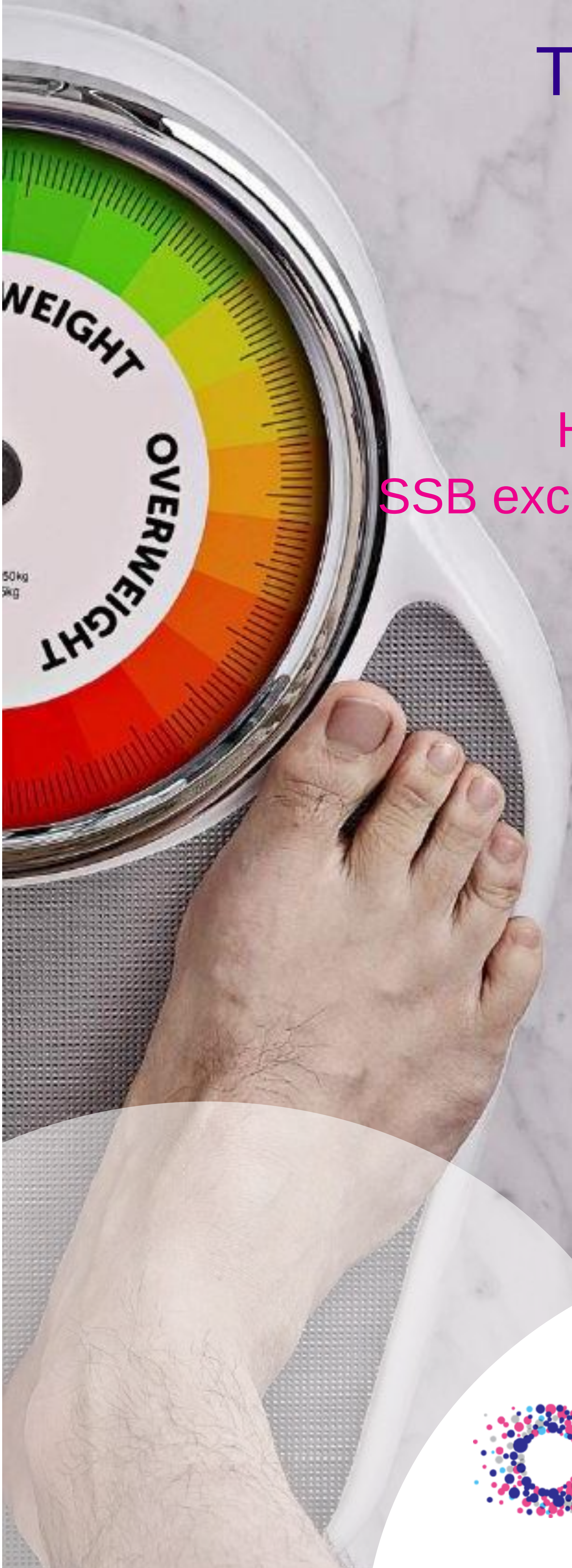
Technical Report



Baseline scenario
Hypothetical scenarios
SSB excise tax policy scenario

CANCER RESEARCH UK

UK HEALTH PREVENTION FIRST FORUM

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About the UK Health Forum

The UK Health Forum is a charitable alliance of professional and public interest organisations working to reduce the risk of avoidable non-communicable diseases (NCDs) by developing evidence-based public health policy and supporting its implementation through advocacy and information.

Working with and through our members, we are a centre of expertise in policy research and development, epidemiological and economic modelling of NCDs, and information provision.

UK Health Forum is a registered charity 803286.

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Cancer Research UK is the world's largest independent cancer charity dedicated to saving lives through research. We support research into all aspects of cancer through the work of over 4,000 scientists, doctors and nurses. In 2013/14, we spent £386 million on research institutes, hospitals and universities across the UK – including a £35 million contribution we made to the Francis Crick Institute. We receive no funding from the Government for our research.

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This project has been commissioned by the Cancer Research UK Policy Research Centre for Cancer Prevention. To learn more about this research centre, please visit: http://www.cruk.org/funding-for-researchers/how-we-deliver-research/our-research-partnerships/bupa-foundation-cancer-prevention-initiative/the-policy-research-centre-for-cancer-prevention-prcp

Executive summary

Overweight and obesity are major risk factors for a range of non-communicable diseases (NCDs) – chiefly cancers, coronary heart disease (CHD), stroke, and type 2 diabetes (T2DM). These NCDs are major causes of morbidity and mortality in the UK, putting strain on an already overstretched National Health Service (NHS), as well as causing productivity losses due to sickness absences and premature deaths. The present project used a state of the art dynamic microsimulation model to project trends in obesity forward to 2035, and tested the impact of interventions to reduce the disease and cost burden of BMI-related diseases.

KEY STATISTICS

If current trends were to continue:

- 72% of the adult UK population could become overweight or obese by 2035.
- 76% of men and 69% of women could become overweight or obese by 2035.
- 'Obese' could become the most common weight category (relative to 'healthy weight' and 'overweight') at some point between 2025 and 2030 for both men and women.
- Obesity prevalence likely to increase across all income quintiles[2].
- Over the next 20 years (2015-2035), there could be 2.9 million[3] new cases of BMI-related cancers. Of this, 670,000 are as a result of rising rates of overweight and obesity.
- In 2035 alone, BMI-related diseases could cost £6.1 billion to the NHS[4] . Of this, £2.5 billion are as a result of the rising rates of overweight and obesity.

Results from the hypothetical scenarios:

Reducing the prevalence of overweight and obesity by 1% each year below the predicted trend:

- Could lead to the prevalence of overweight and obesity reaching 65% by 2035.

[2] Quintiles are five equal groups into which a population can be divided according to the distribution of values of a particular variable.

[3] 2,891,395 cumulative incidence cases of BMI-related cancers are expected to be observed between 2015 and 2035.Note that BMI-related cancers can be caused by risk factors other than overweight or obesity. Examples include smoking and excessive alcohol consumption.

[4] This cost refers to NHS healthcare and NHS social care costs. Note that BMI-related diseases can be caused by risk factors other than overweight or obesity. We caution the use of total costs in this report since the development of a disease following the start of the microsimulation is related to a specific risk factor holding all else constant. In addition, the projected annual total costs of BMI-related diseases do not take into account possible changes in costs as a result of changes in the prevalence of other risk-factors such as alcohol and smoking; thus, summation of smoking and obesity cost figures would result in double counting due to the presence of diseases that are affected by both by both smoking and obesity. 'Costs avoided' figures avoid this problem since they reflect the costs attributable to the risk factor, and provide a better representation of the health impact of a particular intervention in this project.

- Could lead to the avoidance of 7,300[5] new cases of BMI-related cancers in the year 2035 alone.
- Could lead to the avoidance of £300 million in direct NHS costs and £1.3 billion in indirect societal costs in the year 2035 alone.
- Could lead to the avoidance of 64,200[6] new cases of BMI-related cancers over the next 20 years (2015-2035)

Reducing the prevalence of overweight and obesity by 10% each year below the predicted trend:

- Could lead to the prevalence of overweight and obesity prevalence reaching 29% by 2035.
- Could lead to the avoidance of 32,700 new cases of BMI-related cancers in the year 2035 alone.
- Could lead to the avoidance of £1.74 billion in direct NHS costs and £9.82 billion in indirect societal costs in the year 2035 alone.
- Could lead to the avoidance of 0.41 million[7] new cases of BMI-related cancers over the next 20 years (2015-2035)
- Could lead to the avoidance of £16.3 billion in direct NHS costs over the next 20 years (2015-2035).

Results from the SSB tax scenario:

- The introduction of a 20% excise tax on sugary sweetened beverages (SSB) could prevent 3.7 million people from becoming obese by 2025. This is equivalent to a 5% shift in obesity prevalence.
- If current trends were to continue, obesity[i] levels in the UK could increase from 29% in 2015 to 34% by 2025. This increase could be avoided by the introduction of a 20% excise tax on SSBs.
- The introduction of a 20% excise tax on SSBs could save approximately £10 million[ii] in direct NHS healthcare and NHS social care costs in the year 2025 alone.

NB. The BMI prevalence figures in the Key Statistics section present outputs from the microsimulation (Table 8 of the document). Using extrapolated trends in BMI prevalence, the microsimulation simulates a virtual population. Results using extrapolated trends from cross-sectional HSE data (Table 7 of the document) differ slightly from the results from the microsimulation programme since it does not take into account dynamic changes in population changes over time.

Risk factor prevalence

Overweight and obesity is predicted to increase from 72% to 76% in men, and from 63% to 69% in women by 2035. Obesity is projected to increase across all age and income groups,

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[5] 7,267 incidence cases of BMI-related cancers are expected to be avoided in 2035.
[6] 64,207 cumulative incidence cases of BMI-related cancers are expected to be avoided between 2015 and 2035.
[7] 405,265 cumulative incidence cases of BMI-related cancers are expected to be avoided between 2015 and 2035.

apart from 30-39 year old men where trends are expected to be stable over time. Obesity is projected to increase most in the lower income groups.

Health and economic impacts of interventions to reduce obesity

Interventions that are effective in reducing obesity will have an important impact upon the future burden of NCDs. Results of the modelling demonstrated that large avoidances in the number of disease cases can be achieved by implementing hypothetical interventions that shift individuals from the overweight and obese categories into the healthy[8] weight category. However, in reality, shifting individuals from one BMI category to another, and even BMI points, is difficult to achieve and sustain in the long-term. A range of concurrent interventions will be required to curb the high rates of obesity and increased rates expected in the future.

The likely impact that a 20% sugar sweetened beverage tax will have on the prevalence of overweight and obesity, as well as on the number of BMI-related diseases, was modelled. This intervention had an impact on a number of non-cancer diseases; for example, 35,210 and 11,046 cumulative incidence cases of T2DM and CHD, respectively, are expected to be avoidable in the UK by 2035. However, no discernible effect is expected to be observed on the incidence of the less prevalent cancers. This is likely to be due to a combination of the short time horizon of the study, long lag periods of the cancers, and the low prevalence of many of the cancers studied.

Future work needs to continue to employ this microsimulation method in exploring the complexity of the relationships between BMI in combination with other behavioural risk factors, such as physical activity, smoking, alcohol, sugar and fat consumption, as well as the relationships between co-morbidities. Modelling needs to contribute to the evidence base for the effectiveness and cost-effectiveness of large-scale public health interventions that otherwise are challenging to assess.

[8] Healthy weight is usually defined as an individual having a BMI between 18.5 and 25. Those with a BMI under 18.5 are considered underweight. For the purposes of the modelling, all individuals who have a BMI of less than 25 are categorised as 'healthy weight'. This is because very few individuals in the model would shift below a BMI of 18.5. Also, any impact of BMI reductions on underweight would be insignificant since relative risks for underweight are not included. The focus of the model is on the risk of disease from overweight and obesity only.

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Introduction

Obesity has more than doubled since 1980. The World Health Organization estimates that in 2014 more than 1.9 billion adults were overweight and 600 million of these were obese. This trend is mirrored in the UK whereby approximately 25% of adults in the UK are classified as obese [1].

Obesity is a significant risk factor for many diseases, contributing to a global health burden and putting substantial pressure on health systems. Epidemiological studies have identified obesity as a specific risk factor for cardiovascular diseases (e.g. hypertension, coronary heart disease and stroke), diabetes mellitus, osteoarthritis and several types of cancer [2-7]. If obesity rates continue to rise in line with current trends, the burden of these diseases as well as associated health care costs are likely to be colossal.

The problem of NCDs is evident not only among health systems, but also across the wider society, due to increased pressures on productivity and scarce resources [8]. It is estimated that the global economic burden of NCDs will amount to more than £20 trillion by 2030, representing 48% of the projected global GDP [8]. The pervasive and costly nature of NCDs, alongside significant increases in life expectancy [9], has resulted in urgency among policy makers and health authorities to establish preventative public health interventions that are both effective and cost-effective.

Many NCDs are interrelated, and their impacts on population health, public services and the economy need to be better comprehended, so that appropriate policies can be drafted. In order to formulate these well-informed policies, decision makers and health authorities must first be able to answer key questions such as: what the current distributions of risk factors and avoidable NCDs are among different demographics [10]; how these distributions are likely to develop in the future; what the health and economic consequences of NCDs are likely to be; and how these consequences can be attenuated with what we currently know and might come to know. Statistical models which use risk factor projections are able to simulate various intervention scenarios, and present the effects of these interventions in terms of changes in key parameters, such as mortality cases and costs incurred by the public purse. These models are able to identify where a society may be heading should current trends continue, giving policy makers unprecedented opportunities to act to modify the course of events [11].

Project aims

To evaluate the effect of obesity on the future burden of NCDs, Cancer Research UK (CRUK) commissioned the UK Health Forum (UKHF) to project the trends in obesity from 2015 to 2035, evaluate the impacts of obesity on the epidemiology of NCDs – namely CHD, stroke, T2DM, and a range of cancers, and provide an economic case for investment in public health interventions. Projections and simulations were made possible by adapting a predictive microsimulation model originally developed for the Foresight: Tackling Obesities Future Choices report [12]. The key quantitative outputs are summarised in Table 1 below:

Table 1 Output data

Output data from the projection programme

1. Projection of the prevalence of obesity from 2015 to 2035, stratified by sex and 10-year age groups
2. Projection of the prevalence of obesity from 2015 to 2035, stratified by sex and income quintiles

Output data from the microsimulation programme

3. Projection of the prevalence and incidence of obesity related diseases from 2015 to 2035
4. Impact of a range of intervention scenarios on the incidence and prevalence of obesity related diseases
5. Impact of a range of intervention scenarios on the quality of life years (QALY)
6. Impact of a range of intervention scenarios on the costs incurred by the NHS and wider society

Methodology

Data collection

Table 2 provides a summary of the key parameters that were required for input into the UKHF model and for which data were collected. The information sources from which data were extracted for inclusion in the model have been summarised in Appendix 1A and 1B.

Table 2 Input data

Risk factor data

1. Historical and current prevalence of BMI groups (healthy weight, overweight and obese) by age, sex and income quintile

Disease data

2. Most recent incidence, mortality and survival of the diseases of interest, by age and sex
3. Relative risk of acquiring the diseases of interest, by age and sex, where available

Demographic data

4. Most recent UK population, by age and sex
5. Most recent mortality and fertility rates of the UK population

Health economic data

6. Mean utility weights of the diseases of interest without medical intervention
7. Most recent direct NHS cost associated with the diseases of interest
8. Most recent indirect cost associated with the diseases of interest - indirect costs are comprised of productivity loss attributable to premature morbidity and mortality)

Risk factor data

BMI prevalence

Body mass index (BMI, in [kg/m²]) data were extracted from the Health Survey for England (HSE) using the UK Data Service database [13], and included years 2000 to 2012. BMI was categorised according to the World Health Organization (WHO) BMI cut-offs of healthy-weight (<25 kg/m^2), overweight (25-29.9 kg/m^2) and obesity (≥30 kg/m^2) [14, 15].

By socioeconomic status

Socioeconomic data were presented by income quintiles. Equivalised income quintile data were extracted from HSE for years 2000 to 2012.

Disease data

Overview

CRUK commissioned the UKHF to investigate certain diseases, the full list of which is outlined in Table 3 below. The following disease data inputs were required to run the model: incidence, mortality and survival rates, stratified by age and sex; and the BMI-related relative risks. It has been suggested that a probable association exists between greater body fatness and ovarian cancer as well as prostate cancer; however, owing to incomplete data, these two cancers were excluded from this modelling project.

Following discussion with the CRUK Statistical Information team, cancers were classified as having an association with excess weight, based upon published literature that supports this relationship [16].

The UKHF have defined BMI-related cancers as cancers that can be caused by excess weight but may also be caused by other factors such as smoking, alcohol and genetics. Individuals who are overweight or obese are at a *higher risk* i.e. they have more chance of getting a BMI-related cancer than an individual who is healthy weight.

Certain definition issues arose when identifying cancer disease data. Firstly, evidence exists demonstrating an association between obesity and postmenopausal breast cancer; however, the opposite may be true for premenopausal cancer where excess bodyweight may have a protective effect [16]. In light of this, only post-menopausal breast cancer was modelled as part of this study. Furthermore, disease data (i.e. CRUK incidence and mortality data, and ONS survival data) for endometrial cancer was not available. We were advised by CRUK that endometrial cancer accounts for the majority of uterine cancers and therefore, disease data for uterine cancer was to be used to model endometrial cancer in the programme. Finally, it has been suggested that a probable association exists between greater body fatness and gallbladder cancer [16]. Based upon this evidence and following guidance received from CRUK, gallbladder cancer was modelled as a BMI-related cancer.

Table 3 Diseases of interest

Cancers linked to obesity
1. Endometrial cancer
2. Gallbladder cancer
3. Hepatic (liver) cancer
4. Mammary (breast) cancer (postmenopausal)
5. Oesophageal cancer
6. Pancreatic cancer
7. Colorectal (bowel) cancer
8. Renal (kidney) and ureteral cancer
Other diseases linked to obesity
9. Type 2 Diabetes Mellitus (T2DM)
10. Coronary Heart Disease (CHD)
11. Stroke

Incidence and mortality

Incidence and mortality data for cancers of interest were collected from the CRUK statistical information repository. Data for the other NCDs – namely CHD, stroke and T2DM – were identified from the published literature through searches of Science Direct and PubMed databases, and supplemented with searches of Google Scholar and relevant organisational websites. The most recent incidence and mortality data were included if they were presented as a proportion of the population, and stratified by age and sex.

As morbidity and mortality data for CHD were incomplete or unavailable, myocardial infarction (MI) data were used as a proxy for CHD. This was deemed appropriate considering MI is one of the major sub-classification within the category of CHD. It was acknowledged that these figures would underestimate CHD cases in the population.

Survival

Where available, one-year and five-year cancer survival rates for England were obtained from the Office for National Statistics (ONS) [17]. These data were presented as a proportion of the disease prevalence, by age and sex, and were classified by anatomical site using codes in the International Classification of Diseases, 10th Revision (ICD-10).

ONS survival data was not available for gallbladder cancer so this was calculated in the microsimulation programme using the latest incidence and mortality data, based on DISMOD-II equations [18]. In keeping with the definition used in this study, only survival data for post-menopausal breast cancer was included. Survival rates for CHD and stroke were calculated in the microsimulation programme using the latest incidence and mortality data since one-year survival data for these diseases was not available.

Evidence exists demonstrating that only certain morphological subtypes of particular cancers are associated with exposure to obesity. The World Cancer Research Fund (WCRF) / American Institute for Cancer Research (AICR) published evidence demonstrating that obesity is associated with an increased risk of oesophageal adenocarcinoma [16]. However, survival data were only available for all oesophageal cancers.

Relative risks

BMI-related relative risks (RR) for cancers were collected from various data sources that were identified in the CRUK statistical information repository. Where RR data for certain diseases were not available through CRUK, a literature search was undertaken to collect RR data. A set of criteria, outlined in Table 4, was used to review studies for inclusion where several RR datasets where available for a particular disease. As a general observation, most of the RR data that were not available in the CRUK statistical information repository were instead obtained from the Dynamic Model for Health Impact Assessment (DYNAMO-HIA) [19] and World Obesity Federation (formerly International Obesity Task Force (IOTF)) [20]; these repositories provided granular sets of RR data as required for input into the microsimulation programme. All input data are presented in appendix 1B.

Table 4 Inclusion criteria for source of RR data

Criteria	Preference
1. Type of RR data	RR of acquiring disease preferred over RR of death due to death
2. Size of study	Larger studies preferred over smaller ones
3. Study design	Average RR data derived from meta-analysis preferred over types of study design
4. Year of study	More recent data preferred over older ones
5. Granularity of data	RR data stratified by BMI status, age and sex preferred over single RR data

Time lags

A literature review was undertaken to identify data on the latent period, or time lag, between 'exposure' to the behavioural risk factor and the appropriate increase in risk of cancers. Time lag data were only available for several cancers [21, 22]. The relative risk data used in the model have time lag components inherent in them since they are an average of risk across time. Given the lack of availability of time lag data, and the nature of the relative risk data used in the model, it was not deemed appropriate to and 'force fit' time lag data into the model.

Demographic data

National population distribution data, stratified by age and sex, were used in conjunction with national mortality distribution data. Principal projections data were obtained from the ONS as were mortality distribution data [23], and were pre-processed to render them into a form acceptable to the model. Migration of individuals into and out of the country was also modelled. Mortality distributions were used to compute the probability of death for the diseases of interest as well as other unspecified causes of death. Total fertility rates (TFR), stratified by the mothers' age, was used to project increases in the population over time. Further technical details of the method used are presented in Appendix 2.

Health economic data

Utility weights

Several techniques exist for estimating utility weights. For this project, utility weights were represented by EQ-5D scores [24], based on recommendations in the NICE guidelines [25]. To enable comparisons between diseases and to maintain consistency, utility weight figures derived using other elicitation techniques were excluded from the project.

Utility weights for CHD and stroke were derived from an analysis previously undertaken by UKHF [26]. Utility weights for cancers were obtained from a catalogue of UK-specific EQ-5D scores that were based on the ICD-9 disease classification [27]. Utility weights for endometrial, gallbladder, post-menopausal breast cancer and pancreatic cancer were not available in this data source and therefore, EQ-5D scores for conditions that we considered to be the next best alternative were used instead. For endometrial cancer – 'uterine cancer', part unspecified was used; for gallbladder cancer – 'liver and intrahepatic bile duct cancer' was used; and for post-menopausal breast cancer – 'malignant neoplasm of female breast' was used. No other utility weights were identified to be suitable alternatives to those aforementioned cancers. For pancreatic cancer, utility weight was obtained from a study conducted by Romanus and colleagues [28]. The calculation of quality-adjusted life-years (QALYs) is outlined in the statistical analysis section of the report.

US-based community scores were used to derive health-related utility weights for the UK population since UK scores were not available. Furthermore, utility weights for the specific cancers described above were not available in this data source and from a literature search that was conducted. To address these gaps in the data, utility weights were identified from the same data source for conditions that were considered to be suitable proxy measures.

Direct NHS costs

Direct NHS costs were based on healthcare expenditure data obtained from the NHS England programme budgeting cost database [29]. Diseases were categorised into groups; thus, they had to be disaggregated in order to acquire costs for the specific diseases. The total NHS healthcare expenditure figures for each disease were divided by the incidence or prevalence data, as applicable, of the disease to obtain an estimate of the average healthcare cost incurred per individual. Expenditure figures included both healthcare and social care costs incurred by the NHS [29]. For healthcare costs, this was comprised of prevention and health promotion costs; primary care costs (primary care and prescriptions); secondary care (inpatient: elective and day-case, inpatient: non-elective, outpatient and other secondary care); urgent care/emergency care costs (ambulance and Accident and Emergency); community care costs; and cost of care provided in other settings. Social care costs were comprised of non-health and social care costs.

In the NHS budget cost database, only the total healthcare expenditure of diabetes, as opposed to T2DM, was available. Based on prior advice sought from the International Diabetes Federation (IDF), it was assumed that 90% of diabetes prevalence and associated costs were attributable to T2DM. Thus, the total healthcare expenditure of T2DM was estimated by multiplying the total healthcare expenditure of diabetes by 90%. Where only total costs for a group of cancers were available, costs for a specific cancer within that group were estimated in the following manner: the incidence of oesophageal cancers, for example, was divided by the total incidence of gastro-intestinal cancers. This ratio was multiplied by the total healthcare expenditure of gastro-intestinal cancers to obtain the total healthcare expenditure of oesophageal cancer. It was assumed that the average costs per patient for each disease within a group had equal weighting.

Direct NHS costs for endometrial cancer and post-menopausal breast cancer were not available, and therefore costs for uterine cancer and breast cancer were used instead, respectively.

Please note that discounting the costs were outside the scope of this project, so any cost figures may represent slight overestimates of the true cost.

Indirect societal costs

A human capital approach (HCA) was taken to estimate the indirect societal costs associated with the BMI-related diseases [30, 31]. The cancer literature to date has been dominated by the use of the HCA [32-35]. This approach encompasses a societal perspective and estimates an individual's contribution to society by applying labour force earnings as a measure of productivity. It assumes full employment in competitive labour markets with minimum transaction costs. Firms are regarded as profit maximisers, employing workers until the marginal revenue product of labour equals the wage rate. Under these conditions, if a person leaves the labour market (e.g. due to illness), he or she will not be replaced and so an opportunity cost exists until the age of retirement.

Productivity loss attributable to premature mortality (termed premature mortality costs in this report) refers to the loss of potential earnings incurred when an adult dies prematurely. Lost earnings were based on data obtained from the ONS [36]. Patients younger than 65 years of age were assumed to be economically active. The loss of earnings attributable to premature mortality due to the disease for those younger than 65 was calculated across their potential working life. These lost potential lifetime earnings were based on the multiplication of the mean net earnings of UK workers.

Productivity loss attributable to premature morbidity (termed premature morbidity costs in this report) refers to the loss of potential earnings incurred when an individual contracts a disease, which impacts their productivity. The productivity of an individual represents the amount of working time the individual actually spends working. These data were based on data obtained from the Annual Survey of Hours and Earnings (ASHE) [37] and the Labour Force Survey (LFS), which is available from the UK Data Service [14]. The general principle in acquiring premature morbidity costs involves multiplying the average annual number of days off work (termed absenteeism) attributable to morbidity by the mean daily earnings. The number of days off work for a given disease was obtained using modelled outputs from a previous health economic modelling project overseen by the Centre for Health Economics at the University of York and the School of Health and Related Research (ScHARR) at Sheffield University [38].

Please note that discounting the costs were outside the scope of this project.

The UKHF model

A dual-module modelling process written in C++ software, developed by the UK Foresight working group [12], was further refined and then utilised for this study. The future projections of BMI have been used to predict the burden of diseases from 2015 until 2035. Furthermore, the model can be updated to include new data as and when it becomes available.

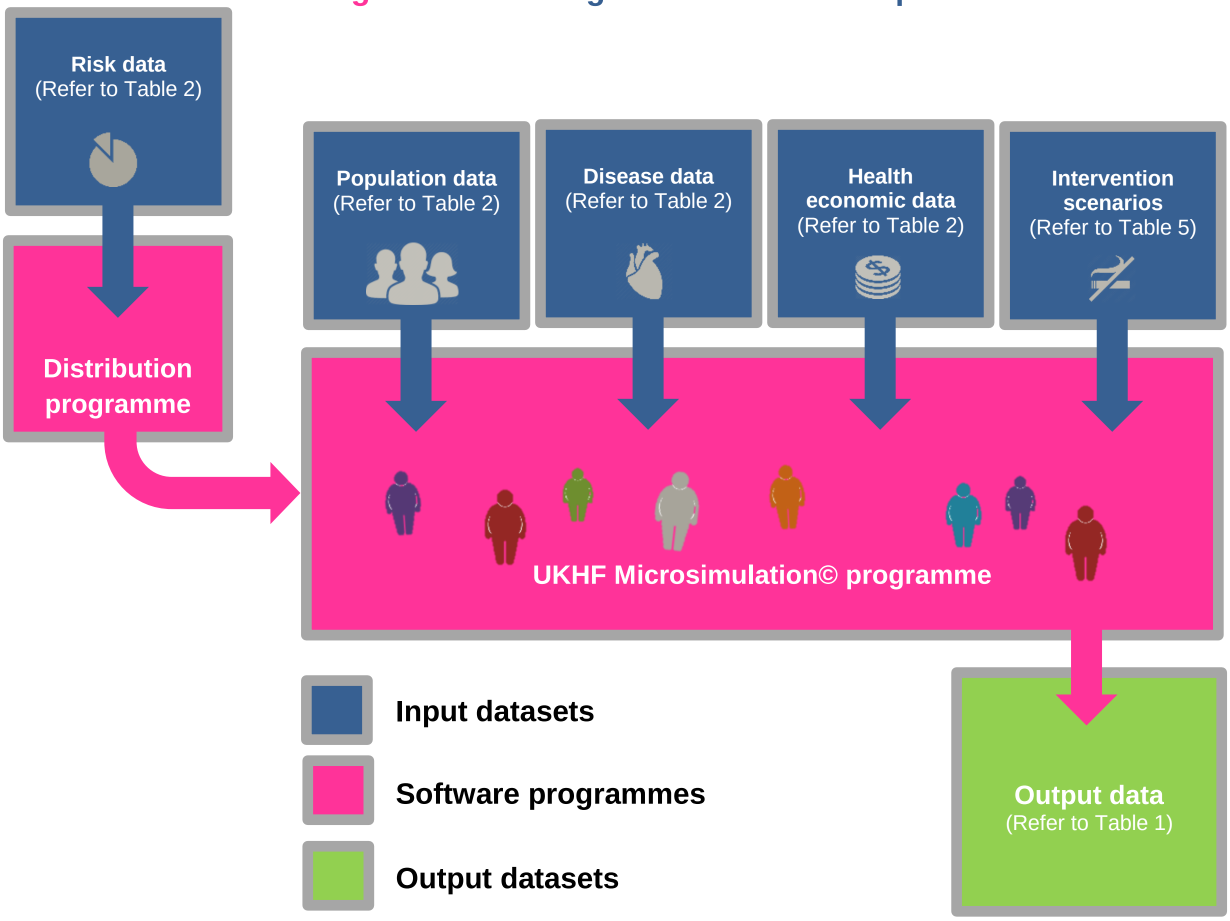
Module one uses a nonlinear multivariate, categorical regression model fitted to cross-sectional risk factor data to create longitudinal projections to 2035. The categories are defined by ten-year age groups and sex. Within each age and sex category of the population, the predicted proportions of each of the risk factor categories are constrained to sum to 100%.

Module two uses a microsimulation as a tool for predicting disease burden using longitudinal projections from module 1. A microsimulation is a computer model of any specified population which accurately reflects age profiles, births, deaths and health statistics to make future projections. The simulations specifically target the relationship between individuals' evolving risk factors and disease incidence. BMI distributions are determined by past and current trends and the model can simulate and compare the impact and cost of various public health interventions. Events compete to occur in each simulated life and a random component embedded in the models ensures that not all individuals at risk of an event may experience it. Individual life trajectories are simulated until death. Within the UKHF model, costs can be assigned to interventions associated with the life events that have been simulated to project a future trend in health spending.

The microsimulation also incorporates an economic module. The module employs Markov-type simulations of long-term health benefits, health care costs and cost-effectiveness of specified interventions. The model is used to project the differences in QALY and total costs over a specified time scale. This QALY approach was used since it allowed the different scenarios to be compared by taking into consideration the quality of life. According to NICE (42), QALYs are determined by *"estimating the years of life remaining for a patient following a particular treatment or intervention and weighting each year with a quality of life score (on a zero to one scale)."* QALYs were aggregated in the microsimulation over the number of simulated years in the microsimulation.

Figure 1 outlines a basic process map of the modelling and simulation component of the project. A wide set of input data, outlined in Table 2, were collected and utilised in order to obtain the output data, outlined in Table 1.

Figure 1 Modelling and simulation map



Building intervention scenarios

The microsimulation programme enables different intervention scenarios to be tested so that policy makers can assess the impact of public health interventions on the epidemiology and health economy of diseases relative to a baseline or ‘no change’ scenario. The agreed set of smoking scenarios to be modelled are summarised in Table 5 below

Table 5 Scenarios and interventions

Scenarios/interventions	Details
Scenario 0 (Baseline scenario)	No adjustment overweight and obesity prevalence projections; maintain projections as predicted using HSE cohort data
Scenario 1	Reduction of baseline overweight and obesity prevalence projections by 1% each year
Scenario 2	Reduction of baseline overweight and obesity prevalence projections by 10% each year
Scenario 3	Reduction of baseline overweight and obesity prevalence projections by 20% each year
Scenario 4	Reduction of baseline overweight and obesity prevalence projections by 50% each year
Scenario 5	Reduction of baseline overweight and obesity prevalence projections by 100% each year
‘SSB excise tax’	20% excise tax applied to SSBs resulting in certain reduction of baseline overweight and obesity prevalence projections

Baseline scenario (scenario 0)

A baseline scenario, based on the future projection of the current and historical trends of BMI prevalence using HSE data from 2000-2012, was modelled.

Hypothetical scenarios (scenario 1-5)

Five hypothetical scenarios, representing different versions of the future, were modelled to estimate the burden of BMI-related NCDs from 2015 to 2035. The following reductions in current BMI prevalence from the baseline trend were agreed with CRUK: 100%, 50%, 20%, 10% and 1%. These BMI scenarios (i.e. 1%, 10%, 20%, 50% and 100%) were modelled by sampling the specified percentage of overweight and obese individuals combined and shifting them to the healthy weight category. This process was repeated at each year of the simulation. For example, a ‘1% BMI reduction’ scenario implies that 1% of the overweight individuals in the population and 1% of the obese individuals in the population are shifted into the healthy weight category, on a year-by-year basis.

This probability was based on the percentage chosen. It was assumed that this scenario only applied to adults in the population (age ≥ 18 years old). The intervention was applied equally to both males and females. If an individual was moved to group B, their new BMI was set within the BMI boundaries of group B. This percentage reduction was applied at each year of the simulation (i.e. 20 times over the course of the simulation period (2015-2035)).

To note, the ‘100% BMI reduction’ scenario (scenario 5) was used in the policy report to approximate the number of disease cases attributable to overweight and obesity.

SSB excise tax policy scenario

The final BMI scenario was a sugar sweet and beverage tax (SSB) of 20% which translated to a BMI reduction of 0.05 (see Appendix 1D). In the simulation this intervention is modelled by reducing an individual’s BMI by 50% of the total BMI reduction (0.05 points) in the start year of the scenario and then applying a 45% reduction of the total BMI reduction in the following year. The final 5% of the total BMI reduction is then applied between 3rd and 10th year of the scenario (Hall et al. 2011). This is outlined in further detail below.

Modelling the SSB excise tax policy scenario

The impact that a 20% excise tax applied to SSBs has on the prevalence of overweight and obesity was modelled. This level of taxation is in keeping with current recommendations proposed by the Academy of Medical Royal Colleges [39]. We implemented a SSB tax in year 1 and modelled an exponential reduction in BMI, as a result of reduced SSB consumption, over a 10-year period. Figure 2 outlines the pathway by which an excise tax applied to SSBs impacts on BMI, and the key assumptions made at the various stages along this pathway are described below. The input data that were used to determine the BMI reduction to be modelled are summarised in Table 6. This SSB intervention modelling approach was adapted from Briggs et al [40]. Further details of the data inputs for this scenario are presented in Appendix 3.

The price of SSBs in the UK

The Living Costs and Food Survey (LCFS) was used to derive the current price of SSBs in the UK. The LCFS is a national UK survey that collects data from a daily food expenditure diary over a two-week period. Two survey categories from LCFS – 'soft drinks, concentrated, not low calorie' and 'soft drinks, not concentrated, not low calorie' were used to define SSBs in this project. This definition excluded diet or low calorie drinks as they do not contain the high sugar levels associated with regular varieties. Expenditure (in £/week/person) and purchase (in ml/week/person) data for both categories of SSBs were extracted from the 2012 LCFS and used to determine the average expenditure and average purchase of SSBs. The average price of sugar sweetened drinks in the UK in 2012 (£0.12/100mL) was derived by dividing average expenditure by average purchase volume.

Pass-on rate

The degree to which the price of a product changes in response to an imposed tax depends on the pass-through rate of the price change from the manufacturer to the consumer [41]. Based on a variation in empirical evidence, it was considered reasonable in the UK to assume a pass-on rate of 100% [42], which indicates that the full price of the tax applied to SSBs would be passed through from the manufacturer to the consumer.

Baseline consumption of SSBs

Data on the consumption of SSBs was derived from the most recent National Diet and Nutrition Survey (NDNS) dataset, 2008-2011. The NDNS is a national survey of diet, nutrient intake and nutritional status of the UK population [43]. Consumption of SSBs (in grams/ person-day), was defined in the survey as 'soft drinks, not low calorie, concentrated', 'soft drinks, not low calorie, carbonated‘ and ‘soft drinks not low calorie, ready to drink, still’ (the latter two categories referred to as ‘soft drinks, not concentrated, not low calorie’ for this project to align with LCFS definitions). Consumption of SSBs (grams/person-day) was converted into millilitres (mL) per day using the standard conversion rule that 1g is equivalent to 1ml.

Change in consumption of SSBs in the UK

In order to predict the effect a change in price would have on individual consumption, recently published price elasticity (PE) of demand for the whole UK population were utilised [40]. These elasticities took account of cross price elasticities by applying a Bayesian approach to achieve an almost ideal demand system. This approach ensures that the substitution patterns estimated are consistent across the different beverage groups in the model.

To delineate the percentage change in consumption, the PEs (specifically OPEs for concentrated and not-concentrated SSBs) were multiplied by the change in SSB price (the percentage increase as a result of the tax). For example, for a 20% excise tax, the OPEs for concentrated and not-concentrated were added together and multiplied by 20. This calculation assumed that the purchase of SSBs would change to the same degree as consumption.

Change in energy intake as a result of fiscal policy applied to SSBs

In order to deduce the effect an excise tax would have in reducing daily energy intake from SSBs, the millilitre consumption of SSBs (ml) was converted to kilojoules (kJ) using recently published energy densities for these beverages [40]. The change in total energy intake was subsequently derived using the baseline daily energy intake (kJ/person-day), deduced from NDNS dataset (2008-2011). Based on the assumption by Wang et al [44], this study assumed that for every 100kJ saved from not consuming SSBs, there would be a 60% net kJ reduction (with 40kJ being substituted by other food and beverage intake).

Change in body weight as a result of fiscal policy applied to SSBs

Change in body weight as a result of reduced total daily energy intake was calculated using the assumption that *“every change of 100kJ per day will lead to an eventual weight loss of 1kg”* [45]. The majority of the predicted weight loss (95%) would be achieved in approximately 3 years, with 50% and 45% of the total weight change being achieved within the first and second years, respectively, and the final 5% being achieved between the third and tenth years [45].

Change in body mass index as a result of fiscal policy applied to SSBs

In order to estimate the change in individual BMI, the average height of a UK adult (1.72 metres) was calculated using HSE 2012 data [46], which was extracted using the UK Data Service database [13]. The change in BMI was calculated using the WHO reference calculation (BMI= kg/m^2) [14, 15].

Figure 2. **Flow diagram of the impact fiscal policy measures applied to SSBs have on health outcomes (Adapted from Briggs et al, 2012)**

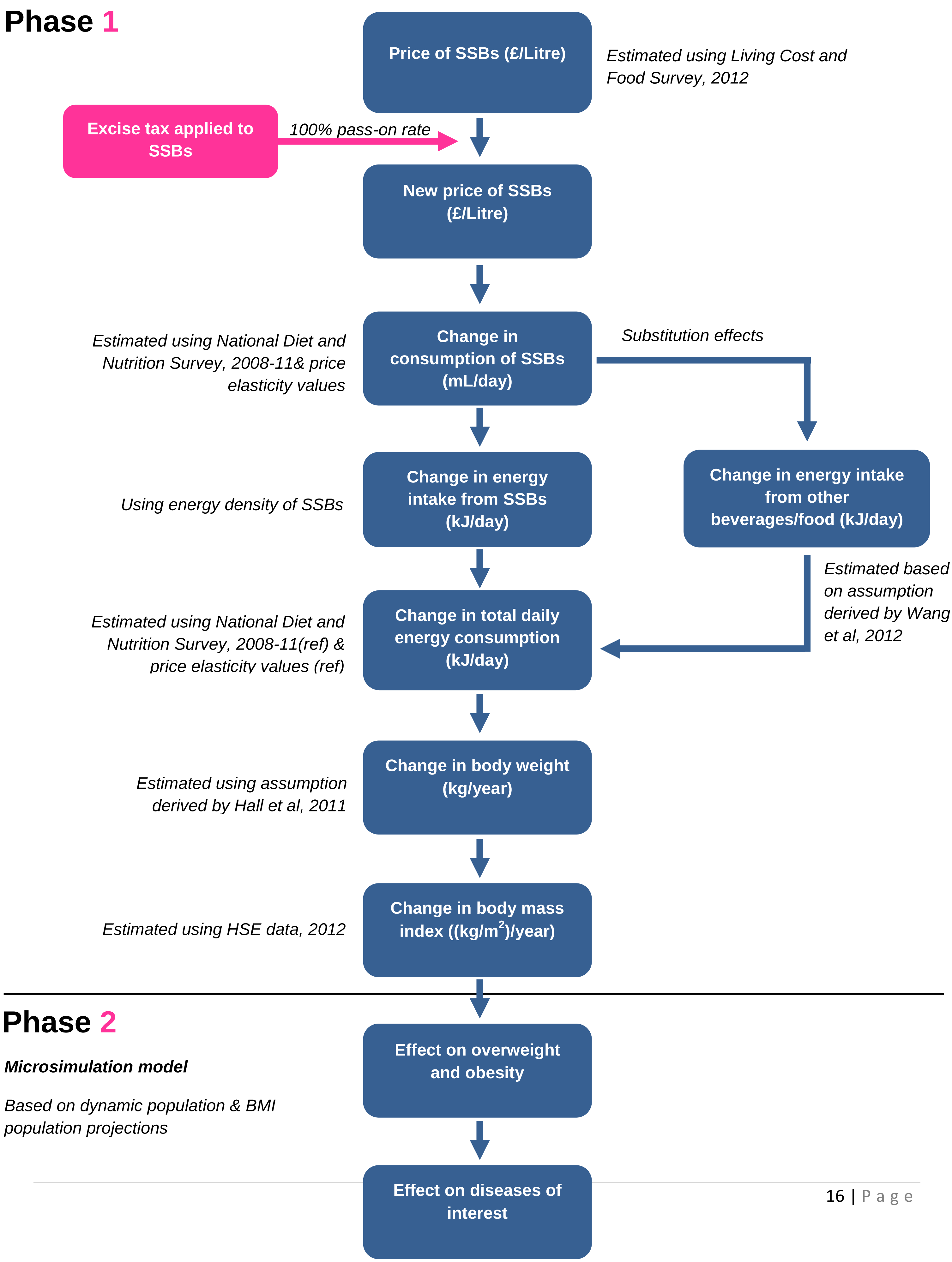


Table 6. Estimated effect a 20% excise tax applied to SSBs would have on BMI

Age	Baseline consumption of SSBs (g/day)		Post-tax consumption of SSBs (g/day)		Reduction in total energy intake accounting for substitutions (kJ/day)	Reduction in body weight (kg/year)	Reduction in BMI (kg/m^2)
	Concentrated	Not concentrated	Concentrated	Not concentrated			
20-39	65.56	107.44	55.83	90.29	24.19	0.24	0.08
40-59	34.49	56.51	29.37	47.49	12.72	0.13	0.04
60+	21.60	35.40	18.40	29.75	7.97	0.08	0.03
Average	40.55	66.45	34.53	55.85	14.96	0.15	0.05

Results

To note, the BMI prevalence figures in the Results section present outputs using extrapolated trends from cross-sectional HSE data. These sets of results differs slightly from the results from the microsimulation programme (Table 8 of the document) since the latter takes into account dynamic changes in population changes over time. The figures from the microsimulation programme were presented in the Key Statistics section of the report.

Future trends in BMI prevalence

Baseline scenario

BMI projections by age and sex

Table 7 presents the projected prevalence of BMI in the adult population (18-100 years) each year. For both sexes combined, obesity is projected to increase from 29% in 2015 to 41% in 2035. In contrast, both healthy-weight and overweight is projected to decrease: healthy-weight is projected to decrease from 33% in 2015 to 26% in 2035 and overweight from 38% to 34%.

Figure 3 to Figure 16 present the projected prevalence of healthy-weight (BMI <25 kg/m^2, in green), overweight (BMI 25-29.9 kg/m^2, in blue) and obese (BMI ≥30 kg/m^2, in red) males and females aged between 18 to 100 years old. BMI prevalence was projected to 2035 in all figures.

Table 7. Prevalence by BMI group, sex and year for 18-100 year olds

	Male						Female						Both					
Year	BMI< 25	+/- 95% CI	BMI25-29.9	+/- 95% CI	BMI≥ 30	+/- 95% CI	BMI< 25	+/- 95% CI	BMI25-29.9	+/- 95% CI	BMI≥ 30	+/- 95% CI	BMI< 25	+/- 95% CI	BMI25-29.9	+/- 95% CI	BMI≥ 30	+/- 95% CI
2015	0.28	0.03	0.43	0.03	0.29	0.03	0.38	0.03	0.33	0.03	0.30	0.03	0.33	0.03	0.38	0.03	0.29	0.03
2016	0.28	0.03	0.43	0.03	0.29	0.03	0.37	0.03	0.33	0.03	0.30	0.03	0.32	0.03	0.38	0.03	0.30	0.03
2017	0.27	0.03	0.43	0.03	0.30	0.03	0.37	0.03	0.33	0.03	0.31	0.03	0.32	0.03	0.38	0.03	0.30	0.03
2018	0.27	0.03	0.43	0.04	0.31	0.04	0.36	0.03	0.32	0.03	0.31	0.03	0.32	0.03	0.37	0.03	0.31	0.04
2019	0.27	0.03	0.42	0.04	0.31	0.04	0.36	0.03	0.32	0.04	0.32	0.04	0.31	0.03	0.37	0.04	0.31	0.04
2020	0.26	0.04	0.42	0.04	0.32	0.04	0.35	0.04	0.32	0.04	0.32	0.04	0.31	0.04	0.37	0.04	0.32	0.04
2021	0.26	0.04	0.42	0.04	0.32	0.05	0.35	0.04	0.32	0.04	0.33	0.04	0.31	0.04	0.37	0.04	0.33	0.04
2022	0.26	0.04	0.42	0.05	0.33	0.05	0.35	0.04	0.32	0.04	0.33	0.05	0.30	0.04	0.37	0.05	0.33	0.05
2023	0.25	0.04	0.41	0.05	0.34	0.05	0.34	0.04	0.32	0.05	0.34	0.05	0.30	0.04	0.36	0.05	0.34	0.05
2024	0.25	0.04	0.41	0.05	0.34	0.06	0.34	0.05	0.32	0.05	0.34	0.05	0.29	0.05	0.36	0.05	0.34	0.05
2025	0.25	0.05	0.41	0.06	0.35	0.06	0.33	0.05	0.32	0.05	0.35	0.06	0.29	0.05	0.36	0.05	0.35	0.06
2026	0.24	0.05	0.40	0.06	0.35	0.06	0.33	0.05	0.31	0.05	0.36	0.06	0.29	0.05	0.36	0.06	0.35	0.06
2027	0.24	0.05	0.40	0.06	0.36	0.07	0.33	0.05	0.31	0.06	0.36	0.06	0.28	0.05	0.36	0.06	0.36	0.06
2028	0.24	0.05	0.40	0.06	0.37	0.07	0.32	0.06	0.31	0.06	0.37	0.07	0.28	0.05	0.35	0.06	0.37	0.07
2029	0.23	0.05	0.39	0.07	0.37	0.07	0.32	0.06	0.31	0.06	0.37	0.07	0.28	0.06	0.35	0.06	0.37	0.07
2030	0.23	0.06	0.39	0.07	0.38	0.08	0.31	0.06	0.31	0.06	0.38	0.07	0.27	0.06	0.35	0.07	0.38	0.07
2031	0.23	0.06	0.39	0.07	0.38	0.08	0.31	0.06	0.31	0.07	0.38	0.08	0.27	0.06	0.35	0.07	0.38	0.08
2032	0.23	0.06	0.38	0.08	0.39	0.08	0.31	0.06	0.30	0.07	0.39	0.08	0.27	0.06	0.34	0.07	0.39	0.08
2033	0.22	0.06	0.38	0.08	0.40	0.09	0.30	0.07	0.30	0.07	0.40	0.08	0.26	0.06	0.34	0.07	0.40	0.08
2034	0.22	0.06	0.38	0.08	0.40	0.09	0.30	0.07	0.30	0.07	0.40	0.09	0.26	0.07	0.34	0.08	0.40	0.09
2035	0.22	0.07	0.37	0.08	0.41	0.09	0.29	0.07	0.30	0.08	0.41	0.09	0.26	0.07	0.34	0.08	0.41	0.09

NB. The BMI prevalence figures above section present outputs using extrapolated trends from cross-sectional HSE data. These sets of results differs slightly from the results from the microsimulation programme (Table 8 of the document) since the latter takes into account dynamic changes in population changes over time.

Males

Table 7 shows that the prevalence of overweight or obese males is projected to increase from the current level of 72% to 78% by 2035. The prevalence of obese males is projected to increase from the current level of 29% to 41% over a period of 20 years. This is accompanied by decreases in the prevalence of overweight and healthy-weight males over the same period: the prevalence of overweight males is projected to decrease from 43% in 2015 to 37% by 2035, whereas the prevalence of healthy-weight males is projected to decrease from 28% to 22%. Year 2032 is the point at which the percentage prevalence of obese males is projected to surpass the percentage prevalence of overweight males.

Figure 3 to Figure 9 present the breakdown of the aforementioned projection by 10-year age groups. The prevalence of obese males is projected to increase across all age groups with the exception of 30-39 year olds which is projected to remain stable at approximately 20% through to 2035. This is accompanied by a clear decrease in the prevalence of healthy-weight males across all age groups. The prevalence of obese males is projected to rise most markedly in males above 40 years old. The obese group is projected to become the predominant BMI group by 2035 for males above 40 years old, although the likelihood with which this will occur for the 80+ year old age group is less certain owing to its smaller sample population size. The 50-59 and 60-69 year old age groups are projected to comprise the highest proportion of obese males (57% for both groups) by 2035.

Females

Table 7 shows that the prevalence of overweight or obese females is projected to increase from the current level of 63% to 71% by 2035. The prevalence of obese females is projected to increase from the current level of 30% to 41% over a period of 20 years. This is accompanied by decreases in the prevalence of overweight and healthy-weight females over the same period: the prevalence of overweight females is projected to decrease from 33% in 2015 to 30% by 2035, whereas the prevalence of healthy-weight females is projected to decrease from 38% to 29%. Year 2025 is the point at which the percentage prevalence of obese females is projected to become the predominant BMI group.

Figure 10 to Figure 16 present the breakdown of the projections by 10-year age groups. The prevalence of obese females is projected to increase across all age groups. This is accompanied by a clear decrease in the prevalence of healthy-weight females across all groups with the exception of 60-69 year olds which is projected to remain stable at approximately 30% through to 2035. The prevalence of obese females is projected to rise most markedly in 70-79 year olds. In addition, this age group is projected to comprise the highest proportion of obese females (64%) by 2035. The obese group is projected to become the predominant BMI group by 2035 for females across all age groups with the exception of 18-29 year olds and 80+ year olds.

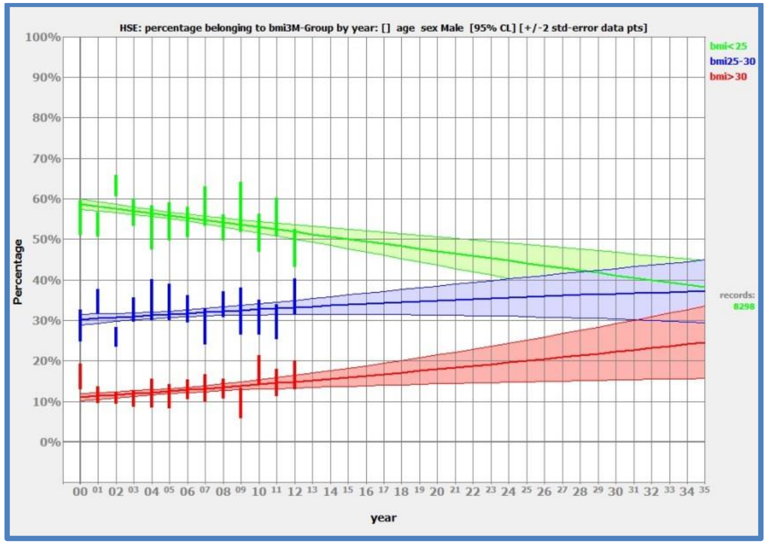


Figure 3. Projected BMI prevalence in 18-29 year old males

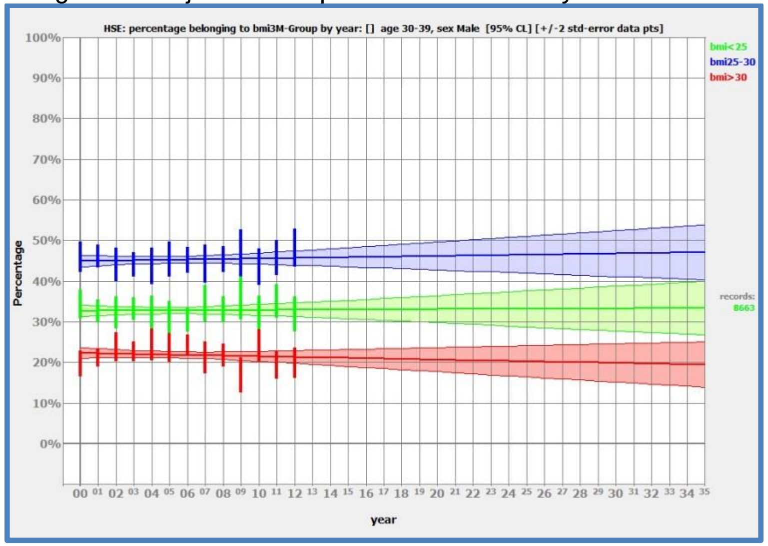


Figure 4. Projected BMI prevalence in 30-39 year old males

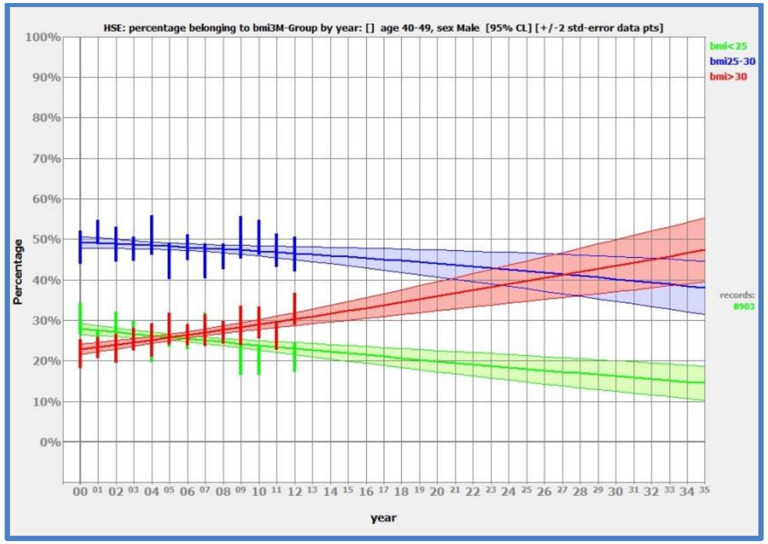


Figure 5. Projected BMI prevalence in 40-49 year old males

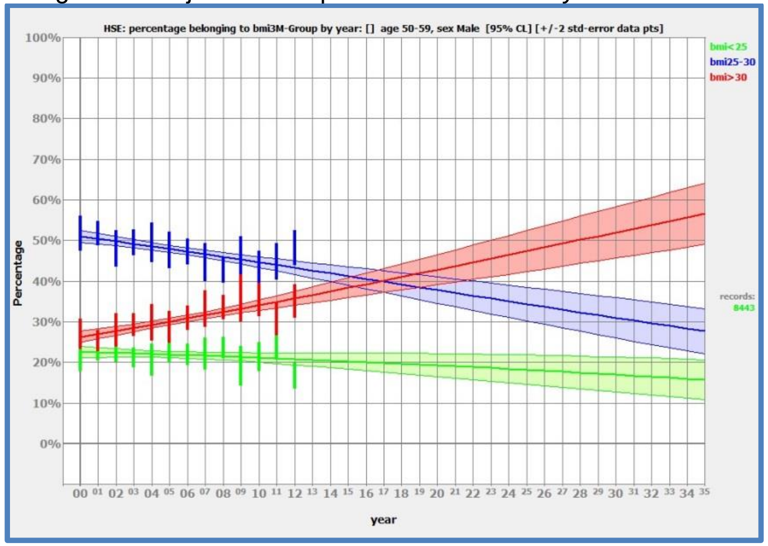


Figure 6. Projected BMI prevalence in 50-59 year old males

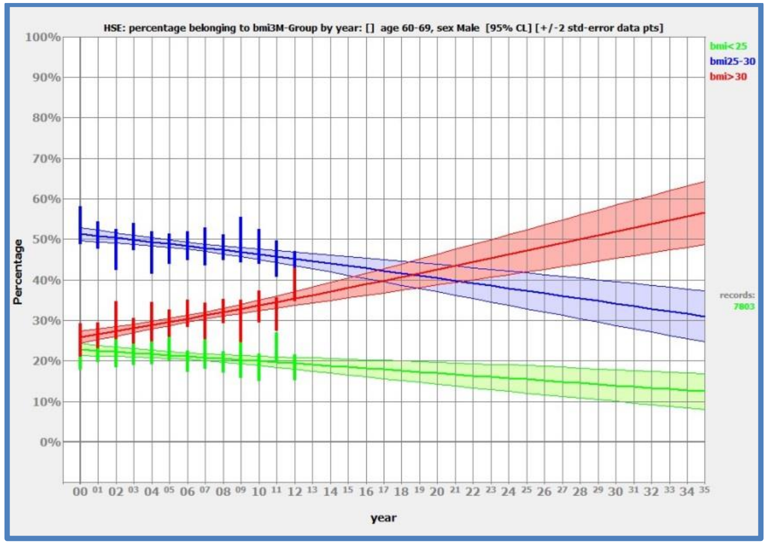


Figure 7. Projected BMI prevalence in 60-69 year old males

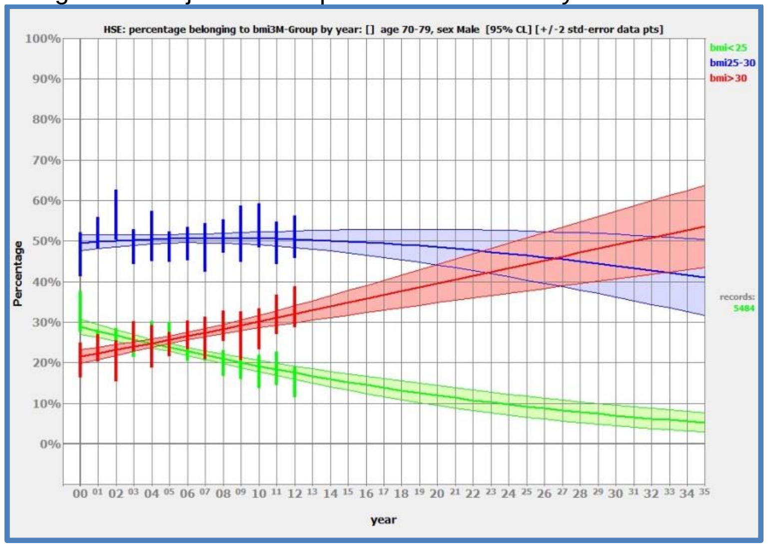


Figure 8. Projected BMI prevalence in 70-79 year old males

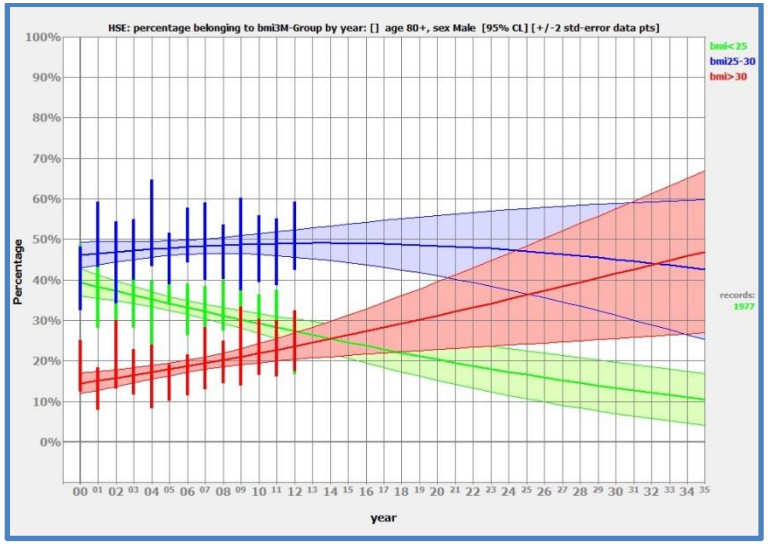


Figure 9. Projected BMI prevalence in 80+ year old males

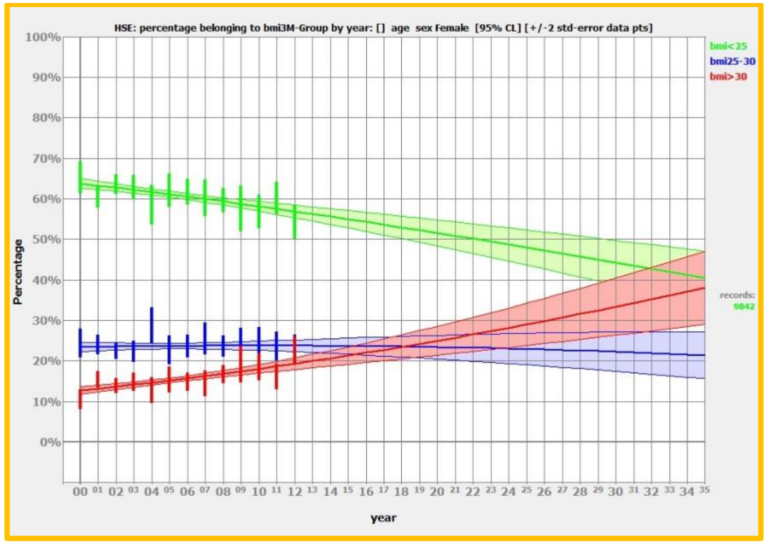


Figure 10. Projected BMI prevalence in 18-29 year old females

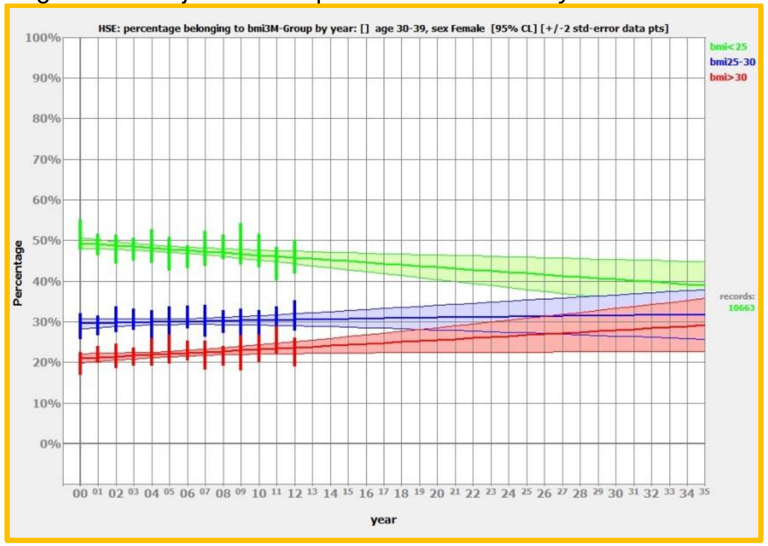


Figure 11. Projected BMI prevalence in 30-39 year old females

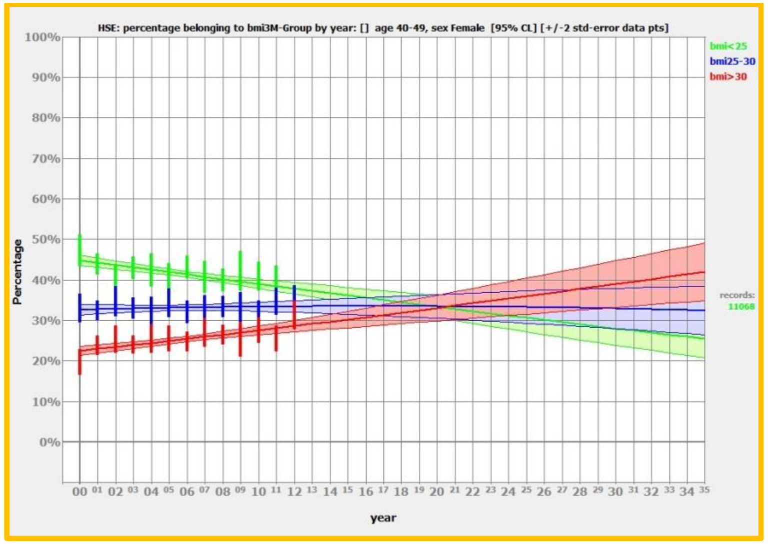


Figure 12. Projected BMI prevalence in 40-49 year old females

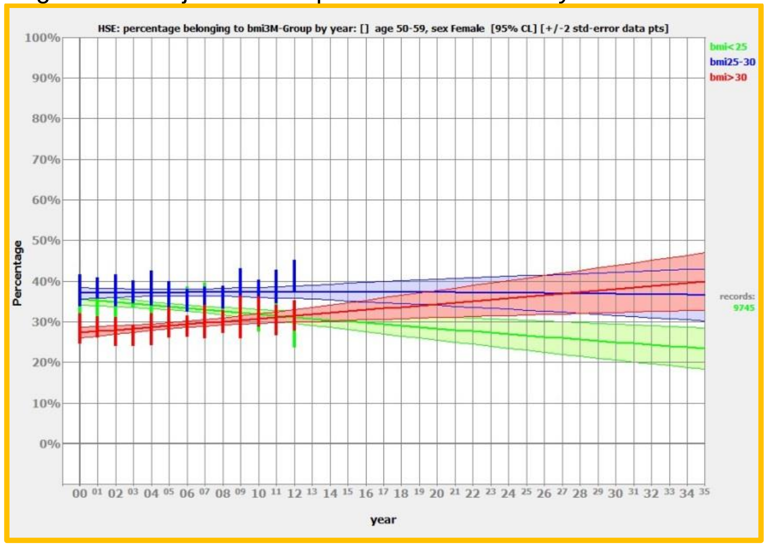


Figure 13. Projected BMI prevalence in 50-59 year old females

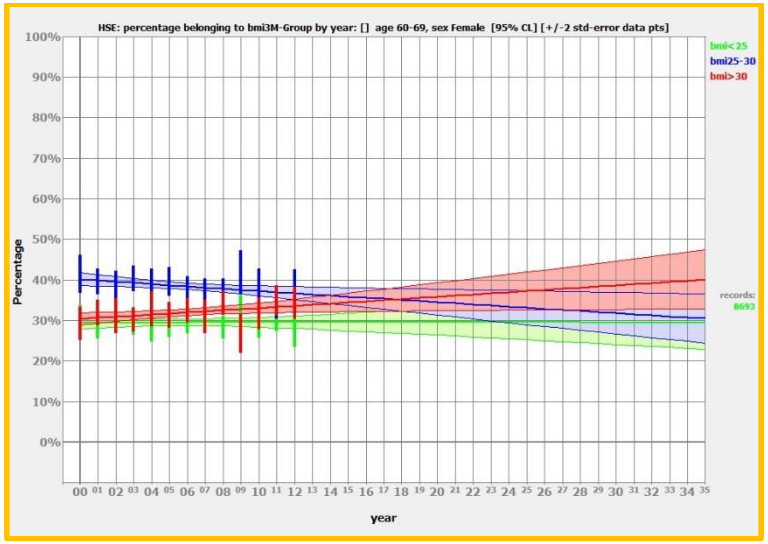


Figure 14. Projected BMI prevalence in 60-69 year old females

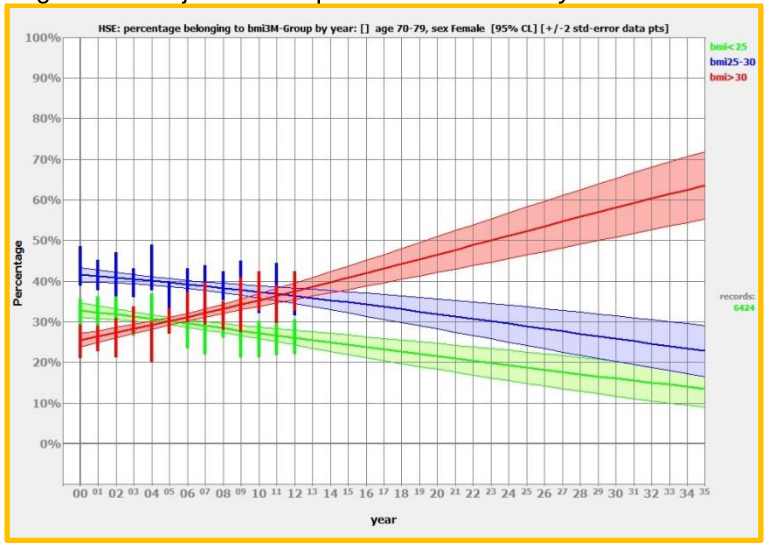


Figure 15. Projected BMI prevalence in 70-79 year old females

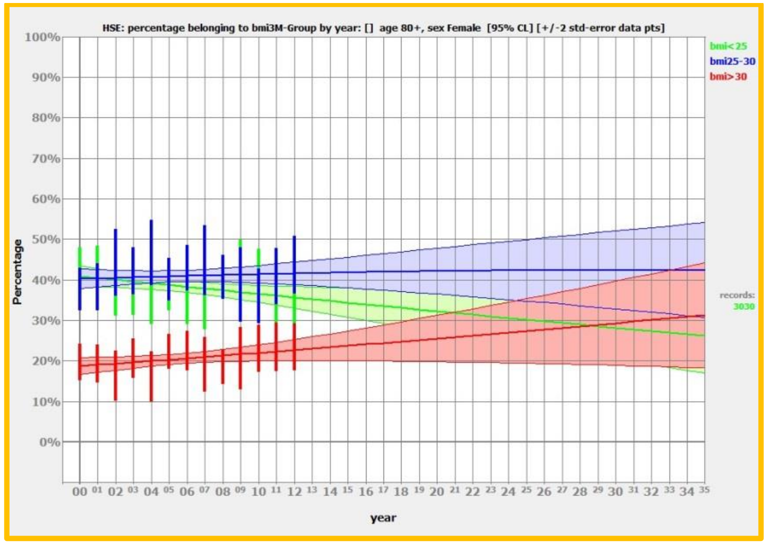


Figure 16. Projected BMI prevalence in 80+ year old females

BMI projections by age and sex and income quintiles

Figure 17 to Figure 26 present the projected prevalence of healthy-weight (BMI <25 kg/m^2, in green), overweight (BMI 25-29.9 kg/m^2, in blue) and obese (BMI ≥30 kg/m^2, in red) males and females aged between 18 to 100 years old. BMI prevalence was projected to 2035 in all figures.

Males

Figure 17 to Figure 21 present the breakdown of the male BMI projection by equivalised income quintile groups (Q1 is the lowest income quintile; Q5 is the highest income quintile). The prevalence of obese males is projected to increase across all income groups. This is accompanied by decreases in the prevalence of overweight and healthy-weight males across all income groups with the exception of Q4 for which the prevalence of overweight males is projected to remain stable. The prevalence of obese males is projected to rise most markedly in males from the lowest income groups. The obese group is projected to become the predominant BMI group by 2035 for the three lowest income groups. The second lowest income group is projected to comprise the highest proportion of obese males (55%) by 2035. Across all income groups, the prevalence of healthy-weight males is projected to range between 12-20% by 2035. In addition, this BMI group is projected to remain the smallest BMI group for all income groups between 2015 and 2035.

Females

Figure 22 to Figure 26 present the breakdown of the female BMI projection by equivalised income quintile groups (Q1 is the lowest income quintile; Q5 is the highest income quintile). The prevalence of obese females is projected to increase across all income groups. The prevalence of obese females is projected to rise most markedly in females in the two lowest income groups. In addition, the obese group is projected to become the predominant BMI group for these two income groups. This is accompanied by decreases in the prevalence of healthy-weight females across all income groups. The prevalence of overweight females is projected to increase in the three highest income groups. The two lowest income groups are projected to comprise the highest proportion of obese females (49%) by 2035. Across all income groups, the prevalence of healthy-weight females is projected to range between 22-29% by 2035. In addition, this BMI group is projected to become the smallest BMI group for all income groups by 2035.

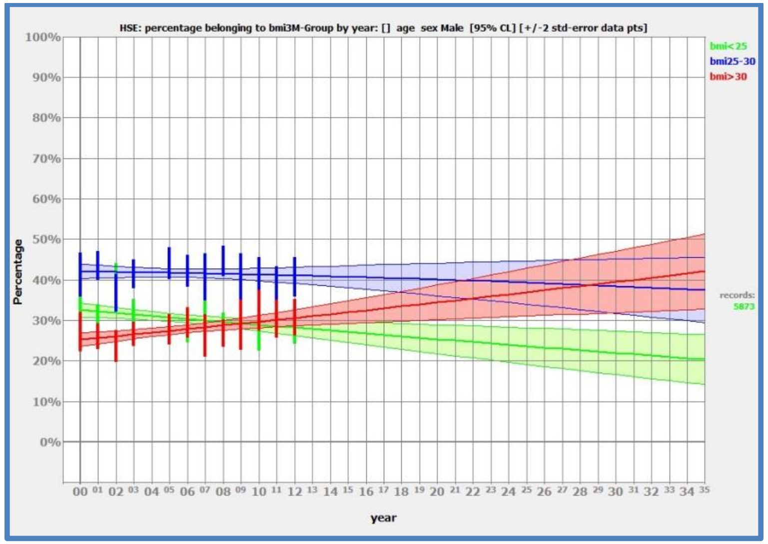


Figure 17. BMI projections for equivalised income Q-1, males

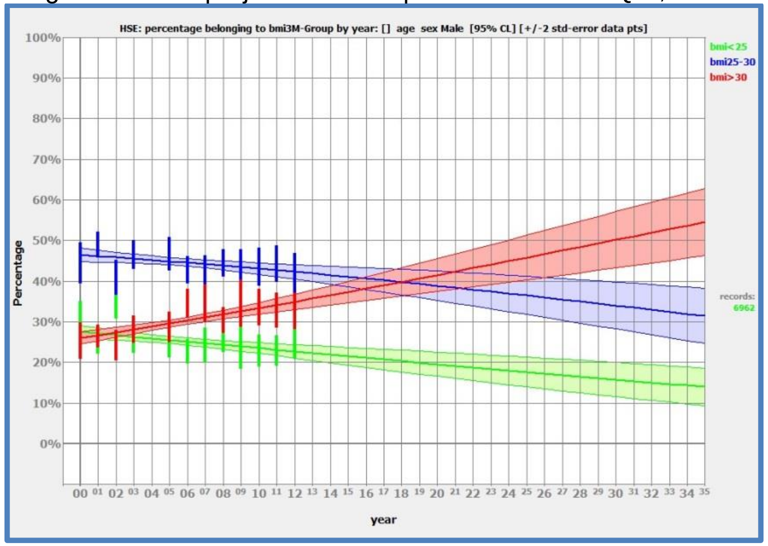


Figure 18. BMI projections for equivalised income Q-2, males

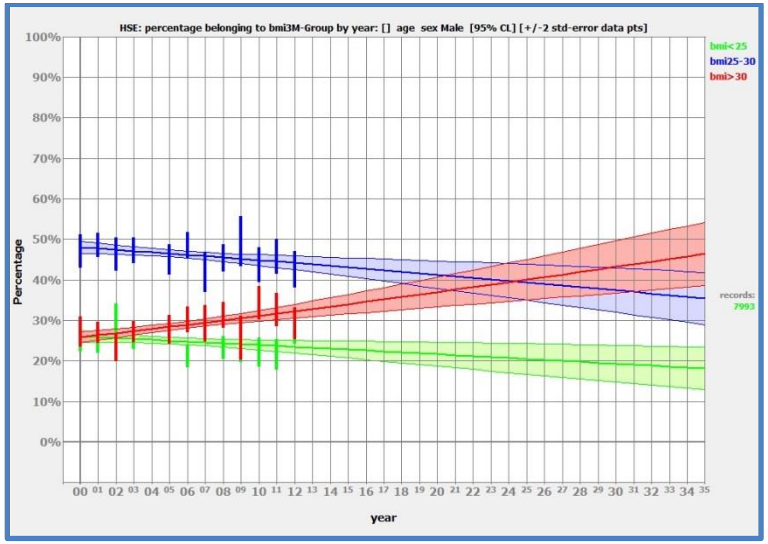


Figure 19. BMI projections for equivalised income Q-3, males

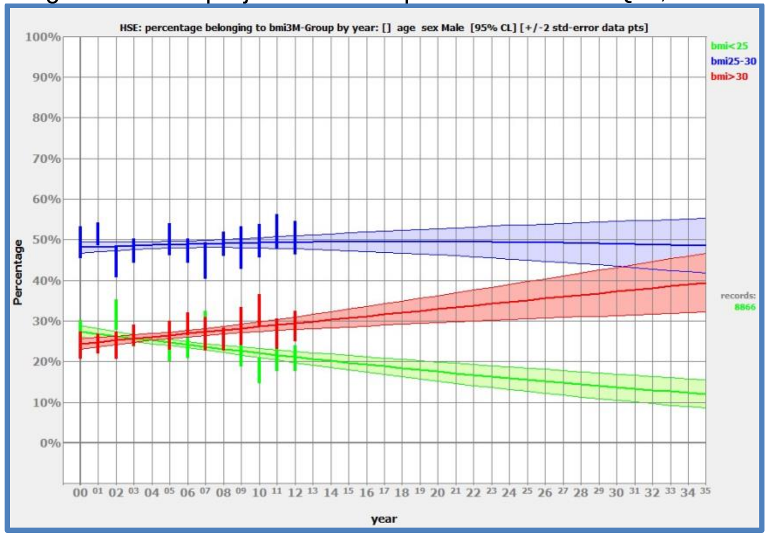


Figure 20. BMI projections for equivalised income Q-4, males

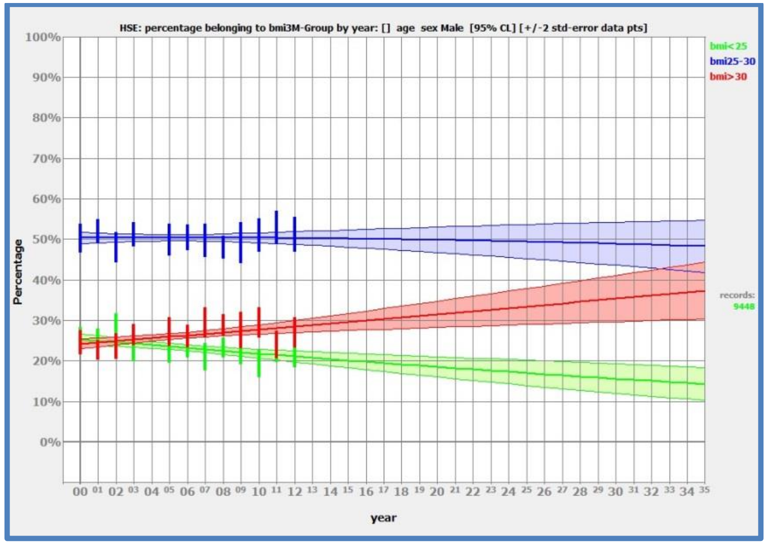


Figure 21. BMI projections for equivalised income Q-5, males

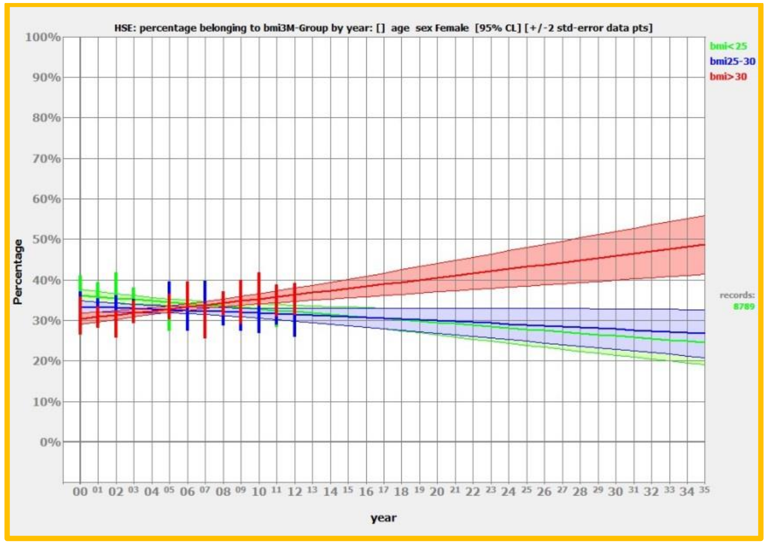


Figure 22. BMI projections for equivalised income Q-1, females

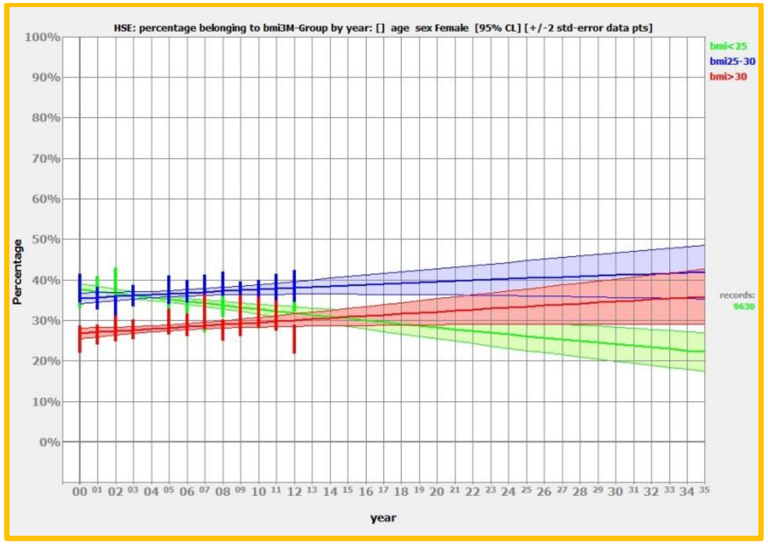


Figure 24. BMI projections for equivalised income Q-3, females

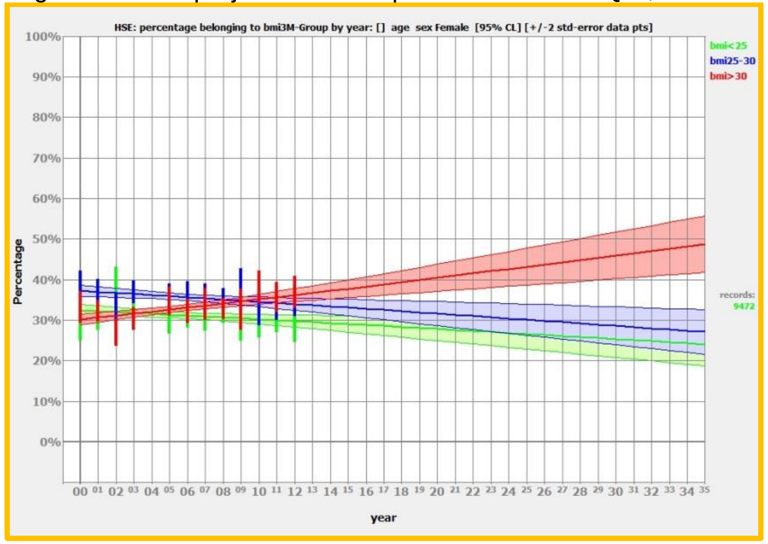


Figure 23. BMI projections for equivalised income Q-2, females

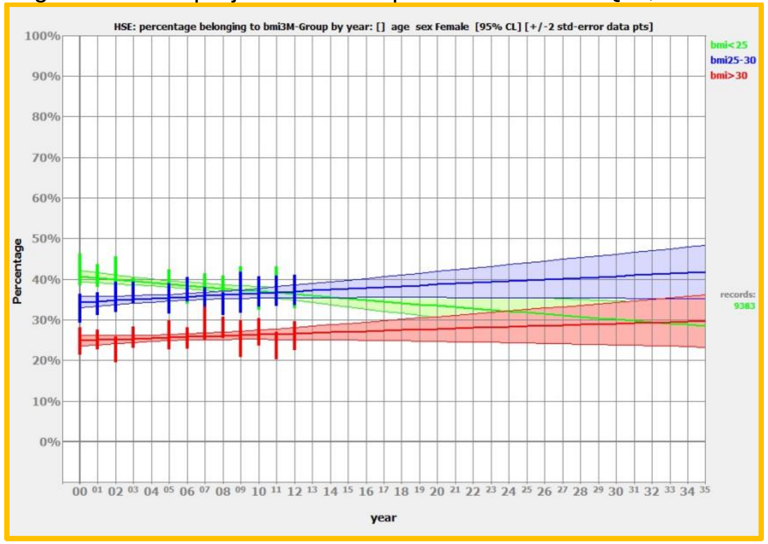


Figure 25. BMI projections for equivalised income Q-4, females

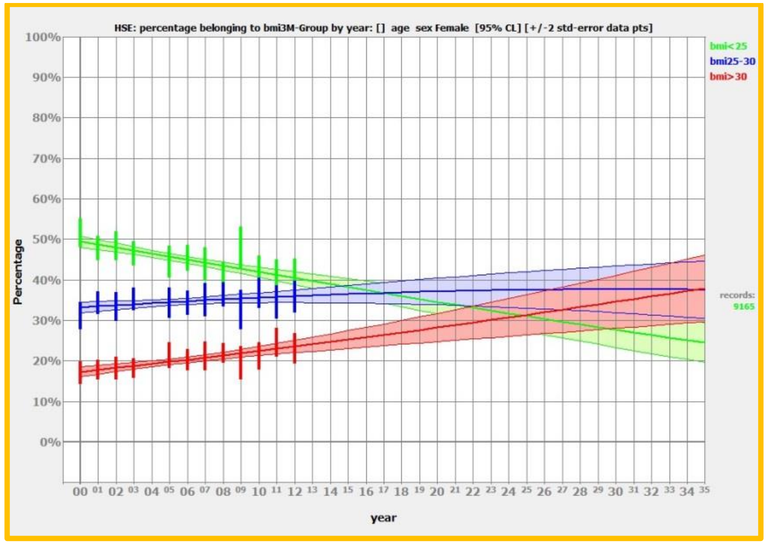


Figure 26. BMI projections for equivalised income Q-5, females

Hypothetical scenarios

Table 8 presents the simulated BMI prevalence by scenario in 2015, 2025 and 2035 for males, females, and males and females combined.

Note that there is a slight variation in the baseline BMI prevalence presented in Table 8 relative to that presented in Table 7 above. This is due to methodological differences between the two outputs. In Table 7, trends were extrapolated forward using past and current cross-sectional BMI data, in this case from Health Survey for England, and adjusted for 2015 population size. People are not simulated in this trend, nor do they die. These BMI projections are input into the simulation to set the distributions of BMI groups throughout the time period of the simulation.

However, the results from the microsimulation programme was used to present BMI prevalence for each of the hypothetical scenarios. Table 8 presents outputs from the microsimulation. Using extrapolated trends in BMI prevalence from the first method, the microsimulation simulates a virtual population (in this case 100million individuals). Both data sets are the same in 2015, although small differences are observed in estimates for the following years. Within the microsimulation, individuals are sampled from the BMI distribution in the start year (2015). This same distribution is modelled through time and may be affected by the BMI projections and individuals dying within the simulation. Individuals at the upper end of the risk factor distribution are more likely to die since they are the ones most at risk in the model. Predictably, this explains why obesity is slightly lower in these estimates[9] than the trends in Table 7. The interplay of BMI, relative risks, diseases and deaths is unique to the microsimulation. It will not replicate the environment that gave rise to the initial extrapolation. However, these differences are still within the CIs.

[9] In addition, a number of assumptions have been made when calculating the total prevalence in this way. Outputs from the simulation are presented in 5 year age groups only. Therefore, the 15-19 age group was used to estimate the prevalence for 18-19 year olds proportioned from ONS population projection data. We assumed that the distribution of overweight and obesity was the same across this group. Further, the prevalence data was scaled from the simulated population rather than the extrapolated trend and so will take account of the population projections included in the population module of the microsimulation.

Table 8. Prevalence of BMI group by scenario for 18-100 year olds

Scenario	Male			Female			Both		
Baseline	BMI <25	BMI 25-29.9	BMI ≥ 30	BMI <25	BMI 25-29.9	BMI ≥ 30	BMI <25	BMI 25-29.9	BMI ≥ 30
2015	28.0%	43.3%	28.7%	37.8%	32.6%	29.6%	33.0%	37.8%	29.2%
2025	26.7%	39.6%	33.6%	35.1%	30.9%	34.0%	31.0%	35.2%	33.8%
2035	23.8%	37.0%	39.1%	31.2%	29.3%	39.5%	27.6%	33.1%	39.3%
scenario 1									
2015	28.0%	43.3%	28.7%	37.8%	32.6%	29.6%	33.0%	37.8%	29.2%
2025	36.0%	35.2%	28.7%	42.9%	28.4%	28.7%	39.5%	31.7%	28.7%
2035	31.6%	35.7%	32.7%	39.0%	27.6%	33.4%	35.3%	31.6%	33.1%
scenario 2									
2015	28.0%	43.3%	28.7%	37.8%	32.6%	29.6%	33.0%	37.8%	29.2%
2025	65.2%	22.3%	12.5%	69.6%	17.4%	13.0%	67.4%	19.8%	12.8%
2035	69.0%	22.9%	8.1%	73.7%	16.7%	9.5%	71.3%	19.8%	8.8%
scenario 3									
2015	28.0%	43.3%	28.7%	37.8%	32.6%	29.6%	33.0%	37.8%	29.2%
2025	80.1%	14.5%	5.4%	82.9%	11.3%	5.8%	81.5%	12.9%	5.6%
2035	80.8%	15.4%	3.8%	84.1%	11.2%	4.8%	82.4%	13.3%	4.3%
scenario 4									
2015	28.0%	43.3%	28.7%	37.8%	32.6%	29.6%	33.0%	37.8%	29.2%
2025	94.2%	4.9%	0.9%	95.2%	3.8%	1.0%	94.7%	4.3%	1.0%
2035	90.6%	6.9%	2.5%	91.9%	5.7%	2.4%	91.3%	6.3%	2.4%
scenario 5									
2015	28.0%	43.3%	28.7%	37.8%	32.6%	29.6%	33.0%	37.8%	29.2%
2025	97.8%	1.6%	0.6%	97.9%	1.6%	0.5%	97.9%	1.6%	0.6%
2035	97.6%	1.5%	0.8%	97.7%	1.7%	0.6%	97.7%	1.6%	0.7%

NB. The BMI prevalence figures above section present outputs from the microsimulation programme. These sets of results differs slightly from the results using extrapolated trends from cross-sectional HSE data (Table 7 of the document) since the former takes into account dynamic changes in population changes over time.

SSB excise tax policy scenario

Table 9 presents the prevalence of healthy weight, overweight and obesity by baseline scenario and SSB scenario. In 2035 obesity levels are estimated to reach 35% following the introduction of an SSB tax relative to 39% if no tax were applied. This translates to a reduction of 3.4million obese people in the UK by 2035 compared to no implementation of the tax. Please note the same methodological caveat applies with baseline in Table 9 as in Table 8.

Table 9. Prevalence of each BMI group by baseline and as a result of an SSB tax, 18-100 year olds

	Male			Female			Both sexes		
Baseline[i]	BMI<25	BMI25-29.9	BMI≥30	BMI<25	BMI25-29.9	BMI≥30	BMI<25	BMI25-29.9	BMI≥30
2015	28.0	43.3	28.7	37.8	32.6	29.6	33.0	37.8	29.2
2025	26.7	39.6	33.6	35.1	30.9	34.0	31.0	35.2	33.8
2035	23.8	37.0	39.1	31.2	29.3	39.5	27.6	33.1	39.3
SSB	BMI<25	BMI25-29.9	BMI≥30	BMI<25	BMI25-29.9	BMI≥30	BMI<25	BMI25-29.9	BMI≥30
2015	28.0	43.3	28.7	37.7	32.6	29.7	33.0	37.8	29.2
2025	39.1	31.6	29.3	39.1	31.6	29.3	34.7	36.8	28.5
2035	25.9	40.3	33.8	34.0	30.6	35.3	30.0	35.4	34.6

i Baseline data are taken from the simulation output

Impact of interventions on future disease burden

This section outlines the results of the microsimulation. The five hypothetical scenarios (for a full list of the scenario definitions, refer to Table 5 of the Methodology) and specific tax interventions were run for obesity as a risk factor using the input data outlined in Appendix 1B.

Terminology

- *Incidence cases*

  The number of new cases of a specified disease in the UK.
- *Incidence cases avoided*

  The number of incidence cases of disease avoided relative to the baseline scenario (i.e. scenario 0). The incidence cases avoided are presented from 2015 to 2035, at 5-yearly increments. A positive value represents the number of cases avoided whereas a negative value represents the number of cases gained. The figures apply to the whole UK population.
- *Cumulative incidence cases*

  The total number of incidence cases over a given period. Cumulative incidence cases are presented from year 2015 to 2035 at 5-yearly increments such that, for example, the 2020 cumulative incidence case figure represents the sum of all of the incidence cases from the start of the simulation to 2020. The figures apply to the whole UK population.
- *Prevalence cases*

  The number of cases of a specified disease in the UK.
- *Prevalence cases avoided*

  The number of prevalence cases of a specified disease avoided relative to the baseline (i.e. scenario 0). The prevalence cases avoided are presented from 2015 to 2035 at 5-yearly increments. A positive value represents the number of cases avoided whereas a negative value represents the number of cases gained. The figures apply to the whole UK population.
- *Cumulative incidence cases avoided*

  The total number of incidence cases of a specified disease avoided relative to the baseline scenario (i.e. scenario 0) over a given period. Cumulative incidence cases avoided are presented from year 2015 to 2035 at 5-yearly increments such that, for example, the 2035 cumulative incidence case avoided figure represents the sum of all of the incidence cases avoided from the start of the simulation to 2035. A positive value represents the number of cases avoided whereas a negative value represents the number of cases gained. The figures apply to the whole UK population.

- *Direct NHS costs*

  The total costs incurred by the NHS. These costs are based on the total costs in 2015 from the NHS England programme budgeting cost database, and scaled to the population for each of the simulation year[10]. Direct NHS costs were comprised of prevention and health promotion costs; primary care costs (primary care and prescriptions); secondary care (inpatient: elective and day-case, inpatient: non-elective, outpatient and other secondary care); urgent care/emergency care costs (ambulance and Accident and Emergency); community care costs; and cost of care provided in other settings. Social care costs were comprised of non-health and social care costs.

- *Direct NHS costs avoided*

  The total direct NHS cost avoided in 2035 relative to the baseline scenario (i.e. scenario 0). The direct NHS cost avoided are presented from 2015 to 2035, 5-year increments. A positive value denotes the amount of direct cost avoided relative to baseline, whereas a negative value denotes the amount of direct cost gained relative to baseline. The figures apply to the whole UK population.

- *Indirect societal costs avoided*

  The total indirect societal costs avoided in 2035 relative to the baseline scenario (i.e. scenario 0). The indirect societal costs refer to productivity costs, which are composed of two components: mortality costs and morbidity costs. Mortality cost refers to the productivity loss attributable to pre-mature mortality due to a given disease. Morbidity cost refers to the productivity loss attributable to pre-mature morbidity due to a given disease. Mortality and morbidity costs are calculated using the human capital approach; to note, morbidity cost reflects absenteeism only for this project. A positive value denotes the amount of indirect cost avoided relative to baseline whereas a negative value denotes the amount of indirect cost gained relative to baseline. The figures apply to the whole UK population.

- *QALYs gained*

  Total number of QALYs gained relative to the baseline scenario (i.e. scenario 0). A positive value denotes the amount of QALYs gained relative to baseline whereas a negative value denotes the amount of QALYs lost relative to baseline. The figures apply to the whole UK population.

[10] We caution the use of total costs in this report since the development of a disease following the start of the microsimulation is related to a specific risk factor holding all else constant. In addition, the projected annual total costs of BMI-related diseases do not take into account possible changes in costs as a result of changes in the prevalence of other risk-factors such as alcohol and smoking; thus, summation of smoking and obesity cost figures would result in double counting due to the presence of diseases that are affected by both by both smoking and obesity. 'Costs avoided' figures avoid this problem since they reflect the costs attributable to the risk factor, and provide a better representation of the health impact of a particular intervention in this project.

The confidence limits that accompany the sets of output data represent the accuracy of the microsimulation (stochastic, or aleatoric uncertainty) as opposed to the confidence of the input data itself (parameter uncertainty). Errors around the input data were not available.

Hypothetical scenarios

The impact of five hypothetical scenarios was tested on a total of 11 diseases, of which 8 were cancers (bowel, endometrial, gallbladder, kidney, liver, oesophageal, pancreatic and post-menopausal breast cancer) and the remaining 3 diseases were CHD, T2DM and stroke.

Impact on incidence and prevalence

The incidence and cumulative incidence was found to be highest for T2DM, followed by CHD and stroke for the baseline BMI scenario (scenario 0) in 2035 (Table 10 and Table 12). These diseases are more prevalent and/or have larger relative risks, which is likely to account for this finding. Of the cancers, bowel and post-menopausal breast cancer were found to have the highest incidence and cumulative incidence at baseline (scenario 0) in 2035.

By 2035, the baseline cumulative incidence in the UK for T2DM, CHD and stroke is expected to reach 5,927,083 cases, 3,191,028 cases and 2,255,536 cases, respectively. The cumulative incidence at baseline in 2035 was predicted to be 969,321 cases and 906,495 cases in the UK population for bowel and post-menopausal breast cancer, respectively.

Overall, the greater the shift of individuals from the overweight and obese category to the healthy weight category, the greater the extent to which cumulative incidence cases and prevalence cases can be avoided in the future. Out of the 11 diseases modelled, a 10% reduction in the prevalence of overweight and obesity (scenario 2) is predicted to have the greatest impact on T2DM (2,841,686 cases), CHD (1,011,436 cases) and stroke (413,550 cases) by 2035 in terms of cumulative incidence cases avoided (Table 13).

Figure 27 outlines the impact that a 10% reduction in the prevalence of overweight and obesity (scenario 2) is expected to have on the cumulative incidence cases avoided of the 8 BMI-related cancers modelled. This scenario is predicted to have a marked impact on oesophageal cancer, endometrial cancer, post-menopausal breast cancer and bowel cancer. A similar trend was observed for prevalence cases avoided, whereby the most marked impact is expected to be observed for endometrial cancer, post-menopausal breast cancer and bowel cancer (Figure 28).

Table 10 Incidence cases in the UK in 2015 and in 2035, by BMI scenario

Scenario	Year	Parameter	CHD	ColerectalC	Diabetes	LiverC	OesC	Stroke	BreastC	EndometrialC	GallbladderC	KidneyC	PancreaticC	All Cancers
Scenario 0	2015	incidence	138,317	45,456	261,049	4,546	9,741	100,004	42,209	9,091	649	11,039	9,741	132,473
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	incidence	182,391	51,593	326,269	5,813	13,080	125,712	47,233	12,353	727	13,080	10,900	154,778
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028
Scenario 1	2015	incidence	137,668	45,456	260,400	5,195	9,741	100,004	41,560	9,091	649	11,039	9,741	132,473
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	incidence	164,951	50,139	281,216	5,813	10,900	118,445	45,779	10,173	727	13,080	10,900	147,511
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028
Scenario 2	2015	incidence	132,473	44,807	242,217	4,546	9,091	98,056	41,560	9,091	649	11,039	9,741	130,525
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	incidence	97,372	45,779	106,092	4,360	5,813	90,832	41,419	5,087	727	9,447	9,447	122,078
		95% CI [+-]	727	727	727	0	0	727	0	0	0	0	0	727
Scenario 3	2015	incidence	125,979	44,158	220,788	4,546	8,442	94,809	40,911	7,793	649	10,390	9,741	126,628
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	incidence	85,745	45,053	77,026	4,360	5,087	84,292	39,966	4,360	727	8,720	9,447	117,718
		95% CI [+-]	727	727	727	0	0	727	0	0	0	0	0	727
Scenario 4	2015	incidence	107,796	42,859	161,045	4,546	7,143	88,964	38,963	6,494	649	9,091	9,091	118,836
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	incidence	82,839	45,053	70,486	3,633	5,087	82,112	40,693	4,360	727	8,720	8,720	116,992
		95% CI [+-]	727	727	727	0	0	727	0	0	0	0	0	727
Scenario 5	2015	incidence	77,276	40,261	59,093	3,896	4,546	76,626	36,365	3,896	649	7,793	8,442	105,848
		95% CI [+-]	649	649	649	0	0	649	0	0	0	0	0	649
	2035	incidence	81,386	44,326	69,032	4,360	4,360	82,112	39,966	4,360	727	8,720	9,447	116,265
		95% CI [+-]	727	0	727	0	0	727	0	0	0	0	0	0

Table 11 Incidence cases avoidable in the UK in 2015 and in 2035, by BMI scenario

Scenario	Year	Parameter	CHD	ColerectalC	Diabetes	LiverC	OesC	Stroke	BreastC	EndometrialC	GallbladderC	KidneyC	PancreaticC	All Cancers
Scenario 1 rel to 0	2015	inc. avoided	649	0	649	-649	0	0	649	0	0	0	0	0
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	inc. avoided	17,440	1,453	45,053	0	2,180	7,267	1,453	2,180	0	0	0	7,267
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028
Scenario 2 rel to 0	2015	inc. avoided	5,844	649	18,832	0	649	1,948	649	0	0	0	0	1,948
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	inc. avoided	85,019	5,813	220,177	1,453	7,267	34,880	5,813	7,267	0	3,633	1,453	32,700
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028
Scenario 3 rel to 0	2015	inc. avoided	12,338	1,299	40,261	0	1,299	5,195	1,299	1,299	0	649	0	5,844
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	inc. avoided	96,645	6,540	249,243	1,453	7,993	41,419	7,267	7,993	0	4,360	1,453	37,059
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028
Scenario 4 rel to 0	2015	inc. avoided	30,521	2,598	100,004	0	2,598	11,039	3,247	2,598	0	1,948	649	13,637
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	inc. avoided	99,552	6,540	255,783	2,180	7,993	43,599	6,540	7,993	0	4,360	2,180	37,786
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028
Scenario 5 rel to 0	2015	inc. avoided	61,041	5,195	201,956	649	5,195	23,378	5,844	5,195	0	3,247	1,299	26,624
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	inc. avoided	101,005	7,267	257,236	1,453	8,720	43,599	7,267	7,993	0	4,360	1,453	38,513
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028

Inc. avoided: incidence avoided; rel to: relative to

Table 12 Cumulative incidence cases in the UK between 2015 and 2035, by BMI scenario

Scenario	Year	Parameter	CHD	ColerectalC	Diabetes	LiverC	OesC	Stroke	BreastC	EndometrialC	GallbladderC	KidneyC	PancreaticC	All Cancers
Scenario 0	2015	cumu. Inc.	138,317	45,456	261,049	4,546	9,741	100,004	42,209	9,091	649	11,039	9,741	132,473
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	cumu. Inc.	3,191,028	969,321	5,927,083	106,322	223,690	2,255,536	906,495	215,405	17,950	247,854	204,358	2,891,395
		95% CI [+-]	2,762	1,381	4,142	690	690	2,762	1,381	690	0	690	690	2,489
Scenario 1	2015	cumu. Inc.	137,668	45,456	260,400	5,195	9,741	100,004	41,560	9,091	649	11,039	9,741	132,473
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	cumu. Inc.	3,021,880	958,965	5,458,301	104,250	209,191	2,187,187	894,068	201,597	17,260	239,569	202,287	2,827,187
		95% CI [+-]	2,762	1,381	3,452	690	690	2,762	1,381	690	0	690	690	2,489
Scenario 2	2015	cumu. Inc.	132,473	44,807	242,217	4,546	9,091	98,056	41,560	9,091	649	11,039	9,741	130,525
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	cumu. Inc.	2,179,592	898,901	3,085,397	88,371	139,461	1,841,987	829,861	133,247	15,189	194,002	187,098	2,486,130
		95% CI [+-]	2,762	1,381	2,762	690	690	2,071	1,381	690	0	690	690	2,489
Scenario 3	2015	cumu. Inc.	125,979	44,158	220,788	4,546	8,442	94,809	40,911	7,793	649	10,390	9,741	126,628
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	cumu. Inc.	1,864,770	874,737	2,187,187	81,467	114,606	1,712,192	802,935	108,393	14,498	177,433	181,575	2,355,644
		95% CI [+-]	2,071	1,381	2,762	690	690	2,071	1,381	690	0	690	690	2,489
Scenario 4	2015	cumu. Inc.	107,796	42,859	161,045	4,546	7,143	88,964	38,963	6,494	649	9,091	9,091	118,836
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	cumu. Inc.	1,641,080	854,025	1,530,616	77,325	96,656	1,612,084	786,365	90,442	13,808	165,006	176,742	2,260,369
		95% CI [+-]	2,071	1,381	2,071	690	690	2,071	1,381	690	0	690	690	2,489
Scenario 5	2015	cumu. Inc.	77,276	40,261	59,093	3,896	4,546	76,626	36,365	3,896	649	7,793	8,442	105,848
		95% CI [+-]	649	649	649	0	0	649	0	0	0	0	0	649
	2035	cumu. Inc.	1,564,446	845,740	1,306,237	75,254	89,752	1,576,183	778,771	84,229	13,808	160,173	174,671	2,222,397
		95% CI [+-]	2,071	1,381	2,071	690	690	2,071	1,381	690	0	690	690	2,489

Cumu. Inc.: cumulative incidence

Table 13 Cumulative incidence cases avoidable in the UK between 2015 and 2035, by BMI scenario

Scenario	Year	Parameter	CHD	ColerectalC	Diabetes	LiverC	OesC	Stroke	BreastC	EndometrialC	GallbladderC	KidneyC	PancreaticC	All Cancers
Scenario 1 rel to 0	2015	Cumu. inc. avoided	649	0	649	-649	0	0	649	0	0	0	0	0
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	Cumu. inc. avoided	169,148	10,356	468,781	2,071	14,498	68,350	12,427	13,808	690	8,285	2,071	64,207
		95% CI [+-]	4,142	2,071	5,523	690	690	4,142	2,071	690	0	690	690	3,311
Scenario 2 rel to 0	2015	Cumu. inc. avoided	5,844	649	18,832	0	649	1,948	649	0	0	0	0	1,948
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	Cumu. inc. avoided	1,011,436	70,421	2,841,686	17,950	84,229	413,550	76,634	82,158	2,762	53,851	17,260	405,265
		95% CI [+-]	4,142	2,071	4,833	690	690	3,452	2,071	690	0	690	690	3,311
Scenario 3 rel to 0	2015	Cumu. inc. avoided	12,338	1,299	40,261	0	1,299	5,195	1,299	1,299	0	649	0	5,844
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	Cumu. inc. avoided	1,326,258	94,585	3,739,896	24,854	109,083	543,345	103,560	107,012	3,452	70,421	22,783	535,750
		95% CI [+-]	3,452	2,071	4,833	690	690	3,452	2,071	690	0	690	690	3,311
Scenario 4 rel to 0	2015	Cumu. inc. avoided	30,521	2,598	100,004	0	2,598	11,039	3,247	2,598	0	1,948	649	13,637
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	Cumu. inc. avoided	1,549,948	115,297	4,396,466	28,997	127,034	643,453	120,130	124,962	4,142	82,848	27,616	631,025
		95% CI [+-]	3,452	2,071	4,833	690	690	3,452	2,071	690	0	690	690	3,311
Scenario 5 rel to 0	2015	Cumu. inc. avoided	61,041	5,195	201,956	649	5,195	23,378	5,844	5,195	0	3,247	1,299	26,624
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	Cumu. inc. avoided	1,626,582	123,582	4,620,846	31,068	133,938	679,353	127,724	131,176	4,142	87,681	29,687	668,997
		95% CI [+-]	3,452	2,071	4,833	690	690	3,452	2,071	690	0	690	690	3,311

Rel to: relative to, cumu inc: cumulative incidence

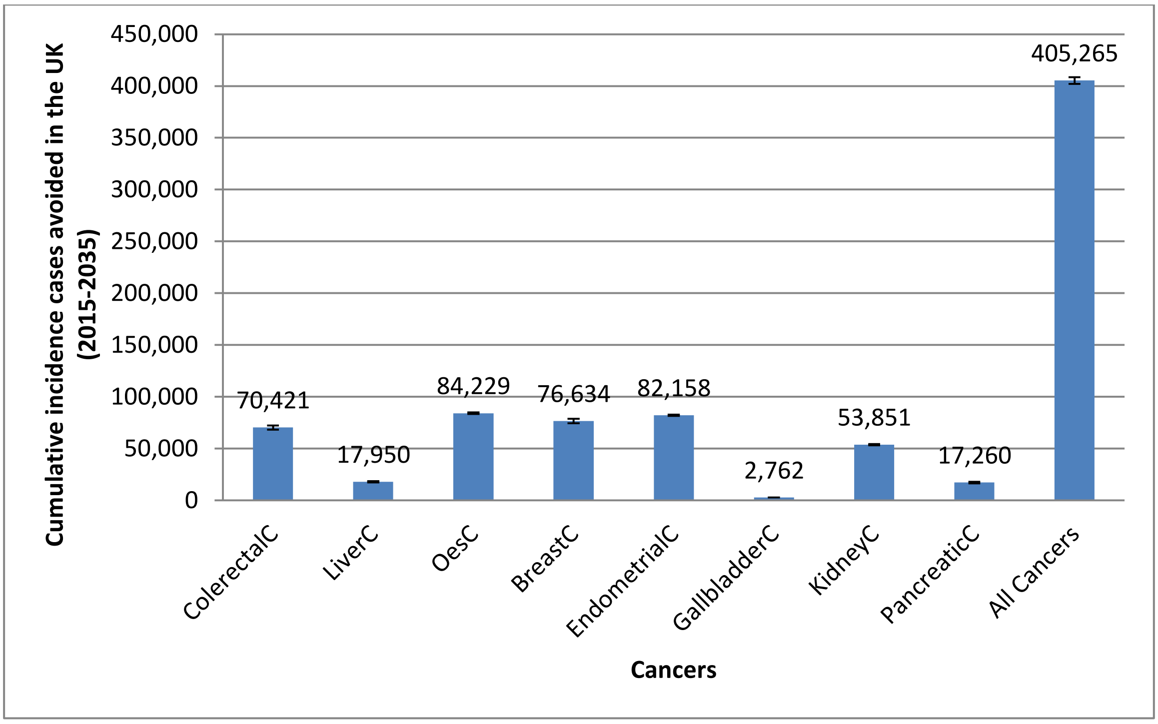


Figure 27 Cumulative incidence cases avoided in the UK between 2015 and 2035 following a 10% reduction in the prevalence of overweight and obesity, relative to baseline BMI scenario

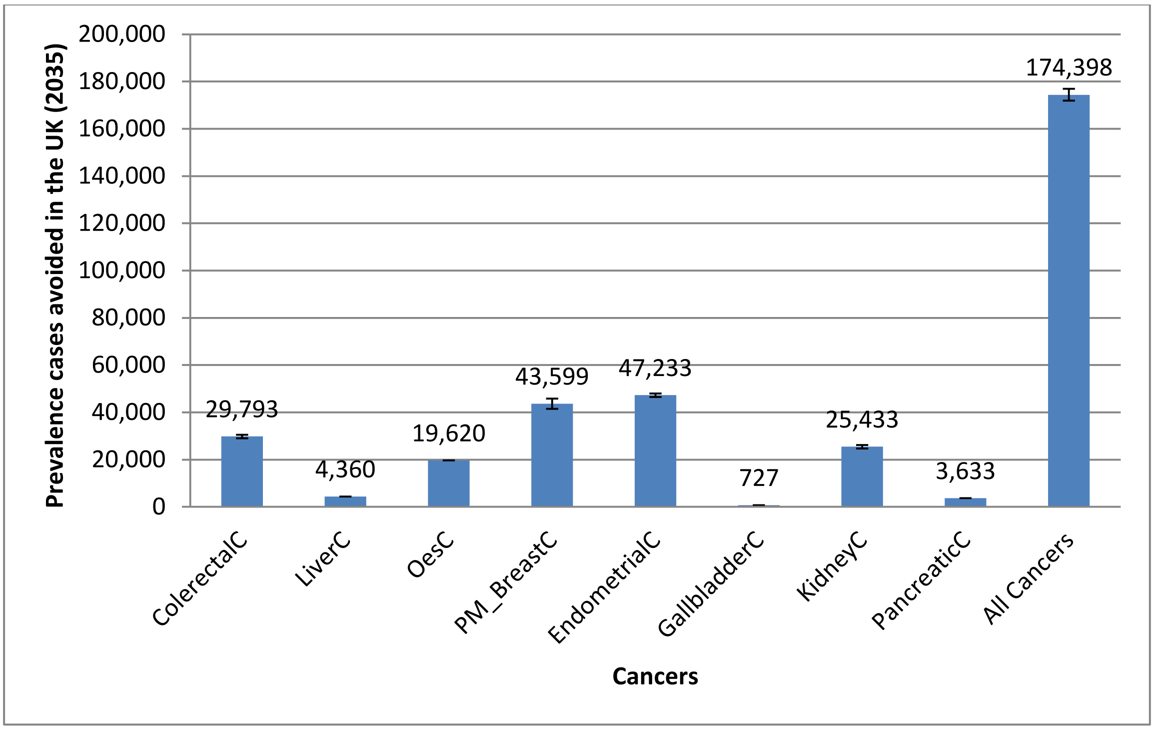


Figure 28 Prevalence cases avoided in the UK in 2035 following a 10% reduction in the prevalence of overweight and obesity, relative to baseline BMI scenario

Impact on direct NHS costs

Table 14 presents the total direct NHS costs avoidable in the UK in 2015 and in 2035, by BMI scenario. To note, we caution the use of total costs in this report since the development of a disease following the start of the microsimulation is related to a specific risk factor holding all else constant. In addition, the projected annual total costs of BMI-related diseases do not take into account possible changes in costs as a result of changes in the prevalence of other risk-factors such as alcohol and smoking; thus, summation of smoking and obesity cost figures would result in double counting due to the presence of diseases that are affected by both by both smoking and obesity. 'Costs avoided' figures avoid this problem since they reflect costs directly attributable to the risk factor, and provide a better representation of the health impact of a particular intervention in this project.

Overall, the greater the shift of individuals from the overweight and obese category to the healthy weight category, the greater the extent to which direct NHS costs can be avoided in the future. Among the 5 hypothetical scenarios, the largest shift in direct NHS costs avoided can be observed between scenarios 1 and 2. For example, with bowel cancer, moving from scenario 1 to scenario 2 results in marked changes in direct NHS cost avoidances (£7 million to £38 million), whereas moving from scenario 2 to scenario 3 does not result in the same level of increase in cost avoidances (£38 million to £48 million).

Of the 11 BMI-related diseases modelled, the most marked impact on direct NHS costs can be observed for CHD, followed by T2DM and stroke. In 2035, a 10% reduction in the prevalence of overweight and obesity (scenario 2) is expected to result in the avoidances of £655 million/year for CHD, £652 million/year for T2DM and £187 million/year for stoke.

Of the 8 BMI-related cancers modelled, the most marked impact on direct NHS costs can be observed for oesophageal cancer, followed by endometrial cancer, post-menopausal breast cancer and bowel cancer. By 2035, a 10% reduction in overweight and obesity prevalence (scenario 2) is expected to result in the avoidance of £75 million/year for oesophageal cancer, £42 million/year for endometrial cancer, £41 million/year for post-menopausal breast cancer and £38 million/year for bowel cancer (Figure 29 and Table 15).

Impact on indirect societal costs

Overall, the greater the shift of individuals from the overweight and obese category to the healthy weight category, the greater the extent to which indirect societal costs can be avoided in the future. A 10% decrease in the overweight and obesity prevalence is expected to result in total indirect societal cost avoidances in the UK of £9.8 billion for all BMI-related diseases by 2035 (Table 15).

Figure 30 presents the indirect societal costs that can be avoided relative to the baseline BMI scenario. The presented cost figures are summations of the costs of all BMI-related diseases under investigation. Substantial cost avoidances can be expected to be achieved on a similar level across scenarios 2 to 5 (between £9.8 billion/year to £14.0 billion/year, respectively for 2035), though the impact of increasing the shift of overweight and obese individuals in to the healthy weight category becomes marginally smaller as one progresses from scenarios 1 to 5. By scenarios 4 and 5 there is no discernible difference in indirect costs avoided between them.

Impact on QALYs

Figure 31 and Figure 32 present the gains in QALY for each hypothetical scenario relative to the baseline BMI scenario. The presented QALY figures are summations of the QALY figures of all BMI-related diseases under investigation. By 2035, a 1% reduction in the overweight and obesity prevalence (scenario 1) is estimated to result in annual gains of 55,300 QALYs (males) and 46,383 QALYs (females), relative to the baseline BMI scenario. A 10% reduction in overweight and obesity prevalence (scenario 2) is expected to result in further, substantial increases of the 'QALYs gained' in the UK population: by 2035, 325,296 QALYs and 274,643 QALYs are expected to be gained relative to the baseline scenario for males and females, respectively. The QALYs gained are marginal thereafter. For example, modelling a 20% reduction in overweight and obesity prevalence (scenario 3 i.e. double the reduction relative to scenario 2) results in 410,957 'QALYs gained' in the UK male population by 2035 – a 26% increase in 'QALYs gained' relative to scenario 2.

Table 14 Direct NHS costs avoidable in the UK in 2015 and in 2035, by BMI scenario

Scenario	Year	Parameter	CHD	ColerectalC	Diabetes	LiverC	OesC	Stroke	BreastC	EndometrialC	GallbC	KidneyC	PancC	All Cancers
Scenario 1 rel to 0	2015	NHS costs avoided (£ millions)	1.9	0.0	0.4	0.0	0.0	-0.5	-0.6	-0.6	0.0	0.0	0.0	-1.2
		95% CI [+-]	2.6	1.4	1.2	0.8	1.0	1.7	1.4	0.5	0.2	0.3	1.2	2.7
	2035	NHS costs avoided (£ millions)	114.2	6.6	111.2	3.0	13.9	32.5	7.5	7.8	1.1	2.3	0.0	42.2
		95% CI [+-]	3.1	1.9	1.6	1.3	1.7	1.9	1.6	0.7	0.2	0.4	2.1	4.0
Scenario 2 rel to 0	2015	NHS costs avoided (£ millions)	6.3	0.0	5.4	0.0	0.0	2.9	1.2	0.0	0.0	0.0	0.0	1.2
		95% CI [+-]	2.6	1.4	1.2	0.8	1.0	1.7	1.4	0.5	0.2	0.3	1.2	2.7
	2035	NHS costs avoided (£ millions)	654.9	38.5	652.3	17.7	74.9	186.8	41.0	42.5	1.1	13.3	18.0	247.1
		95% CI [+-]	2.9	1.8	1.4	1.2	1.5	1.8	1.5	0.6	0.2	0.4	2.1	3.8
Scenario 3 rel to 0	2015	NHS costs avoided (£ millions)	11.4	1.7	10.7	2.6	2.5	3.3	1.8	0.6	0.0	0.3	0.0	9.6
		95% CI [+-]	2.6	1.4	1.2	0.7	1.0	1.7	1.4	0.5	0.2	0.3	1.2	2.7
	2035	NHS costs avoided (£ millions)	820.9	47.9	836.3	20.7	88.7	233.1	52.7	51.6	2.2	16.4	21.6	301.8
		95% CI [+-]	2.8	1.8	1.4	1.2	1.5	1.8	1.5	0.6	0.2	0.4	2.0	3.7
Scenario 4 rel to 0	2015	NHS costs avoided (£ millions)	29.8	4.2	27.7	2.6	9.9	7.6	2.4	2.3	0.0	1.0	3.2	25.8
		95% CI [+-]	2.6	1.4	1.2	0.7	1.0	1.7	1.4	0.5	0.2	0.3	1.2	2.7
	2035	NHS costs avoided (£ millions)	908.9	54.4	951.8	20.7	88.7	260.3	56.8	56.9	2.2	17.5	21.6	318.9
		95% CI [+-]	2.7	1.8	1.4	1.2	1.5	1.8	1.5	0.6	0.2	0.4	2.0	3.7
Scenario 5 rel to 0	2015	NHS costs avoided (£ millions)	60.2	7.5	56.1	5.3	19.8	16.6	5.5	4.1	0.0	1.7	6.4	50.4
		95% CI [+-]	2.6	1.4	1.2	0.7	0.9	1.7	1.4	0.5	0.2	0.3	1.2	2.7
	2035	NHS costs avoided (£ millions)	933.0	55.4	984.0	20.7	91.5	268.8	58.1	58.2	2.2	17.9	21.6	325.6
		95% CI [+-]	2.7	1.8	1.4	1.2	1.5	1.8	1.5	0.6	0.2	0.4	2.0	3.7

Rel to: relative to

Table 15. Indirect societal costs avoidable in the UK in 2015 and in 2035, by BMI scenario

Scenario	Parameter	2015	2020	2025	2030	2035
Scenario 1 rel to 0	Indirect costs avoided (£)	-57,407,478	203,638,842	755,121,794	1,132,212,472	1,312,025,603
Scenario 2 rel to 0	Indirect costs avoided (£)	95,993,172	1,677,770,121	4,467,917,239	7,457,317,243	9,823,927,241
Scenario 3 rel to 0	Indirect costs avoided (£)	-165,166,857	2,642,046,789	6,758,924,690	9,885,597,786	12,404,605,699
Scenario 4 rel to 0	Indirect costs avoided (£)	-179,187,254	4,626,786,485	9,061,461,526	11,816,616,109	13,839,520,752
Scenario 5 rel to 0	Indirect costs avoided (£)	127,990,896	5,499,046,922	9,553,346,670	12,090,524,647	13,973,253,390

Rel to: relative to

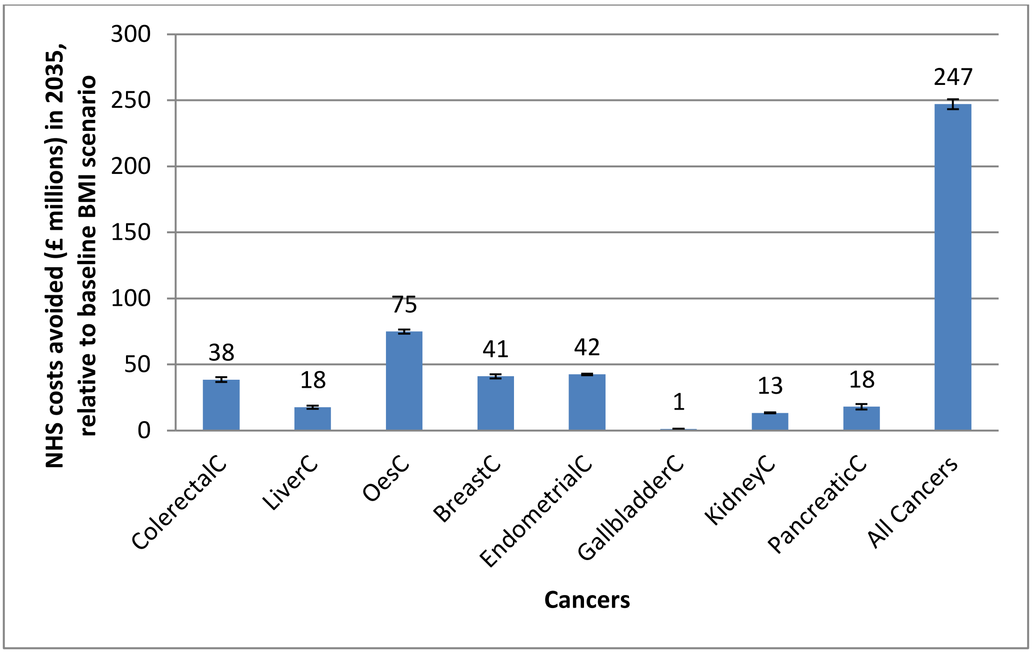


Figure 29 Direct NHS costs avoidable in the UK in 2035 following a 10% reduction in the prevalence of overweight and obesity, relative to the baseline BMI scenario

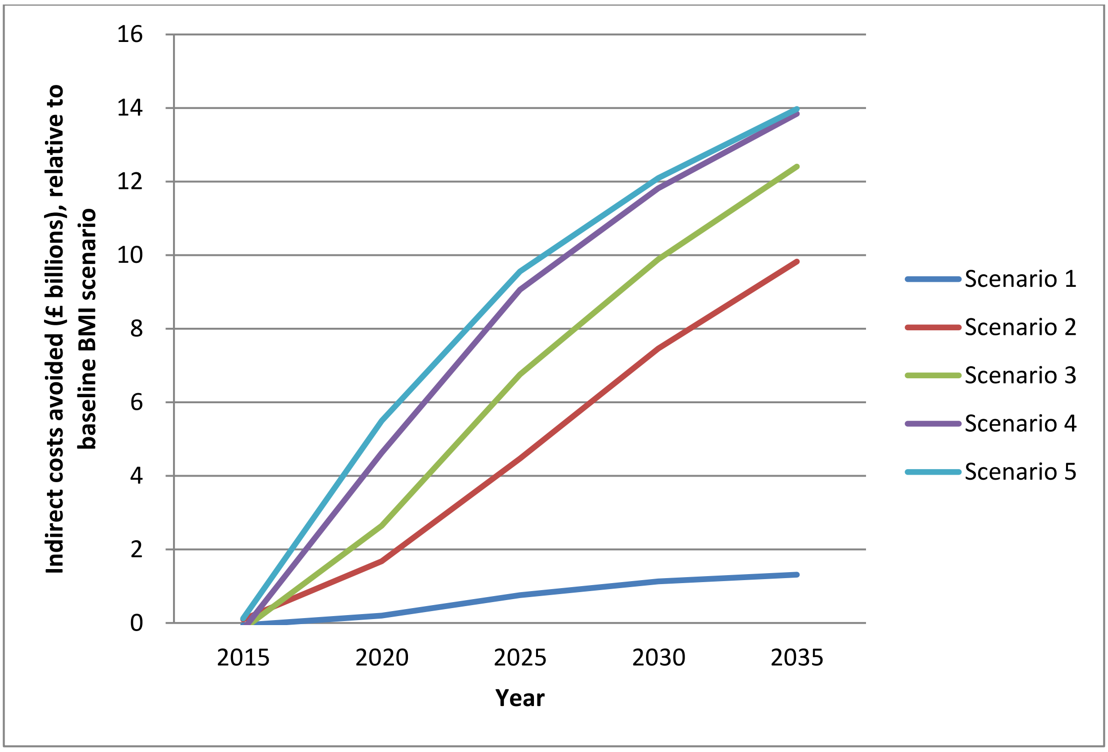


Figure 30 Indirect societal costs avoidable in the UK, relative to the baseline BMI scenario (all BMI-related diseases included)

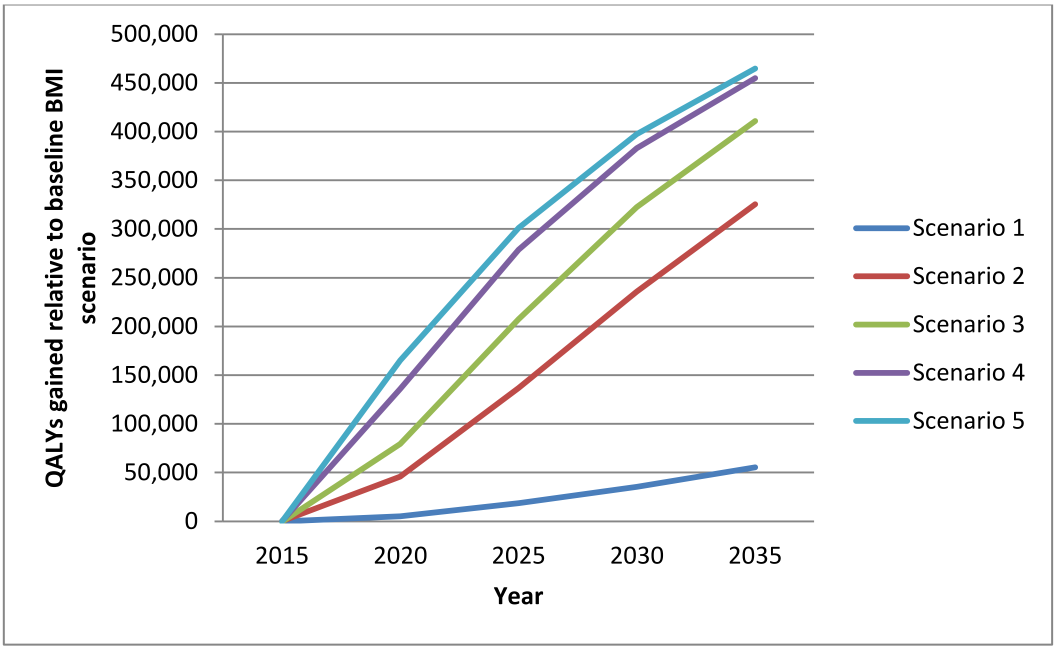


Figure 31 'QALYs gained' in the UK, relative to the baseline BMI scenario – males (all BMI-related diseases included)

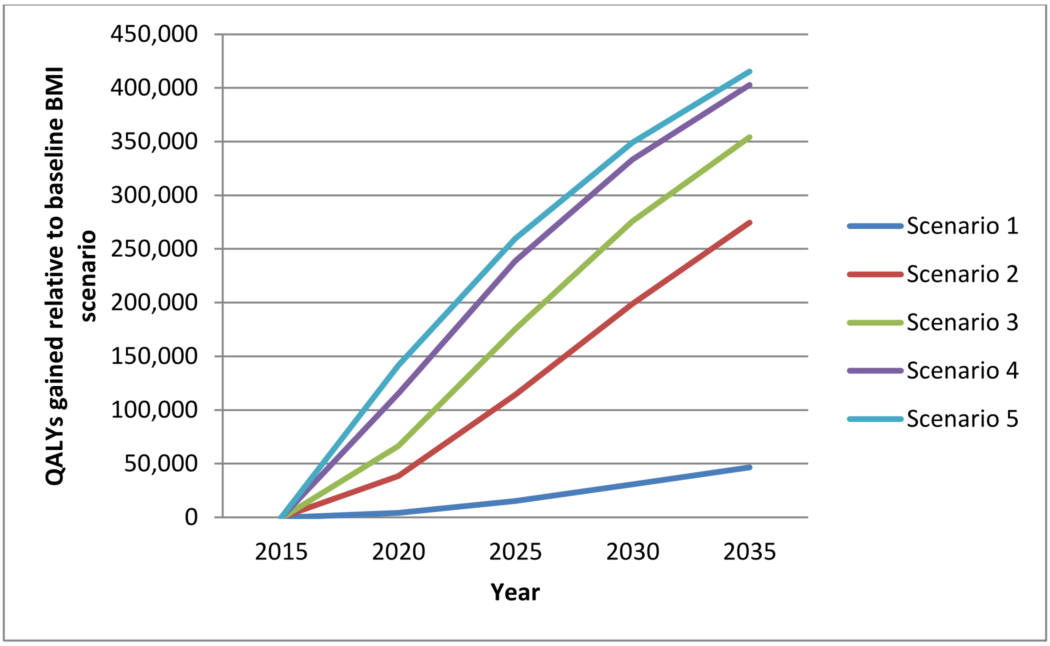


Figure 32 'QALYs gained' in the UK, relative to the baseline BMI scenario – females (all BMI-related diseases included)

SSB excise tax policy scenario

As described in the Methodology section, a 20% SSBs tax was estimated to result in a 0.05 kg/m^2 reduction in BMI – which was then modelled as part of this scenario.

Impact on incidence and prevalence

The incidence of each of the 11 modelled diseases is expected to increase during the 20-year period, for both the baseline (scenario 0) and SSB tax scenarios (Table 16). However, no discernible difference in incidence cases is expected to be observed between the two scenarios, with the exception of a slight difference for T2DM and CHD (Table 17).

By 2035, the SSB tax is expected to have the greatest impact on the cumulative incidence cases avoided of T2DM (35,210 cases), CHD (11,046 cases) and stroke (4,833 cases) (Table 19). Figure 33 reveals that the SSB tax is predicted to have a small effect on the cumulative incidence cases avoided of cancers (3,452 cumulative incidence cases expected to be avoidable by 2035). A similar trend was observed for prevalence cases avoided in terms of cancers (Figure 34). The relatively small BMI relative risks and incidence of cancers are likely to account for the trends seen.

The confidence intervals around these results are wide inferring a high level of uncertainty, which should be taken into consideration when interpreting these findings.

Direct NHS costs and indirect societal costs

Table 20 demonstrates that no discernible difference is expected to be observed between the baseline and the SSB tax scenarios in terms of direct healthcare costs, with the exceptions of T2DM, CHD and stroke. The introduction of an SSB tax is expected to result in the avoidances of £7 million/year for T2DM, £6 million/year for CHD and £2 million/year for stroke, in 2035. Table 21 reveals that £68.6 million/year is expected to be avoidable in indirect costs between the baseline and SSB tax scenarios.

Table 16 **Incidence cases in the UK in 2015 and in 2035, by baseline and SSB tax scenarios**

	Year	Measure	CHD	ColorectalC	Diabetes	LiverC	OesoC	Stroke	PM_BreastC	EndometrialC	GallBladderC	KidneyC	PancreaticC	All Cancers
Scenario 0	2015	incidence	138,317	45,456	261,049	4,546	9,741	100,004	42,209	9,091	649	11,039	9,741	132,473
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	incidence	182,391	51,593	326,269	5,813	13,080	125,712	47,233	12,353	727	13,080	10,900	154,778
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028
SSB tax	2015	incidence	138,317	45,456	260,400	4,546	9,741	100,004	42,209	9,091	649	11,039	9,741	132,473
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	incidence	181,664	51,593	324,815	5,813	13,080	125,712	47,233	12,353	727	13,080	10,900	154,778
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028

rel to: relative to; scen: scenario

Table 17 **Incidence cases avoidable in the UK in 2015 and in 2035; SSB tax scenario relative to the baseline scenario**

	Year	Measure	CHD	ColerectalC	Diabetes	LiverC	OesC	Stroke	PM_BreastC	EndometrialC	GallbladderC	KidneyC	PancreaticC	All Cancers
SSB tax rel to scen 0	2015	inc. avoided	0	0	649	0	0	0	0	0	0	0	0	0
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	inc. avoided	727	0	1,453	0	0	0	0	0	0	0	0	0
		95% CI [+-]	727	727	727	0	0	727	727	0	0	0	0	1,028

rel to: relative to; scen: scenario

Table 18 **Cumulative incidence cases in the UK in 2015 and in 2035, by baseline and SSB tax scenarios**

	Year	Measure	CHD	ColorectalC	Diabetes	LiverC	OesoC	Stroke	PM_BreastC	EndometrialC	GallBladderC	KidneyC	PancreaticC	All Cancers
Scenario 0	2015	Cumu. Inc.	138,317	45,456	261,049	4,546	9,741	100,004	42,209	9,091	649	11,039	9,741	132,473
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	Cumu. Inc.	3,191,028	969,321	5,927,083	106,322	223,690	2,255,536	906,495	215,405	17,950	247,854	204,358	2,891,395
		95% CI [+-]	2,762	1,381	4,142	690	690	2,762	1,381	690	0	690	690	2,489
SSB tax	2015	Cumu. Inc.	138,317	45,456	260,400	4,546	9,741	100,004	42,209	9,091	649	11,039	9,741	132,473
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	Cumu. Inc.	3,179,982	968,631	5,891,872	106,322	222,999	2,250,703	905,805	214,714	17,950	247,163	204,358	2,887,943
		95% CI [+-]	2,762	1,381	4,142	690	690	2,762	1,381	690	0	690	690	2,489

rel to: relative to; scen: scenario

Table 19 Cumulative incidence cases avoidable in the UK between 2015 and 2035; SSB tax scenario relative to the baseline scenario

	Year	Measure	CHD	ColerectalC	Diabetes	LiverC	OesC	Stroke	PM_BreastC	EndometrialC	GallbladderC	KidneyC	PancreaticC	All Cancers
SSB tax rel to scen 0	2015	Cumu. inc. avoided	0	0	649	0	0	0	0	0	0	0	0	0
		95% CI [+-]	649	649	649	0	0	649	649	0	0	0	0	918
	2035	Cumu. inc. avoided	11,046	690	35,210	0	690	4,833	690	690	0	690	0	3,452
		95% CI [+-]	4,142	2,071	5,523	690	690	4,142	2,071	690	0	690	690	3,311

Cumu. Inc. avoided: cumulative incidence avoided; rel to: relative to; scen: scenario

Table 20 Direct NHS costs avoidable in the UK in 2015 and in 2035; SSB tax scenario relative to the baseline scenario

	Year	Measure	CHD	ColorectalC	Diabetes	LiverC	OesoC	Stroke	PM_BreastC	EndometrialC	GallbladderC	KidneyC	PancC	All cancers
SSB tax rel to scen 0	2015	NHS cost (£ millions)	0.0	0.0	0.5	0.0	0.0	-0.5	0.0	0.0	0.0	0.0	0.0	0.0
		95% CI [+-]	2.6	1.4	1.2	0.8	1.0	1.7	1.4	0.5	0.2	0.3	1.2	2.7
	2035	NHS cost (£ millions)	6.4	0.0	7.5	0.0	0.0	1.6	0.0	0.7	0.0	0.4	0.0	1.0
		95% CI [+-]	3.1	1.9	1.6	1.3	1.8	1.9	1.6	0.7	0.2	0.4	2.1	4.0

rel to: relative to; scen: scenario

Table 21 Indirect costs avoidable in the UK in 2015 and in 2035; SSB tax scenario relative to the baseline scenario

	Measure	2015	2020	2025	2030	2035
SSB tax relative to scen 0	Indirect costs avoided (£)	27,761,613	77,307,749	137,763,726	71,037,460	68,635,742

rel to: relative to; scen: scenario

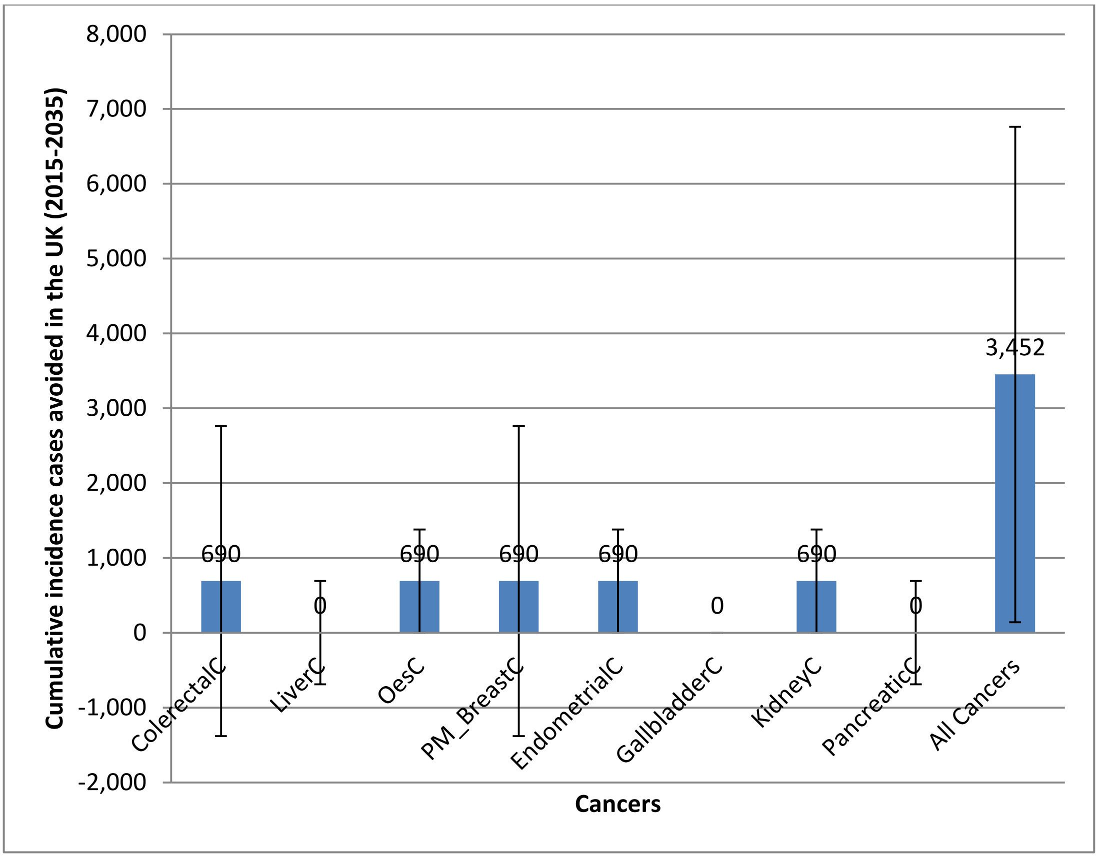


Figure 33 Cumulative incidence cases avoidable in the UK between 2015 and 2035, following the introduction of an SSB tax, relative to the baseline BMI scenario

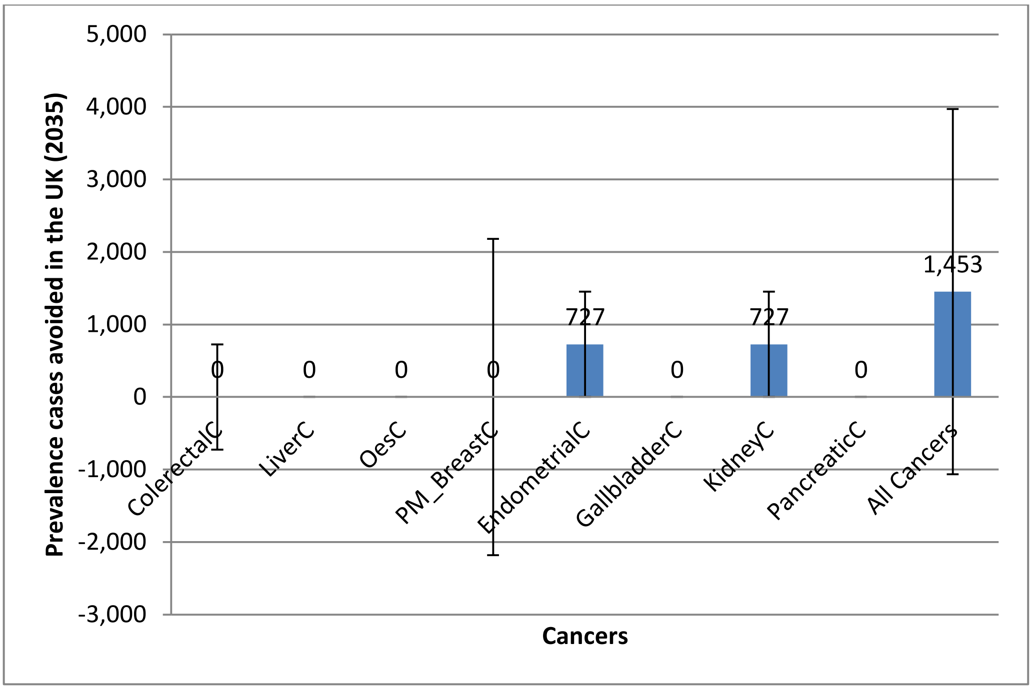


Figure 34. Prevalence cases avoidable in the UK in 2035 following the introduction of an SSB tax, relative to the baseline BMI scenario

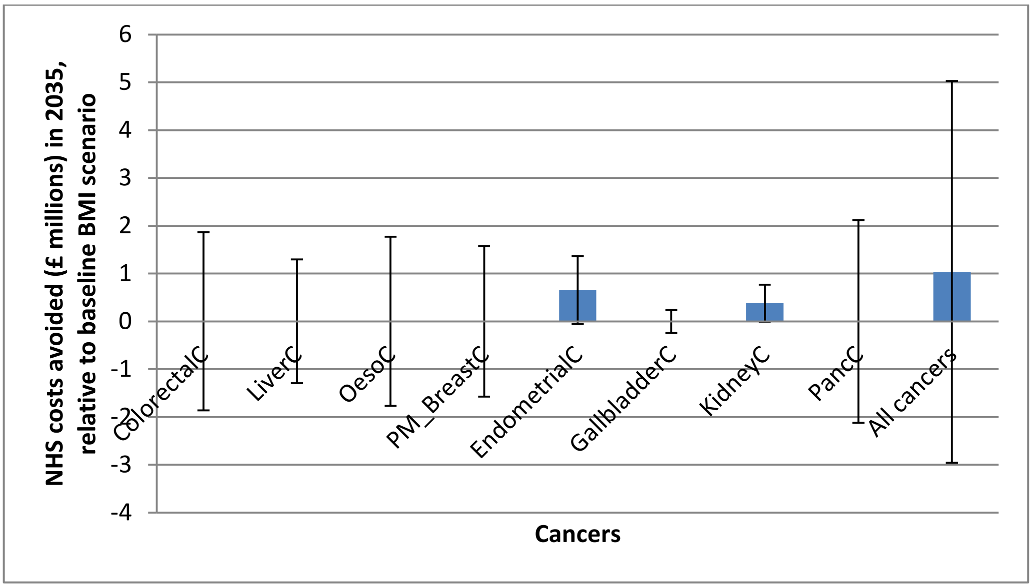


Figure 35 **Direct NHS costs avoidable in the UK population in 2035, following the introduction of an SSB tax, relative to the baseline BMI scenario**

Discussion

This study projected the trends in obesity rates forward to 2035, and tested the impact of these changing risk trends on the future incidence and prevalence of related chronic diseases, as well as on direct NHS direct costs and indirect societal costs. It tested the impact of whole population-level interventions on NCDs. The key findings are presented in the Key Statistics box below.

KEY STATISTICS

If current trends were to continue:

- 72% of the adult UK population could become overweight or obese by 2035.
- 76% of men and 69% of women could become overweight or obese by 2035.
- ‘Obese’ could become the most common weight category (relative to ‘healthy weight’ and ‘overweight’) at some point between 2025 and 2030 for both men and women.
- Obesity prevalence likely to increase across all income quintiles[11].
- Over the next 20 years (2015-2035), there could be 2.9 million[12] new cases of BMI-related cancers. Of this, 670,000 are as a result of rising rates of overweight and obesity.
- In 2035 alone, BMI-related diseases could cost £6.1 billion to the NHS[13] . Of this, £2.5 billion are as a result of the rising rates of overweight and obesity.

Results from the hypothetical scenarios:

Reducing the prevalence of overweight and obesity by 1% each year below the predicted trend:

- Could lead to the prevalence of overweight and obesity reaching 65% by 2035.
- Could lead to the avoidance of 7,300[14] new cases of BMI-related cancers in the year 2035 alone.
- Could lead to the avoidance of £300 million in direct NHS costs and £1.3 billion in indirect societal costs in the year 2035 alone.

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[11] Quintiles are five equal groups into which a population can be divided according to the distribution of values of a particular variable.

[12] 2,891,395 cumulative incidence cases of BMI-related cancers are expected to be observed between 2015 and 2035.Note that BMI-related cancers can be caused by risk factors other than overweight or obesity. Examples include smoking and excessive alcohol consumption.

[13] This cost refers to NHS healthcare and NHS social care costs. Note that BMI-related diseases can be caused by risk factors other than overweight or obesity. We caution the use of total costs in this report since the development of a disease following the start of the microsimulation is related to a specific risk factor holding all else constant. In addition, the projected annual total costs of BMI-related diseases do not take into account possible changes in costs as a result of changes in the prevalence of other risk-factors such as alcohol and smoking; thus, summation of smoking and obesity cost figures would result in double counting due to the presence of diseases that are affected by both by both smoking and obesity. ‘Costs avoided’ figures avoid this problem since they reflect the costs attributable to the risk factor, and provide a better representation of the health impact of a particular intervention in this project.

[14] 7,267 incidence cases of BMI-related cancers are expected to be avoided in 2035.

- Could lead to the avoidance of 64,200[15] new cases of BMI-related cancers over the next 20 years (2015-2035)

Reducing the prevalence of overweight and obesity by 10% each year below the predicted trend:

- Could lead to the prevalence of overweight and obesity prevalence reaching 29% by 2035.
- Could lead to the avoidance of 32,700 new cases of BMI-related cancers in the year 2035 alone.
- Could lead to the avoidance of £1.74 billion in direct NHS costs and £9.82 billion in indirect societal costs in the year 2035 alone.
- Could lead to the avoidance of 0.41 million[16] new cases of BMI-related cancers over the next 20 years (2015-2035)
- Could lead to the avoidance of £16.3 billion in direct NHS costs over the next 20 years (2015-2035).

Results from the SSB tax scenario:

- The introduction of a 20% excise tax on sugary sweetened beverages (SSB) could prevent 3.7 million people from becoming obese by 2025. This is equivalent to a 5% shift in obesity prevalence.
- If current trends were to continue, obesity[iii] levels in the UK could increase from 29% in 2015 to 34% by 2025. This increase could be avoided by the introduction of a 20% excise tax on SSBs.
- The introduction of a 20% excise tax on SSBs could save approximately £10 million[iv] in direct NHS healthcare and NHS social care costs in the year 2025 alone.

NB. The BMI prevalence figures in the Key Statistics section present outputs from the microsimulation (Table 8 of the document). Using extrapolated trends in BMI prevalence, the microsimulation simulates a virtual population. Results using extrapolated trends from cross-sectional HSE data (Table 7 of the document) differ slightly from the results from the microsimulation programme since it does not take into account dynamic changes in population changes over time.

Based on the most recently available data, the prevalence of obese males and females is projected to significantly increase over the next 20 years. The prevalence of obese males is projected to increase across all age groups, with the most marked rise predicted for males above 40 years old. The exception to this trend is males in the 30-39 year old group, whereby the prevalence is projected to remain relatively stable through to 2035. The prevalence of obese females is projected to increase across all age groups. It is unclear why there is an apparent levelling in rates among young males, but monitoring of this trend in the future will allow us to assess whether this is a true flattening or simply an artefact of the data.

[15] 64,207 cumulative incidence cases of BMI-related cancers are expected to be avoided between 2015 and 2035.
[16] 405,265 cumulative incidence cases of BMI-related cancers are expected to be avoided between 2015 and 2035.

Using historical trends in obesity show that without urgent and concerted efforts to prevent further increases in obesity, prevalence could increase at an even faster rate. This is particularly concerning, given that the baseline BMI scenario – where trends continue unabated – will result in catastrophic outcomes in terms of disease incidence and related costs.

The prevalence of obese males and females is projected to increase across all income groups showing the urgent need for whole population level interventions. The most marked rise is predicted in males and females from the lower income groups, which is likely to cause a widening of the social gradient in health. It was not possible to analyse social groups by age group and sex because of the small sample size in each group. Our results are comparable to other findings, demonstrating a negative correlation between BMI-related risk factors and socioeconomic groups [47].

The model assumes that individuals stay on the same BMI percentile throughout their life. In reality, individuals can change their weight status throughout life, sometimes losing or gaining weight, but at a whole population-level, individuals generally stay within the same distribution percentile. That is, relative to others of the same age and sex, individuals stay in the same place within the population distribution. A substantial amount of literature supports this view, showing that weight gain during childhood follows into adulthood [48-51].

A range of hypothetical scenarios were tested, whereby a specified percentage of overweight or obese individuals would become healthy weight at the start of the simulation and stay on this trajectory throughout the course of the simulation. These scenarios are summarised below in Table 22:

Table 22 Scenarios and interventions

Scenarios/interventions	Details
Scenario 0 (Baseline scenario)	No adjustment overweight and obesity prevalence projections; maintain projections as predicted using HSE cohort data
Scenario 1	Reduction of baseline overweight and obesity prevalence projections by 1% each year
Scenario 2	Reduction of baseline overweight and obesity prevalence projections by 10% each year
Scenario 3	Reduction of baseline overweight and obesity prevalence projections by 20% each year
Scenario 4	Reduction of baseline overweight and obesity prevalence projections by 50% each year
Scenario 5	Reduction of baseline overweight and obesity prevalence projections by 100% each year
'SSB excise tax'	20% excise tax applied to SSBs resulting in certain reduction of baseline overweight and obesity prevalence projections

The results illustrate the extent to which disease burden and costs can be avoided if interventions are to be successful in moving individuals into a healthy weight category. However, in reality, no single intervention has been shown to effect this change. Our earlier modelling work (as part of the NICE lifestyle weight management intervention guideline development), showed that, while lifestyle interventions can be effective for weight loss, weight is often regained within a year after the programme ends. Therefore, we recommended continuous weight loss programmes and/or weight maintenance interventions as a possible avenue for ensuring continued weight loss maintenance [26]. The Foresight: Tackling Obesities project [52] concluded that a whole systems approach is needed to tackle obesity. However, this has largely been unheeded, and policies which successfully shift social norms towards lower consumption and greater physical activity have not been seen. Our results illustrate the consequences of inadequate action.

In addition to the hypothetical scenarios, the impact of a 20% SSB tax on future incidence and prevalence of BMI-related chronic diseases was tested. Reductions in the incidence and prevalence were observed for CHD, Stroke, and T2DM; however, no apparent effects were observed for cancers. The higher prevalence rate and relative risks of the CHD, stroke and T2DM, when compared to that of the cancers, are likely to explain this discrepancy. The SSB tax model quantified the impact on disease via BMI only; it did not take account of potential impacts of other dietary factors which are linked to cancers such as red meat consumption and lack of fruit and vegetables in the diet [53]. Our model is able to take a life-course perspective – taking account of changes in behaviour over time. In line with the published literature [45], the SSB tax was implemented in year 1 (2015) of the microsimulation, causing an exponential reduction in BMI by 0.05 kg/m^2 as a result of reduced SSB consumption over a 10 year period. However, while there is good evidence for a reduction in SSB consumption following a levy, there is, as yet, a lack of observed data on the long term impact of SSB tax on BMI [54]. Still, the principal of taking calories out of the diet and initiating shifts in habit and social norm is important if behaviour change is to be sustained.

Strengths of this study

A major strength of this study is the use of the microsimulation method itself. Although data intensive, it has been cited as the most robust method for risk factor and chronic disease modelling [55]. Microsimulation can recreate the characteristics of individuals – such as age, sex and disease state – within a population (as opposed to modelling cohorts of people) that evolve over time.

The microsimulation is the right approach for chronic disease modelling because it is the only modelling approach that is applicable if an individual‘s history matters. For example, an individual‘s history of risk-taking behaviour, such as smoking, alcohol use and nutrition matters for the development of certain diseases especially chronic diseases. An individual‘s history of disease matters for whether they live or die. Microsimulation models are designed to remember an individual‘s history and take it into account to influence their future life course. The UKHF model includes this time series component, enabling the dynamic changes in risk factors over time to be accounted for. Other models, although less data intensive and requiring less computing power, often take a 'static' approach whereby interventions are applied at a single time point. This microsimulation model has developed substantially since its first iteration in Foresight: Tackling Obesities [56] such as the use of more up-to-date and comprehensive epidemiological data as well as the further development of the methodologies and validation techniques. It is now clear that the methodology is reliable and the predictions are as accurate as possible.

The computing power required to run a microsimulation is often cited as a limitation of the method; however, the UKHF model has been built in a modular way such that computation of many millions of individuals on a desktop computer takes only hours. This project ran 100 million individuals which took approximately 8 hours per scenario. Please note that '100 million individuals' in the microsimulation was deemed, during the testing phase, as the appropriate number of runs needed to produce outputs associated with higher levels of certainty and repeatability. The general rule is that the greater the number of individuals simulated in the microsimulation software, the higher the accuracy of the epidemiological and cost outputs. The drawback of simulating large numbers of individuals is the time it takes to complete the simulation. The outputs from the microsimulation are in terms of 'per 100,000 individuals', so the outputs are scaled to the UK population outside of the model in order to derive outputs in terms of the whole UK population.

Challenges and considerations

The challenge with any predictive model is that it does not take account of major future changes in circumstances such as the introduction of new drugs or technologies. In theory, their effects can be estimated by altering parameters in the model but these will significantly increase the degrees of uncertainty. It was beyond the scope of this study, given the time constraints, to carry out an in depth uncertainty and sensitivity analysis. We are aware that this is good practice; however, there is a lack of validated datasets with which we can compare the outputs. Furthermore, given the complexity of the microsimulation involving many thousands of calculations, relative to simpler spreadsheet models, uncertainty analysis would require many thousands of consecutive runs, and would require a super computer to undertake this exercise within a realistic time scale. As part of the EU project EConDA (econdaproject.eu), we validated our models against other models existing in the Netherlands (RIVM NCD model) and US ('Pohem').

One challenge of the microsimulation method is that it is data intensive. Data are often gathered from a variety of sources, and sophisticated statistical techniques are required to standardise the various databases, so that they can be used to populate all of the desired attributes of individuals included in the sample. Incidence data for diseases other than cancers were difficult to acquire. More up-to-date and detailed disease data would be required to make more accurate estimates of future disease incidence. Also, utility weights were derived from US-based community scores for the UK population, since UK scores were not available. Furthermore, utility weights for certain cancers were not available in this data source nor from a literature search that was conducted. These included endometrial cancer, gallbladder cancer and post-menopausal breast cancer. To address these gaps in the data, utility weights were identified from the same data source for conditions that were considered to be suitable proxy measures.

It is important to note other data limitations that we encountered during this study. Firstly, it was not possible to stratify the current consumption of SSBs by BMI group (i.e. healthy weight, overweight and obese); therefore, it was assumed that the consumption of SSBs did not vary by BMI group. Future work with more detailed datasets can extend this analysis. Other data limitations were encountered. For example, the NDNS data are also likely to produce underestimates of consumption. As another example, incidence data were not available for CHD, so MI data were used as a proxy. Additionally, owing to lack of data it was not possible to stratify price elasticity by level of consumption – heavy, moderate or light SSB consumers. In light of this, our outputs are more likely to be conservative estimates of the true effect of an SSB tax on BMI reduction and subsequent disease outcomes. Secondly, it was assumed that an increase in price of SSBs would be passed on directly to the consumer. However, it is not known how the industry would respond to such a tax. Furthermore, the price elasticities used to estimate consumption based on the new price of SSBs were not stratified by gender, age, BMI, SES or branding segment. Thirdly, the effect of the SSB tax was assumed only to affect adults in this model since, to our knowledge, price elasticities for children/young adults have not been published. Fourth, it was beyond the scope of this project to include an extensive sensitivity analysis. The microsimulation model is complex involving many thousands of calculations; therefore sensitivity analysis would require many thousands of consecutive runs using super computers to undertake this within a realistic time scale. Finally, we showed the waning effect of an SSB excise tax over time, such that individuals who reduce SSB consumption would lose the majority of weight in the first two year following implementation. Future work should model an SSB excise escalator, - similar to those implemented for tobacco control - to counteract this physiology and maintain the effect of the tax over time.

The Health Survey for England (HSE) was used for projecting BMI forward, so projections are from England only, since there were insufficient numbers of historical data points for the other UK countries. Risk factor data from England (adjusted for the UK population) was used to estimate disease outcomes. We currently do not have access to the risk factor data that are available for other UK countries. Total prevalence figures show that obesity is higher in England than in Wales (22% obese adults in 2013) [57] and Northern Ireland (23% obese in 2011/12) [58], with 26% of men and 24% of women obese in England in 2013 [59]; similar rates are observed in Scotland with 25.6% obese adults in 2013 [60]. However, more in-depth comparison is necessary to ensure that the data from different health surveys can be similarly compared. It was not possible to find more recent data for Northern Ireland.

The availability of disease cost data was limited. NHS England programme budgeting cost data were used in the model and several assumptions had to be made, which have been highlighted in the methods section of this report. It is acknowledged that the cost outputs produced by this project are crude estimates. Future iterations of the microsimulation model could incorporate a more sophisticated direct cost model that takes account of variation in cost based on disease progression and severity. Please note that discounting the costs (both direct NHS and indirect costs) were outside the scope of this project, so any cost figures may represent slight overestimates of the true cost.

There were few data on the time lag ('latent period') used to define the relevant time period between initiation of health risk behaviours and clinical manifestation of diseases. From a systematic literature search there were a high number of studies [61-65] that looked into the differences in life expectancy between subjects who adopted health risk behaviours such as overconsumption of energy dense, high fat, high sugar foods, and those who did not. These sets of data could not be used for the microsimulation programme since they did not specify when these subjects adopted the health risk behaviours; therefore, an estimate of the time lag period could not be calculated. A recommendation for further research would be to develop longitudinal studies that investigate time lag periods for various types of cancers according to behavioural risk factors such as high BMI.

Future Work

This project explored the independent effect of changing trends in obesity trends over time. Future work will account for combined risk factors on the progression of disease as well as the multi-stages within diseases. Demonstrations of these models can be found in the EConDA project (econdaproject.eu) which was launched in September 2015. By accounting for the multi-stages within a disease it is possible to test the impact of interventions to prevent, screen and treat diseases. Given the good quality of cancer data relative to other chronic disease data and the clear stage-like progression of the disease, further development of the model which includes cancer stages would be valuable.

Following completion of this project the model has since been developed to take account of multi-morbidity - the model is currently being developed to take account of the joint effect of several risk factors on disease incidence and mortality. Future work should include further expanding the scope of the model to take account of technological and economic changes and their potential effects, and also to model the clustering of risk factors and diseases in the same individuals.

For obesity, it is clear that more needs to be done to curb worrying upward trends in prevalence. Further exploration of the impact of an SSB tax would be valuable, such as quantifying the effect of a 100% reduction in SSB consumption on health, and testing the health impact of a SSB tax escalator to account of shifts in inflation. In addition, looking more closely at the upper end of the weight trajectory by categorising the obese group into obese and morbidly obese would be useful. Morbid obesity has been increasing in recent years also, and carries much higher risks even compared with the obese group.

Conclusion

This report sets out the future health and economic impact of obesity prevalence by 2035. The microsimulation method has been cited as the best method for NCD modelling because of its capacity to simulate entire populations at an individual level. However, further work is necessary to combine the UKHF risk factors models in order to draw meaningful conclusions about the total burden of diseases caused by a range of behavioural risk factors.

The economic burden of BMI-related diseases is colossal, projected to cost £6.1 billion/year in NHS costs in 2035 alone (of which £2.5 billion is attributable to overweight and obesity). While tackling obesity will take a huge effort to reduce, it is important to note that if obesity prevalence did indeed shift by ~10% in the last decade (HSE data), it should be possible to shift back 10% in the proceeding 10 years. Such an aspirational target is imperative if we are to avoid a catastrophic increase in BMI-related NCDs.

References

1. OECD Directorate for Employment and L.a.S. Affairs. *Obesity Update*. 2014 [cited 2015 July 2015]; Available from: http://www.oecd.org/els/health-systems/Obesity-Update-2014.pdf.
2. Nguyen, D.M. and H.B. El-Serag, *The Epidemiology of Obesity.* Gastroenterology clinics of North America, 2010. **39**(1): p. 1-7.
3. Eckel Rh Fau - Krauss, R.M. and R.M. Krauss, *American Heart Association call to action: obesity as a major risk factor for coronary heart disease. AHA Nutrition Committee.* (0009-7322 (Print)).
4. Lementowski, P.W. and S.B. Zelicof, *Obesity and osteoarthritis.* (1934-3418 (Electronic)).
5. Ni Mhurchu, C., et al., *Body mass index and cardiovascular disease in the Asia-Pacific Region: an overview of 33 cohorts involving 310 000 participants.* (0300-5771 (Print)).
6. Steppan, C.M., et al., *The hormone resistin links obesity to diabetes.* (0028-0836 (Print)).
7. Suk, S.H., et al., *Abdominal obesity and risk of ischemic stroke: the Northern Manhattan Stroke Study.* (1524-4628 (Electronic)).
8. Health, W.E.F.a.T.H.S.o.P., *The global economic burden of non-communicable diseases*. 2011.
9. Vos, T., et al., *Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010.* Lancet, 2012. **380**(9859): p. 2163-96.
10. UCL Institute of Health Equity, *Review of social determinants and the health divide in the WHO European region: final report*. 2014, World Health Organisation: Denmark.
11. Astolfi, R., L. Lorenzoni, and J. Oderkirk, *Informing policy makers about future health spending: a comparative analysis of forecasting methods in OECD countries.* Health Policy, 2012. **107**(1): p. 1-10.
12. Science, G.O.f., *Foresight Tackling Obesities: Future Choices. Project Report*. 2007.
13. Service, U.D. *Key Data*. 2014; Available from: http://ukdataservice.ac.uk/get-data/key-data.aspx.
14. World Health Oganization Regional Office for Europe. *Body mass index - BMI*. 2015 19/02/2015]; Available from: http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi.
15. World Health Organization. *Obesity and overweight*. 2015 19/02/2015]; Available from: http://www.who.int/mediacentre/factsheets/fs311/en/.
16. WCRF, *Food, Nutrition, Physical Activity, and the Prevention of Cancer: A Global Perspective.*, W.C.R.F.W. DC, Editor. 2007.
17. Office for National Statistics, *Cancer Survival in England: adults diagnosed 2008–2012 and followed up to 2013*. 2014.
18. Organization, W.H. *Health statistics and information systems - Software tools - DISMOD II*. 2014; Available from: http://www.who.int/healthinfo/global_burden_disease/tools_software/en/.
19. (DYNAMO-HIA), A.D.M.f.H.I.A. *United Kingdom vs2.0.6.zip*. 2015 15/11/2014]; Available from: http://www.dynamo-hia.eu/.
20. Obesity, W. *World Obesity Policy and Prevention (formerly IOTF - The International Obesity Task Force)*. 2015 01/01/2015]; Available from: http://www.worldobesity.org/who-we-are/.
21. Pierce, J.P., L. Thurmond, and B. Rosbrook, *Projecting international lung cancer mortality rates: first approximations with tobacco-consumption data.* J Natl Cancer Inst Monogr, 1992(12): p. 45-9.
22. Laura A. Colangelo, S.M.G., Peter H. Gann, Alan R. Dyer, *Cigarette smoking and colorectal carcinoma mortality in a cohort with long-term follow-up.* Cancer, 2004. **100**(2): p. 288-293.
23. Office for National Statistics, *Population estimates 2013*. 2014.
24. EuroQol. *How to use EQ-5D*. 2015 03/01/2015]; Available from: http://www.euroqol.org/about-eq-5d/how-to-use-eq-5d.html.

25. Roberta Ara, A.W., *NICE DSU technical support document 12: the use of health state utility values in decision models*, in *School of Health and Related Research, Report by the decision support unit*. 2011.
26. Martin Brown, T.M., Rtveladze Ketevan, Ric Fordham, Marc Schurcke, David Turner, Richard Little, OyeBanji Filani, *Managing overweight and obesity among children: Report on economic modelling and cost conesquence analysis.* NICE, UK Health Forum, University of East Anglia, 2013.
27. Patrick W. Sullivan, J.F.S., Mark J. Sculpher, Vahram Ghushchyan, *Catalogue of EQ-5D Scores for the United Kingdom.* Medical Decision Making, 2011. **31**(6): p. 800-804.
28. Romanus, D.K., Hedy L.; Archer, Laura; Basch, Ethan; Niedzwiecki, Donna et al., *Does Health-Related Quality of Life Improve for Advanced Pancreatic Cancer Patients Who Respond to Gemcitabine? Analysis of a Randomized Phase III Trial of the Cancer and Leukemia Group B (CALGB 80303)* Journal of Pain and Symptom Management, 2012. **43**(2): p. 205-217.
29. England, N., *2012-13 Benchmarking Tool_Published 21 Feb 2014*. 2014.
30. Hodgson TA, M.M., *Cost-of-illness methodology: a guide to current practices and procedures.* Milbank Mem Fund Q Health Soc, 1982. **60**: p. 429–62.
31. B., L., *How to calculate indirect costs in economic evaluations.* Pharmacoeconomics, 1998. **13**: p. 1–7.
32. Lidgren M, W.N., Jönsson B., *Cost of breast cancer in Sweden in 2002.* Eur J Health Econ, 2002. **8**: p. 5-15.
33. Bradley CJ, Y.K., Dahman B, et al., *Productivity costs of cancer mortality in the United States: 2000-2020.* J Natl Cancer Inst Monogr, 2008. **100**: p. 1763–70.
34. Kim SG, H.M., Choi KS, et al., *The economic burden of cancer in Korea in 2002.* Eur J Cancer Care, 2008. **17**: p. 136–44.
35. Morris S, C.B., Bosanquet N., *Cost of skin cancer in England.* Eur J Health Econ, 2009. **10**: p. 267–73.
36. ONS, *Deaths Registered in England and Wales, 2013*, O.f.N. Statistics, Editor. 2013.
37. ONS. *Annual Survey of Hours and Earnings*. 2014; Available from: http://www.ons.gov.uk/ons/datasets-and-tables/index.html?pageSize=100&sortBy=none&sortDirection=none&newquery=ASHE+2014%2C+Age+Group.
38. Roberts, M.S.G., *Methodology for estimating the Net Production / Wider Societal Impact of treatments*. 2011, University of York and School of Health and Related Research: Personal communication.
39. Colleges, A.o.M.R., *Measuring Up. The Medical Profession's Prescription for the Nation's Obesity Crisis.* 2013. **AoMRC**.
40. Briggs, A.D., et al., *Overall and income specific effect on prevalence of overweight and obesity of 20% sugar sweetened drink tax in UK: econometric and comparative risk assessment modelling study.* Bmj, 2013. **347**: p. f6189.
41. Blakely, T., N. Wilson, and B. Kaye-Blake, *Taxes on sugar-sweetened beverages to curb future obesity and diabetes epidemics.* PLoS Med, 2014. **11**(1): p. e1001583.
42. Institute for Fiscal Studies, *Chapter 4: Value Added Tax and Excises in Dimensions of Tax Design - The Mirrlees Review*. 2010.
43. Beverley Bates, A.L., Ann Prentice, Chris Bates, Gillian Swan *National Diet and Nutrition Survey Headline results from Years 1, 2 and 3 (combined) of the Rolling Programme (2008/2009 – 2010/11)* 2012, Department of Health and Food Standards Agency. p. 1-79.
44. Wang, Y.C., et al., *A penny-per-ounce tax on sugar-sweetened beverages would cut health and cost burdens of diabetes.* Health Aff (Millwood), 2012. **31**(1): p. 199-207.
45. Hall, K.D., et al., *Quantification of the effect of energy imbalance on bodyweight.* Lancet, 2011. **378**(9793): p. 826-37.

46. HSE, *Health Survey for England 2012. Health and Social Care Information Centre. Volume 1 Health, social care and lifestyles* 2012.
47. Observatory, N.O. *Adult slide set*. 2015 [cited 2015 June].
48. Sachdev, H.S., et al., *Anthropometric indicators of body composition in young adults: relation to size at birth and serial measurements of body mass index in childhood in the New Delhi birth cohort.* Am J Clin Nutr, 2005. **82**(2): p. 456-66.
49. Baird, J., et al., *Being big or growing fast: systematic review of size and growth in infancy and later obesity.* BMJ, 2005. **331**(7522): p. 929.
50. Lamb, M.M., et al., *Early-life predictors of higher body mass index in healthy children.* Ann Nutr Metab, 2010. **56**(1): p. 16-22.
51. Ekelund, U., et al., *Upward weight percentile crossing in infancy and early childhood independently predicts fat mass in young adults: the Stockholm Weight Development Study (SWEDES).* Am J Clin Nutr, 2006. **83**(2): p. 324-30.
52. Dr Bryony Butland, D.S.J., Prof Peter Kopelman, Prof Klim McPherson, Prof Sandy Thomas, Jane Mardell, Vivienne Parry, *Foresight Tackling Obesities: Future Choices – Project Report 2nd Edition*. 2007, Government Office for Science.
53. Research., W.C.R.F.A.I.f.C., *Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective.* 2007, AICR: Washington DC.
54. Gibson, S., *Sugar-sweetened soft drinks and obesity: a systematic review of the evidence from observational studies and interventions.* Nutr Res Rev, 2008. **21**(2): p. 134-47.
55. Jillian Oderkirk, F.S., Michele Cecchini and Roberto Astolfi, OECD Health Division, *Toward a New Comprehensive International Health and Health Care Policy Decision Support Tool*. 2012, OECD Directorate for Employment, Labour and Social Affairs.
56. McPherson, K., T. Marsh, and M. Brown, *Tackling Obesities : Future Choices – Modelling Future Trends in Obesity and the Impact on Health.* 2007.
57. Government, W., *Welsh Health Survey.* 2013.
58. Department of Health, S.S.a.P.S., *A Fitter Fututre For All: Framework for Preventing and Addressing Overweight and Obesity in Northern Ireland 2012-2022. Progress Report 2012-2014.*
59. Centre, T.H.a.S.C.I., *HSE 2013: Vol 1 | Chapter 10: Adult Anthropometric Measures, Overweight And Obesity*. 2014.
60. Government, T.S. *Health of Scotland's population - Obesity*. Available from: http://www.gov.scot/Topics/Statistics/Browse/Health/TrendObesity.
61. Grundtvig, M., et al., *Sex-based differences in premature first myocardial infarction caused by smoking: twice as many years lost by women as by men.* Eur J Cardiovasc Prev Rehabil, 2009. **16**(2): p. 174-9.
62. Madala, M.C., et al., *Obesity and age of first non-ST-segment elevation myocardial infarction.* J Am Coll Cardiol, 2008. **52**(12): p. 979-85.
63. Michelle A. Anderson, Eugene Zolotarevsky, Kristine L. Cooper, Simon Sherman, Oleg Shats, David C. Whitcomb, Henry T. Lynch, Paola Ghiorzo, Wendy S. Rubinstein, Kristen J. Vogel, Aaron R. Sasson, William E. Grizzle, Marsha A. Ketcham, Shih-Yuan Lee, Daniel Normolle, Caitlyn M. Plonka, Amy N. Mertens, Renee C. Tripon, Randall E. Brand, *Alcohol and Tobacco Lower the Age of Presentation in Sporadic Pancreatic Cancer in a Dose-Dependent Manner: A Multicenter Study.* Am J Gastroenterol, 2012. **107**(11): p. 1730-1739.
64. Randall E. Brand, J.B.G., Eugene Zolotarevsky, Rhonda Brand, Hongyan Du, Diane Simeone, Anna Zisman, Addi Gorchow, Shih-Yuan (Connie) Lee, Hemant K. Roy, Michelle A. Anderson, *Pancreatic Cancer Patients Who Smoke and Drink are Diagnosed at Younger Ages.* Clin Gastroenterol Hepatol, 2009. **7**(9): p. 1007–1012.
65. M. J. Aguilar Cordero, M.N.S., C. A. Padilla López, M. L. Pimentel Ramírez, A. García Rillo, N. Mur Villar, *Overweight/obesity in women and its implication in breast cancer; age of diagnosis.* Nutr. Hosp., 2012. **27**(5).

i Obesity is classified as a Body Mass Index (BMI) of 30 or above in this report. BMI is a measure of whether a person is a healthy weight for their height, calculated by dividing weight in kilograms (kg) by height in metres (m), then dividing the answer by height in metres again. Whilst BMI is not a perfect measure for all individuals, it is the most widely used population measure for weight classification.

ii This figure is derived from the effect the tax has across all BMI groups. The definitions of overweight and obesity are outlined in the methodology.

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