Obesity 2

Health and economic burden of the projected obesity trends in the USA and the UK

Y Claire Wang, Klim McPherson, Tim Marsh, Steven L Gortmaker, Martin Brown

Rising prevalence of obesity is a worldwide health concern because excess weight gain within populations forecasts an increased burden from several diseases, most notably cardiovascular diseases, diabetes, and cancers. In this report, we used a simulation model to project the probable health and economic consequences in the next two decades from a continued rise in obesity in two ageing populations—the USA and the UK. These trends project 65 million more obese adults in the USA and 11 million more obese adults in the UK by 2030, consequently accruing an additional 6–8·5 million cases of diabetes, 5·7–7·3 million cases of heart disease and stroke, 492 000–669 000 additional cases of cancer, and 26–55 million quality-adjusted life years forgone for USA and UK combined. The combined medical costs associated with treatment of these preventable diseases are estimated to increase by $48–66 billion/year in the USA and by £1·9–2 billion/year in the UK by 2030. Hence, effective policies to promote healthier weight also have economic benefits.

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This is the second in a **Series** of four papers about obesity

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Threat to population health

Increased prevalence of overweight and obesity is a worldwide health concern.[1] In a systemic analysis of epidemiological studies from 199 countries,[1] 1·46 billion adults worldwide were estimated to be overweight in 2008, and of these 502 million were obese. Despite signs of stabilisation in some populations,[2,3] the effects of consistently high prevalence of obesity on population health are far-reaching; societies are burdened by premature mortality, morbidity associated with many chronic disorders, and negative effects on health-related quality of life. The challenge to quantify the effect of these health burdens to inform public policies and health services are pressing. Furthermore, projected increases in these diseases in many ageing populations suggest a substantial cost burden to the health-care system in an era of ever-escalating medical expenditure. In a systematic review of the economic burden of obesity worldwide, Withrow and colleagues[4] concluded that obesity accounted for 0·7–2·8% of a country's total health-care costs, and that obese individuals had medical costs 30% higher than those with normal weight. The combination of rising obesity prevalence and increased spending on obese people has been estimated to account for 27% of the growth in US health-care expenditure between 1987 and 2001.[5] Total health-care costs attributable to obesity and overweight are projected to double every decade to account for 16–18% of total US health-care expenditure by 2030.[6]

Figure 1 shows obesity prevalence in adults and children in selected countries.[7] Since the 1970s, the USA and the UK have had striking increases in the proportion of their populations with a body-mass index (BMI) in overweight (BMI 25–29·9 kg/m²) and obese (BMI ≥30 kg/m²) ranges. If such trends were to continue unabated, the report's authors estimate that about three of four Americans and seven of ten British people will be overweight or obese by 2020.[7] Although population-wide secular trends seem much the same, obesity and overweight cluster differently according to socioeconomic status, educational attainment, and race and ethnic group (figure 2 and figure 3).

Health burden from rising obesity

The health burden from obesity is largely driven by an increased risk of type 2 diabetes, cardiovascular diseases, and several forms of cancer. For instance, every additional 5 kg/m² in BMI increases a man's risk of oesophageal cancer by 52% and for colon cancer by 24%, and in women, endometrial cancer by 59%, gall bladder cancer by 59%, and postmenopausal breast cancer by 12% (the association is strongest in women in the Asia–Pacific

Key messages

- Excess bodyweight is associated with negative effects on longevity, disability-free life-years, quality-of-life, and productivity. The obesity epidemic affects both high and middle-to-low income countries, posing a threat to population health and a substantial burden to many health systems.
- The burden of obesity includes an increased number of fatal and non-fatal diseases—including diabetes, coronary heart disease, stroke, cancer, and osteoarthritis—which impose substantial medical costs from treatment and productivity losses (absenteeism, presenteeism, and loss of productivity from premature deaths).
- The higher the proportion of the population that is overweight and obese, the greater the use of health services, resulting in higher treatment costs for the many obesity-related diseases than in a less obese population.
- The health and cost burden of overweight and obesity has a protracted time course. Epidemiological models such as the one we present enable us to link changes in obesity at the population level to disease burdens decades later, a crucial exercise for public policy.
- A systematic understanding of the potential morbidity and cost implications of specified hypothetical changes in body-mass index trajectories, driven by policy changes or otherwise, is crucial for formation of effective and cost-effective strategies, establishment of research and funding priorities, and creation of the political will to address the obesity epidemic.

region).[8] Excess bodyweight also contributes to non-fatal but costly or disabling disorders such as osteoarthritis.[9] Moreover, rapidly expanding evidence suggests that excess bodyweight is linked to many additional disorders, including benign prostate hypertrophy,[3] infertility,[4] asthma,[5,6] and sleep apnoea,[7] further contributing to the cost burden. Maternal obesity has been linked to an increased risk of congenital anomalies.[10] Because in many populations the prevalence of obesity is greater at a much younger age than in previous generations, present trends in obesity project a growth in the proportion of the population living with chronic disabilities. Some researchers have postulated a potential threat to the continued increase in life expectancy achieved by medical and public health advances during the past century.[11]

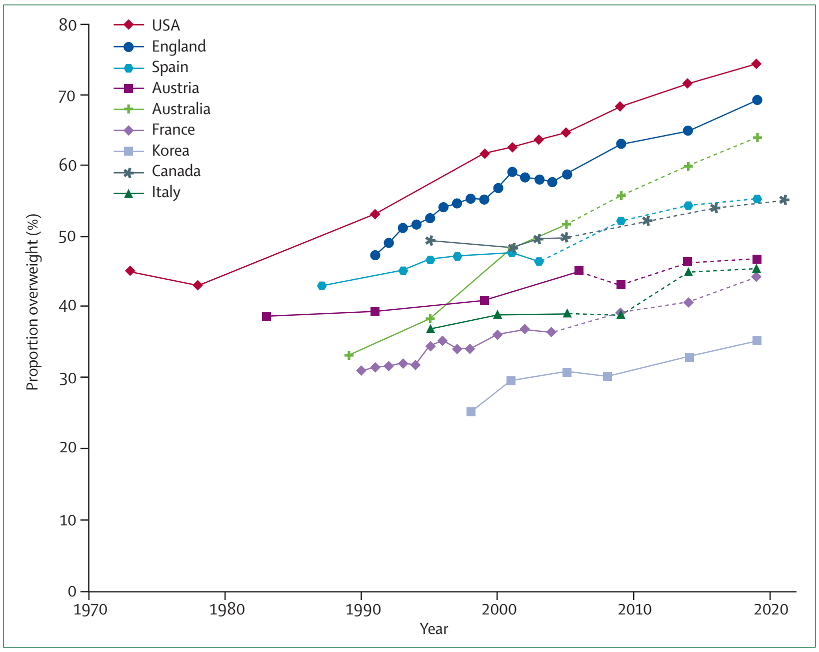

Figure 1: **Past and projected prevalence of overweight (BMI ≥25 kg/m²)**
Reproduced from the Organisation for Economic Co-operation and Development.[7]

Economic cost of rising obesity

The many chronic and acute health disorders associated with excess bodyweight burden a society not only by negatively affecting the health-related quality of life[12,13] of its people but also by incurring substantial costs to the individuals affected and to society, notably from increased health-care costs and lost productivity.

The medical costs of obesity represent the monetary value of health-care resources devoted to managing obesity-related disorders, including the costs incurred by excess use of ambulatory care, hospitalisation, drugs, radiological or laboratory tests, and long term care (including nursing homes). In a systematic review of the direct health-care costs of obesity, Withrow and colleages[4] estimated that obesity accounted for up to 2·8% of health-care expenditure, noting that the studies were generally very conservative, such that the actual amount was likely to be higher. On the basis of the most recent US data, Finkelstein and colleages[14] reported that, compared with normal-weight individuals, obese patients incur 46% increased inpatient costs, 27% more physician visits and outpatient costs, and 80% increased spending on prescription drugs. The annual extra medical costs of obesity in the USA were estimated as $75 billion in 2003[15] and accounted for 4–7% of total health-care expenditure.[16] In the early 1990s, obesity was estimated to account for 2% of health-care costs in France,[17] 4% in the Netherlands,[18] and 2% in Australia.[19] The application of similar methodology to all member states of the European Union has provided estimates for the combined direct and indirect costs of obesity in 2002 of roughly €33 billion a year.[20,21] In 2007, a report developed by the UK's Office for Science Foresight Programme[22] projected that the

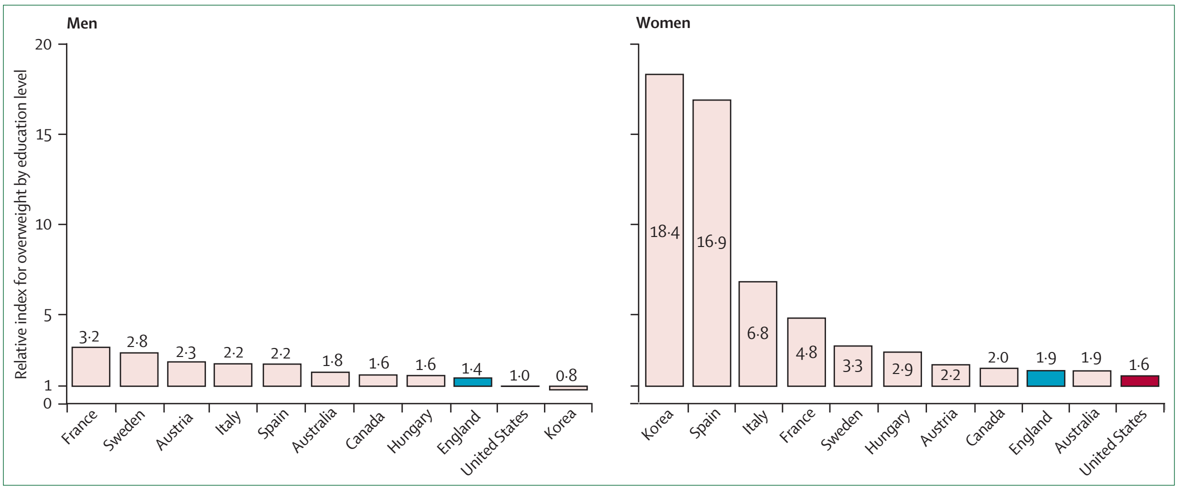

Figure 2: **Relative index of inequality in obesity by education level**
The relative index of inequality provides a measure of how many times more likely to be obese are those at the lower end of the education spectrum relative to those at the upper end. Reproduced from the Organisation for Economic Co-operation and Development.[7]

continuing rise in obesity will add £5·5 billion in medical costs to the National Health Service by 2050.

In addition to medical costs, society incurs substantial indirect costs from obesity as a result of decreased years of disability-free life, increased mortality before retirement, early retirement, disability pensions, and work absenteeism or reduced productivity (also known as presenteeism). Although individual estimates vary, several studies suggest that the monetary value of lost productivity is several times larger than medical costs.[23–25] For example, in Sweden individuals who are obese are 1·5–1·9 times more likely to take sick leave, and 12% of obese women have disability pensions attributable to obesity, togther costing about US$300 for every adult woman in the population.[26] For US employees, Finkelstein[25] reported that annual missed workdays ranged from 0·5 more days in men who were overweight to 5·9 more days in men who were classified grade III obese (BMI ≥40 kg/m²) than in men of healthy weight. Moreover, they estimated that the annual cost from presenteeism in men who were very obese (BMI ≥40 kg/m²) was the equivalent of 1 month of lost productivity and cost employers $3792 per year.

Quantification of the costs from the health consequences of obesity is complex; costs are mediated by factors such as a changing demography, food system, and the economy. Estimation of the cost from lost productivity is especially challenging because of the scarcity of data and the assumptions needed for the labour market structure. However, a valuable lesson learned from the UK Foresight Project is that definition of the size of the problem can be the beginning of a movement to raise awareness and mobilise political will to address the problem. In the following case studies, we applied the Foresight modelling framework to the US and the UK to provide updated projections for obesity trends and increases in health-care expenditure consequent on increases in obesity-related diseases. Of the 11 countries described in the OECD report,[7] the USA and UK had the highest prevalence of obesity (figure 1) and were two of only three countries (the other being South Korea) with periodic objectively measured BMI data.

The health-care burden of obesity

BMI trends

We analysed two nationally representative surveys to obtain trends in BMI: the National Health and Nutrition Examination Survey (NHANES)[27] from the USA and the Healthy Survey for England (HSE)[28] from the UK. Both surveys contain objectively measured weight and height data (table 1 and panel). Separately for the two countries, a set of two projections were made to provide a probable range of the outlook of growth in obesity prevalence within populations in the next 20 years. The historic trend projection was constructed from two decades of measured BMI data (since 1988 in the USA and 1993 in the UK)—depicting the fast-growing obesity trend that is repeatedly reported. The recent trend, a more optimistic projection, is based on data from 2000 onwards, guided by several publications suggesting a levelling-off of obesity trends.[2,49,50]

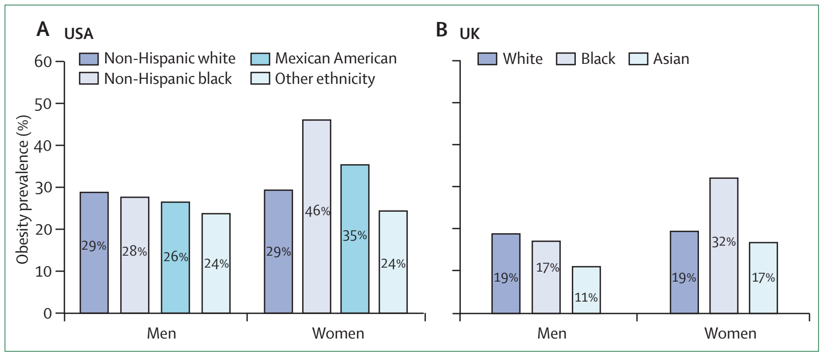

Figure 3: **Adult prevalence of obesity by ethnicity in USA and UK**
Reproduced from the Organisation for Economic Co-operation and Development.[7]

Past trends in BMI growth projected an increase of obesity prevalence in US adults from about 32% in 2007–08, (the latest available data) to 50–51% (corresponding to recent–historic projections) in 2030 for men, and from 35% to 45–52% for women (figure 4). These projections are similar to previously published estimates with different projection models.[6,51] By contrast, past trends in the UK would forecast a rise in obesity prevalence in men from 26% to 41–48% and in women from 26% to 35–43%. With the exception of US men, the recent trend projections have slopes that are substantially flatter than the slopes under the historic trend. Because of the fewer datapoints, these projections also have more uncertainty than historic trends, as shown by wider confidence intervals.

Combined with the shift in age structure—the ageing of the so-called baby boom generation in both countries—these projections suggest that, for the USA, there would be as many as 65 million more obese adults in 2030 than in 2010, 24 million of whom would be older than 60 years (figure 5); and for the UK, up to 11 million more obese adults, 3·3 million of whom would be older than 60 years.

Health burden of obesity epidemic

For the USA, in the next two decades, the historic trends since the early 1990s would project an excess of 8 million cases of diabetes, 6·8 million cases of coronary heart disease and stroke, and over 0·5 million cases of cancer (table 2, scenario 1). By comparison, from a more optimistic recent trend we would predict an excess of 6 million cases of diabetes, 5 million of coronary heart disease and stroke, and more than 400 000 of cancer. Although the prevalence of obesity in the UK is less than in the USA, and data since 2000 suggest some stabilisation of projected growth (figure 4), a substantial disease burden is associated with obesity and overweight in the UK population. During the next 20 years, we projected that obesity-attributable disease risks will add an excess of 544 000–668 000 cases of

	USA	UK
Population characteristics		
BMI distribution	NHANES 1988–2008[27]	HSE 1993–2008[28]
Population size	US census and projections[29]	UK census and projections[30]
Incidence of disease		
Hypertension	NHLBI 2006 chart book[31]	British Heart Foundation statistics
Coronary heart disease	Framingham heart study 1980–2003, National Institute of Health–NHLBI[32]	European cardiovascular disease statistics 2008[33]
Diabetes	National health interview survey, Centers for Disease Control and Prevention, National Centre for Health Statistics.[34]	British Heart Foundation statistics
Stroke	Framingham heart study 1980–2003[32]	Stroke statistics 2009,British Heart Foundation[35]
Cancer	US cancer statistics: 1999–2005	UK Cancer Research statistics (CancerStat)[36]
Arthritis	Cohort study based on population-based administrative health-care database[37]	Office for National Statistics
Relative risks of obesity on disease risks	International Association for the Study of Obesity, 2010[38]	..
Cost of treatment		
Hypertension	Heart disease and stroke statistics, 2009 update[39]	British Heart Foundation statistics (adjusted for inflation)
Coronary heart disease	Heart disease and stroke statistics, 2009 update[39]	UK coronary heart disease statistics 2009–10[40]
Diabetes	American Diabetes Association[41]	Diabetes in the NHS report[42]
Stroke	Heart disease and stroke statistics, 2009 update[39]	Stroke statistics 2009 from British Heart Foundation,[35] calculated for per-case cost based on estimated prevalence.
Cancer	National Cancer Institute[43]	UK Foresight programme[22]
Arthritis	Medical expenditure panel survey[44]	UK Foresight programme[22]
Disease-specific mortality		
Coronary heart disease	Heart disease and stroke statistics, 2009 update[39]	British Heart Foundation statistics
Diabetes	American Diabetes Association[41]	British Heart Foundation statistics
Stroke	Heart disease and stroke statistics, 2009 update[39]	British Heart Foundation statistics
Cancer	National Cancer Institute (SEER database 1999–2006)	UK Cancer Research statistics[36]
Quality-of-life weights	Published HRQL estimates[12] using the EQ-5D measures in the 2000 US MEPS data (n=13 646)	N/A (assumed same as US HQRL weights)
Forgone productivity		
Absenteeism	2008 National health and wellness survey[45]	N/A
Presenteeism	2008 National health and wellness survey[45]	N/A

NHANES=National Health and Nutrition Examination Survey. HSE=Health Survey for England. NHLBI=National Heart, Lung and Blood Institute. HRQL=health-related quality-of-life weights. SEER=Surveillance Epidemiology and End Results. MEPS=Medical Expenditure Panel Survey. NA=not available.

Table 1: **Sources of data inputs for USA and UK**

For more on the **British Heart Foundation statistics** see http://www.heartstats.org

For more on **US cancer statistics** see http://wonder.cdc.gov

For more on the **UK Office for National Statistics** see http://www.statistics.gov.uk

For more on the **US National Cancer Institute SEER database** see http://seer.cancer.gov

diabetes, 331 000–461 000 of coronary heart disease and strokes, and 87 000–130 000 of cancer.

In addition to these diseases are several non-fatal, but nevertheless debilitating disorders such as osteoarthritis and hypertension; together they pose a substantial threat to the population's healthy life span. We estimated that a continuing trend in obesity would present a loss of 2·2–6·3 million quality-adjusted life-years (QALYs) in the UK and 24·5–48·2 million QALYs in the USA during 2010–30.

Projected health-care costs attributable to obesity-related diseases

If trends continue, further increases in obesity in the two populations project an expansion of obesity-related and mostly chronic diseases with substantial implications for health-care expenditure. Compounded by an ageing population, in the next two decades, extrapolation of the historic trend in the USA would project an increase in annual medical cost from treating obesity-related disorders of US$28 (95% CI 8–49) billion per year by 2020 and $66 (19–112) billion per year by 2030 (figure 6). The recent trend would project a lower, but still substantial increase in costs: $22 (–28 to 72) billion per year by 2020 and $48 (–47 to 143) billion per year by 2030. To put these numbers into context, a $22–66 billion increase in health-care spending represents a 0·8%–2·6% increase from the $2·5 trillion US health-care spending in 2009. The top contributors to this cost burden are arthritis, coronary heart disease, and diabetes, and about half these costs would be incurred by individuals 65 years and older (covered by the publicly funded Medicare programme).

A substantial health-care cost burden is expected in the UK (figure 6). Historic BMI trends would project £648 (95% CI 352–944) million higher costs annually

Panel: Data sources and statistical methods

Population-representative measured body-mass index data
UK–Healthy Survey for England (HSE): HSE is a nationally representative, cross-sectional survey of health and nutrition in adults and children in England. Since 1993, HSE datasets have been produced annually. In this report, we used 16 waves of HSE from 1993 to 2008 (n=241 580) to produce the historic trend, and the 2001–08 surveys to produce the recent trend.
US–National Health and Nutrition Examination Survey (NHANES): NHANES is a nationally representative, cross-sectional survey of health and nutrition in adults and children in the USA. Since 1999, NHANES datasets have been produced every two years. We used the most recent five waves of surveys (1999–2000, 2001–2, 2003–4, 2005–6, and 2007–8) in addition to NHANES III (1988–1994) to produce the historic trend, and the post 1999 data to produce the recent trend. The total sample size from NHANES was 85 602.

Categorisation of body-mass index
We defined three mutually exclusive categories of body-mass index (BMI): not overweight (<25 kg/m²), overweight (25–29·9 kg/m²), and obese (≥30 kg/m²). For children and adolescents between 2 and 19 years of age, we applied the age-specific and sex-specific BMI percentiles from the US Centers for Disease Control and Prevention growth standards: not overweight (BMI <85th percentile), overweight (85–94th percentile), and obese (≥95th percentile).

Statistical methods
We undertook the two-part modelling process developed by the UK Foresight working group.[22,46,47] The first module implements a regression analysis based on series of cross-sectional data; the second module implements a microsimulation programme to produce longitudinal projections.

In the first module, we fit multivariate, categorical regression models to the cross-sectional BMI data series from each country and by sex. We included age and calendar year as covariates, and constrained the predicted proportions of population in each BMI category to always sum up to 100%. The 95% CI for the projected prevalence were calculated from the Bayesian posterior distribution of the regression parameters.

Microsimulation of obesity-related disease consequences
Within the Foresight microsimulation framework,[22] we created virtual US and UK individuals on the basis of projected BMI distributions in 2010–30. We probabilistically assigned BMI values as a function of age, sex, and calendar year. Assuming an individual's BMI ranking (ie, percentile) in the same-age cohort is constant over time, we longitudinally simulated the BMI trajectories of a large number of individuals as they age. Population size and age distributions were based on the published projections from the US and UK censuses.

Every year, each simulated individual in the model had a probability of getting a specific disease if he or she was free of the disease at the beginning of the year. This risk is a predetermined function of age, sex, and BMI. For individuals with a disease, possible outcomes are recovery, continuation of the disease, or death from the disease. The progress of any disease was determined by the appropriate survival and case-fatality statistics.

A review of epidemiological publications was undertaken to determine country-specific incidence, case-fatality rates, and rough annual treatment costs for the obesity-related diseases of type 2 diabetes, coronary heart disease, stroke, arthritis, and obesity-related cancer, by age and BMI. Relative risks of BMI for these diseases individually are taken from a systematic review of epidemiological studies.[32] Health-related quality of life (HRQL) weights as a function of BMI were based on published US estimates done with the EQ-5D instrument.[12] We assumed that the relative risks of high BMI on the incidence of diseases and the average quality-of-life weights were the same for the US and the UK. We calculated quality-adjusted life-years by taking the product of length of life and HRQL, aggregated for 20 years. Excess annual costs of each disease due to rising obesity were obtained from estimates from governmental data or the best available published work (table 1). For instance, cost of coronary heart disease in the USA was obtained from Heart Disease and Stroke Statistics—2009 update, which reports the aggregate direct medical expenditure due to coronary heart disease, including costs from hospitals, nursing homes, physicians and other professionals, and drugs. These aggregate values were then divided by total number of patients at baseline to estimate annual medical cost per case. We probabilistically assigned diseases and associated costs, and quality-of-life weights, in all subsequent years as a function of individual BMI trajectories using a Monte Carlo simulation method.[48] We simulated 20 million individuals, by sex, for all scenarios and scaled them up to represent the total census population. Excess numbers of diseases and associated health-care costs were calculated by taking the difference between the estimates for a specific scenario (eg, recent trend) and a reference scenario, which assumed that the BMI distributions were fixed at the 2008 level—the most recent data available. The 95% CI for the projections were derived from simulation of the BMI distributions corresponding to the upper and lower bounds of all obesity growth scenarios.

The simulation model was programmed in C++ (version 12·0, Embarcadero Technologies). Further details of the two-part modelling process can be found in the Foresight report[31] and webappendix pp 7–9.

See Online for webappendix

in 2020 and £2 (95% CI 1·2–3·0) billion higher costs annually in 2030 to be spent on treating obesity-related diseases. The equivalent estimates with the recent trend projections would amount to £613 (–426 to 1653) million excess spending in 2020 and £1·9 (–0·8 to 4·5) billion in 2030. A £613 million–£2 billion increase would

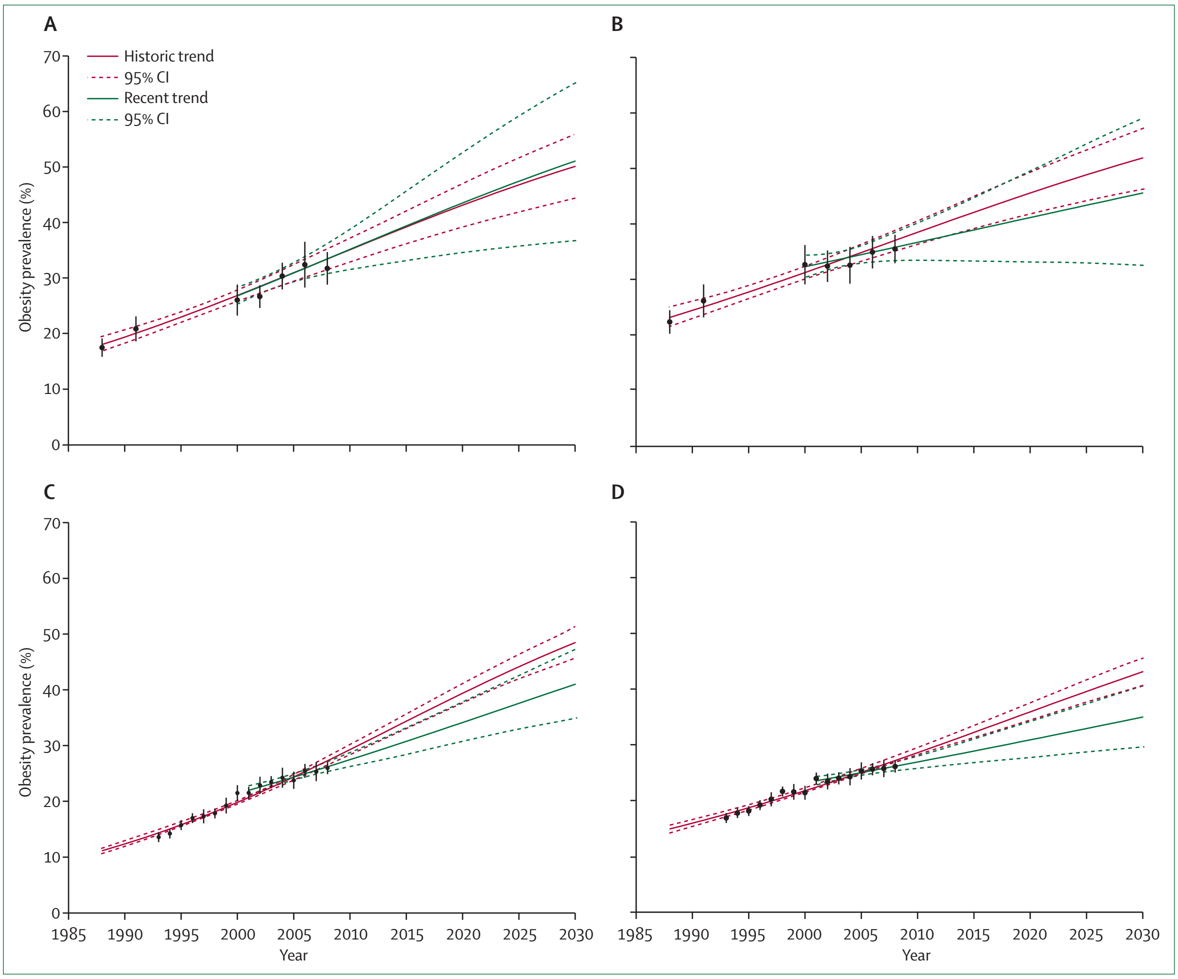

***Figure 4:* Historic and recent trends in adult obesity prevalence in men and women in USA and UK**
A=US men; B=US women; C=UK men; D=UK women. Black dots (bars=95% CI) show recorded prevalence from national surveys; each dot=one data point. Historic trend used all data points; recent trend used data points after 2000.

correspond about 0·5%–2% of the total health-care spending in 2009 in the UK (£109·7 billion).

Effects of ameliorating or reversing the obesity epidemic

In view of the substantial health and cost burdens of obesity, an obvious policy question is; what would be the health and economic benefit were the rising obesity trend to be ameliorated? Table 2 summarises the projected downstream changes in disease burdens, QALYs, and obesity-related health-care costs according to two hypothetical scenarios.

Consider a hypothetical programme that enables a 1% reduction in BMI across the entire population (scenario 2, table 2). A 1% reduction is equivalent to a weight loss of roughly 1 kg for an adult of average weight. This change might sound small, but such a scenario would have a substantial effect on consequent health burdens. Compared with a scenario in which past trends continue (recent *vs* historic), a 1% BMI reduction across the US population would avoid up to 2·1–2·4 million incident cases of diabetes, 1·4–1·7 million cardiovascular diseases, and 73 000–127 000 cases of cancer, with a gain of about 16 million QALYs. The equivalent scenario in the UK would avoid 179 000–202 000 incident cases of diabetes, 122 000 cardiovascular diseases, and 32 000–33 000 incident cases of cancer with a gain of about 3 million QALYs over 20 years. Because a 1% reduction in BMI is roughly 1 kg weight reduction per person, according to the principle developed by Hall and colleagues,[52] it would need a net caloric reduction of 20 kcal per day that was sustained for 3 years.

A more aggressive scenario (scenario 3, table 2) envisions a drastically lower prevalence of obesity by a return to 1990 prevalence. Between 1990 and 2007–08, the period for which we have similar data for both the USA and the UK, the average bodyweight had risen by 9–18 kg (dependent on country and sex). This difference in weight corresponds to a 200–400 kcal per day difference in energy intake or expenditure sustained for 3 years.

Loss of productivity

The economic costs from the excess morbidity and mortality attributable to obesity-related diseases go beyond health-care costs alone, perhaps most notable are the consequent losses in productivity. The shortage of consistent and high-quality data precludes cross-country comparisons. We explored the size of this indirect cost burden for the USA alone in the context of the health-care costs projected by our model. After incorporation of estimates by Finkelstein and colleagues[43] of the incremental lost workdays and costs of absenteeism and presenteeism from high BMI—based on the 2008 National Health and Wellness Survey—we would expect a loss of 1·7–3 million productive person-years in working US adults, representing an economic cost as high as $390–580 billion.[43]

Discussion

In this report, by drawing similar statistics from the USA and the UK into the same modelling structure, we have had the opportunity to describe how the seemingly similar obesity epidemic unfolds in two populations. In the years 2010–30, the continuing rise in obesity was projected to add a combined 6–8·5 million incident cases of diabetes, 5·6–7·3 million incident cardiovascular diseases, and more than half a million new cancers in the USA and the UK. In addition to compromising the populations' healthy, productive life span, by 2030, these increases in obesity-related diseases were projected to add to health-care costs by $48–66 billion a year in the USA and by £1·9–2 billion a year in the UK. The prevalence of obesity is lower in the UK than in the USA; however, we projected a more rapid increase in health-care costs in the UK during the next 20 years than in the USA. This rapid increase is partly attributable to the UK's older population (figure 5), for example, US men in 2007 were on average 2 years younger than men in the UK (average ages 36·1 and 38·3 years, respectively). If past trends continue, during the next 20 years, we projected a 13–16% increase in annual costs of obesity-related diseases in the USA, 4% of which is from population ageing alone. In the UK, the equivalent annual increase would be 24–25%, 10% from ageing alone.

These projections are mere extrapolations from available data, and inherent uncertainties exist when making predictions. Although the increase in obesity prevalence in the past several decades has been steady in the USA and the UK (figure 4) and the rest of the world,[1,3] past trends do not always predict the future. Consideration of several projection scenarios is therefore vital. For instance, we produced a more pessimistic trend from data since 1990, and a more optimistic trend using the flatter, more recent data, both with confidence bounds. How the continuing trend will respond to the changing world (eg, food prices, agriculture policy, or technological innovation) in the next 5 or 10 years can only be examined with hindsight. However, human physiology for energy regulation suggests that weight change in response to a shift in energy intake or expenditure is a gradual process, with a half-life spanning several years.[52] Whether the USA

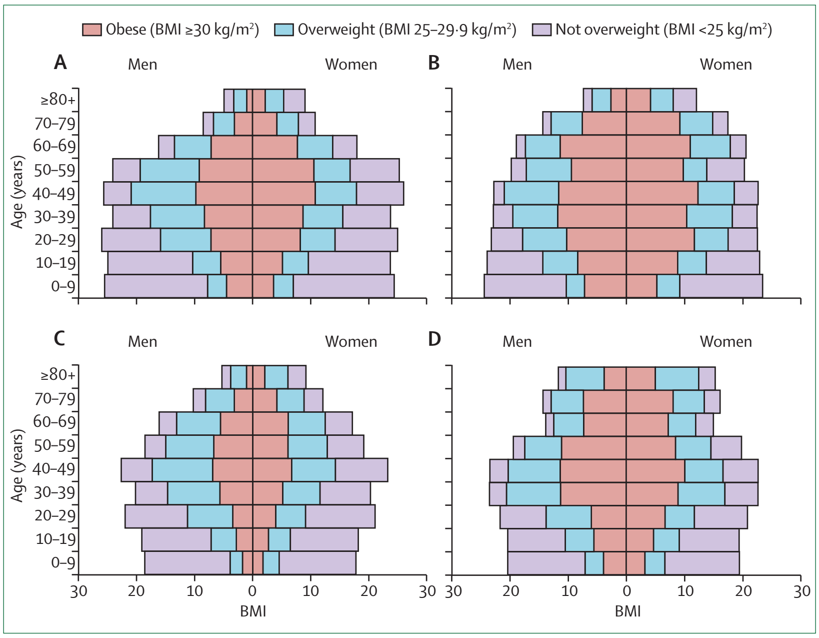

Figure 5: **US and UK population projections 2010 *vs* 2030, by overweight or obesity status, assuming historic trend in BMI**
A=USA, 2010; B=USA, 2030; C=UK, 2010; D= UK, 2030. Population pyramid. Size of bars shows the size of projected census population (×100 000) by BMI status, sex, and age category in USA and UK.

	UK		USA	
	Recent trend	Historic trend	Recent trend	Historic trend
Scenario 1. Past trends continue unabated				
Diabetes (×1000)	+545 (432)	+668 (159)	+5503 (3524)	+7855 (1618)
Coronary heart disease and stroke (×1000)	+331 (407)	+461 (128)	+5365 (3359)	+6836 (1537)
Cancer (×1000)	+87 (108)	+130 (34)	+405 (265)	+539 (123)
Gain or loss in QALYs (×1000)	−2219	−6300	−24 488	−48 259
Scenario 2. 1% reduction in BMI for every adult at baseline				
Diabetes (×1000)	−179 (385)	−202 (139)	−2051 (2922)	−2420 (1461)
Coronary heart disease and stroke (×1000)	−122 (374)	−122 (116)	−1431 (2799)	−1704 (1400)
Cancer (×1000)	−32 (100)	−33 (33)	−73 (219)	−127 (109)
Gain or loss in QALYs (×1000)	+3011 (930)	+3195 (395)	+15 988 (1911)	+16 135 (781)
Scenario 3. If obesity rates had remained at 1990 levels				
Diabetes (×1000)	−897 (216)	−1021 (159)	−8664 (3524)	−11 016 (1618)
Coronary heart disease and stroke (×1000)	−634 (204)	−763 (128)	−7670 (3359)	−9141 (1537)
Cancer (×1000)	−177 (54)	−220 (34)	−534 (265)	−668 (123)
Gain or loss in QALYs (×1000)	+7073	+11 155	+58 177	+81 948

Scenario 1=past trends continue unabated; scenario 2=1% reduction in BMI for every adult at baseline; scenario 3=obesity rates remained at 1990 levels. Recent trend estimates were based on projections with data from 1990, which implied a slower increase in obesity, while historic trend estimates were projected from all available data from 1988, showing a steeper rate of increase in obesity. Data are cases (SE) unless otherwise stated. QALY=quality-adjusted life-years.

Table 2: **Projected health and quality-adjusted life-year outcomes, 2010–30, under three hypothetical scenarios of population-wide change in body-mass index distribution**

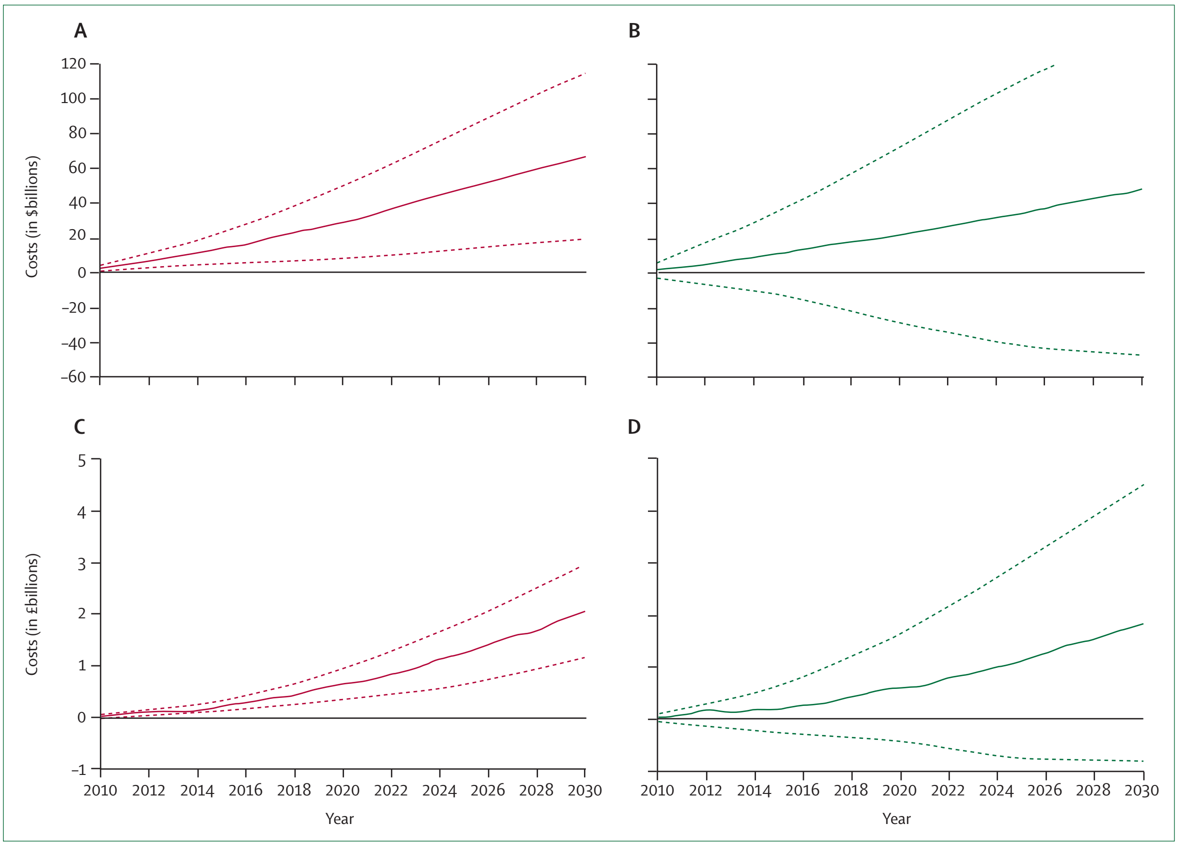

Figure 6: **Projected health-care costs from obesity-related diseases in USA and UK, 2010–30**
A=USA, historic trend; B=USA, recent trend; C=UK, historic trend; D=UK, recent trend. Dashed lines=95% CI. Costs are $ for USA and £ for UK.

and the UK have plateaued or even turned the corner will be a focal point for the next several datapoints from periodic surveys. As we look beyond these two countries and examine the similarities and differences across other populations,[3] the availability of high-quality national surveillance data becomes increasingly crucial. Nevertheless, we hope that our dire predictions will serve to mobilise efforts to reduce obesity so that our predictions do not become reality.

Undoubtedly the costs associated with treatment of obesity-related morbidity are high, but would a reduction in obesity result in net cost savings?[53–56] Some researchers argue that prevention of obesity could result in lengthened lifespan, which in turn could lead to increased costs in a person's lifetime for treatment of diseases associated with ageing but not directly related to obesity, such as senile dementia. van Baal and colleagues[55] predicted that a 20-year-old obese individual might incur lower total cost for health-care during his or her lifetime than a normal weight adult of the same age because of their roughly 5 years shorter life expectancy. Rappange and colleagues[54] advocated the inclusion of unrelated medical costs in life-years gained in all economic evaluations of preventive interventions, although they acknowledge the practical challenge and scarcity of comprehensive data for doing so. By contrast, another analysis[57] showed that lifetime medical costs are substantially higher in adults who are obese in the USA. Other researchers[53,58] argue that inclusion of unrelated future costs distorts decision making about resource allocation.

One key distinction is between the projected lower lifetime health-care costs for an obese individual (versus those of health weight) and the higher cost for an obese population at a specific time or during a particular period (eg, 2010–30). An obese population will incur greater health-care costs at a particular time than will a lean population of the same age distributions, and this expenditure is preventable.[56] In our case studies, we estimated the cross-sectional health-care costs of US and UK adults older than 20 years according to counterfactual scenarios of lower BMI distribution (eg, 1% lower or resumption of 1990 prevalence). The effect of these scenarios on life expectancy was relatively small. However, we have accounted for obesity-related medical costs for these added months, capturing the most costly disorders such as cardiovascular diseases, cancer, and osteoarthritis. Without a doubt, health-care expenditure is high for elderly people, but these costs should not be used to justify the cost-savings of dying younger, or to suggest that obesity-prevention has no benefit. In fact, van Baal and colleagues[55] emphasised that, although prevention might not always be a cure for increasing expenditures, it can be a "cost-effective cure for much morbidity and mortality, and importantly, contribute to the health of nations".

Irrespective of the aim of the models being descriptive, explanatory, or assessable,[59] for a model to be useful, a crucial capacity is to link changes in population weight distribution to immediate and future health and cost outcomes. By contrast with traditional epidemiological investigations—such as randomised controlled trials, observational studies, and meta-analyses—simulation models such as the one we used fill a methodological gap by overcoming several challenges with respect to quantification of obesity-attributable health consequences: the detrimental health effects of excess weight take many years to manifest, and demographic shifts (eg, ageing population) or health-system factors can result in substantial differences in the magnitude and bearers of such burden. In this analysis, we project the future health and associated medical costs on the basis of a list of obesity-related diseases. This so-called top-down approach is similar to the methods used previously[60–62] but tends to be conservative. Rapidly expanding evidence suggests that many additional disorders beyond those we included could be linked to excess weight.[9] For example, increased abdominal adiposity causes benign prostatic hypertrophy in men,[63] and infertility is clearly related to higher BMI categories in young women in prospective studies.[64] Asthma risk is directly related to adiposity in children and possibly adults.[65,66] Sleep apnoea is directly related to adiposity, yet has been omitted from cost estimates to date.[67] Moreover, this approach inevitably makes simplifications on variations between individual patients such as treatment intensity, stage of disease, and comorbidities. The correlation between conditions is often not considered—eg, an obese individual can have both high blood pressure and diabetes, and the medical visits might treat more than one condition. An alternative approach is to bypass the process of making a list of obesity-related disorders altogether and instead using existing health services data systems to obtain direct estimates of use for insured patients, classified according to BMI.

In an increasing number of studies,the financial effect of overweight and obesity is examined by directly contrasting medical expenditure or health-services use in individuals at different BMIs.[14,68] However, this approach for projection, especially for multicountry comparison, is problematic. Not only does a nationally representative expenditure data system have to be available, but also extensive adjustments need to be made to ensure the reported expenditure differences can truly be attributed to BMI. For instance, availability and type of health insurance coverage might be correlated to BMI and highly predictive of health-care use (especially in a decentralised market-driven system like that in the USA). The association between health-care costs and specific disease categories (eg, cancer) is unclear.

The USA and the UK are unusual in having decades-long, periodic population surveys that use objective measures of BMI. Despite the excellent BMI measurements, census and vital statistics, and disease registry infrastructures in these two countries, several methodological challenges exist. The surveys we used for these two countries were not perfectly representative: US NHANES samples only the non-institutionalised population, and HSE only represents England, but not Scotland, Northern Ireland, or Wales. We noted a substantial variation in the quality, study population, collection frequency, and disease definition in the statistics available. For example, the disparate incidence rates between the two countries could be a result of differences in diagnosis and coding practices. This variation is particularly challenging for non-fatal diseases such as osteoarthritis. In addition to measurement issues, because of the vastly different health-care systems, the cost of treatment of the same disease (a function of treatment intensity and unit cost of a specific service) can differ drastically. Finally, despite many previous studies[69–71] suggesting that most of the cost burden of obesity could come from productivity loss, consistent measures to track and compare forgone productivity across different populations are scarce.

In addition to data inputs, our study had several other limitations. Our model only partly addressed the differences in medical costs by category of obesity[9,10] (ie, severely obese individuals use many more health services than do moderately obese individuals[72]) and by demographic factors such as ethnicity and socioeconomic status.[11] We also had to make necessary mathematical assumptions—for example, to ensure the simulated population would produce BMI distributions that matched cross-sectional data, we assumed BMI rankings between same-aged individuals were the same over time. This assumption, however, is likely to have a small effect, because an individual's bodyweight tracks strongly over time, and instances of substantial weight gain or weight loss are likely to negate each other when summed across the whole population.

Because of the 20-year timeframe, we probably underestimated the future effect of childhood obesity. High bodyweight early in life increases future cardiovascular disease risk, independent of adult BMI.[73] Bibbins-Domingo and colleagues[74] estimated that by 2035, the present prevalence of overweight and obesity in adolescents could lead to a 5–16% increase in coronary heart disease. Finally, our projections incorporated population ageing, but we have not accounted for other less predictable, but important, population changes such as immigration, health-care system reform, or technological advances for disease treatment.

The morbidity and economic burden of obesity is a practical metric for comparative assessment of health risks, as exemplified by its use by international organisations such as the World Bank, WHO, and the OECD.[7] Quantification of the size of the problem creates awareness of the need for action and garners political will to mobilise resources, but it is only the first step towards a solution.[75] In their systematic review, Withrow and colleagues[4] concluded that further investigation is needed to answer when, where, why, and, how costs accrue in obese populations.

For future studies, how the overall health burden of obesity might differently affect the budgets of various segments of health systems, and how these burdens might create disparate incentives for obesity prevention programmes, are important issues. Furthermore, quantification of health consequences and the potential cost offsets forms the foundation of comparative effectiveness inquiries into strategies to mitigate obesity. One example is Australia's accessing cost-effectiveness programme,[76] which uses a simulation framework (including a disease modelling component similar to Foresight[22]) to weigh potential future health-care costs avoided against the implementation costs of obesity prevention programmes.[77] Cecchini and colleagues[78] used a microsimulation framework to assess the cost-effectiveness of a range of programmes tackling unhealthy diets, physical inactivity, and obesity in seven countries. They reported that many population-based prevention policies are cost effective, largely paying for themselves through future health gains and resulting reductions in health expenditures.

Contributors
YCW and MB did the analyses and drafted the report. MB constructed the Foresight model and did all simulations. YCW designed scenario analyses and identified US data inputs. KM, TM, and SLG provided critical guidance and edits. All authors reviewed, approved and edited the report.

Conflicts of interest
We declare that we have no conflicts of interest.

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