Economic impacts of overweight and obesity: current and future estimates for eight countries – Supplementary materials

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Appendix 1: Methods

Introduction

We assess the economic impacts of overweight and obesity for children and adults in Australia, Brazil, India, Mexico, Saudi Arabia, South Africa, Spain, and Thailand. The countries in this study were selected to represent diverse geographic and economic national contexts and based on general data availability. Overweight is defined as a body mass index (BMI) of 25 kg/m^2 to 29.9 kg/m^2 in adults and obesity as BMI of 30 kg/m^2 and above, while for children overweight is defined as weight that is one to two standard deviations above the median and obesity as more than two standard deviations above the median.[1] Hereafter, we will use the term 'obesity' to refer to both overweight and obesity. We included 28 obesity-related diseases in this study (Table 1). These are the 28 diseases identified in the Global Burden of Disease (GBD) database for which evidence of their high BMI risk linkages were graded as being convincing or probable (based on the World Cancer Research Fund [WCRF] grades of convincing, probable, possible, or insufficient evidence).[2]

Table 1: Obesity (High BMI) attributable diseases in Global Burden of Disease study (GBD)

Cause	Cause Group
1. Esophageal cancer	Neoplasms
2. Liver cancer	Neoplasms
3. Breast cancer	Neoplasms
4. Uterine cancer	Neoplasms
5. Colon and rectum cancer	Neoplasms
6. Gallbladder and biliary tract cancer	Neoplasms
7. Pancreatic cancer	Neoplasms
8. Ovarian cancer	Neoplasms
9. Kidney cancer	Neoplasms
10. Thyroid cancer	Neoplasms
11. Non-Hodgkin lymphoma	Neoplasms
12. Multiple myeloma	Neoplasms
13. Leukemia	Neoplasms
14. Ischemic heart disease	Cardiovascular diseases
15. Ischemic stroke	Cardiovascular diseases
16. Intracerebral hemorrhage	Cardiovascular diseases
17. Subarachnoid hemorrhage	Cardiovascular diseases
18. Hypertensive heart disease	Cardiovascular diseases
19. Atrial fibrillation and flutter	Cardiovascular diseases
20. Asthma	Chronic Respiratory diseases
21. Gallbladder and biliary diseases	Digestive Diseases
22. Alzheimer's disease and other dementias	Neurological disorders
23. Chronic kidney disease	Chronic kidney disease
24. Osteoarthritis	Musculoskeletal disorders
25. Low back pain	Musculoskeletal disorders
26. Gout	Musculoskeletal disorders
27. Cataract	Sense organ diseases
28. Diabetes mellitus type 2	Endocrine diseases

We employ a cost-of-illness approach to estimate the economic cost of obesity (both direct and indirect costs) from a societal perspective. This approach translates the adverse effect of obesity into monetary terms.[3] The estimates are useful for understanding the impact of obesity for policy prioritization and agenda setting. In addition, they are useful for facilitating cross-national comparisons of obesity consequence across different contexts[4]. The time horizon of the analysis includes current costs in the index year (2019) as well as projections to 2060 (Table 2). Model parameters and values were sourced from publicly available global database and peer reviewed literature (see Table 1 in main manuscript). Detailed steps for estimations are explained in the following sections.

Estimating current impact of obesity

The total economic cost of obesity is the sum of direct and indirect costs attributable to obesity.

$$\text{Total Economic Cost} = \text{Direct Costs} + \text{Indirect Costs}$$

Direct costs:

These refer to the total healthcare expenditures resulting from treating obesity-related diseases. This includes medical resources used in treating these conditions (direct medical costs) as well as non-medical resources that are expended while seeking treatment (direct non-medical costs). It is noted that many countries with low spending on health provide limited care for many of the obesity-related diseases we are measuring. This serves to underestimate the total economic impact of obesity in those countries.

Direct medical costs (DMC): Cost of medical resources to treat illness

Direct medical costs measure the cost of health care goods and services consumed for personal health care due to obesity and includes curative care, rehabilitative care, preventative care, ancillary services and medical goods.[5] The commonly used methodologies for quantifying these costs are the top-down approach and the bottom-up approach. In principle, the top-down approach estimates DMC by multiplying cost of treating obesity-attributable illnesses – typically derived from aggregate data – with an obesity attributable fraction or ratio.[6] A commonly used parameter is the population attributable fraction (PAF) or population attributable risk (PAR). This is used to quantify how much a risk factor (in this case obesity) contributes to a disease or death. It can be defined as the reduction in disease or mortality that would occur at the population level if exposure to a risk factor is reduced to an alternative ideal exposure scenario (e.g. if no one experiences obesity).[7] The fraction of co-morbidities attributed to obesity has a great influence on the cost calculation and can lead to an over or underestimation of costs attributable to obesity.[6]

Alternatively, the bottom-up approach estimates the resources used per individual and extrapolates the per-capita costs to the population with obesity. Included costs are drugs, hospitalization, physician costs, inpatient and outpatient costs, etc.[6] Estimation of resources used per individual can be done through econometric modelling. This approach requires having nationally representative individual-level medical expenditure and anthropometric data. Due to the data constraints in many LMICs, this approach is impractical for the scope of this project. Microsimulation models can also be used to make economic projections of cost over the medium or long-term time horizon.

We estimate DMC in this study by employing a hybrid of a top-down and bottom-up approach; using obesity attributable fraction (OAF) for cost calculated using a bottom-up approach. The OAF is the proportion of total health expenditure that can be attributed to obesity. This represents the cost of health care goods and services for personal health care and includes curative care, rehabilitative care, preventative care, ancillary services and medical goods.[5] This proportion is then applied to national health expenditure data to calculate obesity-related medical costs.

$$\mathrm{DMC} = \mathrm{OAF} \times \text{Total Healthcare Expenditures}$$

Aggregate data on total health expenditure is available for most countries from the WHO Global Health Expenditure Database. To estimate the direct medical cost or obesity-attributable healthcare expenditures, we identified studies from our literature search that reported the proportion of health expenditure attributable to obesity or obesity-attributable fractions (OAF) for a country. We found the OAFs from the OECD report (for the 52 countries in the report) to be the most appropriate because they are based on the Global Burden of Disease study and include the same number of obesity-related diseases as this paper (Appendix 1: Table 1)[5]. The reported OAFs from the OECD report are the health expenditure associated with overweight and obesity as a percentage of total health expenditure and were presented as an average between 2020-2050. All eight countries in this study were included in the OECD report except for Thailand.

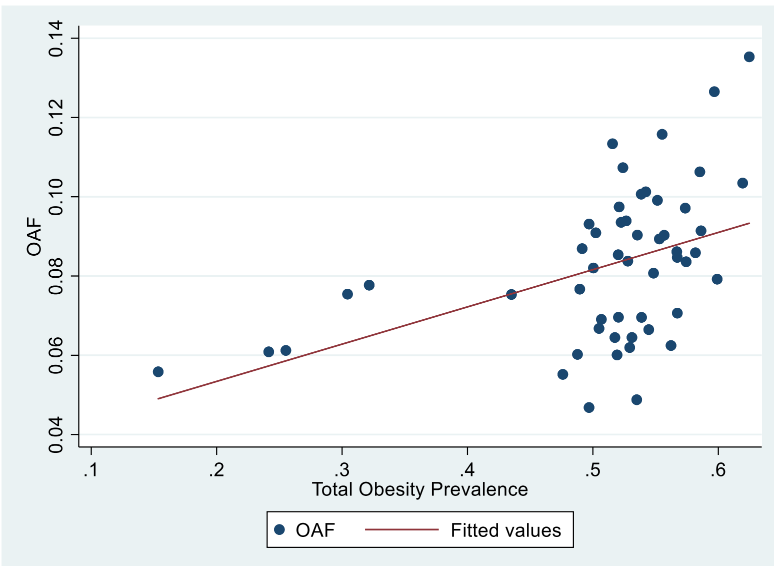
Deriving obesity attributable fraction (OAF)

To estimate OAF for countries not included in the OECD report (Thailand) and for projections, we regressed the available OAFs of the 52 countries from the OECD report on each country's obesity prevalence to produce coefficients that are applied to other countries. This coefficient β is estimated with a simple linear regression of OAF on obesity prevalence following the approach used by Goodchild and colleagues for tobacco attributable fraction.[8]

$$\mathrm{OAF_i} = \beta * \mathrm{Prev_i} + \varepsilon$$

There is a significant positive association between OAF and obesity prevalence ($\beta=0.094$, $F=12.92$, $p=0.001$) (Figure 1). The regression coefficient and intercept from the estimated equation were used to estimate the OAF for all countries including Thailand [5,9]. We also apply the regression outputs to estimated future obesity prevalence to 2060 to calculate future OAFs as explained subsequently. While this approach may not be representative for all income groups, the majority (about 95%) of global health expenditure based on the 2018 WHO Global Health Expenditure database is accounted for by these 52 countries in the OECD report. The averaging out effect of the regression results in the estimated OAFs in 2019 for some outlier countries to be lower than the raw OAFs from the OECD report. Hence, to avoid discordance between current and future direct medical costs and to allow for useful comparisons, we used the estimated OAFs from the regression outputs in computing direct medical costs in 2019 for all eight countries instead of the raw values from the OECD report. The estimated OAFs and the Raw OAFs are strongly and positively correlated (r= 0.81, p<0.027)

Figure 1: Plot of OAF and obesity prevalence



Direct non-medical costs: Cost of non-medical resources to treat illness

Direct non-medical costs measure the additional cost incurred during the process of seeking medical care. This can include travel expenses to health facilities or doctor appointments, cost incurred by caregivers, cost of food and lodging during inpatient care, and cost of home modifications. This study includes an estimation of travel expenses and caregiver costs expected to be incurred by people living with obesity.

Travel costs

This is estimated separately for inpatient (hospitalization) and outpatient care. We calculated this by multiplying the average transport cost per trip (proxied by country-specific daily average transportation expenditure per capita) by the population with obesity. For outpatient visits and hospitalizations (number and length), we use a global estimate due to the paucity of country-specific data.

$$\text{Inpatient Travel Costs} = \text{ATC} \times \text{N}_{\text{in}} \times \text{Population with Obesity}$$

where:

ATC is the average travel cost to and from health facility;

N_{in} is the average number of inpatient consultations by population with obesity compared to normal weight population.

$$\text{Outpatient Travel Costs} = \text{ATC} \times \text{N}_{\text{out}} \times \text{Population with Obesity}$$

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where:

ATC is the average travel cost to and from health facility;

N_{out} is the average number of outpatient consultations by population with obesity compared to normal weight population.

The total travel cost is the sum of outpatient and inpatient travel costs.

Informal Caregiver (ICG) costs

These are estimated for impatient care and include both time cost (value of time spent) by informal caregivers during inpatient care and travel cost of informal caregivers (assuming 1 informal caregiver per patient).

$$\text{ICG Time Costs} = \text{Average Daily Wage} \times N_d \times \text{Employed caregivers for Pop. with Obesity}$$

where:
Employed caregivers for Pop. with obesity =Employment rate × Working Age Pop. × Obesity Prevalence;

N_d is the average number of hospitalization days by population with obesity compared to normal weight population.

$$\text{ICG Travel Costs} = \text{ATC} \times N_{in} \times \text{Population with Obesity}$$

where:

ATC is the average travel cost to and from health facility;

N_{in} is the average number of inpatient consultations/visits by population with obesity compared to normal weight population.

The time cost for inpatient/outpatient care for population with obesity is assumed to be included within the indirect cost from absenteeism.

Indirect costs

These represent the economic value of lost time, productive capacity, or quality of life due to living with obesity. This includes the economic cost of premature mortality, productivity losses from missed days of work (absenteeism) and reduced productivity while at work (presenteeism), which will be estimated by this study. Other relevant cost-components such as long-term disability and early retirement costs[10] were not included as it was not feasible to measure these across countries. Also, in some societies there may be costs associated with weight bias (e.g. lower academic achievement, reduced emotional support, reduced likelihood of promotion) and in others there may be a premium associated with high BMI;[11] however, the magnitude and direction of these impacts have not been studied across countries.[12] For absenteeism and presenteeism costs, we assume the same employment rates by BMI status. While it is plausible that population with obesity may have a lower employment rate compared to the general population, the existing evidence is mixed and inconclusive.[13–20] See Appendix 5 for a summary of the literature review findings on employment differences between normal weight population and population with obesity.

Economic cost of premature mortality

This is the economic value of life lost prematurely due to obesity-attributable deaths. This is calculated as the number of years of potential life lost by individuals (by age group and sex) who died from obesity multiplied by the economic value of a life year.[3,21–23] We quantify the economic costs of premature mortality using these three steps (adapted from the FCTC Tobacco Investment Case Economic Model, RTI International).[24]

Step 1: Calculating number of years of potential life lost prematurely due to obesity attributable deaths
This denotes the number of years that individuals (by age group and sex) would have lived had they not died from obesity based on the number of years of life expectancy remaining at the age of death. To quantify this, we estimated how many people in each cohort would have been alive in future years if they had not died from obesity-related diseases (ORDs). This is because people die from causes other than ORDs and some of the people who died from obesity may not have made it to their full life expectancy because of dying from other causes. To account for these deaths, our model uses background mortality rates in the country. Background death rates are drawn from country-specific life tables, available online from the United Nations Population Division.

For each age and sex cohort of individuals who died from obesity in their death year, we estimate how many of those people would have been alive in future years if they had not died from obesity in their death year,

$$\text{People}_{i+1} = \text{People}_i \times (1\text{-Deathprob}_i)$$

where People_i is the number of people alive in model year (i=0 for age of death), People_{i+1} is the number of people alive in each successive years of remaining life expectancy, and DeathProb_i is the probability of death in age cohort. This calculation is performed for each age- and sex-specific cohort until no one is left alive based on life expectancy.

Step 2: Life year valuation

This study uses GDP per capita as a proxy for economic value of a life year. Other alternative proxies used in estimating cost of premature mortality include the use of annual average wages and the use of value of statistical life year[25] (see Box 1).

Box 1: Estimating economic cost of premature mortality

Three parameters used in estimating the economic cost of premature mortality include annual wages, value of statistical life year (VSL) and value of life year (VLY).

Annual wages: Some studies in the obesity literature have used average annual wages as a proxy for productivity loss from premature mortality. Average annual wages are used to estimate the foregone economic growth from lost days of work due to premature death. An obvious weakness to this is that future lost earnings do not fully represent the economic contribution of an individual to society. Also, it does not capture the value of the time spent not working such as vacation or leisure.

Value of Statistical Life: The value of a statistical life (VSL) is the local tradeoff rate between fatality risk and money.[13] It is a measure of the population's willingness to pay for reduction in the risk and the marginal cost of safety. It has been adopted by policy analysts as an economically valid measure for benefits that accrue to individuals for enhancements to their health and safety. [13] Typically calculated using contingent valuation methods, VSL calculations are available only for few, typically high-income countries. In addition, studies from the same countries have come up with different estimates of VSL. Hence, while this approach is theoretically sound, it is not practical for the scope of this project that seeks to compare cost across countries.

Value of Life Year: The VLY assigns monetary terms to changes in mortality risk using a full income approach.[12] A country's full income combines changes in national income (e.g. GDP) and the value of change in mortality or life expectancy in a given period. A VLY is defined as the economic value in a country or region of a 1-year increase in life expectancy. Economic loss due to premature mortality from a disease is assessed using GDP adjusted for gains in health or life expectancy in the absence of the risk factor (obesity) attributable death. It is estimated that on average, one VLY is 1.6 (GDP multiplier) times the per-person income globally.[14] There are also estimated values of GDP multiplier for regions.

Our choice of GDP per capita is driven by our inclination to value the economic contribution of every individual in the society across the lifecourse irrespective of employment status. This brings an equity lens to how economic contributions are counted. Also, as part of sensitivity analysis, we adjust GDP per capita for the full income value of a life year (VLY) as developed by the *The Lancet* Commission on Investing in Health (CIH). This combines changes in national income (GDP per capita) and the value of change in mortality or life expectancy in a given period adjusted for the gains in health or life expectancy that would have occurred in the absence of the obesity attributable death.[26] This is done by using a multiplier applied to GDP per capita. The global GDP multiplier was calculated by CIH to be 1.6 based on life year valuation estimates from life expectancy changes between 2000 and 2011.[27] There are also estimations of regional GDP multipliers that more closely reflect variations in gains in different regions of the world (Table 3). We use this approach in sensitivity analysis to estimate an upper bound of premature mortality cost. For more information about the GDP multiplier, see Global Health 2035: A World Converging Within a Generation, Supplementary Web Appendix 3. We use the regional and income-level GDP multipliers (Table 2), although updated GDP multipliers would be ideal but are not yet available.

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Table 2: GDP Multipliers

Country	*GDP Multiplier used for Study**	*Global GDP Multiplier*	*GDP Multipliers based on Income Level groups¥*	*GDP Multipliers for Regions*
Brazil	1.4	1.6	2.3	1.4 (Latin America and the Caribbean)
Australia	1.4	1.6	1.4	2.2 (East Asia and the Pacific)
South Africa	4.2	1.6	2.3	4.2 (Sub-Saharan Africa)
India	2.8	1.6	2.3	2.8 (South Asia)
Mexico	1.4	1.6	2.3	1.4 (Latin America and the Caribbean)
Saudi Arabia	1.4	1.6	1.4	1.4 (Middle East and North Africa)
Thailand	2.2	1.6	2.3	2.2 (East Asia and the Pacific)
Spain	1.4	1.6	1.4	1.9 (Europe and Central Asia)

Source: Appendix 3 of Global Health 2035: A World Converging Within A Generation
*GDP multipliers used are a combination of regional and income level adjusted GDP multipliers
¥Income level groups: High Income (Australia, Saudi Arabia, Spain); Low and Middle Income (Brazil, South Africa, India, Mexico, Thailand)

Step 3: Calculating costs of obesity-attributable mortality

The total cost of premature mortality is calculated by applying the economic value of a life year (proxied by GDP per capita) to the potential years of life lost from age of death to end of life expectancy. All future costs are discounted at a rate of 3% per year to obtain the net present value. All future economic costs associated with current obesity attributable mortality are assigned to the year in which the death occurred. Therefore, the discounted economic costs of future years are added up and assigned to the death year.

The total economic cost of obesity attributable mortality for each sex (S) and age (A) cohort included in the model is calculated as the sum of annual costs from the age of death (i=0) to remaining life expectancy *(RLE)* when no persons from the cohort would remain alive if they had not died from ORDs, where VLY is the value of a life year proxied by GDP per capita in model year DY (death year) and People_i is the number of people who would have still been alive in year *i* had they not died of ORDs.

$$\text{Obesity attributable mortality cost in cohort}_{\text{SA}} = \sum_{\text{i=0}}^{\text{RLE}} \text{VLY} \times \ (1+r)^{-(i)} \times \text{People}_i$$

In the above formula, the net present value of costs of obesity attributable mortality for each cohort is added together. The net present value of the economic cost of obesity-attributable mortality for all cohorts are then added up to give the total economic cost of obesity attributable mortality.

$$\text{Total obesity attributable mortality cost} = \sum \text{Obesity attributable mortality cost in cohort}_{\text{SA}}$$

Productivity losses due to excess absenteeism

Absenteeism denotes when employees miss work due to illness or health conditions. Excess absenteeism refers to the average additional days of work missed because of obesity. The calculation for the cost of lost productivity due to excess absenteeism among the working population with obesity is:

$$\text{Absenteeism Cost} = \text{Employed Pop. with Obesity} \times \text{Excess Days Absent} \times \text{Average Daily Wages}$$

Where:

$$\text{Employed Pop. with Obesity} = \text{Employment rate} \times \text{Working Age Pop} \times \text{Obesity Prevalence}$$

Excess Days Absent = Average number of additional days of absenteeism by working population with obesity compared to normal weight working population.

Average Daily Wages = Calculated from Average Wage Data

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Productivity losses due to excess presenteeism

Presenteeism refers to lower on-the-job productivity resulting from obesity-related impairment and disability. The calculation for the cost of lost productivity due to excess presenteeism among the working population with obesity is:

$$\text{Presenteeism Cost} = \text{Employed Pop. with Obesity} \times \text{Excess Presenteeism Rate} \times \text{Average Annual Wages}$$

where

$$\text{Employed Pop. with Obesity} = \text{Employment rate} \times \text{Working Age Pop.} \times \text{Obesity Prevalence};$$

$$\text{Excess Presenteeism Rate} = \text{Rate of Reduced Productivity among employees with obesity.}$$

$$\text{Average Annual Wages} = \text{Calculated from Average Wage Data}$$

Estimating future impacts of obesity

Our second main research objective is to derive country-level estimates of the projected economic and social costs of overweight and obesity from 2020 to 2030 (to coincide with the Sustainable Development Goals) and to 2060.

The projections for future burden are an extension of the modeling approach used for the current burden estimation. That is, we calculated total costs for future years using projected future estimates for the different parameters in the model. The index year for current burden estimation is 2019, the most recent year with available mortality data from the Global Burden of Disease study. Our projections were therefore from 2020 to 2060.

The underlying dynamic of our model comes from the United Nations Population Division (UNPD) population projections.[28] UNPD population projections consider the three key determinants of population size (mortality, fertility and migration). We used the estimates of the UNPD medium projection variant which is based on defined assumptions of medium fertility, normal mortality, and normal international migration (see UNPD 2020 definitions of projection variants).[29] Data on life expectancy and death rates were also drawn from UNPD database. As shown in Table 3, projections for other parameters such as GDP, GDP Deflator, and Employment Rates up to 2060 were drawn from the OECD Economic Outlook.[30] Total health expenditure projections up to 2050 were drawn from Chang et al (2019).[31] We updated data for the projections to 2019 values for GDP, employment rates, and total health expenditures for the sources listed in Table 1 of the main manuscript and applied the annual percentage change calculated from the projection sources to align the existing long-term projections with baseline in 2019.

Some parameters such as number of inpatient and outpatient consultations, hospitalization days, absenteeism days, and presenteeism rate were assumed to stay constant over the projection period. For financial parameters such as travel cost, we adjusted for inflation in future years using GDP Deflator projections.

Table 3. Summary of parameter projection sources

Projection Type	Future Parameter Values	Source
Projection from secondary sources	Population	United Nations Population Division (UNPD) (projections to 2060)[28]
	Total health expenditure per capita	Chang et al, 2019 (Global Burden of Disease Health Financing Collaborator Network)[31] (projections to 2050)
	All-cause mortality for Obesity related diseases	Foreman et. al, 2019. (projections to 2040)[32]
	Life expectancy	United Nations Population Division (projections to 2060)[28]
	Background death rates	United Nations Population Division (projections to 2060) [28]
	Annual GDP for Australia, Brazil, India, Mexico, Saudi Arabia, South Africa, Spain	OECD Economic Outlook - Long-term baseline projections (projections to 2060)[33]
	Annual GDP for Thailand	World Bank World Development Indicators[34]
	GDP Deflator for Australia, Brazil, India, Mexico, Saudi Arabia, South Africa, Spain	OECD Economic Outlook (Long-term baseline projections to 2060) [33]
	GDP Deflator for Thailand	World Bank World Development Indicators[34]
	Labor Force Size and Employment Rates for Australia, Brazil, India, Mexico, Saudi Arabia, South Africa, Spain	OECD Economic Outlook (Long-term baseline projections to 2060) [33]
	Labor Force Size and Employment Rates for Thailand	International Labour Organization (ILO)[35]

Projection by authors	Overweight and Obesity prevalence for ages under and above 20 years and by sex.	NCD-Risk Factor Collaboration (1975-2016)[36]
	Obesity Attributable Fraction (OAF) of Health Expenditures.	Current OAF estimations from OECD study[5] and projected prevalence.
	Wages	ILO Global Wage Report[37], OECD[38]
Assumed to stay constant (financial parameters adjusted for inflation)	Average travel cost to and from health facility; Average number of inpatient consultations by population with obesity; Average number of hospitalization days of population with obesity; Average number of outpatient consultations by population with obesity; Absenteeism days; Presenteeism rate.	Peer-reviewed studies.

We estimated future values for parameters for which we found no existing long-term projections. These are annual wages, obesity prevalence, obesity attributable fraction of health expenditures, and obesity attributable mortality. For future annual wages, we extrapolated historical average annual growth rate to future years. The projections for the other parameters were modelled as described below.

Future Obesity prevalence

Obesity is a complex chronic disease process resulting from the interaction of various environmental factors such as high energy dense nutrition, decline in physical activity, and stress along with genetic susceptibility.[39] The global upward trend in obesity prevalence globally has been attributed to increased intake of energy-dense foods which are high in fats and sugars as well as decreases in physical activity. Decline in physical activity has been attributed to increasingly sedentary nature of many forms of work, changing modes of transportation and increasing urbanization.[40] Similar patterns have been implicated in developing countries where the rapid upward trend in overweight and obesity have been associated with ongoing economic, demographic and nutritional transitions.[41,42]

We employed a regression-based approach for projecting future overweight and obesity prevalence. We used the historical trend of country-level annual overweight and obesity prevalence estimates from 1975 to 2016 sourced from NCD Risk Collaboration group.[36] The data set provides estimates separately for males above 20 years old (referred to as men), females above 20 years of age (women), males below 20 years of age (boys) and females below 20 years of age (girls). Hence our projections are done for these four groups separately. Then, male, female and total prevalence are calculated using the population estimates for each group. We identified some variables that could serve as proxies for key drivers of trends in overweight and obesity prevalence. These are:

- Age: modelled separately for above and below 20 years of age.
- Sex: modelled separately for male and female
- Demographic transition: this refers to the demographic changes over time. We use the proportion of the total population represented by the following aggregated age groups: under 20 years, 20-54 years, 54-74 years and above 75 years. The selected age groups were drawn from Ng and colleagues[43] and reflect different age-specific trends in obesity prevalence globally.
- Nutrition transition: We use urbanization (percentage of population living in urban areas) as a crude proxy.
- Our objective is to estimate future overweight and obesity prevalence if *historical and current trends relating obesity to age, sex, and nutrition continue*. Note that we do not account for unforeseeable changes, such as technology progress that could impact food environment or medical breakthroughs in obesity treatment or prevention and thus drastically change future trends. In addition, prevalence cannot extend beyond 100% of the population, hence we constrain our estimates to an upper bound of 100% using logarithmic transformations.

We estimate a multivariate autoregressive model which combines an autoregressive component (past prevalence observations), a differencing step to ensure stationarity and factors that influence prevalence as covariates.

Our model takes the following form for country *i*, year *t* and sex *s:*

$$\Delta \mathbf{Y}_{i,s,t} = \boldsymbol{\alpha} + \sum_{\mathbf{h}=1}^{\mathbf{n}} \boldsymbol{\beta}_{\mathbf{h}} \Delta \mathbf{Y}_{i,s,t-h} + \boldsymbol{X}_{i,s,t}{}' \boldsymbol{\theta} + \boldsymbol{\varepsilon}_{i,s,t}$$

Where $\Delta \mathbf{Y}_{i,s,t}$ *is* the differenced transformation of obesity prevalence with n degrees of lag included in the model; $\boldsymbol{X}_{i,s,t}$ denotes factors that influence obesity prevalence; and $\boldsymbol{\alpha}$ and $\boldsymbol{\varepsilon}_{i,s,t}$ refers to the intercept and error term respectively. Factors comprising $\boldsymbol{X}_{i,s,t}$ are proxies for demographic changes and urbanization which have been linked to changes in obesity prevalence globally. We use the annual percentage of a country's population in specific age intervals (under 20 years, 20-54 years, 54-74 years and above 75 years which reflect global age trends in obesity prevalence derived from Ng and colleagues[43]) as a measure of population changes over time and annual proportion of a country's population living in urban areas as a measure of urbanization. Data for population and the urbanization measure were drawn from the United Nations Population Division (UNPD) database.

Hence, obesity prevalence for men, women, boys and girls is modelled as dependent on past obesity prevalence, percentage of population in the age intervals ('under 20 years' for boys and girls; '20-54 years', '54-74 years' and 'above 75 years' for adult men and women), and percentage of country's population living in urban areas. All predictor variables are first differenced because we are interested in how their changes over time influence obesity prevalence. The estimated model is then applied to forecast future obesity prevalence using projected estimates of population growth and urbanization.

The first step is to determine the best univariate ARIMA (autoregressive integrated moving average) time series model for obesity prevalence. First-order differencing of the prevalence time series was done to ensure stationarity. Then, the autocorrelation plots and partial auto-correlation plots were used to determine the optimal number of AR (lags) and/or MA terms needed to correct for autocorrelation in the differenced series. The range of specifications explored are ARIMA (1-3,1,0-1). The ACF and PCF plots as well as AIC and BIC values suggested ARIMA (2,1,0) as the best model consistently across the 4 prevalence groupings for selected countries.

The second step was to determine which combination of covariates together with the selected ARIMA model (ARIMAX model) performed best in terms of model fit and predictive accuracy. Model fit was assessed using the Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC). Forecast accuracy was assessed using root mean squared error values (RMSE) from pseudo-out-of-sample forecasting. Pseudo-out-of-sample forecasting was conducted in three sets using observed data for years 1995-2016, then 2006-2016 and finally 2011-2016 as out-of-sample data. The model which performed best in terms model fit (i.e. most parsimonious) and predictive accuracy (minimized RMSE values) was selected as the final model. Our final model is as shown below:

$$\Delta \mathbf{Y}_{i,s,t} = \boldsymbol{\alpha} + \sum_{\mathbf{h}=1}^{2} \boldsymbol{\beta}_{\mathbf{h}} \Delta \mathbf{Y}_{i,s,t-h} + \boldsymbol{X}_{i,s,t-1}{}' \boldsymbol{\theta} + \boldsymbol{\varepsilon}_{i,s,t}$$

Thus, we apply a lag of two degrees to the autoregressive component and first-order differencing to all variables. As mentioned earlier, we used a scaled logit-transformation on the data parameters to constrain forecasted prevalence estimates to a lower bound of 0% and upper bound of 100% and then re-converted back to real numbers.[44]

Forecasts for male, female and total (national) overweight and obesity prevalence was generated using a bottom-up approach.[44] That is, forecasts for each series of prevalence for men, women, boys and girls together with their population sizes was used to calculate male (combining under and above 20 years male prevalence); female (combining under and above 20 years female prevalence); and total (combining prevalence for male and female under and above 20 years population) overweight and obesity prevalence.

Table 4 shows the historical overweight and obesity prevalence estimates from 1975 through 2016 and projections to 2060 for select years. Projected total overweight and obesity prevalence in 2060 ranged from 57.3 percent in India to 92.8 percent in Saudi Arabia. Our obesity prevalence estimates are in a similar range to other studies that have projected overweight and obesity prevalence. (See Box 2 for a summary of relevant studies). Kilpi and colleagues[45] adapted the Foresight modelling framework (a two-part modeling process made up of a cross-sectional regression analysis and a microsimulation program [McPherson and colleagues[46]; Wang and colleagues[47]]) to estimate that overweight and obesity prevalence will rise to 92% in men and 75% in women by 2050 in Saudi Arabia. In another study of 10 countries in Latin America, overweight and obesity levels in 2050 are estimated to exceed 90 percent for males in two countries (Cuba and Panama) and above 85 percent for females in six countries (Chile, Cuba, Nicaragua, Panama, Peru, and Uruguay).[48]

Table 4: Overweight and obesity (OAO) prevalence-historical and projected estimates

Country	Year	OAO Prevalence (males over 20 years)*	OAO Prevalence (females over 20 years)*	OAO Prevalence (males under 20 years)*	OAO Prevalence (females under 20 years)*	OAO Prevalence (males)¶	OAO Prevalence (females)¶	Total OAO Prevalence¶
Australia	1975	48.0%	38.1%	19.5%	20.3%	37.4%	31.8%	34.6%
Australia	2016	72.9%	59.8%	35.6%	32.6%	63.2%	53.2%	58.2%
Australia	2019	74.2%	61.2%	36.4%	33.0%	64.4%	54.3%	59.3%
Australia	2060	89.6%	79.5%	57.2%	50.1%	82.1%	73.1%	77.6%
Brazil	1975	25.5%	31.2%	5.9%	8.5%	15.4%	19.7%	17.6%
Brazil	2016	59.4%	57.1%	30.0%	26.6%	50.2%	48.2%	49.1%
Brazil	2019	61.6%	58.6%	32.4%	28.0%	52.9%	50.1%	51.5%
Brazil	2060	85.9%	78.1%	73.6%	59.9%	83.5%	74.9%	79.1%
India	1975	4.6%	6.6%	0.3%	0.4%	2.4%	3.4%	2.9%
India	2016	18.5%	22.4%	7.5%	6.1%	14.3%	16.4%	15.3%
India	2019	20.4%	24.2%	9.4%	7.5%	16.4%	18.3%	17.3%
India	2060	54.5%	56.2%	70.4%	57.1%	58.2%	56.4%	57.3%
Mexico	1975	33.6%	43.2%	10.1%	12.3%	20.1%	25.9%	23.0%
Mexico	2016	65.4%	67.6%	35.8%	35.2%	54.2%	56.3%	55.3%
Mexico	2019	67.2%	68.9%	37.4%	36.7%	56.3%	58.1%	57.2%
Mexico	2060	88.2%	84.2%	73.1%	65.4%	84.7%	80.2%	82.4%
Saudi Arabia	1975	34.6%	44.6%	5.7%	8.5%	19.4%	24.6%	21.9%
Saudi Arabia	2016	70.1%	73.7%	38.1%	32.1%	60.8%	58.2%	59.7%
Saudi Arabia	2019	72.1%	75.0%	40.8%	33.4%	63.4%	59.8%	61.9%
Saudi Arabia	2060	93.7%	94.4%	91.5%	84.7%	93.3%	92.2%	92.8%
South Africa	1975	16.2%	40.3%	1.4%	3.8%	8.5%	21.7%	15.1%
South Africa	2016	42.0%	67.2%	20.2%	29.4%	33.5%	53.2%	43.5%
South Africa	2019	44.5%	68.7%	25.4%	34.2%	37.2%	56.1%	46.8%
South Africa	2060	74.7%	86.2%	34.0%	62.1%	63.1%	79.9%	71.8%
Spain	1975	45.5%	39.0%	17.2%	15.4%	34.9%	30.9%	32.9%
Spain	2016	70.9%	55.8%	36.7%	30.7%	63.9%	51.1%	57.4%
Spain	2019	72.2%	56.6%	37.4%	31.8%	65.2%	52.0%	58.5%
Spain	2060	88.4%	72.7%	61.4%	54.6%	83.7%	69.9%	76.6%
Thailand	1975	6.8%	11.0%	1.0%	1.3%	3.7%	5.9%	4.8%
Thailand	2016	30.3%	36.8%	25.1%	19.3%	29.0%	32.7%	30.9%
Thailand	2019	33.8%	39.5%	28.9%	21.9%	32.6%	35.6%	34.1%
Thailand	2060	73.6%	75.7%	91.0%	80.2%	76.6%	76.4%	76.5%

**Prevalence estimates for 1975-2016 are historical data drawn from NCD RisC; Projected prevalence estimates are from 2017 to 2060.*
¶Authors' calculations from prevalence estimates for male and female under and above 20 years of age.

Box 2: Bibliography of selected studies that forecasted overweight and obesity prevalence

- Wang, Y., Beydoun, M. A., Liang, L., Caballero, B., & Kumanyika, S. K. (2008). Will all Americans become overweight or obese? estimating the progression and cost of the US obesity epidemic. *Obesity (Silver Spring, Md.)*, *16*(10), 2323–2330. https://doi.org/10.1038/oby.2008.351
  - ✓ Authors fitted linear regression models with the prevalence as the dependent variable and the survey time as the predictors for different sociodemographic groups in the US.
  - ✓ By 2048, all American adults would become overweight or obese, while black women will reach that state by 2034.
- Relevant studies that used/adapted the two-part modelling process developed by the UK Foresight Working Group. The first module employs a regression analysis based on series of cross-sectional data; while the second module uses a microsimulation program to produce longitudinal projections
  - ✓ McPherson K, Marsh T, Brown M. Foresight. Tackling obesities: future choices—modelling future trends in obesity & their impact on health. London: Government Office for Science, 2007.
    - The extrapolation of current trends, which underpins the microsimulation, indicates that, by 2015, 36% of males and 28% of females will be obese.
    - By 2050, 60% of males and 50% of females could be obese. The proportion of men having a healthy BMI (18.5–25kg/m2) declines from about 30% at present to less than 10% by 2050.
  - ✓ Webber, L., Kilpi, F., Marsh, T., Rtveladze, K., Brown, M. and McPherson, K., 2012. High rates of obesity and non-communicable diseases predicted across Latin America. *PloS one*, *7*(8), p.e39589.
    - Projections for 10 Latin America countries-Argentina, Bolivia, Chile, Colombia, Costa Rica, Cuba, Nicaragua, Panama, Peru, Uruguay for males and females aged 20+ years.
    - Projections in 2050 exceed 90 percent for males in 2 countries and above 85 percent for females in 6 countries.
  - ✓ Pineda, E., Sanchez-Romero, L.M., Brown, M., Jaccard, A., Jewell, J., Galea, G., Webber, L. and Breda, J., 2018. Forecasting future trends in obesity across Europe: the value of improving surveillance. *Obesity facts*, *11*(5), pp.360-371.
    - The four countries that are estimated to have the highest obesity prevalence were: Georgia (77%; 95% CI 58–97%); Romania (50%; 95% CI 43–57%); and Serbia (47%; 95% CI 0–175%) and Croatia (47%; 95% CI 26–68%).
    - From the 15 countries that had the best quality data (score ≥ 25 points), obesity prevalence was projected to reach between 13 and 43% by 2025. Ireland was predicted to have the highest prevalence, with 43% (95% CI 28–58%) of the population was predicted to be obese by 2025, followed by Scotland, with 37% (95% CI 29–45%).
  - ✓ Keaver, L., Webber, L., Dee, A., Shiely, F., Marsh, T., Balanda, K. and Perry, I., 2013. Application of the UK foresight obesity model in Ireland: the health and economic consequences of projected obesity trends in Ireland. *PLoS One*, *8*(11), p.e79827.
    - Overweight and obesity are projected to reach levels of 83% and 74% in males and females respectively by 2020. Overweight and obesity are projected to reach levels of 89% and 85% in males and females respectively by 2030.
  - ✓ Kilpi, F., Webber, L., Musaigner, A., Aitsi-Selmi, A., Marsh, T., Rtveladze, K., . . . Brown, M. (2014). Alarming predictions for obesity and non-communicable diseases in the Middle East. *Public Health Nutrition, 17*(5), 1078-1086. doi:10.1017/S1368980013000840
    - Statistical modelling of overweight/obesity trends was carried out in nine Middle East countries (Bahrain, Egypt, Iran, Jordan, Kuwait, Lebanon, Oman, Saudi Arabia and Turkey).
    - Overweight and obesity are projected to reach levels of 92% and 75% in males and females respectively by 2050.

Obesity-attributable fraction (OAF) of health expenditure

We estimated future Obesity-Attributable Fraction (OAF) of health expenditure with the following approach as explained previously: We sourced credible estimates of OAFs for 52 countries from the OECD cross-country economics of obesity report. We estimated a simple linear regression of these OAFs on obesity prevalence.

$$\mathrm{OAF_i} = \beta.\mathrm{P_i} + \varepsilon_i$$

where $\mathrm{OAF_i}$= OAF for country i; $\mathrm{P_i}$=prevalence of overweight or obesity (point prevalence). We then use the estimated prevalence for future years to generate future OAFs based on the estimated regression coefficient and intercept.

$$\widehat{\mathrm{OAF}}_t = \beta.\widehat{\mathrm{P}}_t + \widehat{\varepsilon_i}$$

Obesity attributable mortality

All-cause mortality estimates for Obesity-related diseases (ORDs) were obtained from projections by Foreman and colleagues (estimates for 2040).[32] We follow the approach below to estimate values for remaining years.

Deriving obesity attributable deaths for future years

From the current burden estimation, the following parameters are derived from GBD 2019: All-cause mortality by sex and age group for ORDs, Obesity Attributable Mortality, and Population attributable fraction for mortality (Death-PAFs).

Steps:

1. We derived All-cause mortality (total deaths) for the included obesity related diseases (ORDs) from 2020 to 2060 using projections for 2016 and 2040 presented in Foreman and colleagues.[32]
    a. We calculated annualized rate of change by ORDs (AROC).

$$\text{AROC} = \left(\frac{\text{Value in Year (t+h)}}{\text{Value in Year t}}\right)^{\frac{1}{h}} - 1$$

Applying the AROC h times to the starting value will result in the value for the ending year.

$$M_{t+h} = M_t * (\text{AROC} + 1)^h$$

    b. We used the derived AROC to calculate total deaths by cause for each projected year and assume a constant rate of change till 2060.

2. We derived PAF for each year by sex, cause and age group.
    a. First, we used calculated PAF from GDB 2019 to calculate relative risk which is defined below.

$$\text{Relative Risk (RR)} = \frac{\text{Probability of disease in exposed population}}{\text{Probability of disease in unexposed population}}$$

Relative Risk enters the equation for PAF. Hence in other to calculate PAF in future years, we need to derive the relative risk.

$$\text{Population Attributable Fraction (PAF)} = \frac{P\,(RR-1)}{1+P\,(RR-1)}$$

Re-arranging the equation above gives RR as shown below.

$$\text{Relative Risk (RR)} = \frac{\text{PAF}+\text{Prev}_t\,(1-\text{PAF})}{\text{Prev}_t\,(1-\text{PAF})}$$

    b. We calculated PAF for each ORD by sex, age and year using projected obesity prevalence for each year, age group and sex and derived RR. We make a plausible assumption that RR is constant over time.

$$\text{Population Attributable Fraction } (\text{PAF}_{t+h}) = \frac{\text{Prev}_{t+h}\,(RR-1)}{1+\text{Prev}_{t+h}\,(RR-1)}$$

3. We then calculated risk factor or obesity attributable deaths (OADs) for projected years (t) by sex, age group and cause.

$$\sum_{s,a,c,t} \text{RFA deaths} = \sum_{s,a,c,t} \text{PAF} * \sum_{s,a,c,t} \text{Total deaths}$$

Currency conversions

All costs were computed in 2019 constant US dollars. Data was collected in local currency units (LCU) where possible and then adjusted to 2019 values. To adjust to 2019 values, GDP deflator data from the World Bank World Development Indicators Database and the OECD Stat database was used to account for inflation.[30,34] Next, the

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2019 LCU values were converted to USD using the average annual exchange rate from the World Bank.[34] The formula for obtaining the final amount in 2019 USD is expressed as:

$$\text{2019 USD amount} = \text{2019 LCU to USD exchange rate} \times \left[\left(\frac{\text{GDP deflator for LCU in 2019}}{\text{GDD deflator for LCU in data year}}\right) \times \text{LCU in data year}\right]$$

Estimates were also produced to account for purchasing power parity (PPP). The methods for adjusting for inflation using GDP deflator remain the same, however, instead of using an LCU to USD exchange rate, an LCU PPP conversion factor was used. PPP conversion factors were drawn from the World Bank World Development Indicators Database, which contains PPP conversion factors for GDP and for private consumption.[34] The PPP conversion factor for GDP was used for GDP and healthcare expenditures, while the PPP conversion factor for private expenditure was used for wages and travel costs. Where only USD costs were available, costs were converted into LCU, then adjusted for inflation, and then converted to 2019 USD or PPP. By first adjusting for inflation in the local currency and then converting to USD, the final amount will more accurately reflect the price changes for local non-tradable resources, especially labor, than by first converting to USD and then adjusting for inflation using US inflation rates.[49]

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Appendix 2: Additional Figures

Figure A1: Direct medical and non-medical costs of obesity per capita, 2019 – 2060 (in 2019 constant USD)

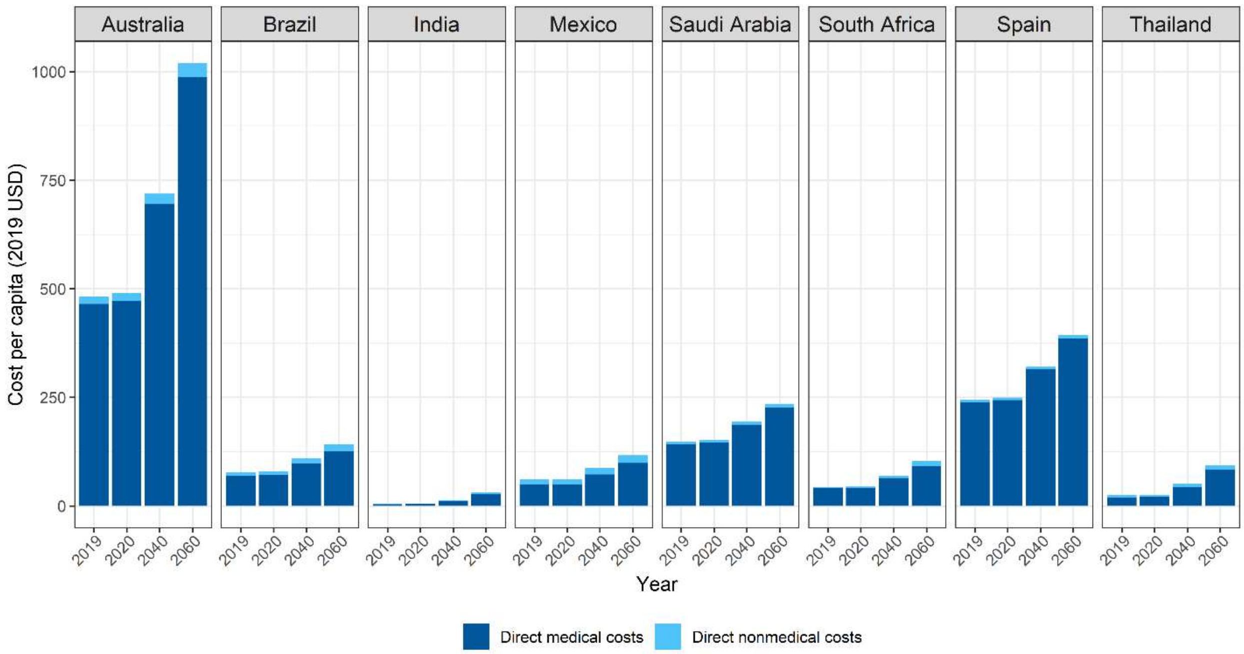


Figure A2: Indirect costs of obesity per capita, 2019 – 2060 (in 2019 constant USD)

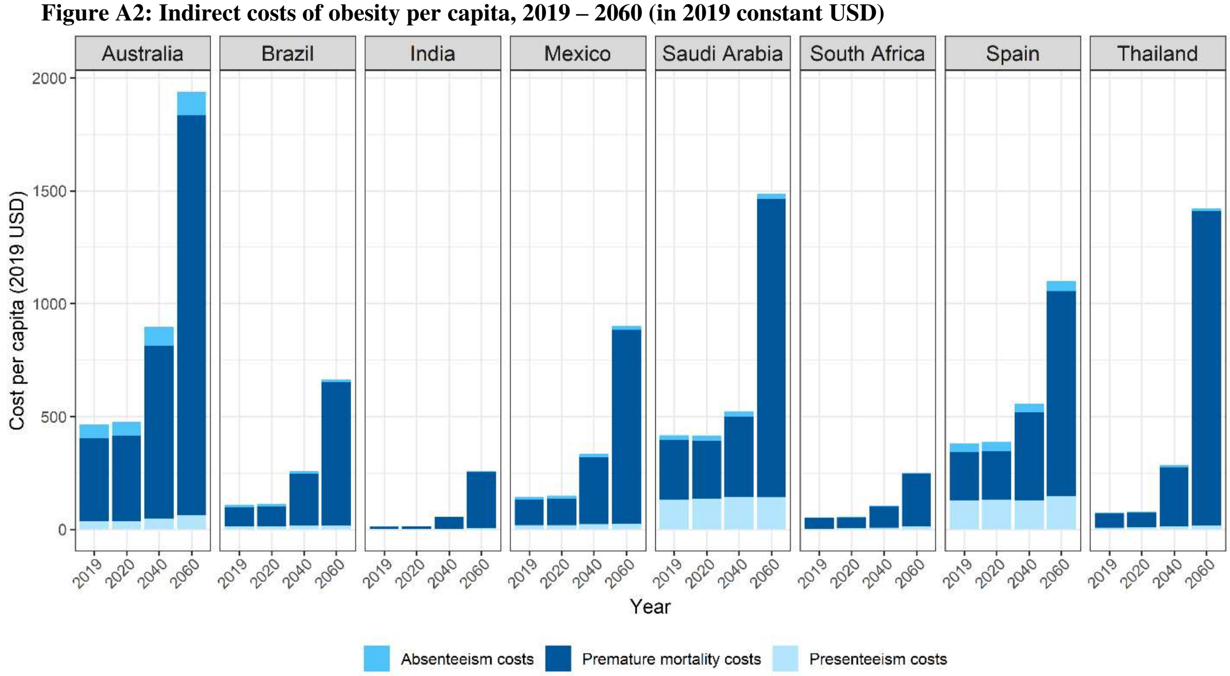


Figure A3: Total costs of obesity per capita (in 2019 USD and as a percent of GDP) and obesity prevalence, 2019 – 2060

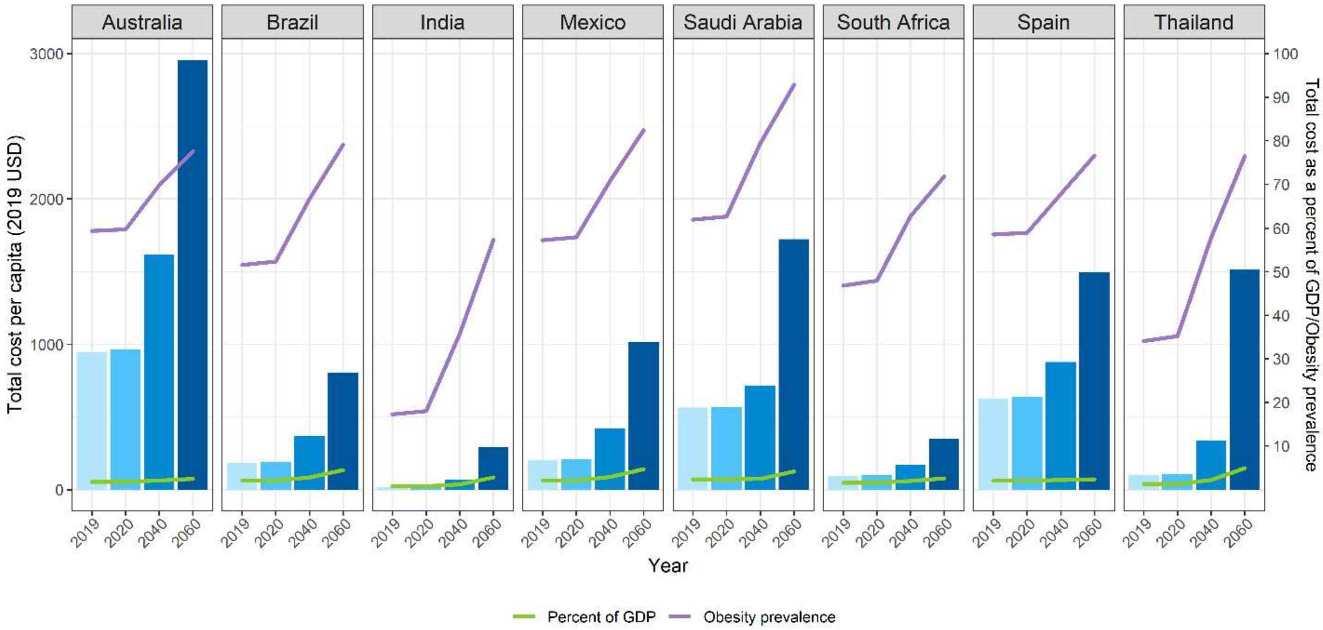


Figure A4: Total cost of obesity in purchasing power parity (PPP) dollars (in billions of constant 2019 PPP USD) and total cost as a percent of GDP, 2019 – 2060

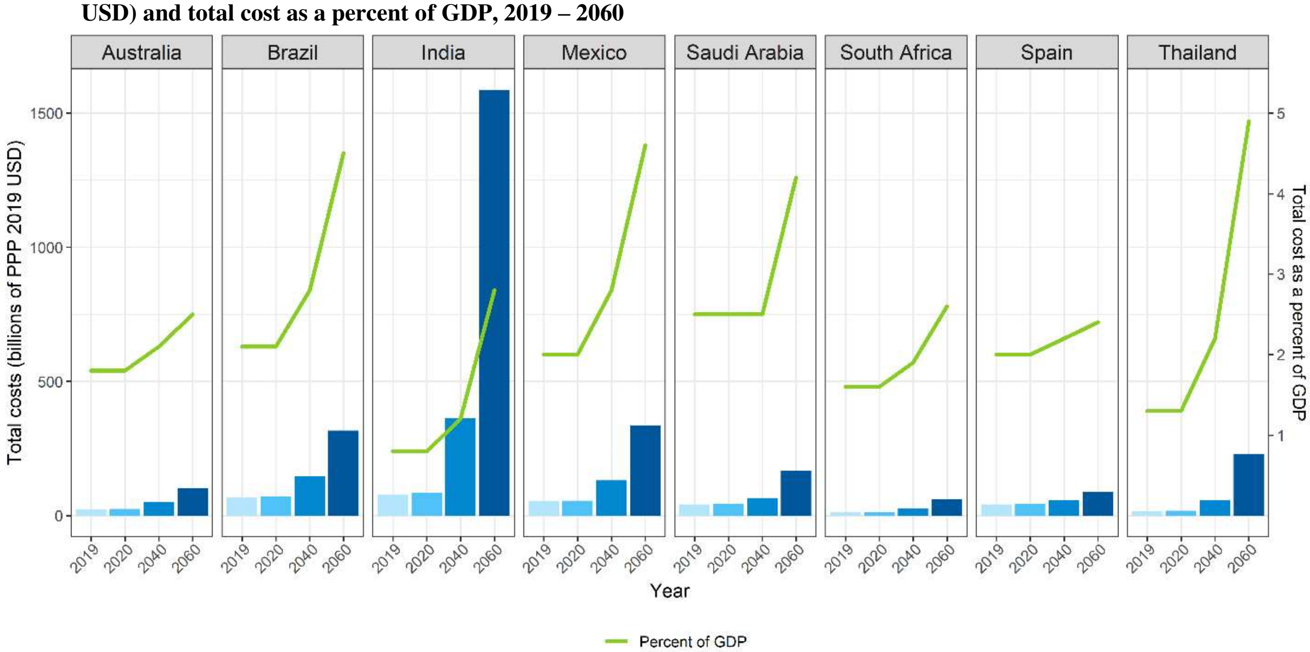
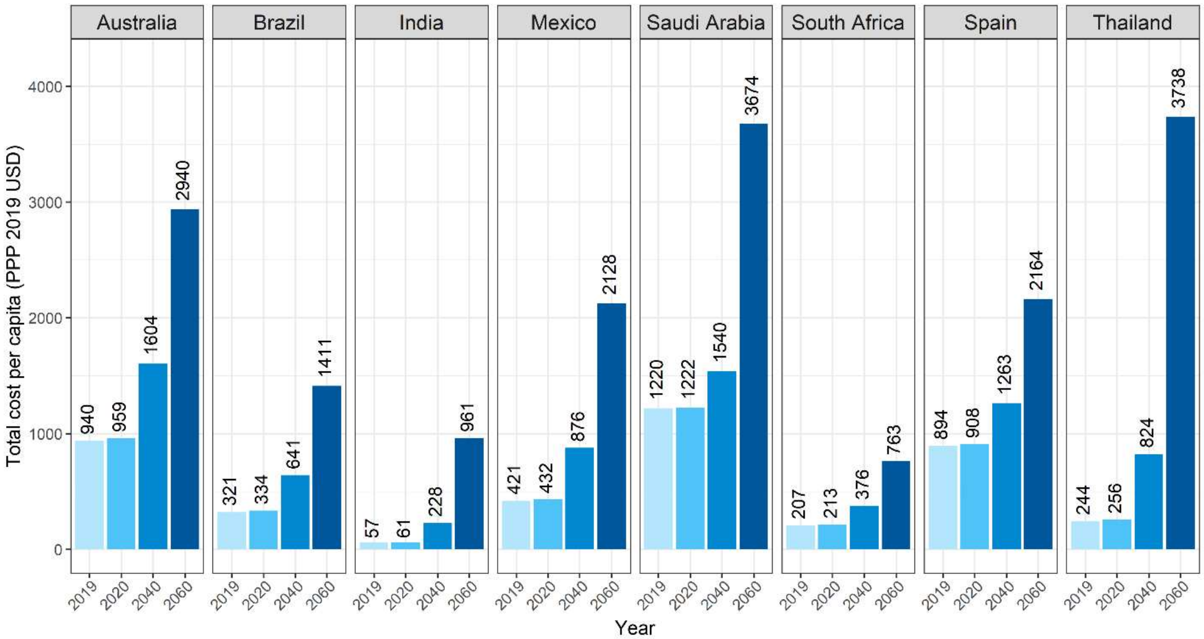


Figure A5: Total cost per capita in purchasing power parity (PPP) dollars (2019 PPP USD), 2019 – 2060



Appendix 3: Additional Tables

Table A1: Current Burden Results, 2019 (in 2019 USD) with GDP multiplier*

	GDP multiplier used for sensitivity analysis**	Direct medical costs (billions)	Direct non-medical costs (millions)	Total direct costs (billions)	Absentee-ism costs (billions)	Presentee-ism costs (billions)	Premature mortality costs (billions)	Total indirect costs (billions)	Total costs (billions)	Total costs per capita (USD)	Total costs as percent of GDP
Australia	1·4	11.58	538.87	12.12	1.94	1.14	12.86	15.94	28.06	1113	2.07%
Brazil	1·4	14.35	2054.65	16.41	2.49	3.11	24.65	30.25	46.65	221	2.54%
India	4·2	5.13	1091.71	6.22	1.34	1.82	39.8	42.96	49.18	36	1.70%
Mexico	2·8	6.11	1701.36	7.81	1.86	2.65	20.05	24.56	32.37	254	2.55%
Saudi Arabia	1·4	4.82	212.30	5.03	0.73	4.6	12.64	17.97	23.	671	2.90%
South Africa	1·4	2.33	161.33	2.49	0.04	0.21	11.87	12.12	14.61	250	4.16%
Spain	2·2	11.02	366.70	11.39	2.37	7.76	13.86	23.99	35.38	757	2.54%
Thailand	1·4	1.34	373.69	1.72	.47	0.62	9.44	10.54	12.26	176	2.25%

***Source: Lancet Commission on Investing in Health, Appendix 3 of Global Health 2035: A World Converging Within A Generation**
****GDP multipliers used are a combination of regional and income level adjusted GDP multipliers**

Table A2: Projections assuming a 5% reduction in obesity prevalence, years 2020, 2030, 2040, 2050, and 2060 (in 2019 constant USD)

	Direct medical costs (USD billions)	**Direct nonmedical costs (USD billions)**	**Total direct costs (USD billions)**	**Absenteeism costs (USD billions)**	**Presenteeism costs (USD billions)**	**Premature mortality costs (USD billions)**	**Total indirect costs (USD billions)**	**Total costs (USD billions)**	**Total costs per capita (USD)**	**Total costs as a percent of GDP**
Australia	..	..	..	..	..	..	..	..	..	..
2020	11.43	0.41	11.84	1.48	0.87	9.15	11.51	23.35	916	1.67%
2030	15.24	0.53	15.77	1.89	1.11	14.11	17.11	32.89	1,167	1.82%
2040	20.24	0.69	20.93	2.40	1.41	22.38	26.19	47.11	1,541	1.99%
2050	26.05	0.85	26.90	2.91	1.71	36.22	40.84	67.74	2,064	2.16%
2060	33.00	1.03	34.03	3.43	2.00	59.68	65.11	99.14	2,837	2.40%
Brazil	..	..	..	..	..	..	..	..	..	..
2020	14.13	1.70	15.83	2.07	2.59	18.05	22.71	38.54	181	2.00%
2030	17.75	2.11	19.86	2.45	3.06	30.89	36.40	56.26	251	2.26%
2040	21.25	2.54	23.78	2.73	3.40	50.73	56.87	80.65	352	2.69%
2050	24.06	2.95	27.02	2.81	3.51	83.95	90.27	117.29	512	3.35%
2060	26.94	3.51	30.44	2.83	3.53	138.14	144.50	174.94	780	4.38%
India	..	..	..	..	..	..	..	..	..	..
2020	5.14	0.80	5.94	1.05	1.43	12.97	15.45	21.39	15	0.69%
2030	9.42	1.58	11.00	1.90	2.59	32.60	37.09	48.09	32	0.85%
2040	16.33	2.73	19.06	3.08	4.21	73.33	80.61	99.68	63	1.12%
2050	26.52	4.20	30.72	4.57	6.25	160.49	171.31	202.04	123	1.58%
2060	42.70	5.89	48.59	6.30	8.62	386.22	401.13	449.72	272	2.59%

Mexico	..	..	..	..	..	..	..	..	..	..
2020	6.06	1.44	7.50	1.59	2.26	14.46	18.31	25.81	200	1.99%
2030	8.14	1.79	9.92	1.97	2.80	24.25	29.02	38.94	276	2.29%
2040	10.31	2.11	12.42	2.28	3.25	42.94	48.47	60.89	407	2.75%
2050	12.44	2.44	14.88	2.53	3.60	75.25	81.38	96.26	620	3.43%
2060	14.83	2.72	17.55	2.66	3.78	131.40	137.84	155.39	989	4.54%
Saudi Arabia	..	..	..	..	..	..	..	..	..	..
2020	4.79	0.20	4.99	0.69	4.35	8.75	13.80	18.79	540	2.31%
2030	6.21	0.25	6.46	0.85	5.31	9.54	15.70	22.16	564	2.25%
2040	7.59	0.29	7.88	0.91	5.69	14.80	21.41	29.28	689	2.42%
2050	8.83	0.33	9.16	0.95	5.96	28.38	35.29	44.45	997	2.92%
2060	9.86	0.38	10.24	0.97	6.08	58.83	65.89	76.12	1,679	4.05%
South Africa	..	..	..	..	..	..	..	..	..	..
2020	2.31	0.14	2.46	0.04	0.19	2.84	3.06	5.52	93	1.51%
2030	3.27	0.26	3.52	0.06	0.32	4.19	4.57	8.09	123	1.68%
2040	4.32	0.39	4.72	0.09	0.48	6.57	7.14	11.86	166	1.87%
2050	5.51	0.57	6.08	0.13	0.68	10.75	11.56	17.63	234	2.14%
2060	6.88	0.82	7.70	0.18	0.91	17.79	18.88	26.58	340	2.51%
Spain	..	..	..	..	..	..	..	..	..	..
2020	10.77	0.26	11.03	1.71	5.61	9.59	16.91	27.95	598	1.98%
2030	12.41	0.27	12.68	1.76	5.76	12.52	20.04	32.72	708	2.05%
2040	13.52	0.26	13.78	1.66	5.46	16.72	23.84	37.62	832	2.09%
2050	14.34	0.25	14.59	1.60	5.24	23.34	30.17	44.76	1,026	2.17%
2060	15.15	0.28	15.42	1.72	5.65	35.74	43.11	58.54	1,426	2.32%
Thailand	..	..	..	..	..	..	..	..	..	..
2020	1.34	.28	1.62	.36	.47	4.12	4.96	6.58	94	1.17%
2030	2.00	.38	2.38	.48	.62	8.16	9.26	11.64	166	1.53%
2040	2.85	.47	3.32	.57	.75	17.18	18.50	21.81	316	2.11%
2050	3.79	.55	4.34	.66	.86	37.47	38.99	43.33	657	3.08%
2060	4.87	.61	5.48	.74	.97	82.74	84.45	89.93	1,458	4.70%

Table A3: Projections assuming constant obesity prevalence, years 2020, 2030, 2040, 2050, and 2060 (in 2019 constant USD)

	Direct medical costs (USD billions)	Direct nonmedical costs (USD billions)	Total direct costs (USD billions)	Absenteeism costs (USD billions)	Presenteeism costs (USD billions)	Premature mortality costs (USD billions)	Total indirect costs (USD billions)	Total costs (USD billions)	Total costs per capita (USD)	Total costs as a percent of GDP
Australia	..	..	..	..	..	..	..	..	..	..
2020	12.00	0.45	12.45	1.59	0.93	9.57	12.10	24.54	963	1.76%
2030	15.25	0.53	15.78	1.88	1.10	14.06	17.05	32.83	1,165	1.81%
2040	19.28	0.64	19.92	2.24	1.31	21.39	24.94	44.85	1,467	1.89%
2050	23.86	0.74	24.60	2.58	1.52	33.56	37.66	62.26	1,897	1.99%
2060	29.28	0.86	30.14	2.91	1.71	53.94	58.56	88.70	2,538	2.15%
Brazil	..	..	..	..	..	..	..	..	..	..
2020	14.87	1.86	16.72	2.23	2.79	18.80	23.82	40.55	191	2.11%
2030	17.38	2.03	19.40	2.37	2.96	30.46	35.80	55.20	247	2.22%
2040	19.49	2.19	21.67	2.42	3.02	47.86	53.30	74.98	327	2.50%

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2050	20.83	2.33	23.16	2.32	2.90	76.35	81.57	104.72	457	2.99%
2060	22.19	2.57	24.76	2.20	2.75	121.93	126.88	151.63	676	3.80%
India	..	..	..	..	..	..	..	..	..	..
2020	5.59	1.07	6.67	1.32	1.80	15.28	18.41	25.07	18	0.81%
2030	8.92	1.32	10.24	1.68	2.29	30.00	33.97	44.22	29	0.79%
2040	13.35	1.58	14.93	2.04	2.78	55.68	60.50	75.43	47	0.85%
2050	18.83	1.82	20.65	2.39	3.24	104.24	109.87	130.52	80	1.02%
2060	26.77	2.05	28.82	2.70	3.66	214.89	221.25	250.07	151	1.44%
Mexico	..	..	..	..	..	..	..	..	..	..
2020	6.37	1.56	7.93	1.70	2.42	14.95	19.07	27.00	209	2.08%
2030	8.08	1.76	9.84	1.95	2.77	24.17	28.89	38.74	275	2.28%
2040	9.70	1.90	11.61	2.11	3.00	41.52	46.63	58.23	389	2.63%
2050	11.14	2.03	13.17	2.21	3.14	70.94	76.28	89.45	577	3.19%
2060	12.73	2.13	14.86	2.21	3.14	121.40	126.74	141.60	901	4.14%
Saudi Arabia	..	..	..	..	..	..	..	..	..	..
2020	5.02	0.21	5.23	0.74	4.63	8.98	14.35	19.58	562	2.40%
2030	6.06	0.24	6.31	0.83	5.18	9.48	15.48	21.79	554	2.22%
2040	6.92	0.25	7.17	0.82	5.14	14.32	20.28	27.45	646	2.26%
2050	7.59	0.26	7.85	0.81	5.07	26.84	32.72	40.57	910	2.66%
2060	8.12	0.28	8.40	0.79	4.97	54.70	60.46	68.86	1,518	3.67%
South Africa	..	..	..	..	..	..	..	..	..	..
2020	2.43	0.16	2.59	0.04	0.21	2.94	3.19	5.78	97	1.58%
2030	3.10	0.23	3.34	0.06	0.30	4.10	4.46	7.80	118	1.62%
2040	3.91	0.33	4.23	0.08	0.41	6.14	6.63	10.87	152	1.71%
2050	4.80	0.45	5.25	0.10	0.53	9.69	10.33	15.58	206	1.89%
2060	..	..	..	..	..	..	..	..	..	..
Spain	63.59	1.25	64.84	8.11	26.60	92.73	127.44	192.29	4,365	10.25%
2020	11.32	0.29	11.61	1.84	6.04	10.12	17.99	29.60	633	2.10%
2030	12.53	0.27	12.80	1.78	5.83	12.66	20.27	33.07	715	2.07%
2040	13.07	0.24	13.32	1.59	5.20	16.21	22.99	36.31	803	2.01%
2050	13.25	0.22	13.48	1.44	4.71	21.71	27.85	41.33	947	2.00%
2060	13.42	0.23	13.65	1.47	4.82	32.04	38.33	51.98	1,266	2.06%
Thailand	..	..	..	..	..	..	..	..	..	..
2020	1.42	0.32	1.74	0.41	0.53	4.45	5.39	7.13	102	1.27%
2030	1.83	0.32	2.15	0.41	0.54	7.39	8.34	10.49	149	1.38%
2040	2.28	0.31	2.59	0.40	0.53	13.74	14.66	17.25	250	1.66%
2050	2.73	0.30	3.03	0.40	0.52	27.33	28.24	31.27	474	2.22%
2060	3.22	0.30	3.52	0.39	0.51	56.38	57.28	60.80	986	3.17%

Table A4: Current burden results, 2019 (in 2019 PPP USD)

	Direct medical costs (PPP billions)	**Direct nonmedical costs (PPP billions)**	**Total direct costs (PPP billions)**	**Absenteeism costs (PPP billions)**	**Presenteeism costs (PPP billions)**	**Premature mortality costs (PPP billions)**	**Total indirect costs (PPP billions)**	**Total costs (PPP billions)**	**Total costs per capita (PPP)**	**Total costs as percent of GDP**
Australia	11.55	0.51	12.07	1.85	1.09	9.16	12.10	24.17	959	1.79%
Brazil	25.19	3.38	28.57	4.09	5.11	30.90	40.10	68.67	325	2.13%

India	16.98	3.65	20.63	4.48	6.08	47.05	57.60	78.23	57	0.82%
Mexico	12.87	3.16	16.03	3.47	4.92	30.15	38.54	54.57	428	2.04%
Saudi Arabia	10.21	0.48	10.69	1.66	10.41	19.13	31.20	41.89	1,222	2.49%
South Africa	5.06	0.34	5.40	0.09	0.45	6.14	6.68	12.08	206	1.58%
Spain	16.20	0.48	16.68	3.13	10.24	14.54	27.91	44.60	954	2.18%
Thailand	3.32	0.89	4.21	1.14	1.48	10.60	13.22	17.43	250	1.30%

Table A5: Baseline projections, years 2020, 2030, 2040, 2050, and 2060 (in 2019 constant PPP USD)

	Direct medical costs (PPP billions)	Direct nonmedical costs (PPP billions)	Total direct costs (PPP billions)	Absenteeism costs (PPP billions)	Presenteeism costs (PPP billions)	Premature mortality costs (PPP billions)	Total indirect costs (PPP billions)	Total costs (PPP billions)	Total costs per capita (PPP)	Total costs as a percent of GDP
Australia	..	..	..	..	..	..	..	..	..	..
2020	12.02	0.43	12.45	1.53	0.90	9.59	12.01	24.46	959	1.76%
2030	15.99	0.55	16.54	1.94	1.14	14.72	17.80	34.34	1,219	1.90%
2040	21.18	0.70	21.89	2.45	1.43	23.26	27.15	49.03	1,604	2.07%
2050	27.21	0.87	28.08	2.96	1.73	37.55	42.25	70.33	2,143	2.25%
2060	34.42	1.05	35.47	3.47	2.03	61.77	67.27	102.74	2,940	2.50%
Brazil	..	..	..	..	..	..	..	..	..	..
2020	26.28	3.09	29.37	3.71	4.63	33.19	41.53	70.89	334	2.10%
2030	32.87	3.78	36.65	4.35	5.43	56.48	66.26	102.90	460	2.35%
2040	39.18	4.51	43.69	4.81	6.01	92.35	103.17	146.85	641	2.79%
2050	44.24	5.21	49.45	4.94	6.16	152.29	163.39	212.84	930	3.46%
2060	49.41	6.15	55.56	4.95	6.18	249.94	261.06	316.62	1,411	4.52%
India	..	..	..	..	..	..	..	..	..	..
2020	18.72	3.73	22.45	4.56	6.19	51.63	62.38	84.84	61	0.82%
2030	33.88	6.55	40.43	7.66	10.45	122.54	140.66	181.08	120	0.97%
2040	58.06	10.62	68.67	11.89	16.24	266.04	294.18	362.86	228	1.24%
2050	93.38	15.73	109.11	17.14	23.44	570.60	611.18	720.30	439	1.70%
2060	149.26	21.54	170.80	23.14	31.68	1360.64	1415.46	1586.26	961	2.76%
Mexico	..	..	..	..	..	..	..	..	..	..
2020	13.48	2.93	16.41	3.19	4.53	31.60	39.32	55.73	432	2.04%
2030	18.03	3.60	21.63	3.93	5.58	52.77	62.28	83.91	596	2.35%
2040	22.76	4.23	26.99	4.53	6.44	93.15	104.13	131.12	876	2.81%
2050	27.40	4.85	32.24	5.01	7.12	162.84	174.98	207.22	1,336	3.51%
2060	32.59	5.38	37.97	5.25	7.46	283.81	296.52	334.50	2,128	4.64%
Saudi Arabia	..	..	..	..	..	..	..	..	..	..
2020	10.70	0.49	11.19	1.68	10.57	19.09	31.35	42.53	1,222	2.46%
2030	13.80	0.62	14.42	2.04	12.82	20.71	35.58	50.00	1,272	2.40%
2040	16.81	0.69	17.50	2.18	13.68	32.06	47.92	65.42	1,540	2.55%
2050	19.50	0.79	20.29	2.28	14.27	61.36	77.91	98.20	2,204	3.04%
2060	21.73	0.91	22.64	2.32	14.53	127.13	143.99	166.63	3,674	4.19%
South Africa	..	..	..	..	..	..	..	..	..	..
2020	5.34	0.34	5.68	0.09	0.44	6.43	6.96	12.64	213	1.59%
2030	7.49	0.60	8.09	0.14	0.73	9.44	10.31	18.39	279	1.76%
2040	9.89	0.90	10.79	0.22	1.10	14.73	16.04	26.83	376	1.95%

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2050	12.57	1.30	13.87	0.30	1.53	24.02	25.85	39.72	526	2.21%
2060	15.66	1.87	17.53	0.40	2.06	39.66	42.12	59.64	763	2.60%
Spain	..	..	..	..	..	..	..	..	..	..
2020	16.70	0.38	17.08	2.44	8.01	14.92	25.38	42.45	908	2.05%
2030	19.19	0.38	19.58	2.50	8.19	19.40	30.09	49.67	1,074	2.12%
2040	20.87	0.37	21.23	2.36	7.72	25.81	35.89	57.12	1,263	2.16%
2050	22.08	0.36	22.43	2.25	7.39	35.89	45.53	67.97	1,558	2.24%
2060	23.28	0.39	23.67	2.42	7.94	54.79	65.16	88.83	2,164	2.40%
Thailand	..	..	..	..	..	..	..	..	..	..
2020	3.55	0.80	4.35	1.00	1.31	11.19	13.50	17.84	256	1.29%
2030	5.26	1.03	6.29	1.28	1.67	21.59	24.55	30.83	438	1.64%
2040	7.42	1.24	8.66	1.50	1.96	44.78	48.24	56.90	824	2.22%
2050	9.84	1.42	11.26	1.71	2.24	96.68	100.64	111.89	1,697	3.22%
2060	12.58	1.57	14.15	1.90	2.48	212.08	216.45	230.61	3,738	4.88%

Table A6: Baseline projections, years 2020, 2030, 2040, 2050, and 2060 (in 2019 constant USD) with GDP multiplier

	Direct medical costs (USD billions)	Direct non-medical costs (USD billions)	Total direct costs (USD billions)	Absent-eeism costs (USD billions)	Presenteeism costs (USD billions)	Premature mortality costs (USD billions) (Regional GDP multiplier)	Total indirect costs (USD billions)	Total costs (USD billions)	Total costs per capita	Total costs as a percent of GDP
Australia	..	..	..	..	..	..	..	..	..	..
2020	12.05	0.60	12.65	2.19	1.27	13.46	16.91	29.56	1,159	2.12%
2030	16.03	0.80	16.83	2.90	1.68	20.66	25.25	42.08	1,493	2.32%
2040	21.24	1.04	22.28	3.78	2.18	32.65	38.61	60.89	1,992	2.57%
2050	27.28	1.31	28.59	4.67	2.70	52.71	60.08	88.67	2,702	2.83%
2060	34.51	1.61	36.12	5.63	3.25	86.69	95.57	131.69	3,768	3.19%
Brazil	..	..	..	..	..	..	..	..	..	..
2020	14.97	2.27	17.24	2.71	3.39	26.47	32.57	49.81	234	2.59%
2030	18.73	2.88	21.61	3.36	4.20	45.05	52.61	74.21	332	2.98%
2040	22.32	3.54	25.87	3.95	4.93	73.66	82.54	108.41	473	3.62%
2050	25.21	4.24	29.45	4.38	5.47	121.48	131.33	160.78	702	4.59%
2060	28.15	5.08	33.23	4.74	5.91	199.36	210.01	243.23	1,084	6.09%
India	..	..	..	..	..	..	..	..	..	..
2020	5.66	1.28	6.94	1.75	2.17	43.68	47.59	54.53	40	1.75%
2030	10.24	2.26	12.50	2.97	3.70	103.67	110.33	122.83	82	2.18%
2040	17.54	3.74	21.28	4.69	5.86	225.06	235.62	256.89	161	2.90%
2050	28.21	5.72	33.93	6.98	8.73	482.70	498.41	532.34	325	4.16%
2060	45.10	8.18	53.28	9.83	12.32	1151.02	1173.17	1226.44	743	7.05%
Mexico	..	..	..	..	..	..	..	..	..	..
2020	6.40	1.74	8.14	1.93	2.73	21.01	25.66	33.81	262	2.60%
2030	8.56	2.19	10.75	2.44	3.45	35.09	40.98	51.73	367	3.05%
2040	10.81	2.66	13.47	2.93	4.15	61.93	69.01	82.48	551	3.72%
2050	13.01	3.14	16.15	3.37	4.77	108.26	116.40	132.55	854	4.73%
2060	15.48	3.59	19.07	3.70	5.24	188.69	197.63	216.69	1,379	6.33%

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Saudi Arabia	..	..	..	..	..	..	..	..	..	..
2020	5.05	0.24	5.28	0.82	4.96	12.61	18.39	23.68	680	2.91%
2030	6.51	0.31	6.82	1.05	6.31	13.68	21.04	27.86	708	2.83%
2040	7.93	0.37	8.30	1.22	7.33	21.18	29.73	38.03	895	3.14%
2050	9.20	0.45	9.65	1.40	8.42	40.53	50.35	60.01	1,347	3.94%
2060	10.25	0.53	10.79	1.53	9.18	83.98	94.69	105.48	2,326	5.62%
South Africa	..	..	..	..	..	..	..	..	..	..
2020	2.46	0.19	2.65	0.05	0.25	12.43	12.73	15.37	259	4.21%
2030	3.45	0.33	3.78	0.08	0.41	18.25	18.74	22.52	341	4.67%
2040	4.55	0.50	5.05	0.13	0.63	28.48	29.23	34.29	480	5.41%
2050	5.79	0.73	6.52	0.18	0.91	46.45	47.54	54.05	716	6.55%
2060	7.21	1.06	8.27	0.25	1.25	76.69	78.19	86.46	1,106	8.17%
Spain	..	..	..	..	..	..	..	..	..	..
2020	11.36	0.43	11.80	2.84	9.19	14.22	26.25	38.05	814	2.70%
2030	13.06	0.47	13.53	3.11	10.06	18.48	31.65	45.19	977	2.83%
2040	14.20	0.50	14.69	3.27	10.58	24.59	38.44	53.14	1,175	2.95%
2050	15.02	0.53	15.56	3.46	11.18	34.20	48.83	64.38	1,475	3.12%
2060	15.84	0.58	16.42	3.70	11.94	52.20	67.85	84.27	2,053	3.34%
Thailand	..	..	..	..	..	..	..	..	..	..
2020	1.44	0.39	1.83	0.50	0.65	9.97	11.12	12.95	186	2.31%
2030	2.13	0.55	2.68	0.70	0.92	19.24	20.86	23.54	335	3.09%
2040	3.00	0.72	3.72	0.92	1.20	39.89	42.01	45.73	663	4.41%
2050	3.98	0.87	4.86	1.11	1.45	86.14	88.71	93.57	1,419	6.64%
2060	5.09	1.00	6.09	1.28	1.67	188.95	191.90	197.99	3,209	10.34%

Table A7: Average annual percentage change in total costs, cost per GDP, and obesity prevalence between 2019 and 2060

Country	Total costs	Cost per GDP	Obesity prevalence
Australia	3.64%	0.86%	0.66%
Brazil	3.81%	1.87%	1.05%
India	7.62%	3.01%	2.97%
Mexico	4.51%	2.02%	0.89%
Saudi Arabia	3.47%	1.32%	0.99%
South Africa	3.96%	1.20%	1.05%
Spain	1.82%	0.36%	0.66%
Thailand	6.56%	3.33%	1.99%

Appendix 4: Identified cost-of-illness studies of obesity from literature review

Table A8: PubMed Search Strategy

Search	Query
#17	Search #1 AND #13 AND #16
#16	Search #14 OR #15
#15	Search "Health Services Accessibility"[Mesh] OR "Public Health/economics"[Mesh] Sort by: [pubsolr12]
#14	Search ("Costs and Cost Analysis"[Mesh] OR "Cost Sharing"[Mesh] OR "Cost Savings"[Mesh] OR "Cost of Illness"[Mesh] OR "Economics"[Mesh] OR "Cost-Benefit Analysis"[Mesh] OR "Health Care Costs"[Mesh] OR "Direct Service Costs"[Mesh] OR "Hospital Costs"[Mesh] OR "Employer Health Costs"[Mesh] OR "Drug Costs"[Mesh] OR "Health Expenditures"[Mesh]) Sort by: [pubsolr12]
#13	Search #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12
#12	Search ("transitional country" OR "transitional countries") Sort by: [pubsolr12]
#11	Search (lmic OR lmics OR "third world" OR "lami country" OR "lami countries") Sort by: [pubsolr12]
#10	Search low NEAR/3 middle NEAR/3 countr* Sort by: [pubsolr12]
#9	Search (low* NEXT (gdp OR gnp OR "gross domestic" OR "gross national")) Sort by: [pubsolr12]
#8	Search (developing OR less* NEXT developed OR "under developed" OR underdeveloped OR "middle income" OR low* NEXT income) NEXT (economy OR economies) Sort by: [pubsolr12]
#7	Search (developing OR less* NEXT developed OR "under developed" OR underdeveloped OR "middle income" OR low* NEXT income OR underserved OR "under served" OR deprived OR poor*) NEXT (countr* OR nation* OR population* OR world) Sort by: [pubsolr12]
#6	Search (Romania OR Rumania OR Roumania OR Russia OR Russian OR Rwanda OR Ruanda OR "Saint Kitts" OR "St Kitts" OR Nevis OR "Saint Lucia" OR "St Lucia" OR "Saint Vincent" OR "St Vincent" OR Grenadines OR Samoa OR "Samoan Islands" OR "Navigator Island" OR "Navigator Islands" OR "Sao Tome" OR Principe OR Senegal OR Serbia OR Montenegro OR "Sierra Leone" OR "Sri Lanka" OR Ceylon OR "Solomon Islands" OR Somalia OR Somaliland OR "South Africa" OR "South Ossetia" OR Sudan OR Suriname OR Surinam OR Swaziland OR Syria OR Tajikistan OR Tadzhikistan OR Tadjikistan OR Tadzhik OR Tanzania OR Thailand OR Tibet OR Togo OR "Togolese Republic" OR Tokelau OR Tonga OR Transnistria OR Trinidad OR Tobago OR Tunisia OR Turkey OR Turkmenistan OR Turkmen OR Tuvalu OR Uganda OR Ukraine OR Uruguay OR USSR OR "Soviet Union" OR "Union of Soviet Socialist Republics" OR Uzbekistan OR Uzbek OR Vanuatu OR "New Hebrides" OR Venezuela OR Vietnam OR "Viet Nam" OR "Mekong valley" OR "Mekong delta"• OR "Western Sahara" OR Sahrawi OR "West Bank" OR Yemen OR Yugoslavia OR Zambia OR Zimbabwe OR Zanzibar OR Rhodesia) Sort by: [pubsolr12]
#5	Search (Macedonia OR FYROM OR Macao OR Madagascar OR "Malagasy Republic" OR Malaysia OR Malaya OR Malay OR Sabah OR Sarawak OR Malawi OR Nyasaland OR Mali OR "Marshall Islands" OR Mauritania OR Mauritius OR "Agalega Islands" OR Mexico OR Micronesia OR "Middle East" OR Moldova OR Moldovia OR Moldovian OR Mongolia OR Montenegro OR Morocco OR Ifni OR Mozambique OR Myanmar OR Myanma OR Burma OR Namibia OR Nauru OR Nepal OR Nicaragua OR Niger OR Nigeria OR Niue OR Pakistan OR Palau OR Palestine OR Panama OR Paraguay OR Peru OR Philippines OR Philipines OR Phillipines OR Phillippines OR Polynesia) Sort by: [pubsolr12]
#4	Search (Djibouti OR "French Somaliland" OR Dominica OR "Dominican Republic" OR "East Timor" OR "East Timur" OR "Timor Leste" OR Ecuador OR Egypt OR "United Arab Republic" OR "El Salvador" OR Eritrea OR Ethiopia OR Eswatini OR Fiji OR Gabon OR "Gabonese Republic" OR Gambia OR Gaza OR Georgia OR Georgian OR Ghana OR "Gold Coast" OR Grenada OR Guatemala OR Guinea OR Guiana OR Guyana OR Haiti OR Honduras OR India OR Maldives OR Indonesia OR Iran OR Iraq OR Jamaica OR Jordan OR Kashmir OR Kazakhstan OR Kazakh OR Kenya OR Kiribati OR Korea OR DPRK OR Kosovo OR Kyrgyzstan OR Kirghizia OR "Kyrgyz Republic" OR Kirghiz OR Kirgizstan OR "Lao PDR" OR Laos OR Lebanon OR Lesotho OR Basutoland OR Liberia OR Libya) Sort by: [pubsolr12]
#3	Search (Abkhazia OR Afghanistan OR Albania OR Algeria OR Angola OR Antigua OR Barbuda OR Argentina OR Armenia OR Armenian OR Artsakh OR Aruba OR Azerbaijan OR Bahamas OR Bangladesh OR Barbados OR Benin OR Byelarus OR Byelorussian OR Belarus OR Belorussian OR Belorussia OR Belize OR Bermuda OR Bhutan OR Bolivia OR Borneo OR Bosnia OR Herzegovina OR Hercegovina OR Botswana OR Brasil OR Brazil OR Bulgaria OR "Burkina Faso" OR "Burkina Fasso" OR "Upper Volta" OR Burundi OR Urundi OR Cambodia OR "Khmer Republic" OR Kampuchea OR Cameroon OR Cameroons OR Cameron OR Camerons OR "Cape Verde" OR "Cabo Verdeâ€• OR "Central African Republic" OR Chad OR Chile OR China OR Colombia OR Comoros OR "Comoro Islands" OR Comores OR Congo OR DRC OR "Congo-Brazzavilleâ€• OR "Congo-Kinshas"• OR Zaire OR "Cote d'Ivoire" OR "Ivory Coast" OR Cuba) Sort by: [pubsolr12]
#2	Search (Africa OR Asia OR Caribbean OR "West Indies" OR "South America" OR "Latin America" OR "Central America") Sort by: [pubsolr12]
#1	Search ("overweight"[Mesh] OR "obesity"[Mesh]) Sort by: [pubsolr12]

Global economic evaluations of obesity (n=2)

- OECD, *The Heavy Burden of Obesity: The Economics of Prevention*. 2019, OECD Health Policy Studies, OECD Publishing: Paris.
- Dobbs, et al., *Overcoming obesity: An initial economic analysis*. 2014, McKinsey Global Institute, McKinsey & Company.

Economic evaluations of obesity in LMICs (n=9)

- Direct and Indirect Costs Included (n=2)
  - Li, Q., et al., *Economic burden of obesity and four obesity-related chronic diseases in rural Yunnan Province, China.* Public Health, 2018. 164: p. 91-98.
  - Pitayatienanan, P., et al., *Economic costs of obesity in Thailand: a retrospective cost-of-illness study*. BMC Health Serv Res, 2014. 14: p. 146.
- Only Indirect Costs Included (n=1)
  - Riantoro, B.D., S.A. Kristina, and D. Endarti, *Estimating Premature Mortality Cost of Cancers Attributable to Obesity in Indonesia*. Asian Pac J Cancer Prev, 2019. 20(1): p. 87-90.
- Only Direct Costs Included (n=6)
  - Bahia, L., et al., *The costs of overweight and obesity-related diseases in the Brazilian public health system: cross-sectional study*. BMC Public Health, 2012. 12: p. 440.
  - de Oliveira, M.L., L.M. Santos, and E.N. da Silva, *Direct healthcare cost of obesity in brazil: an application of the cost-of-illness method from the perspective of the public health system in 2011.* PLoS One, 2015. 10(4): p. e0121160.
  - Qin, X. and J. Pan, *The Medical Cost Attributable to Obesity and Overweight in China: Estimation Based on Longitudinal Surveys*. Health Econ, 2016. 25(10): p. 1291-311.
  - Rtveladze, K., et al., *Obesity prevalence in Mexico: impact on health and economic burden*. Public Health Nutr, 2014. 17(1): p. 233-9.
  - Rtveladze, K., et al., *Health and economic burden of obesity in Brazil*. PLoS One, 2013. 8(7): p. e68785.
  - Shi, J., et al., *Direct health care costs associated with obesity in Chinese population in 2011*. J Diabetes Complications, 2017. 31(3): p. 523-528.

Economic evaluations of obesity in high-income countries (n=48)

- Direct and Indirect Costs Included (n=15)
  - Blouin, C., et al., *The economic consequences of obesity and overweight among adults in Quebec*. Can J Public Health, 2017. 107(6): p. e507-e513.
  - Breitfelder, A., et al., *Relative weight-related costs of healthcare use by children--results from the two German birth cohorts*, GINI-plus and LISA-plus. Econ Hum Biol, 2011. 9(3): p. 302-15.
  - Chang, C., et al., *Costs Attributable to Overweight and Obesity in Working Asthma Patients in the United States.* Yonsei Med J, 2017. 58(1): p. 187-194.
  - Effertz, T., et al., *The costs and consequences of obesity in Germany: a new approach from a prevalence and life-cycle perspective*. Eur J Health Econ, 2016. 17(9): p. 1141-1158.
  - Fallah-Fini, S., et al., *The Additional Costs and Health Effects of a Patient Having Overweight or Obesity: A Computational Model*. Obesity (Silver Spring), 2017. 25(10): p. 1809-1815.
  - Finkelstein, E., et al., *The Costs of Obesity in the Workplace*. Journal of Occupational and Environmental Medicine, 2010. 52(10): p: 971-76.
  - Kang, J.H., et al., *Socioeconomic costs of overweight and obesity in Korean adults*. J Korean Med Sci, 2011. 26(12): p. 1533-40.
  - Kjellberg, J., et al., *The Socioeconomic Burden of Obesity*. Obes Facts, 2017. 10(5): p. 493-502.
  - Konnopka, A., M. Bodemann, and H.H. Konig, *Health burden and costs of obesity and overweight in Germany*. Eur J Health Econ, 2011. 12(4): p. 345-52.
  - Krueger, H., J. Krueger, and J. Koot, *Variation across Canada in the economic burden attributable to excess weight, tobacco smoking and physical inactivity*. Can J Public Health, 2015. 106(4): p. e171-7.
  - Lee, J.W., et al., *Trends in socioeconomic costs of morbid obesity among Korean adults, 2009-2013: Data from National Health Insurance Service*. Obes Res Clin Pract, 2018. 12(4): p. 389-393.

  - Lehnert, T., et al., *Health burden and costs of obesity and overweight in Germany: an update*. Eur J Health Econ, 2015. 16(9): p. 957-67.
  - Samouda, H., et al., *Metabolically healthy and unhealthy weight statuses, health issues and related costs: Findings from the 2013-2015 European Health Examination Survey in Luxembourg.* Diabetes Metab, 2019. 45(2): p. 140-151.
  - Su, W., et al., *Modeling the clinical and economic implications of obesity using microsimulation*. J Med Econ, 2015. 18(11): p. 886-97.
  - Waters, H. and M. Graf, *America's Obesity Crisis: The Health and Economic Costs of Excess Weight*. 2018, The Milken Institute, Santa Monica.
- Only Indirect Costs Included (n=3)
  - Andreyeva, T., J. Luedicke, and Y.C. Wang, *State-level estimates of obesity-attributable costs of absenteeism*. J Occup Environ Med, 2014. 56(11): p. 1120-7.
  - Lehnert, T., et al., *Sick leave days and costs associated with overweight and obesity in Germany*. J Occup Environ Med, 2014. 56(1): p. 20-7.
  - Neovius, K., et al., *Lifetime productivity losses associated with obesity status in early adulthood: a population-based study of Swedish men*. Appl Health Econ Health Policy, 2012. 10(5): p. 309-17.
- Only Direct Costs Included (n=30)
  - Alter, D.A., et al., *Obesity, lifestyle risk-factors, and health service outcomes among healthy middle-aged adults in Canada*. BMC Health Serv Res, 2012. 12: p. 238.
  - An, R., *Health care expenses in relation to obesity and smoking among U.S. adults by gender, race/ethnicity, and age group: 1998-2011*. Public Health, 2015. 129(1): p. 29-36.
  - Au, N., *The health care cost implications of overweight and obesity during childhood*. Health Serv Res, 2012. 47(2): p. 655-76.
  - Bell, J.F., et al., *Health-care expenditures of overweight and obese males and females in the medical expenditures panel survey by age cohort.* Obesity (Silver Spring), 2011. 19(1): p. 228-32.
  - Biener, A., J. Cawley, and C. Meyerhoefer, *The Impact of Obesity on Medical Care Costs and Labor Market Outcomes in the US*. Clin Chem, 2018. 64(1): p. 108-117.
  - Black, N., R. Hughes, and A.M. Jones, *The health care costs of childhood obesity in Australia: An instrumental variables approach*. Econ Hum Biol, 2018. 31: p. 1-13.
  - Cawley, J. and C. Meyerhoefer, *The medical care costs of obesity: an instrumental variables approach*. J Health Econ, 2012. 31(1): p. 219-30.
  - Cecchini, M., *Use of healthcare services and expenditure in the US in 2025: The effect of obesity and morbid obesity*. PLoS One, 2018. 13(11): p. e0206703.
  - Colao, A., et al., *Healthcare usage and economic impact of non-treated obesity in Italy: findings from a retrospective administrative and clinical database analysis*. BMJ Open, 2017. 7(2): p. e013899.
  - Copley, V.R., et al., *Estimating the variation in need for community-based social care by body mass index in England and associated cost: population-based cross-sectional study*. BMC Public Health, 2017. 17(1): p. 667.
  - Doherty, E., A. Dee, and C. O'Neill, *Estimating the amount of overweight and obesity related health-care use in the Republic of Ireland using SLAN data*. The Economic and Social Review, 2012. 43(2): p. 227-250.
  - Fujita, M., et al., *Medical costs attributable to overweight and obesity in Japanese individuals*. Obes Res Clin Pract, 2018. 12(5): p. 479-484.
  - Harris, J.A., et al., *The Relationship of Obesity to Hospice Use and Expenditures: A Cohort Study*. Ann Intern Med, 2017. 166(6): p. 381-389.
  - Iski, G., S.E. Rurik, and I. Rurik, *Expenditures Of Metabolic Diseases - An Estimation on National Health Care Expenditures of Diabetes and Obesity, Hungary 2013*. Exp Clin Endocrinol Diabetes, 2019. 127(1): p. 62-67.
  - Janicke, D.M., et al., *The relationship among child weight status, psychosocial functioning, and pediatric health care expenditures in a medicaid population*. J Pediatr Psychol, 2010. 35(8): p. 883-91.
  - Kent, S., et al., *Hospital costs in relation to body-mass index in 1.1 million women in England: a prospective cohort study*. Lancet Public Health, 2017. 2(5): p. e214-e222.
  - Konig, H.H., et al., *Health service use and costs associated with excess weight in older adults in Germany.* Age Ageing, 2015. 44(4): p. 616-23.

- Kuhle, S., et al., *Use and cost of health services among overweight and obese Canadian children*. Int J Pediatr Obes, 2011. 6(2): p. 142-8.
- Larg, A., J.R. Moss, and N. Spurrier, *Relative contribution of overweight and obesity to rising public hospital in-patient expenditure in South Australia*. Aust Health Rev, 2019. 43(2): p. 148-156.
- Laxy, M., et al., *The Non-Linear Relationship between BMI and Health Care Costs and the Resulting Cost Fraction Attributable to Obesity*. Int J Environ Res Public Health, 2017. 14(9).
- Lee, C.M.Y., et al., *The cost of diabetes and obesity in Australia*. J Med Econ, 2018. 21(10): p. 1001-1005.
- Lette, M., et al., *Health care costs attributable to overweight calculated in a standardized way for three European countries*. Eur J Health Econ, 2016. 17(1): p. 61-9.
- Mora, T., J. Gil, and A. Sicras-Mainar, *The influence of obesity and overweight on medical costs: a panel data perspective*. Eur J Health Econ, 2015. 16(2): p. 161-73.
- Sairenchi, T., et al., *Impact and attribute of each obesity-related cardiovascular risk factor in combination with abdominal obesity on total health expenditures in adult Japanese National Health insurance beneficiaries: The Ibaraki Prefectural health study*. J Epidemiol, 2017. 27(8): p. 354-359.
- Song, H.J., et al., *The impact of obesity and overweight on medical expenditures and disease incidence in Korea from 2002 to 2013.* PLoS One, 2018. 13(5): p. e0197057.
- Wang, Y.C., et al., *Severe Obesity In Adults Cost State Medicaid Programs Nearly $8 Billion In 2013*. Health Aff (Millwood), 2015. 34(11): p. 1923-31.
- Wang, L.Y., et al., *Long-term health and economic impact of preventing and reducing overweight and obesity in adolescence*. J Adolesc Health, 2010. 46(5): p. 467-73.
- Wenig, C.M., *The impact of BMI on direct costs in children and adolescents: empirical findings for the German Healthcare System based on the KiGGS-study*. Eur J Health Econ, 2012. 13(1): p. 39-50.
- Wijga, A.H., et al., *Healthcare utilisation and expenditure of overweight and non-overweight children.* J Epidemiol Community Health, 2018. 72(10): p. 940-943.
- Yang, Z. and N. Zhang, *The burden of overweight and obesity on long-term care and Medicaid financing*. Med Care, 2014. 52(7): p. 658-63

Appendix 5: Identified studies on employment differences by BMI categories from literature review

We did a targeted search of PubMed for differential rates of employment between those with overweight and obesity and those with healthy weight for the eight countries included in our analysis. Our search yielded 211 results of which 22 were selected as possibly containing data on differential rates of employment by BMI category and were further reviewed.

Search terms: (("employment"[Title/Abstract] OR "labor"[Title/Abstract]) AND ("obesity"[Title/Abstract] OR "overweight"[Title/Abstract] OR "BMI"[Title/Abstract]) AND ("australia*"[Title/Abstract] OR "brazil*"[Title/Abstract] OR "mexico"[Title/Abstract] OR "saudi"[Title/Abstract] OR "south africa*"[Title/Abstract] OR "thai*"[Title/Abstract] OR "spain"[Title/Abstract] OR "india*"[Title/Abstract] OR "spanish"[Title/Abstract] OR "mexican"[Title/Abstract])) AND ((english[Filter]) AND (2010:2021[pdat]))

The table below presents the eight most relevant publications and summarizes key findings. There are six countries represented in the table; no study was identified from Brazil or Thailand.

Title	**Journal**	**Authors/Year**	**Location**	**Findings**
Obesity and hiring discrimination.	Economics and human biology	Campos-Vazquez RM and Gonzalez E (2020)	Mexico	Paper examines discrimination in callbacks using resumes that include photographs but does not study actual employment. There is clear evidence of discrimination against obese women, but not obese men. The callback rate for the non-obese women is 29.1%; for obese women it is 21.3%.
Labor market engagement and the BMI of working adults: Evidence from India.	Economics and human biology	Dang A and Maitra P and Menon N (2019)	India, urban	This paper examines the relationship between BMI and sector and physical intensity of work among urban adults in India and finds a positive association between BMI and labor market inactivity. Broadly, the non-working group had higher average BMI than the blue-collar and high-activity occupation groups, but similar to those in white-collar occupations. The paper does not report employment rates by BMI category.
Decomposition of Gender Differences in BMI in Saudi Arabia using Unconditional Quantile Regression	International journal of environmental research and public health	Al-Hanawi MK and Chirwa GC and Kamninga TM (2020)	Saudi Arabia	This study examines factors associated with gender differentials in BMI in Saudi Arabia. It concludes that there is "persistently higher BMI for employed individuals across all quantiles", however, there are no employment rates provided by BMI category.

Cardiovascular risk factors, lifestyle, and social determinants	The British journal of general practice	Palomo L et al. (2014)	Spain, sub-national	The aim of this study is to analyze the relationship between major cardiovascular risk factors and socioeconomic indicators. Unemployed females had a statistically significantly higher chance of having obesity than those in paid employment. However, the study does not include those with overweight or those comparative employment rates.
The association of health and employment in mature women	Journal of women's health	Pit SW and Byles J (2012)	Australia	This study does not consider overweight and only includes women aged 45 to 50 at baseline. This analysis shows that obesity is significantly associated with being unemployed, but association becomes statistically insignificant when quality of life is added to the model.
The association of pain with labor force participation, absenteeism, and presenteeism in Spain.	Journal of medical economics	Langley PC et al. (2011)	Spain	While this paper does provide odds ratios for labor force participation for overweight (1.165) and obesity (0.998) in Spain, neither is statistically significant.
Social drift of CVD risk factors in Africans from the North West Province of South Africa: the PURE study.	Cardiovascular journal of Africa	Pisa PT and Behanan R and Vorster HH and Kruger A (2012)	South Africa, sub-national	While this study does show that employed men and women have higher average BMI than unemployed men and women, it does not give data by BMI category or employment rates.
Socio-Economic and Demographic Correlates of NCD Risk Factors Among Adults in Saudi Arabia.	Frontiers in medicine	Al-Hanawi MK and Keetile M (2021)	Saudi Arabia	While this study does include overweight and obesity compared to normal weight, it shows only that, relative to unemployment, the only statistically significant odds ratio is for being a government employee (1.22). The OR for being non-government employee, homemaker, retired, self-employed, and student are all statistically insignificant.