National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9·1 million participants

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Summary

Background Excess bodyweight is a major public health concern. However, few worldwide comparative analyses of long-term trends of body-mass index (BMI) have been done, and none have used recent national health examination surveys. We estimated worldwide trends in population mean BMI.

Methods We estimated trends and their uncertainties of mean BMI for adults 20 years and older in 199 countries and territories. We obtained data from published and unpublished health examination surveys and epidemiological studies (960 country-years and 9·1 million participants). For each sex, we used a Bayesian hierarchical model to estimate mean BMI by age, country, and year, accounting for whether a study was nationally representative.

Findings Between 1980 and 2008, mean BMI worldwide increased by 0·4 kg/m² per decade (95% uncertainty interval 0·2–0·6, posterior probability of being a true increase >0·999) for men and 0·5 kg/m² per decade (0·3–0·7, posterior probability >0·999) for women. National BMI change for women ranged from non-significant decreases in 19 countries to increases of more than 2·0 kg/m² per decade (posterior probabilities >0·99) in nine countries in Oceania. Male BMI increased in all but eight countries, by more than 2 kg/m² per decade in Nauru and Cook Islands (posterior probabilities >0·999). Male and female BMIs in 2008 were highest in some Oceania countries, reaching 33·9 kg/m² (32·8–35·0) for men and 35·0 kg/m² (33·6–36·3) for women in Nauru. Female BMI was lowest in Bangladesh (20·5 kg/m², 19·8–21·3) and male BMI in Democratic Republic of the Congo 19·9 kg/m² (18·2–21·5), with BMI less than 21·5 kg/m² for both sexes in a few countries in sub-Saharan Africa, and east, south, and southeast Asia. The USA had the highest BMI of high-income countries. In 2008, an estimated 1·46 billion adults (1·41–1·51 billion) worldwide had BMI of 25 kg/m² or greater, of these 205 million men (193–217 million) and 297 million women (280–315 million) were obese.

Interpretation Globally, mean BMI has increased since 1980. The trends since 1980, and mean population BMI in 2008, varied substantially between nations. Interventions and policies that can curb or reverse the increase, and mitigate the health effects of high BMI by targeting its metabolic mediators, are needed in most countries.

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Introduction

Excess bodyweight is an important risk factor for mortality and morbidity from cardiovascular diseases, diabetes, cancers, and musculoskeletal disorders, causing nearly 3 million deaths every year worldwide.[1–4] National, subnational, and multicentre studies have shown that adiposity, as measured by body-mass index (BMI), has increased in recent decades in many populations,[5–12] although BMI seems to have been stable or even decreased in some groups.[6,7,9,13]

Some have argued that increasing BMI is a pandemic[14,15] that could reverse life-expectancy gains in high-income nations.[16] Therefore, there is substantial interest in curbing or reversing rising BMI trends. Reliable information about these trends is needed to assess the implications of rising BMI on population health, set policy priorities, and

evaluate their success. Several studies used national health surveys, multicentre studies, or reviews of published studies to estimate adult BMI levels or trends worldwide and in specific regions, or did cross-country comparative analyses.[6,17–21] Some of these studies used BMI data based on both measured and self-reported weight and height,[19] even though self-reported measures are biased.[22] Others focused exclusively on women[20] or selected countries,[6,19–21] relied mainly on community studies,[6,17] or combined community and national studies without distinguishing them.[18] Many recent high-quality national health examination surveys have measured BMI, providing an opportunity to systematically and comprehensively assess regional and national trends.

We reviewed and accessed published and unpublished studies to collate comprehensive BMI data. We developed

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and applied statistical methods to systematically address measurement comparability, missing data, non-linear trends and age patterns, and national versus subnational and community representativeness. With these data and methods, we estimated BMI trends and their uncertainties by country between 1980 and 2008.

Methods
Study design
We estimated 1980–2008 trends in mean BMI and their uncertainties, by sex, for 199 countries and territories in the 21 subregions of the Global Burden of Diseases, Injuries, and Risk Factors study, which are grouped into seven merged regions (webappendix p 19). 1980 was selected as the beginning of the analysis period because few data were available earlier. Evidence suggests that central adiposity measures—eg, waist circumference—might best predict disease risk at the individual level;[23] other evidence indicates that central adiposity and BMI independently predict mortality risk.[24] However, many more population-based studies have measured BMI than central adiposity. We used mean BMI, instead of obesity prevalence, as our main outcome because the association with most diseases is continuous.[2,3] We also estimated overweight and obesity as secondary

outcomes because, although not as relevant for population health as mean BMI, they are commonly used for public communication.

Our analysis included three steps: (1) identification of data sources, and accessing and extracting data; (2) conversion of extracted data to a comparable metric; and (3) application of a statistical model to estimate BMI trends by country and sex. We analysed the uncertainty in estimates, taking into account sampling error and uncertainty from statistical modelling in steps 2 and 3.

Data identification, access, and extraction
We obtained data from health examination surveys and epidemiological studies with anonymised data available to Collaborating Group members, multicentre studies, a review of published articles, and unpublished data identified through the WHO Global InfoBase (figure 1 and webappendix pp 2–3). We identified duplicate sources of data by comparing studies from the same population-year (eg, when data from a MONICA project site were also reported separately); and we used the source with most detail. Importantly, we used only BMI data from measured weight and height because self-reported measures are systematically biased.[22]

425 health surveys and epidemiological studies analysed by Collaborating Group members representing 529 country-years

3 multicentre epidemiological studies representing 175 country-years

7219 articles identified in Medline and Embase

3207 articles excluded based on title and abstract review

4012 articles remaining after exclusion based on title and abstract review

2088 articles excluded based on full text review and 279 articles excluded because we could not retrieve the full text or because we could not translate the article

1645 articles remaining after exclusion based on full text review

1502 articles excluded because data were not accessible by age and sex, because they were based on the same study as another article, or because the same data were available from Collaborating Group members

3 reports with 4 country-years received through personal communication

Data extracted from 146 published studies representing 181 country-years

75 additional country-years of data retrieved from WHO Global InfoBase

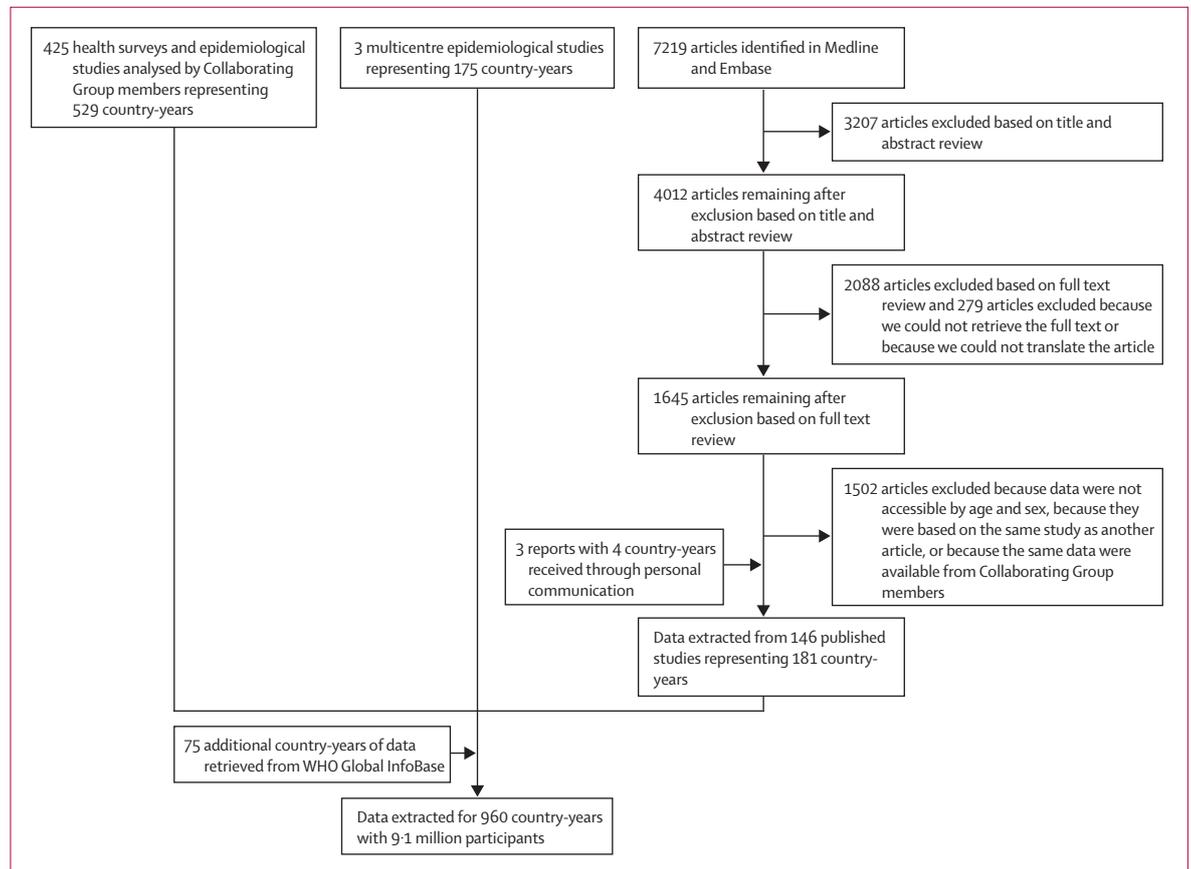Data extracted for 960 country-years with 9·1 million participants

Figure 1: **Flow diagram for data identification and access**

Collaborating Group members analysed anonymised data from health examination surveys and epidemiological studies. BMI mean was calculated by sex and age group, incorporating appropriate sample weights when applicable.

We identified data sources by searching Medline and Embase for relevant articles; webappendix pp 2–3 and figure 1 provide detailed information about the search strategy, exclusion criteria, and the number of articles identified and retained. In brief, studies were included if they were from a representative sample, including from a national, subnational, or community population, and if the data were based on measured (*vs* self-reported) height and weight. If a published article met the inclusion criteria but did not report data by age and sex, we invited the corresponding author to join the Collaborating Group by contributing stratified data. There were no restrictions on the language of publication. All articles for which we could identify a translator were screened for inclusion in the data sources.

We identified additional data sources through personal communications with researchers, including inquiries about additional data from authors of published studies. This process led to access to data from multicentre studies (eg, the MONICA Project and INTERSALT and INTERMAP studies), published government reports, published sources not identified in our review, and unpublished data. These data were used only if information about study population and measurement methods were available. We applied the same exclusion criteria to these data sources as to published articles.

Data stratified by age and sex were extracted into standard data extraction files. Extracted data included BMI mean and SD, and prevalence of overweight or obesity, or both; sample sizes, standard errors, or confidence intervals; survey population and sampling strategy; and selected other study characteristics (webappendix pp 20–51). When sample weights were provided, we calculated weighted mean BMI. Importantly, for each data source we recorded whether the data were national (separated into weighted and unweighted), covered multiple subnational regions, or were from individual communities (denoted as coverage hereafter); and whether the study population was rural, urban, or both (webappendix pp 20–51). This information was used to account for potential bias and additional uncertainty in data sources that were not representative of their national populations.

Conversion between mean BMI and prevalences of overweight and obesity

Some published studies reported overweight and obesity prevalence, but not mean BMI, which was our primary outcome. In such cases, we developed linear regressions to estimate mean BMI from overweight or obesity prevalence. The dependent variable in these so-called cross-walking regressions was mean BMI; the independent variables were overweight and obesity prevalence, age, sex, year of survey, and whether the country was high income. A separate regression was developed for each overweight/obesity prevalence definition used in at least one published study. Webappendix pp 18 and 52–56 provides the details of the cross-walking regression models and their coefficients.

A similar approach was also used to estimate overweight (BMI ≥25 kg/m²) and obesity (BMI ≥30 kg/m²) prevalences, which were our secondary outcomes, from our estimates of mean BMI. For this analysis, we applied regression models to mean BMI by age group, sex, country, and year, to estimate either the prevalence of overweight or that of obesity. The dependent variable in each of these two regressions was the logit of prevalence, and the independent variables were mean BMI, age, sex, year of survey, and whether the country was high income. We used a logit transformation to restrict the estimated prevalences to between 0 and 1. Webappendix pp 18 and 57 provides the details of these reverse cross-walking regressions and their coefficients. The uncertainty of the estimated prevalences included the uncertainties of the estimated country mean and uncertainty associated with converting mean to prevalence. Subregion estimates for each year were calculated as population-weighted averages of the country estimates by age group and sex.

Statistical analysis

Despite our extensive data access, many country-years were without data or without nationally representative data, because yearly risk factor data are available for very few countries. Further, some studies covered only some age or sex groups, or only rural or urban populations. We developed a statistical model to estimate mean BMI over time, by age group, sex, and country. We did all analyses by sex, because BMI levels and trends can differ in men and women.[9] We used a Bayesian hierarchical model to make estimates for each age-country-year unit; the estimates were informed by data from that unit itself, if available, and by data from other units. Specific model features, and their motivations, are described briefly below. Webappendix pp 4–17 provides complete details about the statistical model and about model validation and testing.

We used a hierarchical model in which BMI levels and trends in countries were, in turn, nested in subregional, regional, and global levels and trends. The hierarchical model borrows information across countries, subregions, and regions, appropriately compromising between (overly) uncertain within-unit estimates and (overly) simplified aggregate cross-unit estimates. It borrows information to a greater degree when data are non-existent or non-informative (ie, have large uncertainty), and to a lesser degree in data-rich countries, subregions, and regions.

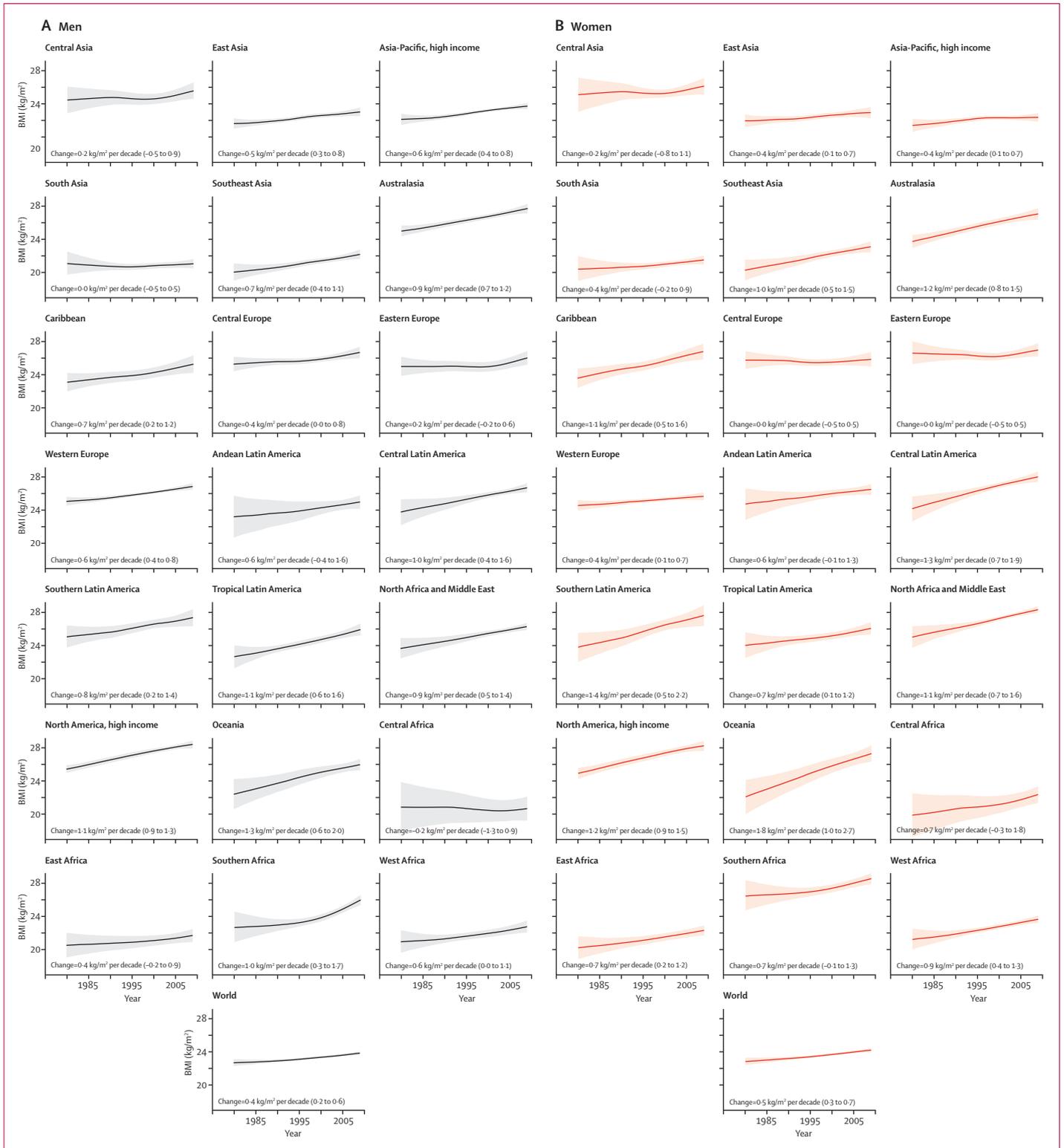Trends over time were modelled as non-linear, consisting of a linear trend plus a smooth non-linear

Figure 2: **Trends in age-standardised mean BMI by subregion between 1980 and 2008 for men (A) and women (B)**
Webappendix pp 74–76 shows trends by region and webappendix pp 84–118 trends by country. The solid line represents the posterior mean and the shaded area the 95% uncertainty interval.
BMI=body-mass index.

trend at all levels. Both components were modelled hierarchically. Time-varying country-level covariates informed the estimates. The covariates, described elsewhere,[25] were national income (Ln per-head gross domestic product converted to international dollars in 1990), urbanisation (proportion of population that lived in urban areas), and national availability of multiple food types. The associations of BMI with the first two covariates were allowed to change over time—eg, because income associations might change as social and scientific factors affect diet and physical activity. To reduce the effect of fluctuations of covariates between years and to reflect potentially cumulative associations, we used a weighted average of the past 10 years, with progressively smaller weights in the more distant past.

Subnational and community studies might systematically differ from nationally representative ones, because they may be undertaken in low-BMI or high-BMI areas; they might also have larger variation than national studies. Our model included time-varying offsets for subnational and community data, and additional variance components for subnational and community data and for national data without sample weights. These variance components were estimated empirically and allowed national data with sample weights to have more effect on estimates than other sources. BMI might differ systematically between rural and urban populations, with the difference depending on the country's extent of urbanisation. Therefore, our model accounted for differences between study-level and country-level urbanisation.

Mean BMI might be non-linearly associated with age and the age association might flatten or decrease in older ages. The age association of BMI might vary across countries, and might be steeper when mean BMI is high. Therefore, we used a cubic spline age model, with parameters estimated as a function of BMI at a baseline age.

Mean BMI was estimated from the model by 5–10-year age groups for adults 20 years and older. Subregional and regional estimates for every year were calculated as population-weighted averages of the country estimates by age group and sex. For presentation, age-specific estimates for each country or region and year were age-standardised to the WHO reference population,[26] which corresponds to the 2000–25 world population.

We quantified the following sources of uncertainty (webappendix pp 4–17): sampling uncertainty in the original data sources; uncertainty associated with fluctuations between years in national data, because of unmeasured study design factors (eg, national data from the USA and Egypt in webappendix pp 119–531) or because some had not used sample weights; additional uncertainty associated with data sources that were not national, because of variation across subgroups within each country; uncertainty associated with statistical methods for conversion between mean BMI and prevalences of overweight or obesity; and uncertainty due to

use of a model to estimate mean BMI by age group, country, and year when data were missing.

We fitted the Bayesian model with the Markov chain Monte Carlo (MCMC) algorithm and obtained samples from the posterior distribution of model parameters, reflecting the sources of uncertainty, which were in turn used to obtain the posterior distribution of mean BMI. The uncertainty intervals represent the 2·5–97·5 percentiles of the posterior distribution of estimated means from the Bayesian model. We also report the posterior probability that an estimated increase or decrease corresponds to a truly increasing or decreasing BMI trend. Change was estimated as linear trend over the 28 years of analysis and is reported as change per decade. Posterior probability is not a p value; posterior probability would be 0·50 in a country or region in which an increase is statistically indistinguishable from a decrease, and larger posterior probability indicates more certainty.

Role of the funding source
The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The Writing and Global Analysis Group had access to all data sources and has responsibility for the contents of the report and the decision to submit for publication.

Results
Our analysis included 960 country-years of data, with 9·1 million participants (figure 1). 361 country-years were from 29 high-income countries and 599 covered 140 additional countries. Japan had the most national data with 16 national data sources since 1980, followed by China with eight national sources and 64 subnational or community sources. There were 30 countries for which we could not identify any data. The Caribbean had the most countries with no usable data (seven of 20).

There were more data for women (924 country-years) than for men (790 country-years), especially in sub-Saharan Africa and other low-income and middle-income regions, where 26% of sources, mainly Demographic and Health Surveys, had only data for women (webappendix pp 65–71). 54% of country-years did not have data for people older than 70 years. About half of data in low-income and middle-income regions were from the 2000s (59% of national data), and another 34% from the 1990s, whereas in high-income regions data were evenly distributed over time (webappendix pp 69–71).

Between 1980 and 2008, age-standardised mean BMI for men increased in every subregion apart from central Africa and south Asia (figure 2). The global change was 0.4 kg/m² per decade (95% uncertainty interval 0·2–0·6, posterior probability of being a true increase >0·999), ranging from –0·2 kg/m² per decade (–1·3 to 0·9, posterior probability=0·61) in central Africa to 1·3 kg/m² per decade (0·6–2·0, posterior probability >0·999) in
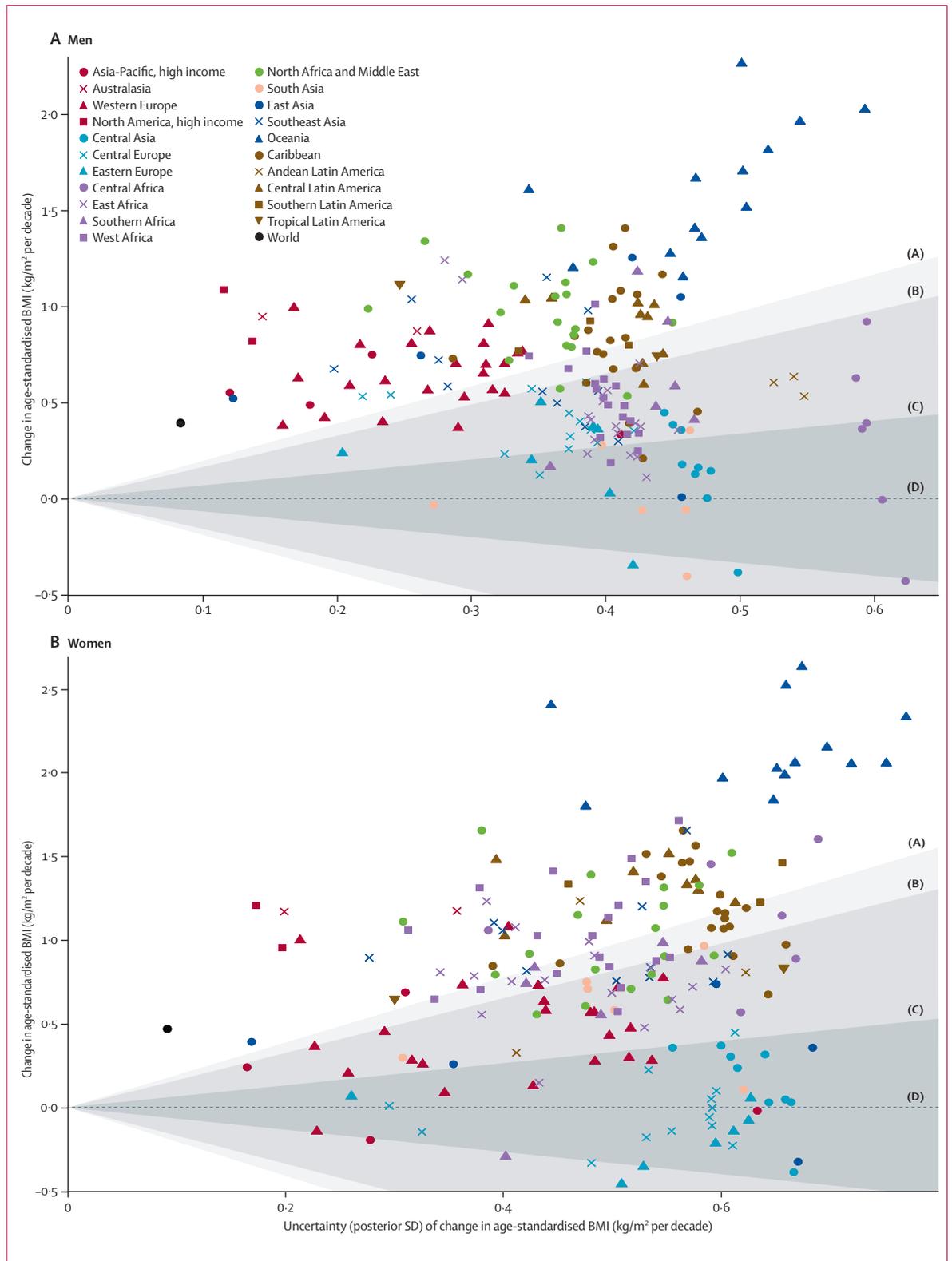
***Figure 3*: Change in country age-standardised BMI between 1980 and 2008 in relation to its uncertainty for men (A) and women (B)**
The shaded areas roughly represent the following ranges of posterior probability (PP) of an estimated increase or decrease being a true increase or decrease:
PP>0·975 (A); 0·95<PP<0·975 (B); 0·75<PP<0·95 (C); and PP<0·75 (D).

Oceania. Male BMI in six other subregions increased by 0·9–1·1 kg/m² per decade (figure 2). In fact there was an increase in male BMI in all but eight countries, with 173 countries having posterior probabilities of being a true increase of 0·75 or more (figure 3). The increase was more than 2 kg/m² per decade in Nauru and Cook Islands (posterior probability >0·999). In high-income countries, male BMI rose most in the USA (1·1 kg/m² per decade, 0·9–1·3, posterior probability >0·999), followed by the UK (1·0 kg/m² per decade, 0·7–1·3, posterior probability >0·999) and Australia (0·9 kg/m² per decade, 0·7–1·2, posterior probability >0·999), and least in Brunei, Switzerland, Italy, and France, with increases ranging 0·3–0·4 kg/m² per decade.

In 2008, age-standardised mean BMI in men was highest in North America (28·4 kg/m², 27·9–28·7) and Australasia (27·6 kg/m², 27·1–28·1). Male BMI was lowest in sub-Saharan Africa (apart from southern Africa) and in east, south, and southeast Asia, ranging 20·6–22·9 kg/m². As a result of the differential trends, the gap between subregions with the highest and lowest male BMI increased from 5·4 kg/m² in 1980 to 7·8 kg/m² in 2008. Male BMI in 2008 was highest in a few countries in Oceania (figure appendix and webappendix pp 77–83), reaching 33·9 kg/m² (32·8–35·0) in Nauru. Men in some countries in the Caribbean, north Africa and Middle East, and USA also had mean BMI greater than 28 kg/m² (figure 4). The lowest estimated male BMIs, all less than 21 kg/m², were recorded in a few countries in sub-Saharan Africa and south and southeast Asia (figure appendix). Japan and Singapore had the lowest male BMI in high-income countries, both less than 24·0 kg/m² (figure appendix).

Globally, female BMI increased by 0·5 kg/m² per decade (0·3–0·7, posterior probability >0·999) between 1980 and 2008. The largest rise in female BMI occurred in Oceania (1·8 kg/m² per decade, 1·0–2·7, posterior probability >0·999), followed by BMI rises of 1·3–1·4 kg/m² per decade in southern and central Latin America. Female mean BMI trends in central and eastern Europe and central Asia were indistinguishable from being flat, with changes less than 0·2 kg/m² per decade and posterior probabilities of change 0·65 or smaller. The increase in east and south Asia, Asia-Pacific, and western Europe was also less than 0·4 kg/m² per decade. By contrast with Asia-Pacific and western Europe, female BMI increased by about 1·2 kg/m² per decade (posterior probabilities >0·999) in Australasia and North America.

Nationally, female BMI might have decreased in 19 countries (posterior probabilities 0·50–0·81). Of the 180 countries with increasing mean BMI, BMI rose in 76, with posterior probability greater than 0·975. The largest of these increases, with an average rise of 2·0 kg/m² or more per decade, occurred in nine countries in Oceania (figure 3). Of high-income countries, women in the USA, New Zealand, and Australia had the greatest gain in BMI, with increases

of 1·2 kg/m² per decade (posterior probabilities >0·999), whereas women in Italy and Singapore might have had a modest BMI decrease of 0·1–0·2 kg/m² per decade (posterior probabilities <0·75).

Globally, age-standardised mean BMI in 2008 was 23·8 kg/m² (23·6–24·0) for men and 24·1 kg/m² (23·9–24·4) for women. Men had higher BMI than did women in high-income subregions, and lower BMI in most low-income and middle-income regions (figure 2). Although the difference between the lowest and highest mean female BMI across subregions was about 7 kg/m² in both 1980 and 2008, the ordering of countries changed. In 1980, women in central and eastern Europe and southern Africa, with mean BMI of 25·8–26·6 kg/m², had the highest values; in 2008, subregions with the highest female BMI were North America, north Africa and Middle East, and southern Africa (all ≥28 kg/m²; figure 2). In 1980, the lowest female BMI was in low-income subregions of central, east, and west Africa and south and southeast Asia (all ≤21·2 kg/m²); in 2008, west Africa and southeast Asia were replaced by east Asia and high-income Asia-Pacific subregions, with BMIs ranging 21·4–22·9 kg/m² (figure appendix). As with men, women in countries in Oceania had the highest BMI, with mean BMI in Nauru (35·0 kg/m², 33·6–36·3) being the highest of any country. Female BMI was also 29 kg/m² or greater in several countries in north Africa and Middle East and Caribbean, and in South Africa (figure appendix).

Women in the USA had the highest mean BMI of high-income countries, almost one full unit of BMI more than the next highest, New Zealand (figure appendix). Women in several countries in east, south, and southeast Asia and east Africa had mean BMI less than 21·5 kg/m², which was more than 14 kg/m² lower than those in Tonga and Nauru. Women in Japan, with mean BMI of 21·9 kg/m² (21·3–22·4), were more similar to women in low-income countries than to those in most high-income countries (figure appendix).

Male BMI in the world's two most populated countries was lower than the world average in 2008, by 0·9 kg/m² in China and 2·8 kg/m² in India (figure appendix). Male BMI in China increased faster than the global mean, but in India the trend was estimated to be flat. Mean female BMI was lower than the global average by 1·2 kg/m² in China and by 2·8 kg/m² in India; increase in female BMI was less than the global average in both countries (figure appendix). Despite the increases in BMI, both countries were among the 30% of countries with the lowest male and female mean BMI in 2008.

Worldwide, age-standardised prevalence of obesity was 9·8% (9·2–10·4) in men and 13·8% (13·1–14·7) in women in 2008, which was nearly twice the 1980 prevalences of 4·8% (4·0–5·7) for men and 7·9% (6·8–9·3) for women (figure 4). An estimated 205 million men (193–217 million) and 297 million women (280–315 million) older than 20 years worldwide were obese in 2008; 1·46 billion (1·41–1·51 billion) adult men
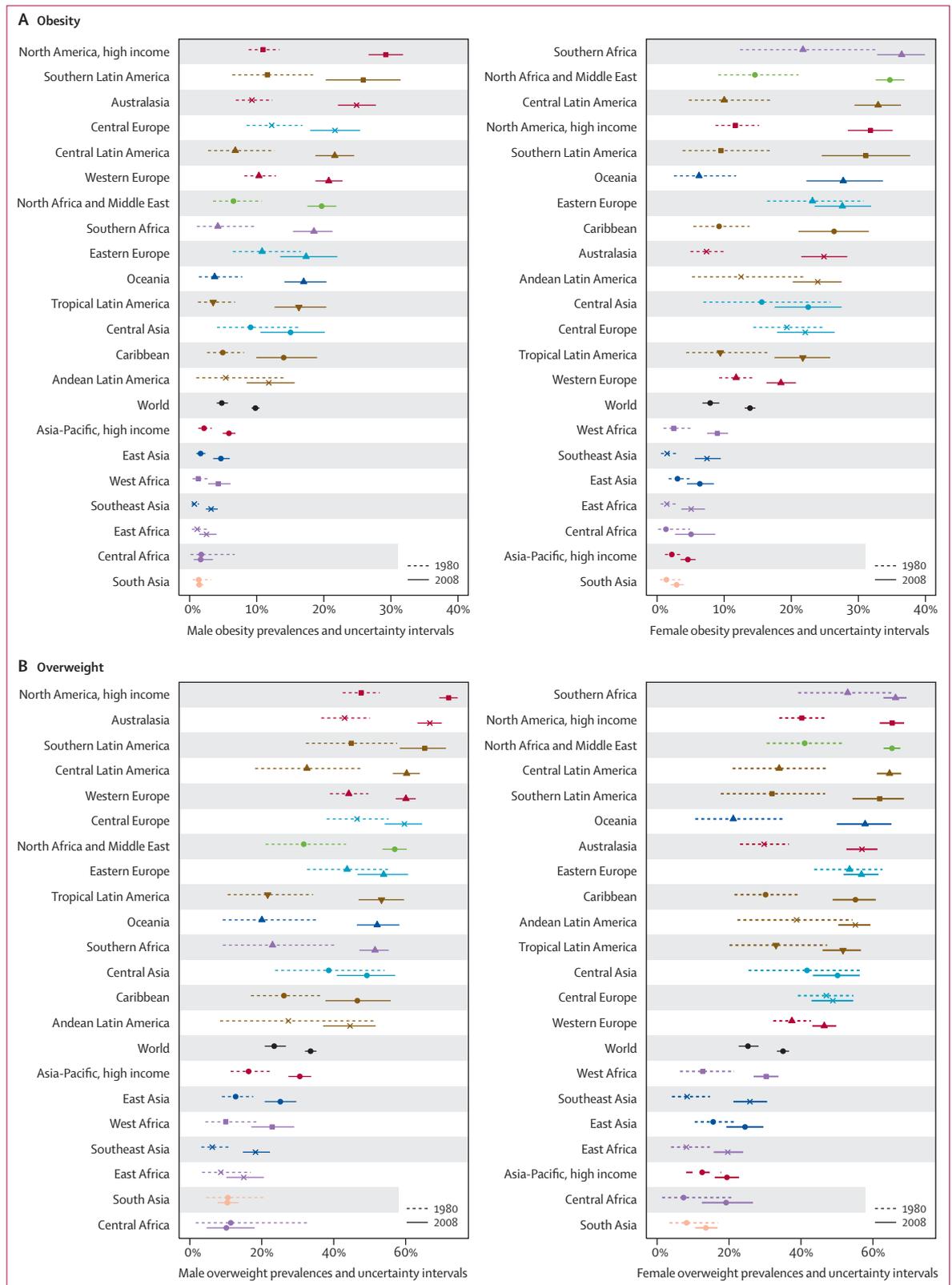
Figure 4: Prevalences of obesity (BMI ≥30 kg/m²; A) and overweight (BMI ≥25 kg/m²; B) in 1980 and 2008
BMI=body-mass index.

and women had BMI of 25 kg/m² or greater, representing an age-standardised prevalence of 34·3% (33·2–35·5). The prevalence of obesity in 2008 was highest in North American men, with an age-standardised prevalence of 29·2% (26·7–31·8), and in southern African women at 36·4% (32·8–39·9; figure 4). In addition to southern Africa, female obesity prevalence was also greater than 30% in North America and three low-income and middle-income subregions. Obesity prevalence was lowest in south Asia in both men (1·4%, 1·0–2·1) and women (2·9%, 2·0–4·0), followed by central and east Africa for men and high income Asia-Pacific and central and east Africa for women (figure 4).

Discussion

Between 1980 and 2008, age-standardised mean global BMI increased by 0·4–0·5 kg/m² per decade in men and women. We noted substantial differences across regions and sexes. Notably, the subregion trends spanned a 1·4 kg/m² range per decade for men and 1·9 kg/m² per decade for women, with BMI rise largest in Oceania in both sexes. The regions with almost flat trends or even potential decreases were central and eastern Europe for women, and central Africa and south Asia for men. An implication of these heterogeneous trends was an increasing gap between the lowest and highest BMI subregions for men and a reordering for women.

Our results for both BMI rise and the rare places where it was stable are consistent with national and multicentre studies.[5–13,19,20] For example, we estimated small differences between 1980 and 2008 in women in Brazil, Japan, and Taiwan; previous studies recorded increases in some groups and stable or decreasing trends in others.[7,9,27] Our estimated stable or decreasing trends in central and eastern Europe (for women) were also consistent with other analyses.[6,28]

The strengths and innovations of this study include analysis of long-term trends; the large amount of high-quality measured population-based data accessed and used, including data for either mean BMI or overweight or obesity prevalence, and systematically converting all metrics to mean BMI; the Bayesian hierarchical model to estimate mean BMI, incorporating non-linear age associations and time trends; incorporation of study coverage as offset and variance components in the statistical model; and systematic quantitative analysis and reporting of uncertainty. Coverage-specific offsets and variances allowed our estimates to use all available data and to follow data from nationally representative studies more closely than other sources. Further, the coverage-specific variance components are larger for less representative data sources, resulting in larger uncertainty when we did not have nationally representative data, propagating through the Bayesian model into our uncertainty intervals, thereby representing the true availability of information.

The main limitation of our study is that data gaps remained despite our extensive data seeking, especially in the 1980s, and for men during the 1990s. Our analysis did not consider trends in central adiposity because of insufficient population-based data, nor did it quantify within-country disparities by socioeconomic status or race.[29–31] Underweight, specifically as measured by low BMI, was not an outcome of our study. Although most research into undernutrition has focused on child growth and increased risk of mortality from infectious diseases, maternal low BMI is a risk factor for neonatal mortality.[32] We noted that in 1980, mean female BMI in several countries in sub-Saharan Africa and south and southeast Asia was less than 19 kg/m², suggesting that a substantial proportion of the population would be clinically underweight (BMI ≤18·5 kg/m²). By 2008, the lowest mean female BMIs had reached around 21 kg/m², suggesting that underweight prevalence has decreased, but that underweight might still affect some populations. Finally, we did not estimate childhood and adolescent adiposity, which is important because weight gain during childhood could have larger adverse effects than could weight gain during adulthood because of the longer exposure.

Although our estimates have quantitative uncertainty, the relatively large amount of data used makes our conclusions fairly robust. However, the interpretation of the findings and their research and policy implications might be less clear. Research is undoubtedly needed into the proximal and distal causes of the recorded trends. For example, to what extent have changes in physical activity versus increases in caloric intake or changes in dietary composition brought about BMI rise?[33,34] What explains the heterogeneous BMI levels and trends, including by sex, in high-income countries (Asia-Pacific vs western Europe vs Australasia and North America) or in Africa's subregions?

Learning from our understanding of the causes of recorded trends, and as we investigate and debate these causes,[35] we should design and rigorously test interventions and policies that curb or reverse the harmful trends, or attenuate their adverse effects through reduction of mediator effects such as blood pressure and lipids.[36] Randomised studies of diet change, some of which increase the amount of exercise, have shown moderate weight loss benefits for up to 2 years,[37–39] but long-term and community effectiveness of such interventions is not clear.[40] Simple advice and exercise alone have not been efficacious, even in trials.[39] Structural, regulatory, and economic interventions have potential to change physical activity or dietary patterns for whole communities and populations,[41,42] but few have shown effects on weight.[43] That interventions on metabolic mediators might partially mitigate the health effects of rising BMI is supported by results from randomised trials, and more importantly from the fact that many countries have successfully reduced blood pressure and

lipids despite rising BMI,[6,25,44] and by a larger amount in people with high BMI.[45] Although such interventions might reduce the effects of BMI on cardiovascular diseases, they do not address effects on other chronic diseases, especially diabetes, for which investigation of pharmacological interventions' effects on cause-specific and total mortality is in progress.[46–49]

Finally, we should analyse carefully the mortality and morbidity effects of high BMI and of interventions. International cohort studies have quantified the associations between high BMI and different diseases in populations worldwide.[2,3] Additional research is needed into how the duration of being overweight or obese affects risk, and whether the health benefits of prevention of weight gain are similar to those of weight loss.

Our systematic analysis of population-based data sources has helped to analyse the so-called global obesity pandemic by country, region, and sex. As we design and implement interventions and policies to address this important risk factor, high-quality national surveillance is essential to provide reliable data for setting of priorities and assessment of such efforts.

Contributions

GD and ME developed the study concept. GAS, HRG, YL, and ANB undertook reviews of published studies and managed databases. GAS, JKL, MJC, GMS, and members of Country Data Group analysed health survey and epidemiological study data. MMF and CJP developed the Bayesian statistical model with input from GD and ME. MMF, JKL, GMS, and GAS analysed databases and prepared results. GAS and ME wrote the first draft of the report. Other members of the Writing and Global Analysis Group contributed to study design, analysis, and writing of report. ME, GAS, GD, and CJP oversaw the research. ME is the study guarantor for this report.

Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Body Mass Index)

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Conflicts of interest

JKL holds stock in Johnson & Johnson. CJP holds stock in Pfizer. GAS has received funding from Harvard University for travel purposes. ANB has received consulting fees or honoraria and support for travel to meetings for the study or other purposes from Harvard University. ME has chaired a session at the World Cardiology Congress, which was sponsored by the organiser. All other authors declare that they have no conflicts of interest.

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