 24.5%. Fiji (24.5% [18.5 to 29.5]), the Cook Islands (24.2% [17.9 to 29.6]), and American Samoa (22.3% [17.7 to 25.8]) had the three highest PAFs. In contrast, the lowest PAFs were found in Somalia (0.6% [0.2 to 1.2]), Niger (0.8% [0.5 to 1.3]), and Chad (0.8% [0.4 to 1.3]) (Figure S7 and Table S4).

In 2019, the age-standardised DALY rate of the diseases attributable to EBW ranged from 503.3 to 10,000.6 per 100,000. Kiribati (10,000.6 [6266.5 to 14,159.2]), Nauru (9955.8 [6678.3 to 13,517.4]), and Fiji (9579.6 [6864.7 to 12,694.3]) had the three highest age-standardised DALY rates. In contrast, the lowest

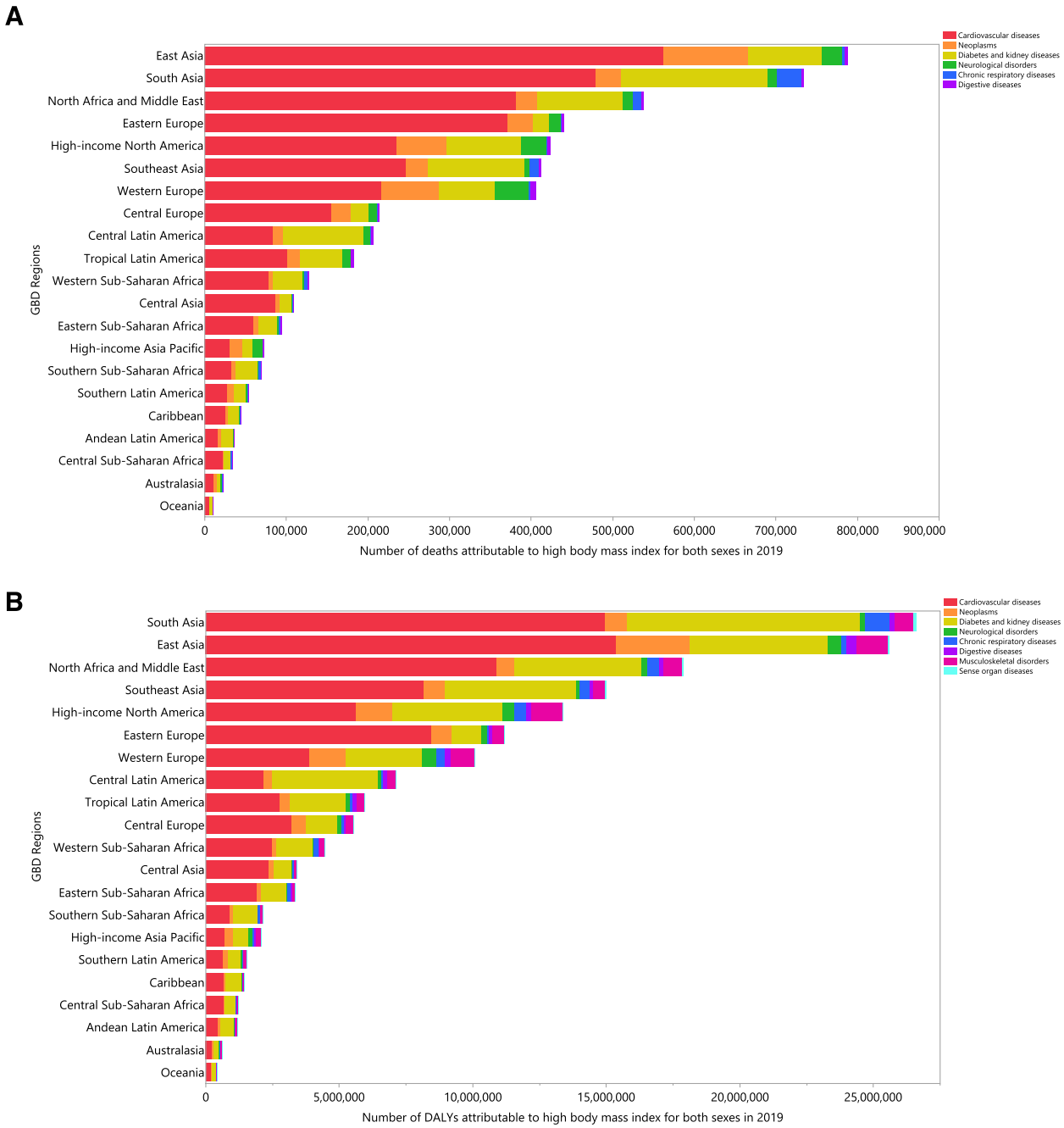

Fig. 1 Number of disease deaths (**A**) and DALYs (**B**) attributable to high body mass index in 2019 by disease type and GBD region. DALY = disability-adjusted-life-years (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool)

rates were observed in Japan (503.3 [199.9 to 888.7]), the Republic of Korea (752.1 [362.3 to 1202.7]), and the Democratic People's Republic of Korea (816.9 [177.1 to 1847.1]) (Figure S8 and Table S4). Mozambique (193.1% [78.1 to 617.8]), Nepal (189.7% [84.9 to 553.5]), and Equatorial Guinea (176.9% [45.8 to 750.8]) showed the largest increases in the age-standardised DALY rates over the measurement period. In contrast, the Republic of Korea (-43.4% [-54.1 to -14.3]), Bermuda (-38.2% [-46.9 to -26.5]), and Ireland (-35.6% [-43.5 to -23.4]) had the largest decreases over the same period (Table S4). Risk exposure was highest in countries neighbouring the Persian Gulf (e.g., Saudi Arabia) and in the United States (Figure S9).

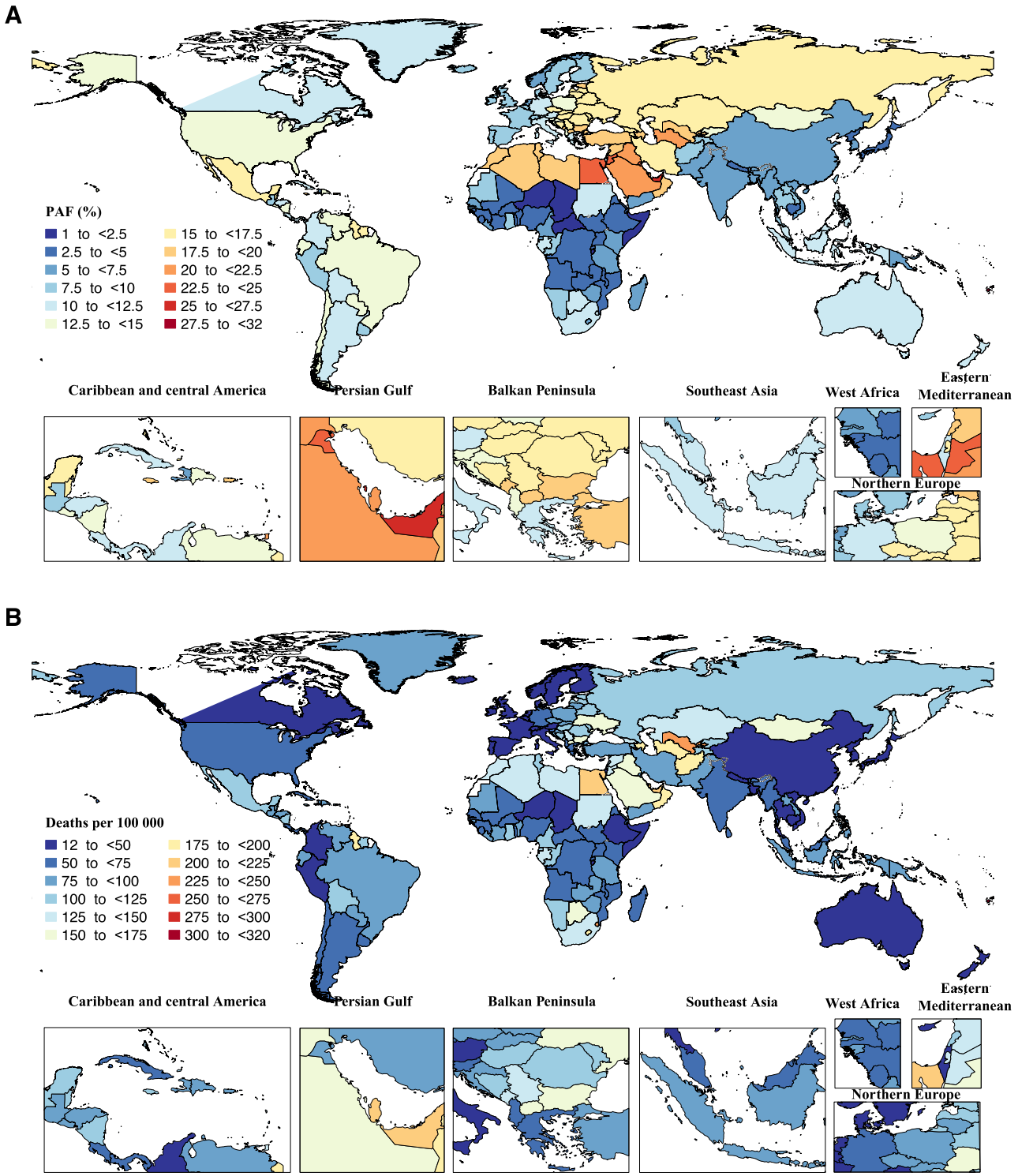

Fig. 2 Population attributable fraction (PAF) (**A**) and age-standardised rates (**B**) of deaths attributable to high body mass index in 2019, by country. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool)

Age and sex patterns

In 2019, the global number of deaths from EBW-related diseases began to increase in the 20–24 age group and peaked in the 65–69 age group for both sexes. The death rate for diseases attributable to EBW steady increased to the 80–84 age group and then dramatically increased in the oldest (95^{+}) age group for both sexes. There were no substantial differences between males and females in terms of the number of deaths or the death rate (Fig. 3A). In addition, the global number of DALYs and the DALY rate in 2019 followed similar patterns (Fig. 3B).

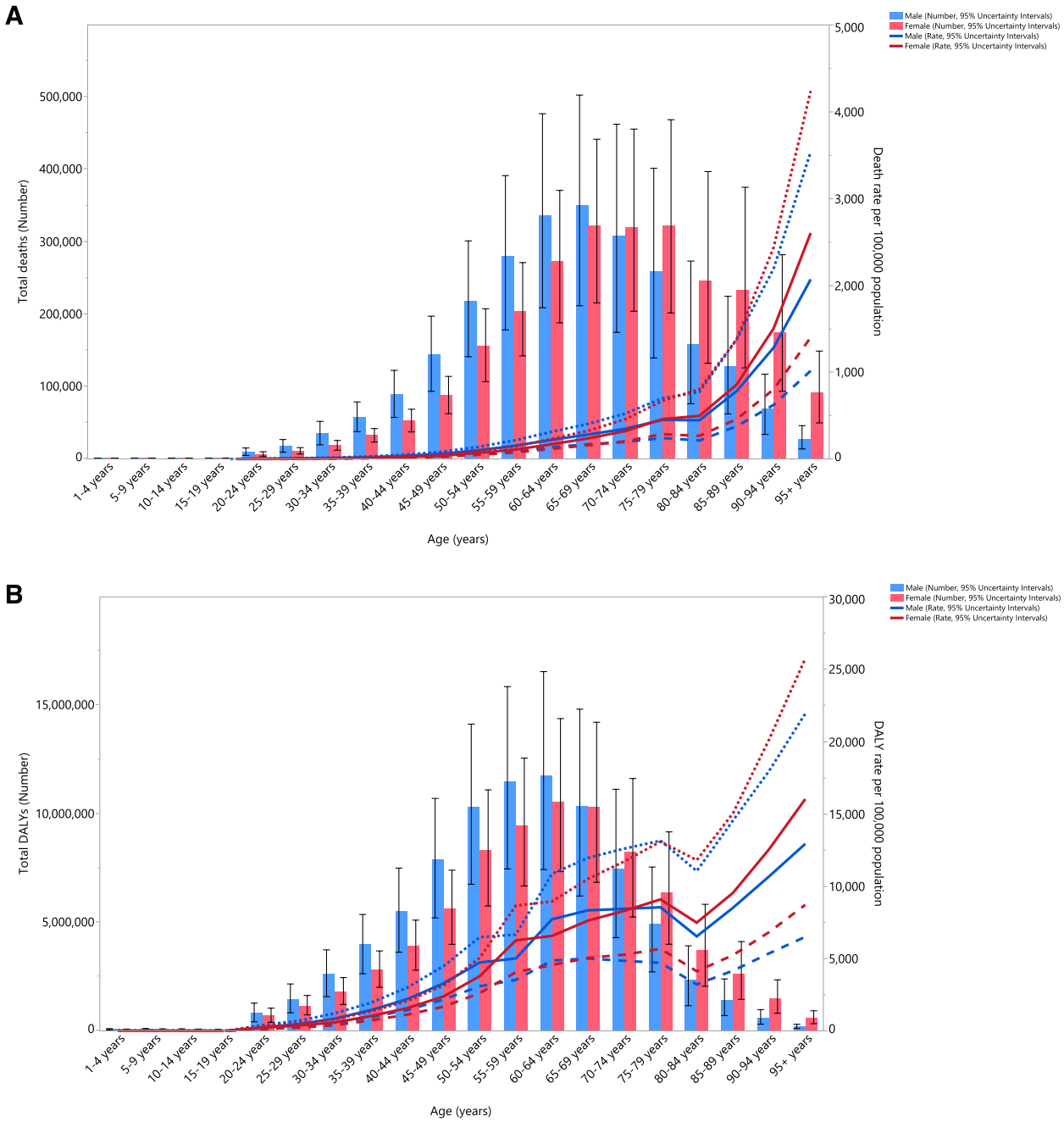

Fig. 3 Global number of deaths and death rate (**A**) and the global number of DALYs and DALY rate (**B**) of diseases attributable to high body mass index (per 100,000) by age and sex in 2019; Dotted and dashed lines indicate 95% upper and lower uncertainty intervals, respectively. DALY = disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool)

Burden of EBW-attributable diseases by Socio-demographic Index (SDI)

A non-linear association was identified between regional SDIs and the corresponding age-standardised DALY rates for diseases attributable to EBW over the period 1990 to 2019. Most of the GBD regions exhibited an increase in the age-standardised DALY rate over the measurement period. Eastern Europe, Central Europe, Central Asia, North Africa and Middle East, and Oceania had higher than expected burdens from 1990 to 2019. In contrast, lower than expected burdens were found for High-income Asia–Pacific, Western Europe, Andean Latin America, Southern Latin America, South Asia, East Asia, and Southeast Asia during the same period (Fig. 4).

In 2019, a non-linear association was observed between SDI and the age-standardised DALY rate for the diseases attributable to EBW. The age-standardised DALY rate increased up to an SDI of 0.6 and then decreased to the higher SDI levels. Countries and territories such as Kiribati, Nauru, the Solomon Islands, Fiji, and Micronesia had much higher than expected burdens. In contrast, the burdens were lower than expected for countries such as the Democratic People's Republic of Korea, Ethiopia, Bangladesh, Viet Nam, the Maldives, and China (Figure S10).

Discussion

This study found that the global burden of EBW increased over the period 1990–2019, with no significant sex differences observed. In 2019, EBW accounted for approximately 5 million deaths and 160.3 million DALYs. However, there was no clear relationship between socio-odemographic development and the burden of diseases attributable to EBW.

The present study shows that the age-standardised DALY rate attributable to EBW has increased by about 18% over the last 30 years. While global life expectancy increased—rising from 62.5 to 69.0 years for males and from 67.1 to 74.8 years for females between 1990 and 2015—the death rate attributable to EBW remained relatively constant [17]. The total number of DALYs attributable to EBW began increasing in the 20–24 age group, reaching its peak in the 60–64 age group, before decreasing with age due to shrinking age group populations. In contrast, the DALY rate increased with age. It is important to note that the slope of the DALY rate accelerates after the 80–84 age group, making it difficult to distinguish from the burden of other comorbid diseases. According to the life expectancy table, females have higher life expectancies than males across all age groups [17]. Moreover, the global population pyramid for 2019 shows that males outnumber females up to the age of 50, after which females become the predominant

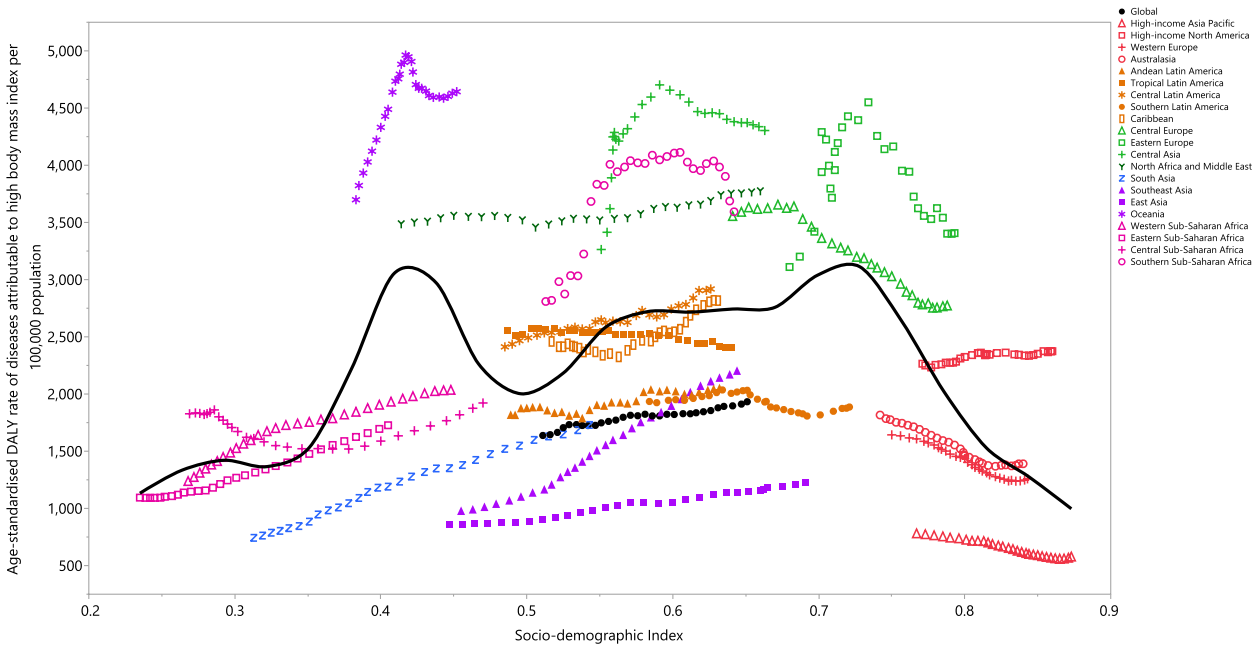

Fig.4 Age-standardised DALY rates of diseases attributable to high body mass index for the 21 Global Burden of Disease regions by Socio-demographic Index, 1990–2019; Expected values based on Socio-demographic Index and disease rates in all locations are shown as the black line. Thirty points are plotted for each GBD region and show the observed age-standardised DALY rates from 1990 to 2019 for that region. DALY = disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool)

gender, with this predominance increasing with age [18]. This demographic shift towards a larger female population in older age groups suggests an increase in attributable DALYs is plausible, though the precise etiology remains unknown. According to a global physical activity levels study, inactivity rates are generally higher among women than men in most countries and age groups, with this disparity becoming more pronounced with advancing age [19]. Consequently, a sedentary lifestyle and lack of physical activity may contribute to the sex differences in the prevalence of EBW.

The present study shows an increase in the number of DALYs attributable to EBW in almost all regions, which is consistent with previous studies [20]. In the current study, decreases in the age-standardised death rates were found in High-income Asia Pacific, Australia and Western and Central Europe, while six regions experienced significant increases in the death rate among those with EBW. The same regions that experienced declines in death rates also saw significant reductions in DALY rates. In contrast, significant increases in both death and DALY rates were found in Central Asia, Central Latin America, East Asia, Southeast Asia, Oceania, South Asia, Southern Sub-Saharan Africa, Western Sub-Saharan Africa, and Eastern Sub-Saharan Africa.

The "nutrition transition" refers to the increasing consumption of high-fat and high-sugar foods in developing countries, contributing to rising global obesity and diet-related illnesses. This shift is linked with globalisation, which influences agriculture and food systems, affecting the availability, variety, cost, and appeal of food. Understanding the relationship between globalisation and this transition is essential for developing effective food-related policies to combat chronic diseases [21].

A study involving 159,827 U.S participants found that men were more prone to obesity than women, and individuals aged 45 and above had a higher risk of obesity compared to their younger counterparts. Higher education and annual incomes over $50,000 were associated with reduced obesity risk [22]. In contrast, a study in Poland found that among 11 socio-demographic factors, only five—sex, age, occupational activity, residing in rural areas, and having a chronic disease—had significantly associated with EBW, while education and financial situation showed no correlation [23]. Another study of 17,724 participants linked higher BMI to factors such as male gender and older age, with a negative association between obesity and higher education [24]. In the present study, the age-standardised DALY rate of diseases attributable to EBW did not show a clear association with the SDI at the regional level.

At the national level, the DALY rate attributable to EBW increased up to an SDI of 0.6, after which a decline was observed as the SDI increased. This pattern may be related to the affordability of healthy food. In countries with the lowest socio-economic levels, such as those in the sub-Saharan region, limited resources hinder the development of adipose tissue and EBW. Conversely, high SDI countries have access to healthier diets that are rich in protein and low in fat, which helps prevent obesity. However, such diets are often unaffordable in middle SDI countries, leading to higher consumption of junk food and increased obesity rates. There is a correlation between a healthy diet and education level, as more educated individuals are aware of the risks of unhealthy diets. Additionally, education level is linked to a country's SDI. [25, 26].

Previous research has shown that the rate of BMI increase has slowed in high-income and some middle-income countries since 2000, contrasting with the trend observed over the previous century [27, 28]. Nevertheless, if the trends since 2000 continue, the global obesity target will not be achieved. It is predicted that by 2025, the worldwide prevalence of obesity will rise to approximately 18% of men and over 21% of women. Furthermore, the prevalence of severe obesity is expected to increase to over 6% of men and 9% of women by 2025. Despite these trends, being underweight continues to be a common problem, particularly in regions with the lowest incomes, such as South Asia [28]. The GBD 2019 study also revealed that the rate of BMI increase is significantly faster in low-middle and middle SDI regions compared to high-middle and high SDI regions [14].

Trend analyses from affluent nations show a decline in occupational physical activity but a notable increase in leisure-related physical activity among adults [19]. Nonetheless, significant gaps remain in the surveillance of physical activity. In particular, data is absent from approximately one-third of the world's countries, primarily encompassing low- to middle-income countries in regions like Africa and Central Asia. There is also a shortage of information on physical activity patterns. While physical activity generally decreases with age, this decline is more pronounced in individuals aged 60 and above. In addition, research using WHO world regions shows that the highest levels of physical inactivity are found in the Americas, followed by the Eastern Mediterranean and Europe, while the lowest levels are in Southeast Asia and Africa [19]. Interestingly, the pattern of inactivity appears to match the pattern of DALYs and death rates attributable to EBW.

Globally, there has been a troubling increase in the prevalence of obesity among children and adolescents, with rates rising from 0.7% to 5.6% in boys and from 0.9% to 7.8% in girls between 1975 and 2016 [29]. Assessing BMI trends in younger populations provides crucial

insights into the potential future implications of the obesity burden on the broader population. A comprehensive examination of continuous BMI trends in a cohort of 51,505 children, whose anthropometric data were available from childhood through to adolescence, revealed that 90% of children identified as obese at age three continued to experience overweight or obesity throughout their adolescent years [20]. This finding emphasises the importance of diagnosing obesity in childhood and initiating preventive and therapeutic measures to mitigate adverse effects during adolescence.

Strengths and limitations

Although previous studies have explored related topics, the current study distinguishes itself as the most comprehensive to date. One prior study focused solely on the burden of high BMI in Asian countries using GBD 2019 data [30]. Another examined the obesity-attributable burden at global and regional levels but omitted national-level estimates, key metrics such as Summary Exposure Values (SEVs), and mortality rates. It also did not provide cause-specific burdens, which are essential for a complete understanding [31]. A separate study addressed only the cancer burden attributable to BMI, excluding other conditions covered in the GBD, and had differing objectives from ours [32]. Similarly, another study reported on the burden of gastrointestinal cancers attributable to high BMI, but its scope was limited compared to ours [33]. In contrast, our study provides a comprehensive assessment of the burden from cardiovascular diseases, cancers, diabetes and kidney diseases, neurological disorders, chronic respiratory diseases, and digestive diseases attributable to high BMI. This broader scope makes it the most exhaustive report on the health effects of overweight and obesity to date, reinforced by advanced analyses that examine the global burden of diseases associated with EBW over a three-decade period.

This study also had several limitations, most of which arise from a lack of high-quality data in some lower- and middle-income countries, potentially leading to an overestimation or underestimation of the burden attributable to EBW. Furthermore, the GBD study utilised modelling to estimate the burden in countries with low or no data, meaning that in these countries, the figures reported are estimates rather than actual data. There are also a number of conditions that are linked to EBW, such as reproductive issues and psychiatric disorders, that were not included in this study. Furthermore, the study's reliance on BMI for defining overweight and obesity, while omitting more precise techniques like computed tomography or magnetic resonance imaging, is also acknowledged as a limitation. Additionally, the absence of statistics categorised by race/ethnicity is a notable omission, given that sociodemographic factors such as race/ethnicity are known to correlate with EBW. In this study, BMI was defined according to the World Health Organization (WHO) criteria, which are universally applied and recognised for their validity in assessing overweight and obesity across diverse populations. However, we acknowledge that different BMI criteria may be applicable to specific populations, particularly Asian individuals, where thresholds for overweight and obesity may differ due to variations in body composition and associated health risks [34]. Furthermore, the PAF calculation does not take into account the joint effects of multiple exposures. This is a significant limitation because, in real-world scenarios, the joint PAF would account for overlapping contributions and avoid double-counting individuals exposed to multiple risks [35]. This limitation underscores the need for more advanced modelling approaches in future GBD analyses to better address the interplay of multiple risk factors.

Conclusions

In all regions of the world, the number of DALYs and the death rate attributable to obesity have either increased or remained stable, with the exception of high-income Asia, Australia, and Western and Central Europe. It is imperative that future research prioritises the analysis of these evolving age-related trends in obesity and the identification of concealed obesity cases. These insights are essential for developing a comprehensive understanding of the issue and for formulating effective strategies to prevent its progression and associated complications.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12937-025-01082-z.

Supplementary Material 1: Table S1: Number, proportion and age-standardised rates of deaths attributable to high body mass index (per 100,000) in 2019 by sex and location. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 2: Table S2: Number, proportion and age-standardised rates of disability-adjusted-life-years (DALYs) attributable to high body mass index per 100,000 in 2019 by sex and location. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool)

Supplementary Material 3: Table S3: Number, proportion and age-standardised rates of deaths attributable to high body mass index per 100,000 in 1990 and 2019 by location. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 4: Table S4: Number, proportion and age-standardised rates of the disability-adjusted-life-years (DALYs) attributable to high body mass index per 100,000 in 1990 and 2019 by location. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 5 : Figure S1: Numbers of deaths attributable to high body mass index from 1990 to 2019, by region (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 6: Figure S2: Age-standardised death rate (per 100,000 population) of the diseases attributable to high body mass index in 2019, by sex and region. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 7: Figure S3: Percentage change in the age-standardised death rate from 1990 to 2019 of the diseases attributable to high body mass index, by sex and region. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 8: Figure S4: Numbers of DALYs attributable to high body mass index from 1990 to 2019, by region. DALY= disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 9: Figure S5: Age-standardised DALY rate (per 100,000 population) of the diseases attributable to high body mass index in 2019, by sex and region. DALY= disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 10: Figure S6: Percentage change in the age-standardised DALY rate from 1990 to 2019 for the diseases attributable to high body mass index, by sex and region. DALY= disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 11: Figure S7: Population attributable fraction (PAF) of the DALYs attributable to high body mass index in 2019, by country. DALY= disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 12: Figure S8: Age-standardised rates of DALYs attributable to high body mass index in 2019, by country. DALY= disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 13: Figure S9: Summary exposure value of diseases attributable to high body mass index in 2019, by country. DALY= disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

Supplementary Material 14: Figure S10: Age-standardised DALY rates of diseases attributable to high body mass index for 204 countries and territories by Socio-demographic Index, 1990–2019; Expected values based on Socio-demographic Index and disease rates in all locations are shown as the black line. Thirty points are plotted for each GBD region and show the observed age-standardised DALY rates from 1990 to 2019 for that region. DALY= disability-adjusted-life-years. (Generated from data available from http://ghdx.healthdata.org/gbd-results-tool).

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Author notes
This study is based on publicly available data and solely reflects the opinion of its authors and not that of the Institute for Health Metrics and Evaluation.

Dissemination to participants and related patient and public communities
Our results will be disseminated through media outlets and presentations at scientific conferences and academic events. Given that no patients were recruited for the study, there are no plans to disseminate the results to study participants.

Authors' contributions
SS and AAK designed the study. SS analyzed the data and performed statistical analyses. JAG, AGJ, EM, SAN, AF, MJMS and NK drafted the initial manuscript. SS, FS, KS, GSC and AAK supervised the project. All authors reviewed the drafted manuscript for critical content. All authors approved the final version of the manuscript.

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Data availability
The data used for these analyses are all publicly available at https://vizhub.healthdata.org/gbd-results/.

Declarations

Ethics approval and consent to participate
None.

Consent for publication
Not required.

Competing interests
The authors declare no competing interests.

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