A review of the evidence base for modelling the costs of overweight, obesity and diet-related illness for Scotland, and critical appraisal of the cost-effectiveness evidence base for population wide interventions to reduce overweight, obesity and diet-related illness.

Paul McNamee[1], Aileen Neilson[1], Patricia Norwood[1], Alison Avenell[2], Anne Ludbrook[1]

1. Health Economics Research Unit, Institute of Applied Health Sciences, University of Aberdeen, AB25 2ZD, UK.
2. Health Services Research Unit, Institute of Applied Health Sciences, University of Aberdeen, AB25 2ZD, UK.

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Executive Summary

An enduring issue within all health care systems is that the demand for health care exceeds the amount of resources available to meet care needs. There are many reasons for this, but a key factor relates to the health behaviour of the population in terms of engagement with a healthy lifestyle. Harmful levels of alcohol consumption, poor diet and lack of exercise are health behaviours that increase the likelihood that an individual will be overweight or obese. Changing behaviour is challenging however. Obesity is also linked to broader social developments, such as changes in food production, the physical environment and work/home lifestyle patterns. There is good evidence from national surveys that the level of obesity within Scotland, the UK and other developed countries has been steadily increasing over many years. Less is known, however, regarding the costs of obesity within Scotland, and whether population wide interventions, such taxation, advertising or regulation, would be cost-effective ways to reduce levels of obesity associated with unhealthy diet.

It is against this background that Food Standards Scotland (FSS) commissioned this study to review the costs of overweight, obesity and diet-related illness for Scotland, and critically appraise the cost-effectiveness evidence base for population wide interventions affecting diet to reduce overweight, obesity and diet-related illness.

The aim of this research was to develop an improved understanding of the wider economic consequences of diet-related health, by describing and critiquing existing evidence of estimates of cost and cost-effectiveness developed to tackle overweight, obese and diet-related disease in Scotland. The specific objectives were twofold:

(i) to provide a review of the evidence base relating to the costs of overweight, obesity and diet-related illness for Scotland, and
(ii) to review and critique the cost-effectiveness evidence base for population wide interventions affecting diet to reduce overweight, obesity and diet-related illness.

Two rapid reviews were undertaken, one focusing on cost of illness studies relevant to Scotland, and one focusing on the cost-effectiveness evidence of population based interventions affecting diet. Electronic searches for relevant English language studies were carried out on major bibliographic databases, supplemented by grey literature searches. For the cost of illness studies, studies that provided estimates for Scotland, the rest of the UK, and the Republic of Ireland were included. For the cost-effectiveness evidence, studies that provided estimates for the UK (or constituent countries of the UK) and selected other developed nations were assessed.

Our review identified 14 studies that addressed the costs of overweight and obesity and obesity-related illness, and a further 10 studies that estimated the cost-effectiveness of population wide interventions to reduce overweight, obesity and obesity-related illness. We found that there were no recent estimates of the cost of obesity from data collected wholly within Scotland; the most recent estimate uses data from England from 2006/7 and performs an extrapolation to Scotland based on population share Castle et al (2015).

Amongst the 10 population wide intervention studies, all predict that measures such as taxation, subsidies, advertising regulation and food labelling are likely to be cost-saving and cost-effective. The policy that has been most frequently evaluated is a tax on sugar-sweetened beverages. The evidence from these studies suggests that the health care cost savings would be predicted to outweigh the additional costs of the tax. Further, the level of savings appear substantial relative to the costs associated with the intervention. Fewer studies have considered other population-wide interventions such as subsidies, advertising regulation and food labelling.

All of the estimates of cost-effectiveness were based on complex modelling studies. They represent a set of mathematical relationships that link individual health behaviour change to subsequent health events, through a pathway running from dietary consumption, energy intake/expenditure, to weight change. This is necessary as the impacts of obesity and overweight develop over many years, and so a robust assessment of cost-effectiveness of population wide interventions requires extrapolation from available data sources in order to estimate future consequences. However, the models make assumptions regarding how weight is lost and then subsequently re-gained, and so establishing better knowledge and understanding regarding behaviour change over the longer term is a priority. These insights will be important to build into any future modelling studies conducted for Scotland or the rest of the UK, using information from other countries which have already introduced population level interventions.

In terms of future research recommendations, we suggest the following:

1. The lack of recent data from Scotland on cost of illness associated with overweight and obesity, combined with changes in the treatment and management of obesity-related conditions, suggest that it may be useful to explore the potential for linkage of existing secondary data sources such as the Scottish Health Survey with administrative health records from Scotland.

For example, the Scottish Morbidity database contains data relating to length of hospital inpatient stays, diagnostic information and operation and procedure information. Such linkage would allow estimation of current health care costs of overweight and obesity that are specific to Scotland. Estimation of productivity costs associated with overweight and obesity could also be included as part of the cost estimation, as the Scottish Health Survey contains information relating to economic activity (current paid employment and time out of the labour force if not in current employment).

2. Given the availability of a range of existing models of cost-effectiveness for various population-wide policy measures from a range of countries, their potential for adaptation to data from Scotland could be assessed. Initial focus could be placed on the model used by Cecchini et al (2010) for England alongside other countries, which produced estimates relating to advertising regulation, compulsory food labelling and fiscal measures.
3. An important pre-requisite for further model development is prior knowledge of the effectiveness of population wide interventions for reduction of overweight and obesity. This information could be developed from a review of existing reviews of the evidence base relating to effectiveness of population-wide interventions. Such a review should include information from longitudinal studies that have tracked longer term effects of policies on weight change and health.

Abbreviations and acronyms

COI	cost of illness
DALY	disability adjusted life year
FSS	Food Standards Scotland
OECD	Organisation for Economic Cooperation & Development
PAF	population attributable fraction
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QALY	quality adjusted life year
SSB	sugar-sweetened beverage/s
ScotPHN	Scottish Public Health Network

1 Introduction and background

1.1 Background

An enduring issue within all health care systems is that increasing demand for health care continues to outstrip the amount of resources available. There are many reasons for this excess demand, but one key factor relates to the health behaviour of the population in terms of engagement with a healthy lifestyle (Butland et al, 2007; Castle 2015). These include poor diet and lack of exercise that increase the likelihood that an individual will be overweight or obese. Changing behaviour is challenging, as highlighted in the Foresight Report (Butland et al, 2007), where it was noted that “obesity is linked to broad social developments and shifts in values, such as changes in food production, motorised transport and work/home lifestyle patterns…the technological revolution of the 20th century has left in its wake an ‘obesogenic environment”.

A Scottish Parliament enquiry notes that the prevalence of obesity in Scotland is high and the underlying trend is increasing (Health & Sport Committee, 2017). Furthermore, work undertaken by the Scottish Public Health Network (ScotPHN) highlights that new policy development is likely to be required in order to strengthen existing initiatives, including the policies outlined in the Scottish Government Obesity Route Map (Kerr 2015). Although several studies exist on the costs of obesity for Scotland and the UK (e.g. Walker 2003; Scarborough et al, 2010; McKinsey Global Institute, 2014), it has been noted that there is no recent published evidence on obesity costs for Scotland (Scottish Parliament 2017). Similarly, whilst there is literature on interventions for diet-related illness, there has been no recent, substantive attempt to appraise existing cost-effectiveness evidence for population wide interventions.

It is against this background that Food Standards Scotland (FSS) commissioned this study to review the costs of overweight, obesity and diet-related illness for Scotland, and critically appraise the cost-effectiveness evidence base for population wide interventions affecting diet to reduce overweight, obesity and diet-related illness.

1.2 Aims and objectives

The aim of this research was to develop an improved understanding of the wider economic consequences of diet-related health, by describing and critiquing existing evidence of estimates of cost and cost-effectiveness of measures to tackle overweight, obesity and diet-related disease in Scotland. The specific objectives were twofold:

- to provide a review of the evidence base relating to the costs of overweight, obesity and diet-related illness for Scotland; and
- to review and critique the cost-effectiveness evidence base for population wide interventions affecting diet and intended to reduce overweight, obesity and diet-related illness.

Initial discussions with FSS indicated a preference for the research to focus on population-wide policies and interventions that affected the consumption of food and drinks with high fat and/or high sugar content, e.g. advertising, regulation and fiscal measures, rather than individual-level interventions (e.g. physical activity programmes). Further, FSS indicated a preference to exclude some policies that affect diet-related illness, e.g. measures to reduce salt intake or alcohol consumption. Finally, we widened the scope of the search for cost-effectiveness evidence by including studies from OECD countries as well as UK studies.

1.3 Overview of methods

Two rapid reviews were undertaken, one focusing on cost of illness studies relevant to Scotland, and one focusing on the cost-effectiveness evidence of population-based interventions affecting diet. Electronic searches for relevant English language studies were carried out on major bibliographic databases, supplemented by grey literature searches. For the cost of illness studies, studies that provided estimates for Scotland, the rest of the UK, and the Republic of Ireland were judged to be relevant. For the cost-effectiveness evidence, studies that provided estimates for the UK (or constituent countries of the UK) and other OECD countries were judged to be relevant.

1.4 Structure of the report

The remainder of this report is structured as follows: Chapter 2 presents an overview of cost of illness methodology, along with details regarding the literature search that was undertaken to identify relevant studies, and concludes with a narrative summary of the identified studies. Chapter 3 presents an overview of economic evaluation methods, then moves on to include details regarding the literature search that was undertaken to identify relevant studies. We provide a short summary of each paper, drawing out the main strengths and limitations. Section 4 is the concluding section, and synthesises the evidence base across all of the studies, including discussion of common themes.

2 Evidence base relating to the costs of overweight, obesity and diet-related illness

2.1 Overview of cost of illness methods

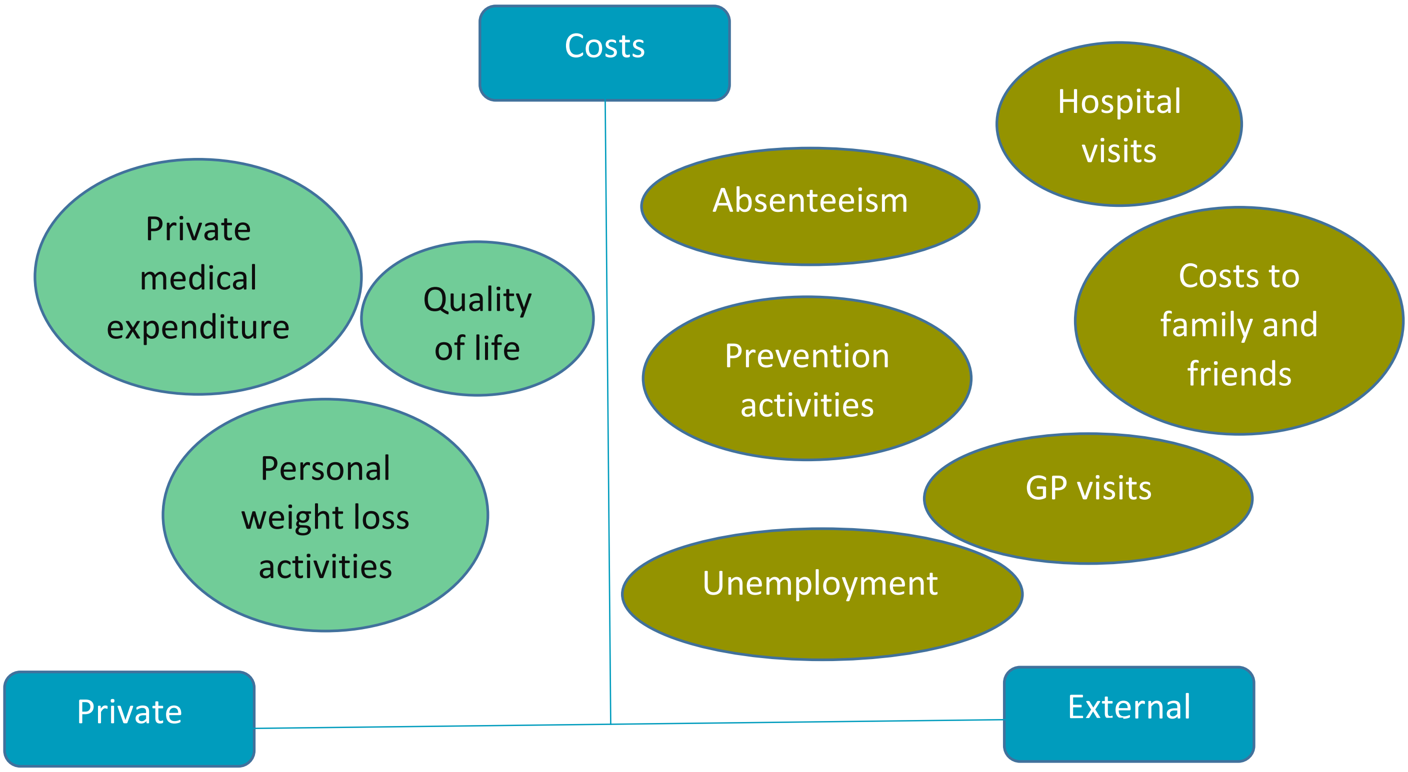
Cost of illness (COI) studies assess the economic burden of health problems at a population wide level (Larg & Moss 2011). Costs that are included in COI studies typically include direct costs, comprising health care and personal social care costs, and productivity costs (also sometimes referred to as indirect costs). In addition to these costs, COI studies may also include "intangible" items, which relate to losses in health-related quality of life. The methods literature identifies broad types of differences between studies in terms of *study perspective*, the types of costs included, e.g. *direct health and personal social care costs, productivity costs* and *intangible items*, and how these costs are calculated.

Study Perspective

In order to interpret and compare the results of different cost of illness studies on the same topic, it is necessary to be clear about the perspective adopted by the study, as this will have a bearing on the scope of the costs that have been included, as well as how these have been measured and valued.

The **total social cost** includes costs to everyone; i.e. it includes the **private costs** borne by the individual, such as personal weight management activities, as well as the **external costs** borne by the rest of society, such as health-related absences from work. **Public sector costs** – those falling on the NHS and other agencies, such as local authorities - are often a particular interest for policy makers and these are a subset of external costs. Some examples of costs are given in Figure 1, but this is not exhaustive.

Figure 1 Overview of costs – adapted from Leontaridi, R. (2003). Alcohol misuse: how much does it cost. *London: Cabinet Office*.



For each type of cost included in the cost of illness calculation, there may be alternative approaches to measuring and valuing costs. Often these will be related to the availability of suitable data. The major cost categories in a cost of illness study are usually broken down into three broad areas: *direct health and personal social care costs, productivity costs* and *intangible items*:

Health and personal social care costs

Treating the health consequences of overweight and obesity gives rise to significant costs which may be borne by individuals and their families directly, or through paying for health insurance; borne by governments through direct health care provision (such as the NHS) or personal social care services, provided or funded by local authorities; or in some circumstances by businesses, through providing health insurance for workers.

Two broad approaches are used to calculate the scale of these costs, and these involve:

(a) identifying population attributable fractions (PAFs) for diseases, such as type 2 diabetes, colon cancer and hypertension, related to overweight and obesity, and applying these to the identified health and personal social care costs of those diseases (often called **"*top-down*"** method). This approach can miss health care costs which arise indirectly through increased costs for managing conditions which are not attributable to obesity, such as pregnancy.

(b) comparing health care costs for overweight or obese people with costs for normal weight people, using data at the individual person-level, observing their use of health and personal care resources over time, and undertaking statistical adjustment to control for other confounding variables (often called **"*bottom-up*"** method). This approach will capture additional costs arising from the management of conditions which are not obesity related.

Within the above two approaches, it is important to ensure that costs unrelated to the health problem are not incorrectly attributed to it (Larg & Moss 2011). These include routine uses of resources such as health check-ups or screening visits. In addition, it is important not to include the costs associated with the health problem that arise through other confounding factors, e.g. increasing age is associated with an increased probability of a range of chronic health conditions (Larg & Moss 2011).

Productivity costs

The potential sources of productivity losses to the economy from overweight and obesity are from higher levels of unemployment and absenteeism amongst those affected and lower productivity when at work. Whether an actual loss arises from unemployment depends on economic conditions; if the economy is not at full employment then other workers would be available to be recruited. Similarly, absenteeism may not give rise to a loss of economic output if the absence is covered by co-workers. Depending on the system of social support available, costs may be borne by the individual (reduced income), the employer (reduced output) or the public sector through social insurance schemes and it is important to avoid double counting. The difficulty in producing reliable estimates means that productivity costs are sometimes excluded in cost of illness studies.

Intangible items

This category covers categories for which there are no markets but where there is a value in avoiding losses. Most notably, this includes the intrinsic value of premature mortality and morbidity, and the pain, grief and suffering associated with death and ill-health. This can be experienced by the individual and by their network of family and friends. Health losses are often expressed as quality adjusted life years (QALYs) or disability adjusted life years (DALYs), but monetary values are not always estimated. There is also a debate as to whether it is appropriate to include these within cost of illness calculations; the argument here is that they are not measures of resource use, and as such, it is more appropriate to include them as an outcome. Their exclusion as a cost also avoids them being double-counted within an economic evaluation (given that, in principle, the results from cost of illness studies could inform some of the cost estimates within an economic evaluation).

Incidence versus prevalence

Incidence based COI studies set out to estimate the potential costs averted if new cases are averted. Therefore they estimate the discounted lifetime costs of new cases arising in the base year. Incidence-based studies can also demonstrate how costs vary with disease duration.

Prevalence-based COI studies measure the actual impact of existing cases compared with an alternative prevalence. Often an implicit or explicit zero prevalence assumption is assumed as the counter-factual. Attributable costs are generally measured over a period of 1 year.

Incidence-based costs are more useful for estimating the likely impact of interventions that aim to prevent cases of overweight and/or obesity, or the likely impact of interventions at particular stages of a condition. In contrast, prevalence-based costs are more useful for demonstrating the current economic burden of illness, amongst a current cross-section of individuals with the condition (Larg & Moss 2011).

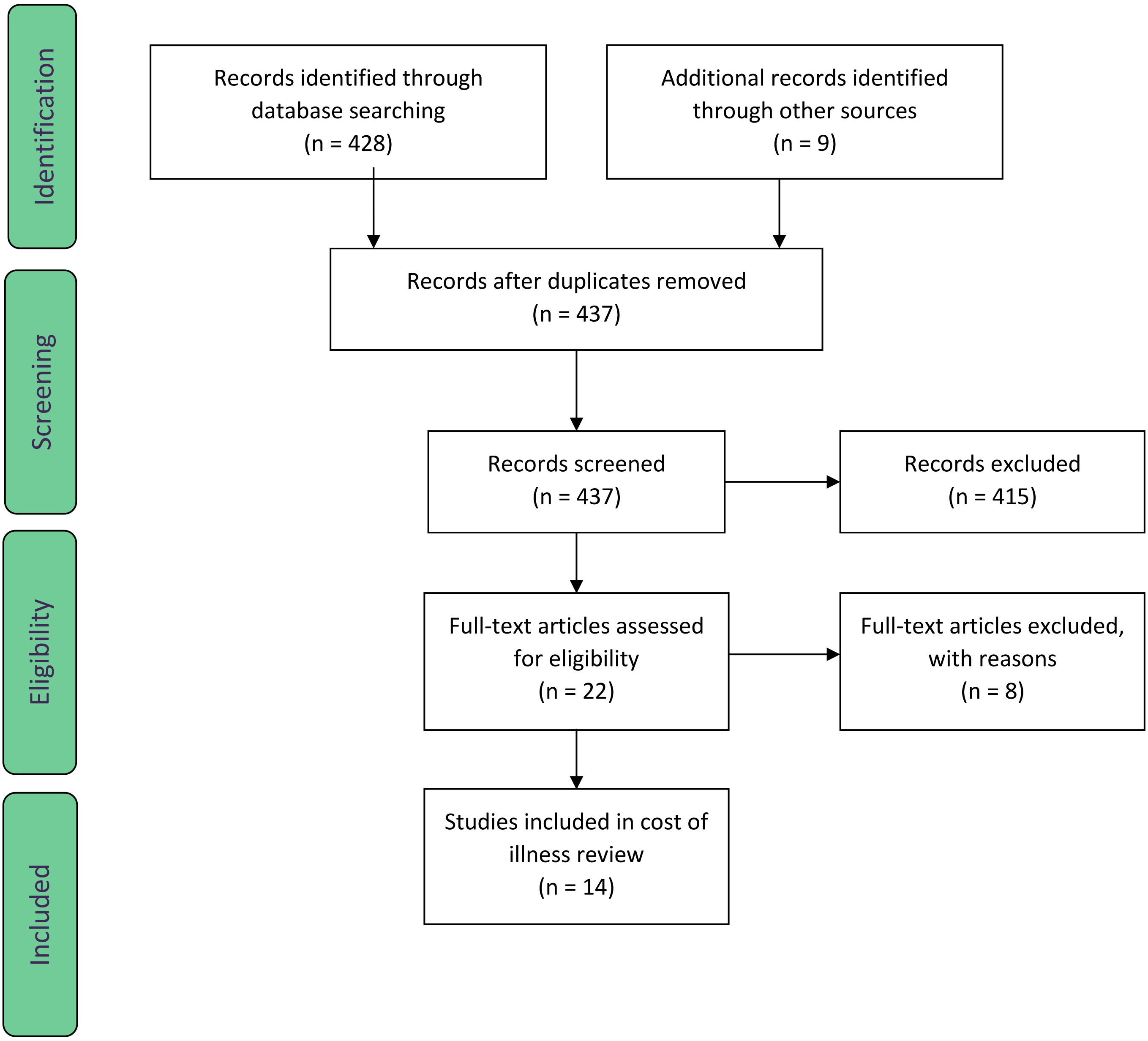
2.2 Literature search

Electronic bibliographic searches for relevant published articles from January 2000 to March 2017 were undertaken in *Medline, Embase,* and *EconLit* databases. The full search strategy is shown in Appendix 1. We also searched for additional studies from the reference lists of studies identified as relevant. In addition, grey literature was identified from 2015-2017 website searches of the Scottish Parliament, Scottish Government, National Institute for Health & Care Excellence (NICE), the Scottish Collaboration for Public Health Research & Policy (SCPHRP), NHS Health Scotland and Public Health England.

Abstracts from the different databases were merged and duplicates removed. One health economist screened titles and abstracts of all citations to identify potentially relevant papers. Full text papers were obtained for these studies, and were assessed for inclusion according to whether or not they matched the definition of a cost of illness study, and whether they produced cost estimates for an overweight and/or obese population of men and/or women. Where necessary, uncertainty regarding inclusion of publications was resolved following discussion with the project lead. Data were then abstracted by one reviewer for those publications that were included.

Figure 2 shows that the total number of studies initially identified was 437. Following inspection of the titles and abstracts by one reviewer, 415 studies were excluded on the grounds that they did not match appear to match the definition of a cost of illness study. This led to 22 studies identified as being potentially relevant. The reference lists of these studies were searched, revealing an additional 9 potentially relevant studies. Eight studies were then excluded after obtaining the full text of the paper. Five were excluded as they focused on obesity in pregnancy (n=5). Of the remaining three, one paper only considered medications costs and cost savings, one paper was a letter/commentary of conference proceedings, and one paper considered BMI 21-25 as well as overweight and obesity. This produced a final total of 14 relevant studies.

Figure 2 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart of cost of illness studies



2.3 Results and critical appraisal

A brief overview of the 14 studies is given below, grouped according to country of origin, study type (“top-down” or “bottom-up”), and year of publication. Nine “top-down” studies were identified - two studies specifically applied to Scotland, two produced estimates for England, and two generated estimates for the UK as a whole. The remaining three studies calculated estimates for Ireland. There were five “bottom-up” studies, two of which produced cost data for England, with the remainder calculating estimates for the UK. Further details regarding the 14 studies can be found in Appendix 2.

The review found that the most recent estimate of the cost of obesity and overweight to **NHS Scotland** is published in a review by **Castle et al (2015),** based on data from England that were collected between 2002 and 2006/7. The figures published by Castle et al are a synthesis of previous figures produced from earlier reports and published studies (House of Commons Health Committee, 2004; McKinsey et al 2014; Scarborough et al 2011). **Castle et al (2015) state that the direct health care costs in Scotland are likely to be up to £600 million per annum (using 2014/15 prices).** This figure is based on data from England from 2006/7 produced by Scarborough et al (2011), where costs were estimated to be £5.1 billion per annum. A pro-rata population multiplier of 0.098 was applied to £5.1 billion, then adjusted to 2014/15 prices, to arrive at a figure of up to £600 million. For several reasons, this could be an under-estimate for Scotland. First, as shown by data from the 2015 Scottish Health Survey and Health Survey for England 2015, the prevalence of overweight and obesity is higher in Scotland than in England (65% v 63% and 29% v 27% respectively). Further, obesity prevalence rates have risen in both Scotland and England since 2006/7. Finally, medical and surgical treatment options for obesity and conditions related to obesity (e.g. diabetes, hypertension, cardiovascular disease) have increased over the last 10 years.

Castle et al (2015) also noted the potential magnitude of the costs of lost productivity due to morbidity and mortality, and with these added to health care costs, reported that **the total economic costs of obesity to Scotland are likely to range somewhere between £0.9 billion to £4.6 billion per year.** The lower estimate is based on a pro-rata inflation-adjusted total cost estimate of £6.6 billion and £7.4 billion for England using 2002 data (House of Commons Health Committee, 2004). The higher estimate of £4.6 billion is based on a calculation produced by McKinsey (2014). It is difficult to identify the reason for the difference in the size of the estimates, as insufficient detail is contained in the McKinsey report regarding the assumptions underlying the global burden of disease methodology. The difference in the lower and upper estimate does indicate however a large degree of uncertainty over the size of total costs.

The only other study that estimated costs for **Scotland** is published by **Walker (2003).** This involved estimation of the costs of GP consultations, GP prescribing and hospital care for 13 conditions related to obesity (hypertension, type 2 diabetes, angina pectoris, myocardial infarction, osteoarthritis, stroke, gallstones, gout, and five cancers – colon; ovarian, prostate, endometrial and rectal). It estimated that the total NHS cost for managing obesity and related conditions was approximately £171 million. Potential limitations of these estimates are that not all obesity-related conditions were included, and wider costs to society were not included. Further, Scottish-specific data were not available for all conditions that were included. However, it is noted that this figure is much higher than if a simple pro-rata estimate had been taken from a related publication by the National Audit Office (2001), where it was calculated that the cost for Scotland would have amounted to £49 million. The reason for the difference related to a range of factors, including higher use of hospital and GP resources in Scotland, a higher prevalence of obesity and related conditions in Scotland, and uprating figures to 2002 prices.

In addition to the two Scottish estimates above, we identified four other studies that provided "top-down" based estimates of the costs of obesity for other constituent parts of the UK, or the UK as a whole. The Comptroller and Auditor General, on behalf of the **National Audit Office (2001)**, estimated the costs in **England** of GP consultations, GP prescribing and hospital care for treating the same 13 conditions as calculated by Walker (2003). Health care costs directly associated with obesity were estimated to amount to £9.4 million in 1998 prices, and the costs associated with treatment for the 13 related conditions totalled £470 million. Earnings lost due to premature mortality were £827 million and lost earnings due to sickness absence were £1,322 million. Adding these estimates together, the total cost of obesity in England was estimated to be £2.6 billion, or 0.3% of GDP. The main limitations identified by the authors were that no data were available on consultations with practice nurses and dietitians in primary care, nor were social care costs included. Further, the costs of drugs was likely to be underestimated as the principal drug used to treat obesity was not licensed for most of 1998. Finally, there were a number of potentially important disease areas that were excluded from the analysis because of lack of data to calculate a population attributable fraction (e.g. depression, hyperlipidemia and back pain).

A further update to the figures produced previously by the National Audit Office (2001) was produced by the Scrutiny Unit, **House of Commons (2004).** It used data from 2002, and extended the costs to a range of other obesity-related conditions, including hyper-lipidemia, back pain and sleep apnoea. Health care costs directly associated with obesity were estimated to amount to between £46-£49 million in 2002 prices, and the costs associated with treatment for the related conditions totalled £945 million and £1.075 billion. Adding on productivity costs, the total cost of obesity in England was estimated to be between £3.3 billion and £3.7 billion, (between 27% and 42% higher than the National Audit Office (2001) estimate). The main limitations are similar to the previous National Audit Office (2001) report, i.e. exclusion of primary and social care costs. Furthermore, they identify that the estimates for population attributable fractions are uncertain, as they almost wholly rely on data from non UK populations.

Also using top-down methods, **Scarborough et al (2011)** estimated that the total health care costs associated with the overweight and obese population in the **UK** was £5.1 billion (2006/7 prices). Health care cost estimates were based on applying the World Health Organisation (WHO) Population Attributable Fractions (PAFs) to hospital activity and expenditure data for primary and secondary care resource use in NHS England, using a Programme Budget approach (classification of activity and expenditure according to disease category). The authors undertook sensitivity analysis on the PAFs, and demonstrated that using alternative PAFs had very little impact on the estimated costs. Similar to other studies, the authors suggest that the costs may be under-estimated, as some conditions which may arise alongside obesity, e.g. depression, were not included.

In another study for the **UK**, using the Foresight model, **Wang et al 2011** projected future obesity trends and calculated the associated health care costs associated with treatment for stroke, coronary heart disease, diabetes, cancer and arthritis. It was estimated that the annual health care costs associated with treatment of these preventable diseases would increase by approximately £1.9–2 billion in the UK by 2030. The Foresight model uses nationally representative data on BMI from the Health Survey for England, and undertakes microsimulation of the current population cohort, projecting future BMI and related disease risk as a person ages, with risk modelled as a function of age, gender and BMI. Related disease risk is modelled from data collected in the United States from the Framingham study. Disease costs relate to data published by the British Heart Foundation and by the Health and Social Care Information Centre in England between 2004/5-2009/10. Similar to other studies, the authors suggest that the costs may be under-estimated, as some conditions were excluded, e.g. infertility, sleep apnoea and benign prostatic hypertrophy. Further, the future influence of childhood obesity may have been underestimated.

Three "top-down" studies were published for Ireland. **Dee et al (2015)** estimated the healthcare costs (including hospital utilisation, GP visits and drug costs) and productivity costs (losses due to work absenteeism and premature mortality) of overweight and obesity for **Ireland** in 2009. Population Attributable Fractions (PAFs) were applied to costs to measure the contribution of obesity and overweight to costs. PAFs were derived from several studies, including a previous systematic review and meta-analysis of international studies. They estimated that total health care costs were €437 million for the **Republic of Ireland (ROI)** and €127.41 million for **Northern Ireland (NI).** Productivity loss due to overweight and obesity was up to €865 million for ROI and €362 million for NI. Adding these estimates together, total costs were €1.3 billion for ROI and €0.5 billion for NI. For ROI, it is possible that productivity costs are under-estimated, as it was not possible to measure long-term absences from work. The authors discuss a range of uncertainties, simplifying assumptions and exclusions in the estimates, the majority of which point most likely towards the published figures being an under-estimate of resource use and costs.

In another study conducted for the **Republic of Ireland**, **Keaver et al (2013)** produced projections for the direct healthcare costs of six major obesity related conditions (coronary heart disease & stroke, cancer, hypertension, type 2 diabetes and knee osteoarthritis) to 2030 using the model developed by the Health Forum (UK) for the Foresight: Tackling Obesities project. Relative risk estimates produced on behalf of the International Association for the study of Obesity were used to calculate the share of disease costs associated with obesity. It was estimated that direct healthcare costs associated with these six conditions will be approximately €5.4 billion by 2030. A number of costs were excluded from the estimates, included medication expenditure related to cancer, and costs amongst children were not included.

A large component of direct healthcare costs relate to stays in hospital, and **Vellinga et al (2008)** estimated this for the **Republic of Ireland**. It was found that the number of days in hospital for obesity related conditions per 1000 days of hospital care increased from 1.5 in 1997 to 4.2 in 2004 for children, and from 3.7 in 1997 to 6.7 in 2004 for adults. Using 2001 prices for an inpatient bed day, the annual hospital cost associated with these bed days was calculated to be €4.4 million in 1997, and €13.3 million in 2004. It is noted by the authors that total costs may be under-estimated, as there is very likely to be under-recording of obesity as a primary or secondary reason for the hospital admission.

The next group of studies considered below are "bottom-up" studies. They tend to use large scale nationally representative samples of respondents, whose use of health care services is linked to existing health care administrative records, or is self-reported, and undertake regression-based methods to estimate the impact of BMI on health care use and/or costs, controlling for all other potential influences on costs.

Kent et al (2017) used data from the Million Women Study cohort to estimate annual inpatient hospital costs associated with overweight and obesity in **England**. Data were estimated over a five year period between 2006 and 2011. Hospital episode statistics were linked to study participants, who self-reported weight, height and other characteristics. Associations of BMI with hospital costs were then projected to the 2013 population of women aged 55–79 years in England, using 2011/12 HRG Reference Costs and 2012 prices. It was found that every 2 unit increase in BMI above 20 was associated with a 7.4% increase in annual hospital costs. These estimates were adjusted for a range of co-variates, including age, region, deprivation, education, parity, age at first birth, smoking, alcohol, and year of data collection. £662 million (14.6%) of the projected £4.5 billion of total annual hospital costs was attributed to excess weight (BMI ≥25). £258 million (39%) of the costs attributed to excess weight were due to musculoskeletal admissions, with knee replacement surgery the most common procedure. A strength of this study is the large sample size and the estimation of costs from routine clinical practice. A potential limitation is that BMI is self-reported; however validation studies suggest that the extent of bias is likely to be negligible. The further limitation is that outpatient, and primary and other costs in the community were not included.

Rudisill et al (2016) estimated annual healthcare costs for obesity that included both primary and secondary care costs. A total of 250,046 participants were identified from a stratified random sample of general practices in **England** between in 2008 and 2013. Costs of healthcare use were calculated from primary care records and linked to routine hospital episode statistics. Linear regression analysis was used to estimate the effects of BMI category, comorbidity and depression on healthcare costs. It was found that, relative to those with BMI less than 25, costs were on average £456 higher per annum for those with BMI>40 (for BMI 35-39, costs were £280 higher, whilst for BMI 30-34, costs were £146 higher per year). There was no significant difference in costs between those with BMI 25-29 and those whose BMI was less than 25. After adjusting for BMI, the additional cost of comorbidity (one or more of coronary heart disease, cancer, stroke and type 2 diabetes) was £1366 (1269-1463) and depression £1044 (973-1115). There was evidence of interaction so that as the BMI category increased, additional costs of comorbidity (£199) or depression (£116) were greater. A strength of this study is the large sample size and the estimation of costs from routine clinical practice. Further, BMI is clinically assessed and not self-reported. A potential limitation is that estimates are drawn from those who consult with a GP, and not from the general population. Another possible limitation is that correlation between BMI and morbidity might result in underestimation of the causal impact of BMI on costs.

Gupta et al (2015) analysed the association between BMI and health-related quality of life (HRQoL), health utilities, health care resource utilization, productivity, activity impairment, and the associated costs. This was a European wide study and included France, Germany, Italy, Spain, and the **UK**. Data were collected from a self-reported National Health and Wellness Survey, a nationally representative, online survey of 58,364 respondents aged 18 years or over (13,617 respondents were based in the UK). Generalized linear regression models were employed to predict outcomes as a function of BMI, adjusting for covariates (age, sex, comorbidities). Among employed respondents (57.7%), overall work impairment increased as BMI increased. Non-obese respondents had lower activity impairment, made fewer visits to primary and secondary care, and lower indirect costs, relative to those with BMI equal to 30 or more. A strength of this study is the comparatively large sample size, the inclusion of "presenteeism" alongside "absenteeism" costs, and the collection of data on health related quality of life. Potential limitations are that length of hospital stay was assumed from a previous survey, and that recruitment was from an on-line panel and may not be representative of the general population. In addition, data were from self-report and the recall period was 6 months, giving rise to potential recall bias. Finally, no specific UK cost estimates were reported.

Tigbe et al (2013) estimated annual health care costs (hospital stays, outpatient visits, medicines, primary care visits) from 3324 randomly selected individuals in 65 general practices across UK who were participants in the **UK Counterweight Programme**. Analyses were based on cross-sectional data collected over 18-

months in 2002-2003. In multivariate analysis, age, sex, BMI, smoking and alcohol consumption were significantly associated with healthcare costs. Adjusted total annual healthcare cost were £16 higher per additional BMI unit. All cost categories were significantly higher for those with BMI >40 compared with BMI <20. A strength of this study is that data were collected from a large number of randomly selected general practices across the UK, and costs included a range of resource use delivered in primary care (GP, practice nurse, health visitor and dietitian). Potential study limitations are that the sample was drawn from the counterweight audit, and it is not clear whether the sample only included current or previous participants in the counterweight weight management programme; if so, the estimates may be subject to selection bias. The authors also note that the normal weight subjects are likely to have health conditions present (by virtue of them having visited their GP practice, and in some cases, having weight recorded), giving rise to a lower cost per BMI change amongst all subjects. Further, BMI was partly measured from self-report amongst some subjects. Alcohol, smoking and physical activity were also self-reported, so there is potential for measurement error and bias. Additional information, such as education, occupation or socio-economic status, which are important determinants of health and healthcare use, was also not measured.

An earlier study on Counterweight was published in 2008 (**Counterweight 2008**). This focused solely on prescribing costs. Medical records were reviewed for all drug prescriptions over an 18-month period for 3400 randomly selected adult patients (18-75 years) stratified by BMI, across 23 primary care practices in seven UK regions. Using 2001 prices, the annual drug cost at BMI 20 was £51 for men and £63 for women. At BMI 25, costs were £77 for men and £79 for women. At BMI 30, costs were £116 for men and £111 for women. At BMI 40, costs were £199 for men and £161 for women. Through subtraction of the expected costs at a normal BMI, attributable cost of overweight and obesity was estimated to account for 23% of spending on all drugs, with 16% attributable to obesity. Using data from the Scottish Health Survey, in order to estimate prevalence of population at each BMI point, and then applying these to the total UK population, attributable drug costs for overweight and obesity were estimated to be £895 million, and £632 million for obesity alone. The same study strengths and limitations outlined above for **Tigbe et al (2013)** are also likely to apply here, in particular, as pointed out by the authors, the normal weight group was probably not a healthy normal weight group, leading to underestimation of the impact of BMI on costs.

2.4 Summary and conclusions

There are no recent and comprehensive calculations of the cost of obesity, or overweight and obesity, in Scotland; figures that have been produced have largely been based on updating previous studies. However, the cost estimates will be increasing over time, not only because of cost inflation but also other factors including changing prevalence, improved methodology and new treatments. This can be put into context by considering that the cost of obesity for the UK was estimated at 3% of GDP in 2012 (Dobbs et al 2014) compared with the 1998 estimate that the cost for England was 0.3% of GDP (Comptroller and Auditor General 2001). This suggests a 10 fold increase over a period of 14 years.

Applying the same percentage to GDP for Scotland in 2016 (Scottish Government 2017) would imply a cost of obesity in the region of £4.77 billion. This is also the basis for the upper estimate of £4.6 billion produced by Castle et al (2015).

Most attention has been given within cost of obesity studies to health care costs. However, where costs to the wider economy have been considered these are substantially greater than the health care costs. The cost to the economy of lost production from premature mortality and sickness absence was 82% of the total estimated for England in 1998 (National Audit Office 2001) and 70% of the updated total in 2002 (House of Commons 2004). The fall in the share was due to improved calculations of health care costs accounting for more attributable diseases and increased treatment of obesity. The latter study also noted that the sickness absence cost calculation excluded self-certified absences and was, therefore, an under-estimate. Including overweight as well as obesity would also increase all of the costs.

More recent estimates indicate that the cost to the economy for the Republic of Ireland is 66% of the total cost of obesity, and 74% for Northern Ireland (Dee et al 2015). However, none of the studies reviewed has attempted to calculate an intrinsic value for the loss of life years and quality of life relating to overweight and obesity.

3 Cost-effectiveness evidence appraisal

3.1 Overview of economic evaluation methods

Economic evaluation is a form of economic analysis that aims to inform decisions regarding the allocation of scarce resources. Applied to the health care system, it addresses the extent to which the use of scarce health care resources used in a particular way offers good value for money relative to deployment in other ways. An economic evaluation compares the costs and outcomes of two or more interventions, services or policies (hereafter, we use the term policy). An incremental approach to the comparison of costs and outcomes is essential: that is, the additional costs and the additional outcomes associated with the policy are compared with another alternative (the alternative chosen is usually current policy, as decision-makers wish to know how well a new policy performs relative to this). Several economic evaluation methods are available, and choices over which one is preferable depends mainly on type of policy under consideration, the policy question to be addressed, and the level of evidence it is possible to gather within the timeframe and resources of the analysis. The main difference between the available methods relates to the measurement and valuation of outcomes, discussed further below.

Cost-Minimisation Analysis

This form of analysis measures only the costs (e.g. health and personal social care costs, productivity costs, costs incurred by patients and/or other family members) of two or more policies. This form of analysis is only appropriate where the outcomes associated with the policies have been demonstrated to be equivalent. If no evidence is presented to demonstrate equivalence, then any cost comparison is not a full economic evaluation. Consequently, such information cannot be used to inform decisions regarding which policy should be recommended on the grounds of cost-effectiveness.

Cost-Effectiveness Analysis

This analysis measures the costs and outcomes of two or more policies. Comparison is made between the policies in terms of a single common outcome, dependent on the main outcome expected to change as a result of the policy. For example, in the case of a tax on sugar-sweetened beverages (SSB), the main outcome could be changes in SSB consumption, calorie intake, or changes in weight/BMI. If more than one outcome is relevant, then the analysis is labelled as a *Cost-Consequence Analysis,* and several incremental cost-outcome comparisons are undertaken. A potential issue here is that it can then be more challenging to make clear recommendations regarding cost-effectiveness, as the comparisons may not always favour one policy over another (in this case, weights may need to be derived to judge whether some consequences are more important than others).

Cost-Utility Analysis

This analysis assesses the cost and outcomes of two or more policies, with the outcomes measured and valued in terms of weighted life years. A common metric here is the Quality Adjusted Life Year (QALY), where life years are weighted according to their relative desirability on a scale where 0=death and 1=perfect health. A related measure is the Disability Adjusted Life Year (DALY), where life years are weighted according to degree of morbidity. The use of a common metric which is multi-dimensional in nature has made the measure attractive to health care decision-makers, as it permits broad comparisons to be made across disease areas and health conditions. There are some challenges however in relation to whether the QALY metric is able to capture changes in dimensions other than health-related quality of life. To take one example, the measure appears less well suited to the evaluation of social care policy interventions, as the main aim is not always to maintain or improve health. A further issue relates to interpretability of the size of QALY difference between the new policy and the relevant comparator - there is no consensus regarding how large the difference needs to be before a policy is judged to be effective and cost-effective. Rather, judgement over cost-effectiveness is usually made according to the magnitude of the difference in cost relative to the magnitude of the difference in QALYs. Typically in the UK an incremental cost of £20,000-£30,000 or less per QALY gained is taken as evidence that the new policy is more cost-effective than the comparator policy.

Cost-Benefit Analysis

Cost-Benefit Analysis assesses the cost and outcomes of two or more policies, with the outcomes measured and valued in monetary terms. In principle, the analysis seeks to measure and value all relevant and important outcomes associated with the policy – potentially attaching monetary values for a range of different outcomes, including both positive and negative changes. This approach has not been extensively used as an economic evaluation method in the health care system, largely because the valuation of outcomes in monetary terms has proved challenging when applied to health. Although more valuation studies are now being conducted in the health care sector, there are fewer examples of valuations form these studies being used within cost-benefit analysis.

3.2 Literature search

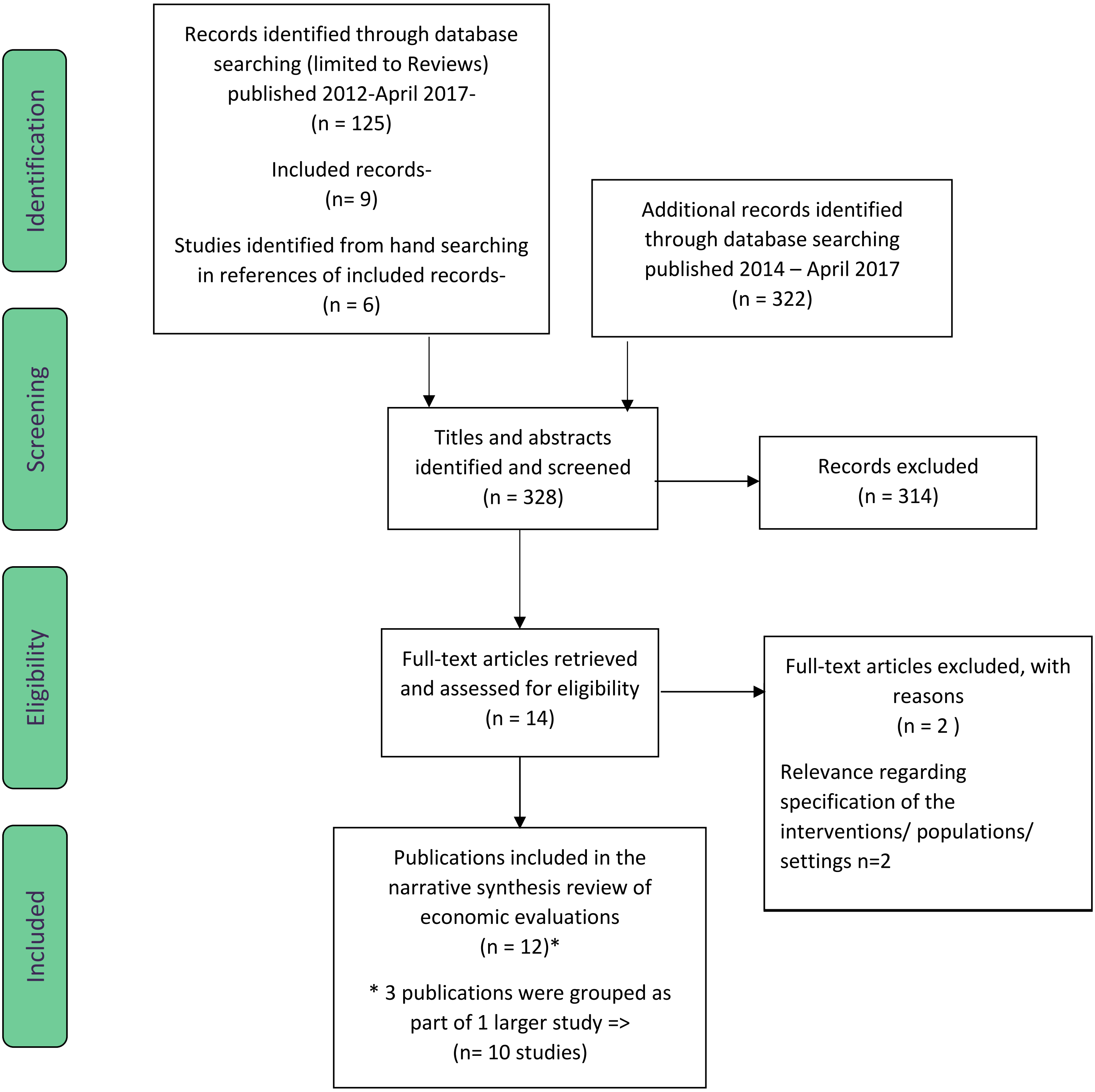
Electronic bibliographic searches for published *review* articles from January 2012 to April 2017, and electronic searches for *original* published articles between January 2014 to April 2017, were undertaken in *Medline, Embase,* and *EconLit* databases. The full search strategy is shown in Appendix 3. In addition to the search for studies in these electronic databases, we also searched for studies that met the inclusion criteria (see below) from the reference lists of articles that were identified as relevant. In addition, grey literature was identified from 2015-2017 website searches of the Scottish Parliament, Scottish Government, National Institute for Health & Care Excellence (NICE), the Scottish Collaboration for Public Health Research & Policy (SCPHRP), NHS Health Scotland and Public Health England.

Abstracts from the different databases were merged and duplicates removed. One health economist screened titles and abstracts of all citations identified as potentially relevant. Full text papers were obtained for studies that appeared to be potentially relevant and were formally assessed for inclusion (see inclusion criteria below). Where necessary, uncertainty regarding inclusion of publications was resolved following discussion with the project lead. Data were then abstracted by one reviewer for those publications that were included.

The inclusion criteria for study eligibility were economic evaluation studies of population-level interventions or polices that affected diet and targeted the whole population, (all children and/or adults), whose main purpose was to reduce overweight, obesity and diet-related illness, and which described explicitly weight loss, weight gain prevention after weight loss, or weight gain prevention as the primary outcome. The exclusion criteria, therefore, were papers that were not considered to be full economic evaluations, using a standard economic evaluation definition (a comparison of both costs and outcomes for the intervention/policy and one of more alternative comparators), and/or did not calculate weight change, and/or were not population-wide interventions that affected diet. Population-wide interventions included changes in prices or taxes (fiscal measures), or new forms of regulation such as nutritional labelling, advertising control, or public information campaigns. Individual health promotion interventions, such as brief nurse or GP counselling, or health care interventions for obesity for which there exists Scottish or UK guidance based on an evidence review, e.g. medicines licensed for the clinical treatment of obesity (e.g. orlistat) and surgical techniques (e.g. bariatric surgery), were excluded. Screening interventions amongst existing overweight and/or obese populations, to manage and treat conditions associated with excess weight (e.g. screening programmes to detect and manage type 2 diabetes amongst overweight and/or obese populations), were also excluded.

Figure 3 below shows that the total number of review studies identified was 125. Nine review articles were judged to be relevant, and from these, the full text versions of 6 original articles within the reference lists of these nine review articles were inspected. The total number of original articles was 322.   Following inspection of the titles and abstracts of the original 322 articles, 314 were excluded on the grounds that they did not meet the inclusion criteria. This led to 14 review and original studies identified as being potentially relevant. Two studies were then excluded after obtaining the full text of the paper, giving a final total of 12 articles from 10 studies.

Figure 3 PRISMA flow chart of rapid review of economic evaluation studies



3.3 Results and critical appraisal

Our review identified 10 studies in total. The detail regarding these studies can be found in Appendix 4 and 5. There are no Scottish specific studies. Two studies produce estimates for the UK, 3 for Australia, and the remaining 5 report estimates for the United States. All are model-based studies that involve data synthesis and extrapolation. One paper (Gortmaker et al 2015a) is a review paper that also reports estimates from two further studies. Below we provide a summary of the 10 studies. We consider the UK studies first of all, and then briefly summarise the remaining studies, presented according to year of publication and type of intervention.

Cecchini et al. (2010), examined the cost-effectiveness of three different population-based interventions for seven countries, including **England**. The interventions included **food advertising regulation,** targeted at fast-food television advertising amongst children ages 2-18 years, **compulsory food labelling,** which involved delivery of information about nutrient contents and serving size, and **fiscal measures** (taxes and subsidies) that involved a price rise of 10% for foods with a high fat content and a price reduction of 10% for fruit and vegetables. The authors used a micro-simulation model that connected a comprehensive set of risk factors (diet, physical activity, BMI and several clinical indicators) to three groups of chronic diseases (cancers, stroke, ischaemic heart disease). The results for England showed that after 50 years, the number of DALYs saved (per million population) were 6,049 with fiscal measures, 2,179 with food advertising, and 4,019 with food labelling. Fiscal measures were cost saving, whilst the cost per DALY averted was US$4,278 with food advertising regulation, and US$5,268 with food labelling. A strength of this study is that a comprehensive range of risk factors were included, the costs of implementing the interventions were measured, and extensive sensitivity analysis was deployed. A potential limitation is that most of the evidence on effectiveness was not derived from the UK (the exception being effectiveness on food advertising regulation).

Collins et al. (2015) modelled the potential impact of a **20% sugary drinks duty** on local authorities in **England** between 2010 and 2030. The authors used a Monte Carlo simulation model that linked sugar sweetened beverage (SSB) consumption, price elasticity of demand (a measure of how the percentage of quantity demanded changes in response to a percentage change in price; where elasticity = 1, percentage change in quantity demanded would equal the percentage change in price; where elasticity is < 1, percentage change in quantity demanded is less than the percentage change in price, where elasticity is > 1, percentage change in quantity demanded is greater than the percentage change in price), current obesity rates, change in obesity rates over time, and substitution of calories from SSBs. The authors calculated that the intervention would result in 2,432 fewer diabetes cases, 1,657 fewer stroke and coronary heart disease cases, 435 fewer cancer cases, and 40,908 QALYs gained per year across England. It was estimated that these averted cases of disease could produce health care cost savings per year of approximately £14.8 million. The authors conducted sensitivity analysis and found that the results were sensitive to changes in assumptions, e.g. the QALY gained ranged from 6,923 to 81,818. A strength of this study is that the effectiveness data were derived from British sources, which showed that a 10% price increase would reduce SSB consumption by 4.6% and a 20% price increase would reduce consumption by 9.1% (a price elasticity of approximately -0.46). One potential limitation is that the price elasticity was assumed the same for all ages, and the same between men and women. Further, no results were shown according to different socio-economic group. Also, the data were collected between 1986-1989, and consumption patterns and price responsive may now be very different today. Finally, the cost impact associated with the intervention, in terms of increased costs for consumers and potential reduced revenue for producers, was not included.

Veerman et al. (2016), focusing on **Australia**, also considered the consequences of an **additional 20% tax on the price of SSBs** on health and health care expenditure for adults aged 20 years or over. They used a cohort multi-state modelling approach to simulate the lifetime effects and costs of weight change on obesity related diseases' incidence. Consumption of SSBs (and change in response to the tax) was translated into energy intake (by age/sex group), then to body weight, with changes in BMI then translated to changes in obesity related disease incidence, mortality and morbidity. The SSB tax intervention was estimated to cost AUD27.6 million and generated health care sector cost savings in overall of AUD609 million. The SBB tax showed gains of 112,000 DALYs for men and 56,000 for women over the remaining lifetime of the cohort. This is a comprehensive modelling study that utilised the best available data for Australia, conducted extensive sensitivity analysis and appeared to conduct the analysis by taking a "conservative approach" to the assumptions, e.g. healthcare costs for non-obesity related disease were included in the model so 'unrelated' healthcare costs in added years of life were included. A potential limitation is that self-report data on consumption were used, which has the potential for under-reporting. Further, the only cross-price elasticity that was included, on the basis that this was statistically significant for Australia, related to consumption of artificially sweetened drinks. Generally, many of the model parameters, including the price elasticities, are specific to the Australian setting and therefore may not be generalizable to Scotland.

Wang et al 2012, in a study that applied to the adult **United States** population aged 25-64 years of age, examined the impact of a **penny-per ounce excise tax on sugar sweetened beverages** (equivalent to twelve cents on a twelve-ounce can of regular soda, or approximately a 15–25 percent increase). A state transition (Markov cohort) model with a 10 year time horizon was used, linking changes in reduced drinks consumption, subsequent weight reduction, changes in risk of type 2 diabetes, and then changes in coronary heart disease and stroke.

The extent to which the proposed tax could reduce consumption was estimated using a price elasticity of −0:8, based on a previously published meta-analysis. Compensatory behaviour was included, so that approximately 40 percent of the calories “saved” by reducing SSB intake are compensated for with other drink consumption (water, diet drinks, milk and juice), producing a net reduction of 60 calories for every 100 calories of SSB not consumed. It was estimated that the tax would reduce consumption of SSB by 15%, and the net caloric saving would be 9 calories per day, resulting in a net reduction in weight of 0.9 pounds per person. This produced a 1.5% reduction in the number of people classified as obese over the 10 year period, and was estimated to prevent 2.4 million diabetes person-years, 95,000 coronary heart events, 8,000 strokes, and 26,000 premature deaths, while avoiding more than $17 billion in medical costs over 10 years. A particular strength of this study is that compensatory behaviour (consumption of other drinks) was explicitly modelled, and the authors found that the results were highly sensitive to these behaviours. The authors noted that a wide range of elasticity estimates (−0:13 to −3:18) exists in the literature, and a critical issue is the use of the most appropriate estimate for each particular country. The authors state that a limitation of their study was that the National Health and Nutrition Examination Survey sample may over represent lower income people in the community, and consumption patterns were self-reported.

Gortmaker et al (2015a) considered the impact of an **excise tax of one cent per ounce on sugar-sweetened beverages** for children within the **United States**. The authors also modelled the **elimination of the tax deductibility of advertising costs** for adverts seen by children. The model structure comprised a Markov cohort model where a multistate life table approach simulated the morbidity and mortality experience of the 2015 US population (aged ≥ 2 years, by sex and 5 year age groups) followed for 10 years (2015-2025) or until death or age 100 years. Estimates of the effectiveness of the interventions were based on evidence from systematic reviews and longitudinal observational studies. At 10 years the SSB tax and TV advertising would save net costs (health care cost savings included); the SSB intervention had net total cost savings of $23.2billion and the TV advertising intervention had total savings of $343million. The SSB excise tax was estimated to avert 101,000 DALYs and both SSB and TV advertising would lead to QALY gains of 871,000 and 4,540 respectively. A strength of this study is that the effectiveness estimates were built from a systematic review of evidence, which was then applied to national level sources where the sample sizes are large and relevant to the national population. Further, probabilistic sensitivity analysis was conducted, along with changes to the structural pathway of the model. A criticism that could be applied to the model structure is that the health effects and benefits of childhood interventions were assumed to lay dormant and were then realised several decades later, i.e. a person was assumed to sustain the behaviour change over their remaining lifetime, and reductions in morbidity were minimal until a person reached age 35 years and older, when obesity-related diseases become more prevalent.

In a similar paper to the above, **Gortmaker et al (2015b)** considered the impact of an **excise tax of one cent per ounce on sugar-sweetened beverages** for children within the **United States**. The authors also modelling two separate interventions: the **elimination of the tax deductibility of advertising costs** for adverts seen by children and adolescents for nutritionally poor foods and beverages, **restaurant menu calorie labelling**. The main difference from the earlier paper is that an individual-level microsimulation model was developed, effects and costs were modelled over a 10 year period, and the focus was only on children. Estimates of the effectiveness of the interventions were based on evidence from systematic reviews and longitudinal observational studies. It was estimated that the SSB tax, excise tax elimination, and restaurant menu calorie labelling prevented 575,936, 129,061 and 41,015 cases of childhood obesity over the ten year period respectively. The authors did not present estimates of the impact of different combinations of the interventions. The tax interventions were found to be cost saving, and the level of savings more than outweighed the costs of the interventions. Restaurant menu calorie labelling was also found to save costs, but these savings were not sufficient to offset costs of the intervention. A strength of this study relates to the use of effectiveness estimates built from a systematic review of evidence, which are then applied to national level sources where the sample sizes are large and relevant to the national population. Similar to the other modelling studies reviewed above, some of the model parameters may well be specific to the U.S. (e.g. health care costs of obesity) and may not generalise to Scotland or the UK.

A further sugar tax study was published by **Basu et al (2013)** for a selected part of the **United States population** receiving Government assistance through the Supplemental Nutrition Assistance Program (SNAP) policy. This considered the cost-effectiveness of **banning or taxing SSBs or subsidizing fruits and vegetables amongst adults** aged 25 to 64 years of age over a 10 year period. Both own intake and cross-price elasticities—the change in food intake after a change in price— determined these probability changes and were calculated from the USDA Quarterly Food-at-Home Price Database using Almost Ideal Demand System modelling. It was estimated that taxing SSB purchases would be expected to avert 114,000 diabetes person-years and 31,000 deaths from MIs and strokes over the next decade, with savings of $513,000 per QALY gained. Across the population, total cost savings were $13 billion, and total QALY gains were 26,000. A 30% produce subsidy would be expected to avert 39,000 diabetes person-years and 4600 cardiovascular deaths over 10 years without effects on food security. Results were found to be sensitive to the intake elasticities of SSBs and produce: a 1% decrease in the amount of SSBs consumed for a given change in price would result in a 2% increase in energy intake scores after a soda tax. A strength of this study is that the elasticity estimates were derived from large scale national data, and then applied to meta-analyses / systematic review studies of energy intake, BMI and disease risk. The authors note that the dietary recall data contained in the NHANES may be subject to recall biases and potential underestimates of food intake.

A further study applied to the **Supplemental Nutrition Assistance Program (SNAP) United States population** was conducted by **An (2015).** The intervention was a **monetary incentive of 30 cents for every dollar spent in participating retailers on fruits and vegetables**, (capped at $60 per household per month). A nationwide one-time implementation cost of $5 per SNAP household was assumed to be incurred within the first year, together with an annual cost of incentive payments of $44 per household. Using a Markov model with a lifetime time horizon, the estimated life-time per capita costs to the Federal government were $1323 (2012 U.S. dollars), and the average QALY gain per participant was 0.082, resulting in an incremental cost-effectiveness ratio (ICER) of $16,172 per QALY gained. Sensitivity analysis using Monte Carlo simulations indicated that there was 94.4%-99.6% probability that the estimated ICER would be lower than the cost-effective threshold of $50,000 and $100,000 per QALY gained, respectively. A strength of this study was that the effectiveness estimates were drawn from a large randomised controlled trial (increased daily consumption of targeted fruit and vegetable of 0.48 servings). Further, implementation costs appeared to be comprehensively measured, and quality of life estimates were taken from a national survey. The author notes that potential limitations are that the total program costs might be underestimated as some recurring items were excluded, e.g. support system update and modification costs. Further, a permanent increase in fruit and vegetable consumption was assumed.

Sacks et al 2011 considered the costs and effects of mandatory, **front-of-pack traffic light nutrition labelling in selected food categories**, and a **tax on a range of unhealthy foods amongst the Australian** population aged 20 years or over. For traffic-light labelling (TLL) estimates of changes in energy intake were based on an assumed 10% shift in consumption towards healthier options in four food categories (breakfast cereals, pastries, sausages and pre-prepared meals) in 10% of adults. For the 'junk-food' tax, price elasticities were used to estimate a change in energy intake in response to a 10% price increase in seven food categories (including soft drinks, confectionery and snack foods). UK estimates of price elasticities were used to model changes in food consumption in response to the tax intervention. Changes in consumption led to changes in energy intake and BMI, which then led to changes in stroke, IHD, hypertensive disease, DM, osteoarthritis, 4 cancers) and ultimately DALYs averted. The lifetime model predicted the mean number of DALYs averted were 45 100 with TLL and 559 000 with the ‘junk-food’ tax. Mean cost outlays were AUD$81 million and AUD$18 million respectively, with total cost offsets of AUD$455 and AUD$5550 respectively. In scenario analysis the effect of the intervention was assumed to progressively decay down to no effect after 10 years, impact was lowered to 2.5% of the adult population for TLL, and the price elasticities were also reduced to be 20 times less than base-case). Under the scenario analysis, the median ICERs (with cost offsets) would increase to AUD$540 000 per DALY averted for TLL, and would remain dominant for the tax intervention. A strength of this study is that some parameter estimates were developed from earlier large-scale observational surveys conducted in Australia, e.g. costs of social marketing.

However, the evidence base for other parameter estimates was not clear, e.g. the effectiveness of traffic light labelling In terms of a 10% shift to healthier options was assumed, and may well be over optimistic.

Finally, **Magnus et al 2009** considered the health benefits and cost-effectiveness **of banning television (TV) advertisements in Australia for energy-dense, nutrient-poor food and beverages** during children's peak viewing times. Changes in BMI were assumed to be maintained through to adulthood. A Markov model was constructed and applied to children aged 5-14 years of age, and changes in their food and drink consumption, along with subsequent changes in disease risk, diseases and morbidity averted (using DALYs) were modelled throughout the remainder of life. Data to populate the model were drawn from a range of sources, including a randomized controlled trial of advertisement exposure and food consumption. Supporting evidence was found in ecological relationships between TV advertising and childhood obesity, and from the effects of marketing bans on other products. The model assumed that every 1% change in energy intake led to a 1.4% change in weight. It was estimated that the intervention had an incremental cost-effectiveness of AUD$ 3.70 per DALY (2001 prices). Total intervention costs were $130,000, and savings in future health-care costs were $300million. Threshold analysis identified that the benefit from the reduced BMI could be almost completely eroded over time, and that this intervention would remain dominant (cost savings exceed costs) because the intervention is very low cost. A strength of this study is that some parameter estimates were developed from earlier randomised controlled trial evidence. Potential study limitations are that the base-case estimates involve assuming that the BMI benefit is maintained over time. Further, it is possible that the impacts on the advertising industry or on producers of energy-dense, nutrient-poor foods might lead to price reduction to offset lost sales, or increase of non TV advertising. Further, it is not clear how the intervention costs were calculated.

3.4 Summary and conclusions

There are two studies from England that estimated the cost-effectiveness of population-level interventions or polices that affected diet and whose main purpose was to reduce overweight, obesity and diet-related illness. These studies focused on food advertising regulation, compulsory food labelling and fiscal measures (a price rise of 10% for foods with a high fat content, a price reduction of 10% for fruit and vegetables; Cecchini et al 2010, and 20% tax on sugar sweetened beverages; Collins et al 2015). Within the study that considered comparative policies (Cecchini et al 2010), fiscal measures were found to be more cost-effective than compulsory food labelling or food advertising regulation.

There is a much larger evidence base from studies produced from outside the UK, with research conducted in Australia and the United States. These studies consider a range of population-level interventions, although the most common focus was a tax on sugar sweetened beverages. However, it is challenging to make comparisons across studies in order to gain insight into which policy appears the most cost-effective. This is related to the usual finding of variation in modelling methods and the use of different assumptions within the studies. However, another reason is that virtually all of the studies do not report their estimates in standardised units, e.g. cost/cost savings/health outcome *per person*. This is problematic where different policies have varying population reach. For example, in Gortmaker et al 2015a, the impacts of tax changes (target population size 313 million) and advertising restrictions (target population size 74 million) were modelled. The tax on SSB had around 100 times the impact of advertising restrictions – but the size of the target population was four times higher for the tax on SSB compared with advertising restrictions.

No studies appeared to include cost savings to the wider economy, e.g. productivity gains through avoidance of sickness absence for paid employment, and included only health care savings. Their inclusion would likely have made the interventions more cost-effective than reported, as the evidence from the cost of illness literature demonstrated that costs to the wider economy are substantially greater than the health care costs. In addition, not every study considered the costs of policy implementation. For example, a policy of taxation would lead to some additional costs in terms of extra staffing to administer the tax, and it would also impose costs on consumers who bear the tax in the form of higher prices.

4 Discussion and conclusions

Our review identified 14 articles that addressed the costs of overweight and obesity and obesity-related illness (hereafter “cost of illness” studies), and a further 12 articles that estimated the cost-effectiveness of population wide interventions to reduce overweight, obesity and obesity-related illness (hereafter “economic evaluation” studies). We found that there were no recent estimates of the cost of illness from data collected wholly within Scotland; the most recent estimate (Castle et al 2015) uses data from England from 2006/7 and performs an extrapolation to Scotland based on population share. More recent studies of cost of illness attempt to isolate the specific independent effects of changes in BMI on costs, through adjusting for potential other influences (e.g. existing health conditions, such as type 2 diabetes, age, and socio-economic characteristics).

In the cost of illness review, we identified 9 papers that adopted a “top-down” approach and calculated costs of obesity for a population at a whole country level, as well as 5 papers that took a “bottom-up” approach by estimating costs at an individual level, e.g. calculation of the expected additional cost per person per year per unit increase in BMI. Both types of study are potentially useful, and the question regarding which is the more appropriate one is best answered according to the particular policy or research question to be addressed, which may itself be influenced by data availability and research resources. For example, a short-term study undertaken amongst individuals may require additional longer term modelling of BMI over time, and link BMI change to changes in disease risk, and so estimates from “bottom-up” studies may be useful for this purpose. On the other hand, in some situations it may be sufficient to use estimates from “top-down” studies, e.g. for evaluation of a policy change that was implemented in one part of the country but not another, where only comparative data are available on obesity prevalence, then cost of illness estimates may allow calculation of the net costs of the policy change. The two study types are not mutually exclusive, e.g. individual level costs can be multiplied with prevalence data to build up an estimate of the cost of illness for a whole country. There was only one example of that approach (Kent et al 2017).

We did not find any examples of incidence-based estimates of cost-of-illness – all studies which estimated cost of illness for a country used data on prevalence of obesity. It may be that data limitations precluded taking an incidence-based approach. It has been argued that incidence-based costs are more useful for estimating the likely impact of interventions that aim to prevent cases of overweight and/or obesity, or the likely impact of interventions at particular stages of a condition (Larg & Moss 2011).

Amongst the population wide intervention studies, all predict that these measures are likely to be cost-saving and cost-effective. The policy that has been most frequently evaluated is a tax on sugar-sweetened beverages (Collins et al 2015; Gortmaker et al 2015a; Gortmaker et al 2015b; Veerman et al 2016; Wang et al 2012). The evidence from these studies suggests that the health care cost savings would be predicted to outweigh the additional costs of the tax. Further, the level of savings appear substantial relative to the costs associated with the intervention. Fewer studies have considered other population-wide interventions such as advertising regulation and food labelling or subsidies (Cecchini et al 2010; Gortmaker et al 2015b; Magnus et al 2009; Sacks et al 2011).

We found that all of the estimates of cost-effectiveness were based on modelling studies. All of these studies are simplified representations of a complex system, typically involving a series of mathematical relationships to estimate outcomes of interest (Carter et al 2009). This is necessary as the impacts of obesity and overweight develop over many years, and so a robust assessment of cost of illness, or of the cost-effectiveness of population wide interventions, requires extrapolation from available data sources in order to estimate future consequences.

The estimates are therefore dependent on model assumptions, and it is therefore important that these assumptions are realistic. It is difficult to gauge the level of realism from a review of published articles, as not all of the details regarding the particular assumptions taken are contained within the articles. One key component of the estimates relates to the effectiveness assumption. Robust estimates of effectiveness are usually generated from evidence from randomised controlled trials, or quasi-experimental studies, and it is not clear whether this was the case in many of the studies; e.g. the sugar-sweetened tax studies tend to be based on data from cross-sectional studies, and extrapolate larger price changes than those observed in the data (Cash & Lacanilao 2007). Further, there are specific challenges in estimating demand functions; e.g. where the causes of price variation are demand-driven (for example, greater demand is likely to lead to price rise), then price elasticities (and therefore effectiveness) are likely to be over-estimated (Briggs et al 2013).

A fundamental assumption within all of the modelling studies relates to how the authors converted changes in dietary intake to changes in weight. The studies appear to be based on dynamic non-linear relationships between energy intake, expenditure and weight, to create more robust weight loss estimates. For example, Veerman et al 2016 use a model whereby each 100kj per day reduction results in an eventual body weight change of approximately 1kg, with half of the weight change achieved in one year, and 95% achieved within three years. However, the models do not always incorporate interactions with other behaviours (e.g. substitution sugar sweetened beverages with other products, or changes in physical activity levels), although these are addressed in sensitivity analysis. Further data to inform the choice of parameters in sensitivity analysis, including estimates regarding whether behaviour change is maintained in the longer term, will be very important to build into any future modelling studies, using information from countries which have introduced population level interventions.

An important question relates to transferability of study results from one country to another. There are many factors that can influence transferability, and these include the relevance of the comparator intervention, the characteristics of the study populations, differences in the costs of health care, between country differences in taxation, pricing, and differential regulation of food and drinks, including the relative availability of "unhealthy" and "healthy" food and drinks within schools, supermarkets and restaurants. Clearly the larger these differences, the more challenging it is to transfer results from one country to another. Identifying the potential price effect from a prior study and transferring elsewhere requires not only that these earlier studies adequately control for confounding factors, but also, that these data are available in the new setting where the results are to be applied.

We found that none of the modelling studies included productivity effects and costs. Their inclusion would have made the interventions appear more cost-effective and cost-saving than estimated. The main reason for the exclusion relates to the perspective adopted by the study, i.e. a study undertaken from a health care payer perspective would only include health care costs. Under these circumstances, the exclusion based on perspective is legitimate.

Very few studies considered and reported how cost-effectiveness may vary by socio-economic group or age group. This is somewhat surprising, especially for fiscal interventions, as there is evidence that younger people, and people with lower incomes, tend to be more responsive to price changes (Powell & Chaloupka 2009). Furthermore, not all studies included an assessment of intervention-related costs (e.g systems for implementation, monitoring and evaluation of the policy), and most tended to focus instead on future obesity-related disease costs offset. This might have led in some instances to an underestimate of the real incremental costs of an intervention when rolled out. Related to this, policies are implemented within a multi-stakeholder environment that requires engagement with industry bodies, and any additional cost associated with these activities needs to be borne in mind.

In terms of the limitations of our review, we focused solely on cost of illness studies relevant to Scotland, and also considered the published cost-effectiveness evidence base of population wide interventions that addressed dietary change. We did not include studies that examined the cost-effectiveness of individual-level interventions to reduce weight and/or obesity, and neither did we consider the *effectiveness* evidence of individual-level interventions or population wide interventions. For the purposes of de novo cost-effectiveness modelling of population wide interventions, or even for the purposes of using or adapting existing models, a systematic review of the effectiveness evidence, or a review of systematic reviews and meta-analyses, would be required. (An example of a relevant study here is published by Briggs et al 2013, who modelled the health effects of a tax on sugar-sweetened drinks using UK data, and explicitly considered substitution to other drinks, and estimated differential effects by income). Further, we did not consider public health interventions amongst people at high risk of obesity. For example, screening programmes to detect and manage type 2 diabetes amongst overweight and/or obese populations, were also excluded. These are being rolled out in England but not in Scotland.

In terms of recommendations for further research, given the lack of recent data from Scotland, and given the changes in the treatment and management of obesity-related conditions, it may be useful to explore the potential for linkage of existing secondary data sources such as the Scottish Health Survey with administrative health records from Scotland. For example, the Scottish Morbidity database contains data since 1981 relating to length of hospital inpatient stays, diagnostic information and operation and procedure information for the entire population resident in Scotland, and can be linked to the Scottish Health Surveys, which have been carried out in 1995, 1998, 2003, 2008 and thereafter annually. Estimation of productivity costs associated with overweight and obesity could also be included as part of the cost of illness estimation, as the Scottish Health Survey contains information relating to economic activity (current paid employment and time out of the labour force if not in current employment).

We found that there has been no recent estimate of the cost of overweight, obesity and diet-related illness for Scotland using up to date methods and data. However, the ScotPHO Global Burden of Disease project has begun the process of producing data related to obesity and this provides an opportunity to produce improved cost estimates for Scotland. Ideally, the ScotPHO estimates for obesity related burden of disease would be extended to consider the additional burden related to overweight and to diet-related illnesses that are not necessarily transmitted through BMI; for example, excessive consumption of salt or sugar are risk factors for hypertension and type 2 diabetes in normal weight individuals.

Additional research to improve the basis on which productivity costs are estimated is also required. This would help employers to identify the potential benefits to them of engaging with relevant aspects of the Scottish Government obesity strategy which is due to be the subject of consultation later in 2017. Improvements are required both in how we measure and how we value economic losses arising from potential reduced productivity at work, absence from work, unemployment and premature mortality.

An overarching issue to address would be the estimation of incidence based costs and not just prevalence-based estimates. Incidence-based costs are more helpful in estimation of the potential reduction in costs arising from successful interventions to reduce overweight and obesity. Other issues within the cost of illness which would be useful to explore would be the distribution of costs across the lifespan and by deprivation.

Finally, given the availability of existing models, their potential for adaptation to data from Scotland could be assessed. Initial focus could be placed on the model used by Cecchini et al 2010 to produce estimates for England relating to advertising regulation, compulsory food labelling and fiscal measures. However, a pre-requisite for further model development is prior knowledge of the effectiveness of population wide interventions for reduction of overweight and obesity. This information could be produced from a review of existing reviews of the evidence base relating to effectiveness of population-wide interventions.

Such a review should include information from longitudinal studies that have tracked longer term effects of policies on weight change and health.

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Appendices

Appendix 1

Medline & Embase search for cost of illness studies

Appendix 2

Cost of Illness studies – Data Extraction Template

Appendix 3

Medline & Embase search for economic evaluation studies

Appendix 4

Economic Evaluation studies – Data Extraction Template

Appendix 5

Summary of the main outcomes from the 10 studies included in the review of economic evaluations

Appendix 1
Medline & Embase search for cost of illness studies

1 exp Obesity/
2 Overweight/
3 (obes* or overweight).tw.
4 Weight Loss/
5 (weight adj1 (los* or reduc* or maint* or control* or manag*)).tw.
6 (obesity adj1 manage*).tw.
7 (anti-obesity or antiobesity).tw.
8 exp Anti-Obesity Agents/
9 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10 exp "Costs and Cost Analysis"/
11 Economics/
12 exp Economics, Hospital/
13 exp Economics, Medical/
14 Economics, Nursing/
15 Economics, Pharmaceutical/
16 exp Budgets/
17 ((health-care or healthcare) adj1 cost*).tw,kw.
18 (cost* adj2 estimate*).tw.
19 (economic* or price* or pricing* or pharmaco-economic* or pharmacoeconomic* or expenditure* or expense* or financ*).tw.
20 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19
21 9 and 20
22 exp united kingdom/ or ireland/
23 21 and 22
24 limit 23 to yr="2000 -Current"
25 limit 24 to english language
26 (letter or editorial or comment or note).pt.
27 25 not 26

Appendix 2
Cost of Illness studies – Data Extraction Template

IDENTIFICATION (Authors, Title, Pub year, Journal)	Definition of obesity	Diseases	Aim	Cost year reported	Type of Costs		Data used		Econometric model	Headline Results	Comments/Limitations
					Healthcare and related resource use	Production losses and Intangible burdens	Direct costs	Indirect Costs			
Comptroller and Auditor General, *Tackling Obesity in England*, 2001, NAO	BMI>30	Hypertension; Type 2 diabetes; Angina pectoris; Myocardial infarction; Osteoarthritis; Stroke; Gallstones; Colon cancer; Ovarian cancer; Gout; Prostate cancer; Endometrial cancer; Rectal cancer	Evaluation of direct and indirect costs in England in 1998	1998	Cost of consultations with general practitioners related to obesity, the cost of hospital admissions and outpatient attendances, and the cost of drugs prescribed to help obese patients lose weight.	Indirect costs of obesity related to earnings lost due to obesity and its consequences. These costs have two components: earnings lost due to premature mortality; and earnings lost due to sickness.	Data on general practitioner consultation rates, hospital inpatient admissions, and hospital outpatient attendances in England. These were then multiplied by published data on unit costs to derive an estimate of the NHS treatment costs for each disease. Prescription costs were taken directly from Prescription Cost Analysis reports for England. These cost estimates where then applied to data on relative risk and age- and sex-specific prevalence of obesity published in the Health Survey for England 19981 to give an estimate of the cost of treating the consequences of obesity.	Lost earnings due to sickness attributable to obesity were estimated using days of certified incapacity from 1 April 1997 to 31 March 1998. Figures for sickness attributed to obesity and its associated diseases were supplied by the Department of Social Security, detailing days of certified incapacity benefit by cause where a claim to benefit was made, drawn from a one per cent sample of claims to benefit in Great Britain. We estimated earnings lost due to premature mortality by first identifying from the literature review the best data on the proportion of all deaths that are attributable to obesity. These data were then applied to the number of age- and sex-specific deaths in England (taken from 'Key Population and Vital Statistics for England', Office of National Statistics) to estimate the number of deaths attributable to obesity in England in 1998. Data on residual life expectancy by age and sex were taken from the Annual		Direct costs of treating obesity in England in 1998 was £9.4 million. Costs of treating disease attributable to obesity was £469.9 million. Earnings lost due to premature mortality were £827 million and lost earning due to sickness absence were £1,322 million. Total cost of obesity in England in 1998 was £2.6 billion, or 0.3% of GDP.	Number of consultations for obesity likely to be underestimated as data was for 1991-92 and prevalence of obesity increased by 1998. No data available on consultations with practice nurses and dietitians in primary care. The costs of drugs also likely to be underestimated as principal drug used to treat obesity not licensed for most of 1998. There are a number of potentially important disease areas that were excluded from the analysis because of a lack of data to allow us to estimate the proportion of treatment costs that could be attributed to obesity. Some of the disease-specific studies from which relative risk was taken applied different cutoff points to define the obese and non-obese groups. Data on relative risk for most associated diseases were taken from international studies due to a lack of comparable data in the United Kingdom. Analysis of the direct costs attributable to obesity comprises only the costs of treatment provided by the National Health Service. It does not for example include the costs to Social Services. The estimate for lost earning due to sickened is almost certainly an underestimate for two reasons. Firstly, the days of absence recorded were based on medically certified days of incapacity where a claim to benefit was made. No data on self-certified days of sickness were available. And secondly, due to the lack of available information on the relative risk for obese individuals, sickness absence due to certain conditions known to be associated with obesity, such as back pain, was excluded from the analysis. Also, calculating lost earnings due to obesity on the basis of mean average earnings probably overstates the true cost. Data from the Health Survey for England show that the prevalence of obesity is higher in people with a lower household income. This indicates that the obese group earns less than the mean average earnings of the population as a whole. In the absence of data on the mean earnings of the obese group, however, mean average earnings offer the best proxy available.

IDENTIFICATION (Authors, Title, Pub year, Journal)	**Definition of obesity**	**Diseases**	**Aim**	**Cost year reported**	**Type of Costs: Healthcare and related resource use**	**Type of Costs: Production losses and Intangible burdens**	**Data used: Direct costs**	**Data used: Indirect Costs**	**Econometric model**	**Headline Results**	**Comments/Limitations**
								Abstract of Statistics and applied to the number of deaths to give an estimate of the years of life lost due to obesity.			
Walker A., *The Cost of Doing Nothing - the economics of obesity in Scotland,* 2003, Report - National Obesity Forum	BMI>25	Hypertension, Type 2 diabetes, Angina Pectoris, Myocardial Infarction, Osteoarthritis, Stroke, Gallstones, Colon Cancer, Ovarian Cancer, Gout, Prostate Cancer, Endometrial Cancer, Rectal Cancer	Apply NAO (Study 1) framework to Scottish data - for NHS costs only	2002	GP consultations, GP prescribing, hospital inpatient, outpatient and day patient		Cost data from Scottish Health Survey for prevalence of diseases. ISD data on cancer registrations. Scottish Continuous Morbidity Recording data for GP consultations. English data used where no Scottish data were available.			Total NHS cost for managing obesity and related costs estimated at more than £171 million for Scotland. Just 2% of the total was spent on directly treating obesity while 98% is spent on treating related diseases.	Includes 13 diseases associated with obesity but authors acknowledges there might be more not accounted for. Wider costs to society not included. Scottish data not available for all services included.
House of Commons Health Select Committee, *Obesity: Third report of session 2003/04*, The Stationery Office, London	BMI>30	All the ones included in the NAO report plus post-menopausal breast cancer, lower back pain (among women only), hyperlipidaemia; sleep apnoea and depression.	This report sets out to give a broad estimate of the cost of obesity in England. It uses the methodology employed by the NAO in Tackling Obesity in England. It updates the data used in that report, from 1998 figures to the latest available, which is 2002 in most cases. It extends the coverage of the calculations to look at a wider range of diseases that are attributable to obesity.	2002	GP consultations, Ordinary admissions, Day cases, Outpatient attendances, Prescriptions	Lost earnings due to attributable mortality and lost earnings due to attributable sickness.	Improved data sources (relative to the NAO report), most notably NHS Reference Costs which give more detailed and accurate cost information for different diagnosis/procedure groups. The unit cost figure for GP consultations used here is from the same source as the NAO but also includes an element for direct care staff.	Incapacity Benefit data was obtained from the Department for Work and Pensions on claimants with obesity and the other co-morbidities		The total cost of obesity in England was £3.3-3.7 billion in 2002. This is 27-42% above the figure given in *Tackling Obesity in England. A* significant part of this increase is due to the inclusion of new co-morbidities in this analysis. An estimated £390-435 million of the increase was due to this. The remaining increase was due to a combination of increased drug costs, take-up and availability, improved data, higher NHS costs and higher earnings (in the economy as a whole) as well as an increase in the number of people who are obese.	All the limitations of the NAO estimate apply to this updated version, specifically the exclusion of any social care data, incomplete data on primary care, reliance on international data on relative risk and the approximate nature of unit costs. The lack of cost data in certain important areas and the number of associated diseases that have not been included means that these figures are still likely to underestimate the true cost of treating obesity and its consequences.

IDENTIFICATION (Authors, Title, Pub year, Journal)	**Definition of obesity**	**Diseases**	**Aim**	**Cost year reported**	**Type of Costs**		**Data used**		**Econometric model**	**Headline Results**	**Comments/Limitations**
					Healthcare and related resource use	**Production losses and Intangible burdens**	**Direct costs**	**Indirect Costs**			
Vellinga, A., O'donovan, D. and De La Harpe, D., *Length of stay and associated costs of obesity related hospital admissions in Ireland*, 2008, BMC Health Services Research, 8(88)	Body mass index over the 95th percentile by age and gender	Overweight, obesity and other hyperalimentation (ICD-9 code 278)	The costs of obesity related illnesses was calculated for the Republic of Ireland from 1997 to 2004 for all children from 6 to 18 years of age and for adults.	2001	Direct hospital costs from obesity and obesity related conditions.		The Hospital In-Patient Enquiry (HIPE) is the principal source of national data on discharges from all acute hospitals. All principal (first listed diagnostic code) and secondary (second and higher codes) diagnoses were used. All discharges with obesity as first code were considered for obesity, obesity related discharges were defined as having a secondary code of obesity. Length of stay was recorded for each hospital stay related to obesity. The average hospital cost per day was derived from the report of the Commission on Financial Management and Control systems in Health Service.			Based on the 2001 figures for cost per inpatient bed day, the annual hospital cost was calculated to be 4.4 Euromillion in 1997, increasing to 13.3 Euromillion in 2004. At a 20% variable hospital cost the cost ranges from 0.9 Euromillion in 1997 to 2.7 Euromillion in 2004.	Due to the lack of personal identifiers in the HIPE database, it is impossible to estimate prevalence from the discharge frequency. Secondly, the dependence on consultants to record obesity is a shortcoming.
Counterweight Project, The, *Influence of body mass index on prescribing costs and potential cost savings of a weight management programme in primary care*, 2008, Journal of Health	BMI <25 kg/m2, 25–30 kg/m2 and >30 kg/m2		Quantify the influence of body mass index (BMI) on prescribing costs, and then the potential savings	2001	Drug costs		Paper and computer-based medical records were reviewed for all drug prescriptions over an 18-month period for 3400 randomly selected adult patients (18–75		Multivariate regression analysis was applied to estimate the cost for all drugs and the 'top ten' drugs at each BMI point.	Drug prescriptions rise from a minimum at BMI of 20 kg/m2 and steeply above BMI 30 kg/m2. Costs were greater by £5.27 (men) and £4.20 (women) for each unit increase in BMI, to a BMI of 25 (men £77.04, women £78.91), then by £7.78 and £5.53, respectively, to BMI 30 (men £115.93 women £111.23), then by £8.27 and £4.95 to BMI 40 (men £198.66, women £160.73). The	All economic analyses involve making assumptions; it was assumed that patients lost to follow-up prior to the 12 m data collection would, regardless of attendance up until this point, have no beneficial effect of having taken part in the intervention. These patients were considered, in the analysis, as having continued to gain weight as if no intervention had taken place. Had we adopted a last observation carried forward approach with these cases, the overall weight change of the treatment group would have resulted in a greater proportion of the cost of delivery of the programme being recouped as per the cost by BMI

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					Healthcare and related resource use	Production losses and Intangible burdens	Direct costs	Indirect Costs			
Services & Research Policy, 13(3), 158-66			attached to implementing a weight management intervention (18 month period between 2000 and 2002)				years) stratified by BMI, from23 primary care practices in seven UK regions. Drug costs from the British National Formulary at the time of the review were used.			relationship between increasing BMI and costs for the top ten drugs was more pronounced. Minimum costs were at a BMI of 20 (men £8.45, women £7.80), substantially greater at BMI 30 (men £23.98, women £16.72) and highest at BMI 40 (men £63.59, women £27.16). Attributable cost of overweight and obesity accounted for 23% of spending on all drugs with 16% attributable to obesity.	modelling. Some underestimation of total prescribing costs may have resulted from omission of people >75 years, in whom prescribing is known to be increased; if this were to generate bias, it would be to be more conservative. Data on prescribing savings from weight management are based on the modelling of costs at varying BMI levels and are therefore theoretical. These savings may not be seen in routine practice as there is reluctance to withdraw certain medications. There may also be more aggressive management, and hence increased prescribing, as patients undergo more intensive screening for CVD risk when attending a weight management clinic, but long term this may again lead to cost offsets. If over the years weight increase is attenuated or delayed a concomitant delay in diagnosis of patients to new or higher disease states should be expected. It is recognized that the benefits from reversing established obesity may be less than those resulting from primary prevention, since years of exposure to obesity may have effects on pathophysiology, e.g. obesity may alter the regulation of blood pressure permanently resulting in irreversible hypertension.
Scarborough, P., Bhatnagar, P., Wickramasinghe, K.K., Allender, S., Foster, C. and Rayner, M.	For overweight/ obesity, the theoretical minimum was taken to be the part of the distribution associated with the lowest risk, i.e. everyone in the population with a body mass index of 21 kg/m2.	Diabetes mellitus; Ischaemic heart disease; Ischaemic stroke; Hypertensive disease; Breast cancer; Colon/rectum cancer; Corpus uteri cancer; Osteoarthritis	This paper reports on an update of the estimates of the economic burden to the NHS of poor diet, physical inactivity, smoking, alcohol and overweight/ obesity to 2006–07 prices, using the updated data on cost by disease category.	2006-2007	Direct hospital costs from obesity and obesity related conditions.		2006–07 NHS costs by disease category from the NHS Programme Budgeting estimates for England from 2006 to 07. The disease-specific cost estimates were collected from all PCTs in England, who were asked to categorize all spending in primary and secondary care services into 23 broad and 57 more detailed disease categories, based on the tenth revision of the International Classification of Disease. The programme budgeting database only provides estimates for costs for the NHS in England. For each disease, we applied the percentage of all		(1) Identification of diseases where overweight/obesity are risk factors. (2) Identification of the total economic cost to the NHS in the UK for these diseases. (3) Identification of the population attributable fractions (PAFs) relating to the risk factors for each disease.(4) Application of these PAFs to economic cost data, to calculate the direct burden of those risk factors. (5) Sensitivity analysis for each estimate.	In 2006–07, overweight and obesity cost the NHS £5.1 billion.	The methods used to develop the estimates in this paper rely on the PAFs calculated by the WHO. These PAFs are based on broad WHO regions (specifically the EUR-A region of developed European countries with very low child and adult mortality) and as such they may not accurately represent the picture in the UK. This limitation has been addressed by a sensitivity analysis, which suggests that using EUR-A PAFs for the UK has very little impact on the estimated costs for alcohol consumption, physical inactivity and overweight/obesity. A separate but related issue is the uncertainty that accompanies these estimates of the cost of risk factors in the UK regarding the PAFs and the use of cause-specific NHS cost estimates. The WHO suggests that the uncertainty associated with the PAFs for physical inactivity, smoking and alcohol consumption is +10%, whereas the uncertainty for the overweight/obesity PAF is about +3%.21 The uncertainty of cause-specific NHS cost estimates provides a significant limitation of the estimates presented here. A further limitation is that the range of diseases associated with each risk factor was taken to be those for which the WHO has calculated a PAF, although there are possibly other additional conditions associated with these risk factors (e.g. physical activity and depression. The possible overlap between risk factors (such as overweight and obesity) was not addressed here but should be considered when calculating the total economic burden of these risk factors.

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					Healthcare and related resource use	**Production losses and Intangible burdens**	**Direct costs**	**Indirect Costs**			
							costs in England to the total budget of the NHS in the UK (under the assumption that the distribution of NHS costs between diseases in England will be broadly representative of the situation in the UK). The total budget of the NHS in the UK for 2006–07 was provided by combining budgets for the NHS in England, Scotland, Wales and Northern Ireland.				
Wang YC, McPherson K, Marsh K, Gortmaker SL, Brown M., *Health and economic burden of the projected obesity trends in the USA and the UK*, 2011, The Lancet, Volume 378, Issue 9793, 27 August–2 September 2011, Pages 815-825	*BMI>=31*	Coronary heart disease; hypertension; diabetes; stroke; cancer; arthritis	Projection of the probable health and economic consequences in the next two decades (2010-30) from a continued rise in obesity in two ageing populations—the USA and the UK.	2010-2030	Excess annual costs of each disease due to rising obesity.		16 waves of HSE from 1993 to 2008 to produce the historic trend, and the 2001–08 surveys to produce the recent trend. A review of epidemiological publications was undertaken to determine country-specific incidence, case-fatality rates, and rough annual treatment costs for the obesity-related diseases of type 2 diabetes, coronary heart disease, stroke, arthritis, and obesity-related cancer, by age and BMI. Excess annual costs of each disease due to rising obesity were obtained from estimates from governmental		Simulation model.Two-part modelling process developed by the UK Foresight working group. The first module implements a regression analysis based on series of cross-sectional data; the second module implements a microsimulation programme to produce longitudinal projections.	Trends project 11 million more obese adults in the UK by 2030. The combined medical costs associated with treatment of obesity related preventable diseases are estimated to increase by £1·9–2 billion/year in the UK by 2030.	The surveys used were not perfectly representative: HSE only represents England, but not Scotland, Northern Ireland, or Wales. In addition to data inputs, the study had several other limitations. The model only partly addressed the differences in medical costs by category of obesity (ie, severely obese individuals use many more health services than do moderately obese individuals) and by demographic factors such as ethnicity and socioeconomic status. Mathematical assumptions had to be made —for example, to ensure the simulated population would produce BMI distributions that matched cross-sectional data – such as that BMI rankings between same-aged individuals were the same over time. This assumption, however, is likely to have a small effect because an individual’s bodyweight tracks strongly over time, and instances of substantial weight gain or weight loss are likely to negate each other when summed across the whole population. Because of the 20-year timeframe, the future effect of childhood obesity was probably underestimated. High bodyweight early in life increases future cardiovascular disease risk, independent of adult BMI. Finally, projections incorporated population ageing, but have not accounted for other less predictable, but important, population changes such as immigration, health-care system reform, or technological advances for disease treatment.

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					Healthcare and related resource use	**Production losses and Intangible burdens**	**Direct costs**	**Indirect Costs**			
							data or the best available published work (detailed in table 1 of paper).				
Tigbe, W.W., Briggs, A.H. and Lean, M.E., *A patient-centred approach to estimate total annual healthcare cost by body mass index in the UK Counterweight programme*, 2013, International Journal of Obesity, 37(8), 1135-9	BMI <25, 25–30 and >30		The present study quantifies the relationship between BMI and total healthcare expenditure , with the patient as the unit of analysis by direct linkage of obesity or BMI data to healthcare expenditure at the individual level	2002-2003	Total healthcare expenditure		Healthcare data included appointments with the general practitioner, practice nurse, health visitor, dietitian and outpatient specialist appointments. They also included accident and emergency attendance and hospital admissions, healthcare consumption at the primary care, outpatient and inpatient costs were calculated based on these indices, adding drug prescription costs.		Analysis of variance was used to explore differences in healthcare costs across each lifestyle factor. In multivariate analyses, the best-fit model was constructed checking for assumptions of linearity, constancy of variance and normality. Annual healthcare costs at quintiles of BMI were compared to assess associations with BMI. Multiple linear regression-modelled change in annual healthcare cost per unit change in BMI. Annual healthcare cost associated with each unit of BMI, adjusting for age, sex and lifestyle (the marginal effect) was obtained. A two-part model, to calculate the association on condition that cost has been incurred, was also tested.	Adjusted total annual healthcare cost was £16 (95% CI d11–d21) higher per unit BMI. All cost categories were significantly (P<0.003) higher for those with BMI >40 compared with BMI <20 kgm_2: prescription drugs (men: £390 versus £16; women: £211 versus £73), hospitalisation (men: £72 versus £0; women: £243 versus £107), primary care (men: £191 versus £69; women: £268 versus £153) and outpatient care (£234 versus £107 women only).	A limitation of the project was variation in how and when weight and height were measured. In this study, height was generally by self-report. Alcohol, smoking and physical activity were self-reported, so the reliability of these measurements is weak. Also, the data in medical records did not include information on education, occupation or socio-economic status, which are important determinants of health and healthcare use.
Castle, A. , *SPICe Briefing – Obesity in Scotland: 15/01*, 2015, Edinburgh: Scottish Parliament	Varies across studies		This paper uses estimates from several previous studies and adjusts them for inflation.	2014/15			Inflation index to uprate costs			For the 3 studies considering health care costs estimates were £223 million, £363 million and £600 million. Costs increased with more recent studies at least in part because of increasing prevalence. Including lost earnings produced an estimate of £860-970 million. Total economic impact estimated in one study as £4.6 billion.	All studies had data limitations and the methodologies are not directly comparable.

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					Healthcare and related resource use	**Production losses and Intangible burdens**	**Direct costs**	**Indirect Costs**			
Dee, A., Callinan, A., Doherty, E., O'neill, C., Mcveigh, T., Sweeney, M.R., Staines, A., Kearns, K., Fitzgerald, S., Sharp, L., Kee, F., Hughes, J., Balanda, K. and Perry, I.J., *Overweight and obesity on the island of Ireland: An estimation of costs*, 2015, BMJ Open, 5 (3)	*BMI≥25*	Cancer of the colon; Cancer of the oesophagus; Cancer of the gallbladder; Cancer of the pancreas; Cancer of the breast; Cancer of the kidney; Type 2 diabetes; Cancer of the endometrium; Obesity; Hypertension; Stroke Ischaemic heart disease; Gallbladder disease; Pulmonary embolism; Low back pain; Asthma	This study aims to estimate the healthcare and productivity costs of overweight and obesity for the island of Ireland in 2009, using both top-down and bottom-up approaches .	2009	Healthcare utilisation and drugs costs	Work absenteeism and Premature mortality	Population attributable fractions (PAFs) calculated by age and gender were applied to national cost data analysis of hospital inpatient, day cases and also prescribing data in the ROI and NI. There were no data availability for which general practitioner (GP) costs could be analysed from a top-down approach, so we based our estimates on work previously carried out by this group, using a bottom-up approach. (Table 1 in the paper outlines the data sources).	PAFs were applied to social welfare data and to national mortality data to calculate the productivity costs due to absenteeism and premature mortality. (Table 1 in the paper outlines the data sources).	Costs were estimated across four categories: healthcare utilisation, drug costs, work absenteeism and premature mortality. Healthcare costs were estimated using Population Attributable Fractions (PAFs). PAFs were applied to national cost data for hospital care and drug prescribing. PAFs were also applied to social welfare and national mortality data to estimate productivity costs due to absenteeism and premature mortality.	The healthcare costs of overweight and obesity in 2009 were estimated at €437 million for the Republic of Ireland (ROI) and €127.41 million for NI. Productivity loss due to overweight and obesity was up to €865 million for ROI and €362 million for NI.	Dee, A., Callinan, A., Doherty, E., O'neill, C., Mcveigh, T., Sweeney, M.R., Staines, A., Kearns, K., Fitzgerald, S., Sharp, L., Kee, F., Hughes, J., Balanda, K. and Perry, I.J., *Overweight and obesity on the island of Ireland: An estimation of costs*, 2015, BMJ Open, 5 (3)
Gupta, S., Richard, L. and Forsythe, A., *The humanistic and economic burden associated with increasing body mass index in the EU5*, 2015, Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 8(327-338)	Normal weight (BMI ≥18.5 kg/m2 and BMI <25 kg/m2), overweight (BMI ≥25 kg/m2 and BMI <30 kg/m2), Obese Class (OC) I (BMI ≥30 kg/m2 and BMI <35 kg/m2), OC II (BMI ≥35 kg/m2 and BMI <40 kg/m2), and OC III (BMI ≥40 kg/m2)		This study evaluated the association of body mass index (BMI) with health-related quality of life (HRQoL), health utilities, health care resource utilization, productivity , activity impairment, and the associated costs.	2013	Cost of traditional provider visits, cost of ER visits, and hospitalization cost	Costs associated with loss in productivity	Total direct costs constituted of three components, including cost of traditional provider visits, cost of ER visits, and hospitalization cost.	Total indirect costs were estimated for each respondent using the human capital method. Wages were multiplied by the percentage of work productivity impairment and then annualized to provide an estimate of the projected annual costs associated with loss in productivity. The Work Productivity and Activity Impairment questionnaire, General Health version, was used to calculate the loss in productivity (ie, absenteeism and presenteeism). The median annual income (18 years or older) was	Generalized linear regression models predicted outcomes as a function of BMI, adjusting for covariates (age, sex, comorbidities).	After adjustments, indirect costs increased as BMI increased. OC II and III respondents were found to have significantly greater absenteeism and presenteeism costs than normal weight respondents. Among the employed, all three OC respondents had significant higher indirect costs than normal weight respondents. Assuming 100% missed work for the unemployed respondents who were employable (18–60 years), an increase in BMI had a significant impact on indirect costs. After adjusting for covariates, total direct costs due to provider visits, ER visits, and hospitalizations increased as BMI increased. Overweight and all three OC respondents had greater provider visit-related costs and total direct costs than normal weight respondents. OC II and III respondents were found to have significantly greater ER visit-related costs than normal weight respondents. No difference was found between normal weight and the hospitalization-related costs of the three OC respondents	Whereas Internet-based surveys are cost-effective and able to reach a large number of potential respondents, the results may not be generalizable to all obese adults in the EU5, as the Internet-based study design may have limited representation of some groups. Further, the data collected were self-reported by respondents, and thus are vulnerable to recall bias and were not able to be independently verified (eg, patient's height, weight, and diagnosis of comorbidities). Only three measures of resource use and two measures of work-related productivity loss were provided in this study, and they were assessed with respect to respondents' health condition in general, such that precise reasons for resource use or work-related productivity loss are unknown. Finally, the data reported are cross-sectional in nature and do not allow for causal inferences to be made. Further, whereas the BMI classification system possesses important utility in studying population health, it is not without its limitations. BMI can be biased when based on self-reported height and weight, with individuals traditionally overestimating their height and underestimating their weight. In addition, BMI classifications can be inaccurate for certain groups (eg, professional athletes or those possessing a high level of muscle mass).

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					Healthcare and related resource use	Production losses and Intangible burdens	Direct costs	Indirect Costs			
								obtained for each EU5 country from Eurostat 2012 annual net income figures			
Rudisill, C., Charlton, J., Booth, H.P. and Gulliford, M.C., *Are healthcare costs from obesity associated with body mass index, comorbidity or depression? Cohort study using electronic health records*, 2016, Clinical Obesity, 6(3), 225-231	Eligible participants' BMI records were evaluated using the categories 18.5–24.9; 25.0–29.9; 30.0–34.9; 35.0–39.9; 40.0–44.9 and 45.0 kg m−2 and above.	Morbidities, including T2DM - type 2 diabetes, CHD – coronary heart disease, stroke and depression were evaluated using medical codes reported previously, while cancer diagnoses were evaluated using codes for malignant neoplasms.	The objective of this study was to evaluate the association between body mass index (BMI) and healthcare costs in relation to obesity-related comorbidity and depression.	2013	The analysis was undertaken from a health service provider perspective (UK National Health Service) and did not consider indirect costs such as loss of productivity or patient and carer time.		Health care utilization was estimated from participants' electronic health records with linked hospital episode statistics (HES) data. Primary and secondary care utilization was evaluated, including primary care consultations at the practice, by telephone, at home, emergency and out-of hours. Secondary care utilization included admissions to hospital, out-patient, day case and emergency visits. Unit costs were applied to the categories of healthcare utilization to estimate healthcare costs. The unit costs were all taken from reference sources based on UK£ 2013 price estimates. The Personal Social Service Research Unit (PSSRU) publication 'Unit Costs of Health and Social Care (2013) was used as the reference for all healthcare costs. To assess prescription costs, Gemscript		A two-part model was used to analyse healthcare costs. In the first stage, a probit model was employed to estimate the probability of healthcare utilization being nonzero. In the second stage, a generalized linear model (GLM), with a log link and gamma errors, was used to evaluate the distribution of costs in participants who utilized health care. This predicted mean costs of care, as the product of the probability of utilizing care and mean costs of care, for men and women in different BMI and morbidity categories for each year of age. In the final stage of analysis, a linear regression model was employed to estimate the effects of the BMI category, comorbidity and depression on predicted healthcare costs, controlling for patient gender and age. Interaction terms for comorbidity and depression and comorbidity and BMI category were included. In order to make the data sufficiently concise	Annual healthcare costs increased with BMI, to a mean of £456 (95% CI 344–568) higher for BMI ≥40 kg m−2 than for normal weight based on a general linear model. After adjusting for BMI, the additional cost of comorbidity was £1366 (£1269–£1463) and depression £1044 (£973–£1115). There was evidence of interaction so that as the BMI category increased, additional costs of comorbidity (£199, £74–£325) or depression (£116, £16–£216) were greater. High healthcare costs in obesity may be driven by the presence of comorbidity and depression. Prioritizing primary prevention of cardiovascular disease and diabetes in the obese population may contribute to reducing obesity-related healthcare costs.	One possible limitation of the study is selection bias from inclusion of participants with a BMI recorded during a clinical consultation, who may be more frequent users of healthcare services and therefore less healthy. Participants' morbidity status was classified using the first diagnosis they received, and we have not accounted for additional diagnoses. The costs associated with the conditions we have highlighted may represent costs from multiple morbidities, which are more frequent in obese patients and we know were present in 18% of the observations. The economics literature has moved towards using an instrumental variables approach to examine the causal effect of obesity on medical costs by using the weight of a biological relative as an instrument. The argument for this method is that the instrument predicts the participants' weight but not their morbidity status, meaning that the effect of weight on costs can be isolated. Such papers have found higher healthcare costs for obesity than noninstrumented methods, so it is possible our models underestimate the magnitude of the relationship.

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					Healthcare and related resource use	**Production losses and Intangible burdens**	**Direct costs**	**Indirect Costs**			
							drug codes for prescriptions in the electronic health records were linked with prescription costs from a dictionary compiled by RESIP UK (Chertsey, Surrey, UK).		for presentation, the comorbidities of T2DM, CHD, stroke and cancer were combined into a single category of 'comorbidity' present or absent for the linear regression analysis.		
Kent, S., Green, J., Reeves, G., Beral, V., Gray, A., Jebb, S.A., Cairns, B.J., Mihaylova, B., Abbiss, H., Abbott, S., Alison, R., Armstrong, M., Baker, K., Balkwill, A., Barnes, I., Beral, V., Black, J., Blanks, R., Bradbury, K., Brown, A., Cairns, B., Canoy, D., Chadwick, A., Ewart, D., Ewart, S., Fletcher, L., Floud, S., Gathani, T., Gerrard, L., Goodill, A., Green, J., Guiver, L., Heath, A., Hogg, D., Hozak, M., Lingard, I., Kan, S.W., Langston, N., Moser, K., Pirie, K., Price, A., Reeves, G., Shaw, K., Sherman, E., Simpson, R., Strange, H., Sweetland, S., Tipper, S., Travis, R., Trickett, L., Webster, A., Wotton, C., Wright, L., Yang, O., Young, H., Banks, E., Beral, V., Carpenter, L., Dezateux, C., Green, J., Patnick, J., Peto, R. and Sudlow, C., Hospital costs in relation to body-mass index in 1.1 million women in	BMI category (18·5 to <20 kg/m^2, 20 to <22·5 kg/m^2, 22·5 to <25 kg/m^2, 25 to <27·5 kg/m^2, 27·5 to <30 kg/m^2, 30 to <35 kg/m^2, 35 to <40 kg/m^2, and 40 kg/m^2 or more). Underweight women were excluded from analysis because of the substantial potential for reverse causality and residual confounding, and the small proportion of such women in the sample (<1%).	Overall and specific health conditions.	We describe and quantify the relation between BMI and costs of hospital inpatient and day-case care, both overall and for specific health conditions, using individual participant data from a large cohort of women older than 50 years in England that is linked to routinely collected hospital admission data. Women in England aged 50–64 years were recruited into the prospective Million Women Study cohort in 1996–2001 through 60 NHS breast cancer screening	2012	Costs of hospital inpatient and day-case care, both overall and for specific health conditions.		Each HES episode (defined as care under a particular consultant) was allocated to a health-care resource group, the classification system used to describe hospital activity in the UK. We calculated the cost of each hospital admission (in UK 2012 prices) as the sum of the costs of all episodes within the admission. The costs do not include outpatient attendances or costs for prescription drugs individuals were taking outside of their hospital stay.		Separate estimates for annual hospital costs, annual admission rates by BMI category, percentage increases in annual costs, and admission rates per 2 kg/m^2 increase in BMI (a change in weight of approximately 5 kg for a woman of average height [162 cm] in England) in women with a BMI above 20 kg/m^2 were calculated overall and for each diagnostic category with generalised linear models with a log-link function and Poisson variance. In all models further adjustments were made for age (in 5 year bands), region of recruitment (nine regions corresponding to the areas covered by the cancer registries in England), quintiles of socioeconomic status based on the Townsend deprivation index, parity (nulliparous, 1, 2, or ≥3), age at first birth (<25 years, 25–29 years, or ≥30 years), smoking (never, past, or current),	Excess body weight is associated with increased hospital costs for middle-aged and older women in England across a broad range of conditions, especially knee replacement surgery and diabetes. Annual hospital costs were lowest for women with a BMI of 20·0 kg/m^2 to less than 22·5 kg/m^2 (£567 per woman per year, 99% CI 556–577). Every 2 kg/m^2 increase in BMI above 20 kg/m^2 was associated with a 7·4% (7·1–7·6) increase in annual hospital costs. Excess weight was associated with increased costs for all diagnostic categories, except respiratory conditions and fractures. £662 million (14·6%) of the estimated £4·5 billion of total annual hospital costs among all women aged 55–79 years in England was attributed to excess weight (BMI ≥25 kg/m^2), of which £517 million (78%) arose from hospital admissions with procedures. £258 million (39%) of the costs attributed to excess weight were due to musculoskeletal admissions, mainly for knee replacement surgeries.	Kent, S., Green, J., Reeves, G., Beral, V., Gray, A., Jebb, S.A., Cairns, B.J., Mihaylova, B., Abbiss, H., Abbott, S., Alison, R., Armstrong, M., Baker, K., Balkwill, A., Barnes, I., Beral, V., Black, J., Blanks, R., Bradbury, K., Brown, A., Cairns, B., Canoy, D., Chadwick, A., Ewart, D., Ewart, S., Fletcher, L., Floud, S., Gathani, T., Gerrard, L., Goodill, A., Green, J., Guiver, L., Heath, A., Hogg, D., Hozak, M., Lingard, I., Kan, S.W., Langston, N., Moser, K., Pirie, K., Price, A., Reeves, G., Shaw, K., Sherman, E., Simpson, R., Strange, H., Sweetland, S., Tipper, S., Travis, R., Trickett, L., Webster, A., Wotton, C., Wright, L., Yang, O., Young, H., Banks, E., Beral, V., Carpenter, L., Dezateux, C., Green, J., Patnick, J., Peto, R. and Sudlow, C., Hospital costs in relation to body-mass index in 1.1 million women in England: a prospective cohort study, 2017, The Lancet Public Health, published online April 5, 2017

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					Healthcare and related resource use	**Production losses and Intangible burdens**	**Direct costs**	**Indirect Costs**			
England: a prospective cohort study, 2017, The Lancet Public Health, published online April 5, 2017			centres. Participants were followed up and annual hospital costs and admission rates were estimated for April 1, 2006, to March 31, 2011, in relation to body-mass index (BMI) at recruitment, overall and for categories of health conditions defined by the International Classification of Diseases 10th revision chapter of the primary diagnosis at admission. Associations of BMI with hospital costs were projected to the 2013 population of women aged 55–79 years in England.						alcohol intake (rarely or never, <7 units per week, or ≥7 units per week), educational qualifications (no qualifications, secondary, technical, or tertiary), HES data year, and the proportion of each HES year with contributed data (some years were incomplete; for example, due to emigration).		

Appendix 3
Medline & Embase search for economic evaluation studies

#	Searches
1	*Economics/
2	exp "Costs and Cost Analysis"/
3	(economic adj2 model*).mp.
4	(cost minimi* or cost-utilit* or health utilit* or economic evaluation* or economic review* or cost outcome or cost analys?s or economic analys?s or budget* impact analys?s).ti,ab,kf,kw.
5	(cost-effective* or pharmacoeconomic* or pharmaco-economic* or cost-benefit or costs).ti,kf,kw.
6	(life year or life years or qaly* or cost-benefit analys?s or cost-effectiveness analys?s).ab,kf,kw.
7	(cost or economic*).ti,kf,kw. and (costs or cost-effectiveness or markov).ab.
8	1 or 2 or 3 or 4 or 5 or 6 or 7
9	exp Obesity/
10	Overweight/
11	(obes* or overwieght*).tw.
12	Weight Loss/
13	(weight adj (loss* or reduc* or maint* or control* or manag*)).tw.
14	(obesity adj1 manag*).tw.
15	(anti-obesity or antiobesity).tw.
16	*Diet/ or *Healthy Diet/ or *Feeding Behavior/
17	nutrition*.hw.
18	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
19	8 and 18
20	Public Health/
21	exp Health Promotion/
22	Community Health Services/
23	Preventive Health Services/
24	Primary Prevention/
25	Program Evaluation/
26	exp Health Education/
27	21 or 22 or 23 or 24 or 25 or 26
28	(population* or communit* or societ* or region* or nation* or macro*).tw,kf.
29	27 and 28
30	exp Nutrition Policy/
31	Food Labeling/
32	Social Marketing/
33	exp Mass Media/
34	(advert* or media or campaign* or tax* or regulat* or legislat*).tw,kf.
35	30 or 31 or 32 or 33 or 34
36	20 or 29 or 35
37	8 and 18 and 36
38	37 not (Animals/ not (Animals/ and Humans/))
39	(letter or editorial or comment or note).pt.
40	38 not 39
41	limit 40 to (english language and yr="2000 -Current")
42	limit 41 to "review articles"
43	43 limit 41 to yr="2014 -Current"

Appendix 4
Economic Evaluation studies – Data Extraction Template

Study Authors, Year, Country, and study type (CoI, CMA, CCA, CEA, CBA), Funder	Decision problem (study question, PICO)	ANALYTICAL APPROACH			DATA USED			RESULTS AND ANALYSIS		Key limitations (study quality, extent of generalisability to Scotland	Comments
		Model structure, perspective, and scope (basic structure, and key assumptions)	Modelling of obesity progression and complications (yes/no; key assumptions used)	Time horizon and mortality (how mortality changes were calculated)	Costs (types of direct and indirect resource use included, and measurement methods)	Clinical, Effectiveness data	Outcomes (types of outcomes reported and measurement / extrapolation methods)	Findings ("headline" results of the base-case analysis, "headline" results from sub-group analyses)	Sensitivity analysis (types of sensitivity analysis conducted, and sensitivity of headline findings to these analysis)		
Cecchini et al. 2010 Multinational modelling study UK (England), Brazil, China, India, Mexico, Russia, South Africa CEA/CUA Funding: none reported, but possible OECE/WHO?	**Aims:** The study examined the cost-effectiveness of various population-based interventions designed to tackle the global burden of obesity by encouraging healthier diets and increased physical activity **Population:** children, adults, different age groups targeted **Intervention(s):** ● **Food advertising regulation** targeted to children ages 2-18. The intervention is intended to limit children's exposure to food advertising on television, particularly in programmes primarily aimed at children and during times of the day when a large proportion of the audience is made up by children in the above age group. The best evidence currently available on the impact of restrictions on food advertising concerns the advertising of fast food (Chou et al., 2008), therefore the intervention designed for the analysis focused on this type of advertising. Two	**Micro-simulation model** (the chronic disease prevention [(**CDP**]) model developed by OECD + WHO. The model connects risk factors to three groups of chronic diseases (cancers, stroke, ischaemic heart disease). The model simulates the population dynamics of a specific country **Cost perspective** not explicitly stated. The CDP **model** included distant risk exposures (several steps away from disease in causation), as well as proximate risk exposures (more closely connected). Disease specific incidence & prevalence in the population of a specific country were matched to recorded (marginal) distributions of risk factors via a calibration procedure, which ensured that the observed distributions were mutually compatible and consistent. Births, deaths, and the incidence and prevalence of risk factors and chronic diseases are	Obesity progression modelled as a series of causal risk factors/exposures including: **Distant/al risk factors** - Fibre (adequate/ low fibre intake) - Fat (low/ medium/ high fat intake) - Physical activity (adequate/insufficient) **Intermediate risk factors** - Body-mass index (normal weight, pre-obesity, obesity) **Proximal risk factors** - Blood pressure (normal, hypertension) - Cholesterol (normal, hypercholesterolemia) - Glycaemia (Normal, Diabetes) **Disease events** - Cancers (including lung, colorectal, and female breast cancer) - Stroke - Ischaemic heart disease	A lifetime horizon (set to 100 years), 20 and 50 years were also considered BMI is directly linked to proximal risk factors, which are then linked to the probability of developing chronic disease events; the incidence of IHD, stroke. BMI (an intermediate risk factor) and fibre (a distal risk factor) are also modelled as directly linked to developing chronic disease events (IHD, Stroke, Cancers). Mortality from all causes of death modelled. Assumes mortality rates for diseases not explicitly modelled remain stable, at rates recorded in the relevant populations	**Types of costs:** per person costs of health services (hospital or primary care visits, prescribed drugs, and diagnostic tests) and the programme costs (administration, training, mass media, and other activities). **Cost estimation approach**: all economic data were from published sources or official listings in each country standardised approach using information on resource use quantities and their respective unit costs US dollars ($), price year 2005, 3% annual discount rate applied ● **Fiscal measures intervention related costs** included basic administration, planning, monitoring, and enforcement at the national level. The latter in particular accounts for most of the cost. Potential revenues from the tax, as well as	The clinical data were from a variety of sources; national health surveys, published studies, the WHO, the United Nations Food and Agriculture Organization, the International Agency for Research on Cancer, the US National Health and Nutrition Examination Survey, and the Health Survey for England. (The epidemiological data were generally from local sources and varied between countries). The impact of reduced obesity on cancer, ischaemic heart disease, and stroke was assumed to be the same for all countries and was from large published cohort studies. Effectiveness data was from a WHO review of published studies on the effectiveness of interventions to improve diets and increase physical activity. (WHO. 2009. Intervention on diet and physical activity: what works. Geneva: World Health Organization) and additionally a number of studies retrieved	**DALYs** averted, Life-years saved (due to the reduction in disease events, the latter not reported) Utility valuations not reported? 3% annual discount rate applied to benefits	In England, after 50 years, the number of DALYs saved (per million population) were 6,049 with fiscal measures, 2,179 with food advertising, and 4,019 with food labelling. The costs for each intervention were not reported separately alongside the DALYs. The incremental cost-utility ratios (over no intervention) were cost saving with fiscal measures, $4,278 with food advertising regulation, and $5,268 with food labelling. The authors stated that in England, US$50 000 DALY is a threshold adopted by the UK's National Institute for Health and Clinical Excellence to denote that an intervention is cost effective. All the interventions were favourable and were either cost saving or within the C/E threshold. Fiscal measures provided the greatest value for money.	A probabilistic sensitivity analysis was carried out, and the analysis and results were reported in an online appendix. The results were quite stable to variations in the model parameters.	Clinical data, resource use and unit costs were generally from appropriate local sources and which should reflect the England setting, but resource use wasn't presented separately. Other data were from official sources such as the WHO, or the United Nations Food and Agriculture Organization, which are likely to provide valid estimates. DALYs were an appropriate benefit measure, but the source of the utility weights (for DALYs) was not clearly reported. Cost perspective used likely to be third-party payer. More detailed information are likely to be described in the online appendix and the related Sassi et al. 2009 OECD Report. Analysis compared each intervention with no intervention, and not against each other. Overall parameter uncertainty in ("headline") results were examined in a PSA, but one-way/deterministic SA not investigated to e.g. identify key drivers in the results.	The CDP model was originally applied to the European A WHO region under the scrutiny of an expert group convened by the OECD. Additional related report by Sassi et al (2009) with further details on the CDP (Chronic Disease Prevention) modelling approach: http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=delsa/hea/wd/hwp(2009 NHS EED abstract and commentary available

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		Model structure, perspective, and scope (basic structure, and key assumptions)	Modelling of obesity progression and complications (yes/no; key assumptions used)	Time horizon and mortality (how mortality changes were calculated)	Costs (types of direct and indirect resource use included, and measurement methods)	Clinical, Effectiveness data	Outcomes (types of outcomes reported and measurement / extrapolation methods)	Findings ("headline" results of the base-case analysis, "headline" results from sub-group analyses)	Sensitivity analysis (types of sensitivity analysis conducted, and sensitivity of headline findings to these analysis)		
	versions of the intervention were assessed in the analysis: the first involving formal government regulation introduced by law and enforced by communication authorities; the second involving self-regulation by the food industry and broadcasters, with the government acting only in a monitoring and supervisory role. ● **Compulsory food labelling** the intervention is intended to affect all consumers. The intervention entails the adoption of a mandatory food labelling scheme for food sold in stores. Labels will deliver information about nutrient contents and serving size. Retailers will post information about how to read labels and about the benefits of a healthy diet. The intervention does not involve other forms of communication. The accuracy of the information reported on labels is verified through an extensive programme of food inspection. ● **Fiscal measures** (taxes and subsides) targeted at the whole population that will both increase the price of foods with a high fat content (e.g. many dairy products) by 10% and will decrease	modelled on the basis of best existing epidemiological evidence for the relevant countries from a range of sources including national health surveys, the WHO, the UNI Food and Agriculture Organization, the International Agency for Research on Cancer, the US National Health and Nutrition Examination Survey, and the Health Survey of England.			expenditures originating from the subsidy, are not accounted for in the analysis, as they represent transfers rather than costs. Tax operating costs, also not included in the analysis, may be driven by a broad range of factors (associated with the nature of the tax base or with characteristics of the tax) which makes it difficult to generalise existing estimates to new taxes or settings. A review of studies up to 2003 concluded that "studies that do address administrative costs suggest that they rarely exceeded 1% of the revenue yield, and more usually come in well below 1% (Evans 2003) ● **Regulation of food advertising to children intervention related costs** included basic administration costs at the national and local levels, as well as monitoring and enforcement costs. In addition, minor training may be required for communication authority staff charged with the task of overseeing the implementation of the scheme. ● **Compulsory**	which were not covered in the WHO review because published after June 2006, not indexed in the literature databases used in the review, or because the relevant interventions were out of the scope of the review. Studies were selected based on those that appeared particularly strong because of the size of the sample, the duration of the study and the robustness of the experimental design. For most of the interventions the authors stated they were able to retrieve multiple studies. In this case, they identified studies which adopted homogenous interventions and combined results. ● **Fiscal measures** altering the prices of fruit and vegetables and foods high in fat - effects modelled only through changes in consumption of fat and fruit and vegetables, based on some of the most conservative estimates of the price elasticity of demand for foods high in fat and for fruit and vegetables, among the nine studies reviewed in a French Government report (Hespel & Berthod-Wurmser 2008 ● **Regulation of food advertising to children** - the effects of children's exposure				Assumptions needed for the long-term effects of the interventions. The results are likely transferable to Scotland with similar income and epidemiological characteristics. The methods were conventional and the results appear to be robust. The webappendix and Sassi et al. 2009 (OECD) report should be consulted for further details on the data sources and some of the methods not clearly presented in the paper itself.	

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		Model structure, perspective, and scope (basic structure, and key assumptions)	Modelling of obesity progression and complications (yes/no; key assumptions used)	Time horizon and mortality (how mortality changes were calculated)	Costs (types of direct and indirect resource use included, and measurement methods)	Clinical, Effectiveness data	Outcomes (types of outcomes reported and measurement / extrapolation methods)	Findings ("headline" results of the base-case analysis, "headline" results from sub-group analyses)	Sensitivity analysis (types of sensitivity analysis conducted, and sensitivity of headline findings to these analysis)		
	the price of fruit and vegetables in the same proportion. No assumptions are made as to what specific measures should be taken to achieve those price changes. **Comparison:** interventions were compared against no preventive policy **Outcome**: the effect of the interventions in reducing obesity and its consequences (on chronic disease prevention); on the incidence of ischaemic heart disease and stroke, and, to a lesser extent, the incidence of cancer				**food labelling intervention related costs** included basic administration, planning, enforcement, preparation and distribution of posters and, finally, resources needed to managed the programme of food inspection. The programme does not account for the additional packaging costs associated with designing printing nutrition labels and fro the potential costs associated with the reformulation of certain foods, likely to be borne by the private sector.	to (fast) food advertising on BMI was estimated on the basis of the findings reported by Chou et al. 2008. The impact of government regulation on children's exposure to food advertising was based on an evaluation of the impact of OFCOM's regulatory measures in the UK (OFCOM 2008). ● **Compulsory food labelling** - main sources of evidence on intervention characteristics and effectiveness were based on evidence provided in Variyam and Cawley (2006) and Varriyam (2008)					
Collins et al. 2015 UK(England) CC/ CUA Funding: none (earlier work funded by NW of England Directors of Public Health)	**Aim:** to estimate the impact of a duty on sugar sweetened beverages (SSBs) at a local (authorities level) in England on reducing obesity and related diseases **Population:** 41 million adults in England (326 lower tier local authorities) **Intervention:** a 20% duty on sugar sweetened **Comparator:** appears to be no intervention/no SBB duty **Outcomes:** obesity, diabetes, CVD, Cancer, QALYs	A policy model was developed (in EXCEL) to estimate the impact of a SBB duty. Model runs as a Monte Carlo simulation using 5 key parameters: SSB consumption, price elasticity of demand, current obesity rates, change in obesity rates over time, substitution of calories form SBBs with 20% duty. A linear function was applied to the estimated change in obesity-related diseases, based on the age-specific consumption data applied to the number of calories derived from SBBs, for each local	As the number of daily calories consumed reduces, obesity rates assumed to fall. This then eventually leads to a decrease in obesity-related disease Baseline obesity rates in the model varied from 21.3% to 27.1% and the SBB consumption varied from 126ml to 473ml per day	Between 2010 and 2030 (20 years) Mortality changes appear not explicitly modelled separately, only the change in cases of disease and the QALY loss associated with these diseases.	Average annual obesity related disease (i.e. direct. healthcare or hospital) cost estimates were from UK published sources. Diabetes (Farmer 2009) CHD and Stroke (NICE 2010) Cancer (bowel) Truemen (2007)	**SBB consumption** (and potential reduction in calories consumed from a 20% duty) was based on data for England from the National Diet and Nutrition Survey 2008-10 and drinks manufacturers data **Price elasticity** came from surveys of both individual dietary intake data and purchasing data in the context of household income and expenditures to provide a picture of patterns and trends in beverage intake and purchases in Great Britain over the 1986–9 period.(Ng et al 2012) [Ng et al. estimated that a 10% price increase would reduce SSB consumption by 4.6% and a 20% price	obesity, diabetes, CVD, Cancer, QALYs	The 20% SSB duty resulted in mean (2.5%/97.5% percentile) 2,432 (412, 4864) fewer diabetes cases, 1,657 (280, 3314) fewer stroke and coronary heart disease cases, 435 (74 to 870) fewer cancer cases, and 40,908 (6,923, 81,818) QALYs gained per year across England. The total health cost savings per year were £14,811,121 (£2,506,497, £29,622,242) Duty might have biggest benefits in urban areas with young populations and in areas with the greatest deprivation. Results were presented using thematic map showing estimated kcal reduction per person per day and QALYs gained by local authority in England as a result of a 20% SSB duty. Size of health gains was driven by population size	A Monte Carlo model simulation was performed (i.e. PSA). A 30% duty resulted in 3,600 fewer diabetes cases, 2,500 fewer stroke/CHS cases, 700 fewer cancer cases and 61,000 QALYs gained (1.5 time effect of a 20% duty – assuming a linear effect).	The methods and data sources were appropriate, Effectiveness evidence was relevant, although certain aspects were not modelled or reported explicitly (e.g. mortality from obesity related diseases, or QALY weights), Although likely to be valid/from appropriate sources, the cost analysis was limited (to disease costs, no intervention/progra mme costs were included), resource use was not reported separately from unit costs. Costing details provided were limited, also uncertainty in	A working version of the EXCEL model used in the study is included as a supplementary file (includes the model, model inputs, SSB consumption, PED, obesity, obesity change, calories from substitution)

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		Model structure, perspective, and scope (basic structure, and key assumptions)	Modelling of obesity progression and complications (yes/no; key assumptions used)	Time horizon and mortality (how mortality changes were calculated)	Costs (types of direct and indirect resource use included, and measurement methods)	Clinical, Effectiveness data	Outcomes (types of outcomes reported and measurement / extrapolation methods)	Findings ("headline" results of the base-case analysis, "headline" results from sub-group analyses)	Sensitivity analysis (types of sensitivity analysis conducted, and sensitivity of headline findings to these analysis)		
		authority (with associated 95% prediction Intervals) Elasticity was the same for all age and gender **Cost perspective** no explicitly stated, but only health care costs appear to be included/ perspective of individual local authorities?				increase would reduce consumption by 9.1% (a price elasticity of approximately -0.46)] **Impact of SBB duty on calorie consumption + health outcomes** Obesity projections were from a previously published model of change in UK obesity related outcomes over 20 years, 2010-2030 using a time series approach taking into account population change (Wang et al. 2011) => i.e. change in disease cases of diabetes, CHD and stroke, cancer and QALYs gained		and age structure.		disease costs not investigated in SA. No discounting of future costs and benefits. The authors compared their results with those from three other studies that showed similar reductions in energy consumption/weigh t/obesity. Results are likely to be generalizable to other settings in the UK, including Scotland.(and at local/regional authority levels) => highlight the greatest impact e.g. in young populations. Model inputs are dependent on the accuracy of other data and models. parameter distributions used in the analysis of uncertainty are appropriate, but would benefit from future research to generate more robust empirical distributions e.g. on behavioural effects of price changes on SBB consumption in young people, ethnic minorities, deprived groups, and future application of the model to incorporate PEDs by income group (based on available data for local authorities/ income deprivation index as proxy)	
Basu et al. 2013 USA CEA/CUA	**Aim:** To estimate the health effects and cost-effectiveness of banning or taxing	A Micro simulation model was constructed In the model,	the effects of the interventions are based on the foods consumed the effect of taxes	10 years (	Average annual medical costs for diabetes, CVD disability, CVD related death came	data were form a variety of sources including the National Health and Nutrition Examination	Annual QALYs lost due to diabetes, CVD disability were based on TUFTS CEA registry data	**Banning SSB purchases** using SNAP benefits would be expected to avert 510,000 diabetes person-years and 52,000 deaths	Sensitivity analyses were conducted by varying parameters across their range of inputs	Input data did not provide information on heterogeneity in response to price changes within the	A supplementary file with details of the model, data sources, policy specifications, parameter values, equations, model

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Funding: N/A, not reported in the paper	SSBs or subsidizing fruits and vegetables purchased with the Supplemental Nutrition Assistance Program (SNAP) **Population:** adults aged 25 to 64 years **Intervention(s)** included : **Policy 1:** Disincentives for purchasing SSBs using SNAP dollars (SSB ban, SSB tax) **Policy 2:** Incentives for purchasing fruits and vegetables using SNAP dollars (Veg subsidy, Veg reward) Policy 3- an increase in overall SNAP benefits **Comparator:** No intervention **Outcomes:** incremental costs, QALYs, BMI, Alternative Healthy Eating Index, Food Security Score, diabetes person-years, and deaths from myocardial infarctions (MIs) and strokes.	individuals were placed into cohorts defined by age, sex, income, race/ethnicity, and participation in SNAP. For each cohort in the model, we simulated individuals' daily food intake over a 10-y simulation period from 2014 to 2025. We sampled from joint probability distributions describing the amount of food consumed per day from each of several standard food groups; the distributions were specific to the demography of each simulated person and their SNAP participation status, based on dietary recall data from the NHANES. We also estimated typical rates of entry and exit of individuals from the SNAP program based on data from the USDA and the impact of entry/exit on food choices. Perspective: government	and subsidies is modelled by decreasing or increasing the probability of intake of each type of food. Intake elasticities—the change in food intake after a change in price—determined these probability changes and were calculated from the USDA Quarterly Food-at-Home Price Database11 using the common Almost Ideal Demand System. Both own-intake elasticity (change in intake of a specific food after a change in the price of that food) and cross-intake elasticity (change in intake of other foods after a change in price of one food) were calculated		from published national sources (2010 Medical Expenditure Panel Survey) The cost of subsidies or taxes were included by multiplying the total demand (including the change in demand due to the subsidy or tax) by the cost of the subsidy or tax per unit demanded. The deadweight loss from taxes needed to finance a subsidy was also computed All costs were in 2012 US dollars Costs and outcomes were discounted at 3% per year.	Survey (dietary recall **food consumption/intake** data), US Department of Agriculture Quarterly Food-at-Home Price Database (**own-intake, cross-intake elasticities**), and SNAP program data. Change in weight due to changes in calorie intake (National Health Institute) Changes in disease risks given a change in e.g. intake of SBB , green leafy vegetables, AHEI score, diabetes stats (Nurse's Health study, Meta-analysis of cohort studies, Whitehall II study, Framingham Study)		from MIs and strokes over the next decade, with a savings of $2900 per QALY saved. Total cost saving $0.3 billion, total QALYs saved 99 000 **Taxing SSB purchases** would be expected to avert 114,000 diabetes person-years and 31,000 deaths from MIs and strokes over the next decade, with a savings of $513,000 per QALY saved. Total cost savings $13 billion, total QALYs saved 26,000 A penny-per-ounce tax on SSBs purchased with SNAP dollars would produce higher cost savings due to tax revenues but avert fewer chronic disease deaths. However, some SNAP participants are likely to preferentially purchase SSBs through their disposable income, indirectly reducing their food security A **30% produce subsidy** would be expected to avert 39,000 diabetes person-years and 4600 cardiovascular deaths over 10 yr without effects on food security.	Probabilistic sensitivity analysis was undertaken (generating mean and 95% confidence interval estimates by Monte Carlo sampling from the distributions of usual food intake, intake elasticity, costs, and QALYs) Results are sensitive to the intake elasticities of SSBs and produce. A 1% decrease in the amount of SSBs consumed for a given change in price would result in a 2% increase in AHEI scores after a soda tax, a 0.02% increase in the number of diabetes person-years averted, and a 0.08% increase in the number of CVD deaths averted. SNAP restrictions on SSBs could lower chronic disease mortality, but further testing should examine indirect effects on disposable income and food security. Subsidizing produce could confer fewer benefits or risks but at higher cost.	SNAP-using population. Limitations identified by the authors included: That though NHANES data could provide reasonable estimates of food intake in the United States. The dietary recall data contained in the NHANES are also subject to recall biases, however, which may lead to underestimates of food intake. – assumption that no dramatic changes will take place in physical activity levels in the population in response to the policy changes, which appears reasonable given the nature of the proposed interventions. We also examined direct impacts of price changes on consumers, not taxes or subsidies that are implemented at the level of producers and then passed through to consumers (which may be affected by levels of absorption by suppliers and other complex supply-side phenomena). - although intake data specific to demographic groups was used,, location specific data available was not available.	calculations, analyses and results are available online (32 pages)
Gortmaker et al. 2015a (and **Long et al. 2015, Sonneville**	**Aim:** To estimate the cost-effectiveness of nationwide	A Markov cohort model using a proportional multistate life table	The model structure uses Logic Pathways/models that link:	10 years (2015-2025) Over the 10	Start-up costs were not included; the intervention was considered "at	Both SSB and TV AD interventions rely on effectiveness as estimated from	Change in BMI, DALYs, QALYs QALY weights were	The first year intervention costs were $1.1 (95% UI: $0.69, $1.42) and $51 (95% UI: 36, $66) million	Probabilistic sensitivity analysis was used extensively by simultaneously	As with similar models the assumption that the health	Further details of the model, evidence reviews are available in an online Appendix ~30 pages

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et al 2015..These studies were also included in the 'overview' **Gortmaker 2015a** publication) CEA/CUA Funding: This work was supported in part by grants from the Robert Wood Johnson Foundation (66284) and CDC (U48/DP00064-00S1), including the Nutrition and Obesity Policy, Research and Evaluation Network, a Centre for Research Excellence in Obesity Policy and Food Systems supported by the Australian National Health and Medical Research Centre (grant number 1041020), the Donald and Sue Pritzker Nutrition and Fitness Initiative, and the JPB Foundation.	implementation of (4) childhood obesity interventions (2 focussed on food/drinks) from the US Childhood Obesity Prevention Cost-Effectiveness Study (CHOICES). **Population:** 2015 US population Intervention: -an excise tax of $0.01 per ounce of sugar-sweetened beverages (estimated pop. reach of 313 million children and adults, intervention reaches all age groups) applied nationally and administered at the state level (SSB) Long 2015; - elimination of the tax deductibility of advertising costs of TV advertisements for "nutritionally poor" foods and beverages seen by children and adolescents (TV AD) Sonneville 2015 (estimated pop. reach 74 million) **Comparator:** not explicitly stated, but appears to be the reference population, assuming no intervention takes place **Outcomes:** cost per unit of BMI reduction and obesity-related healthcare costs averted, DALYs (SBB only), QALYs obesity related diseases included: stroke, ischemic heart disease, hypertensive heart	approach to simulate the morbidity and mortality experience of the 2015 US population (aged ≥ 2 years, by sex and 5 year age groups) followed for 10 years (2015-2025) or until death or age 100 years. The CHOICES model was based on a spreadsheet version used for the ACE in Obesity and ACE-Prevention studies in Australia (e.g. Vos 2010) but modified with US population, health care costs, morbidity, and mortality data. The results were replicated in a complied programming language (JAVA) and data analysed in 2014. **Perspective:** Modified Societal stated (excludes time and other resources that program participants incur in order to participate in a program). The ACE approach was adapted using US data on: population distributions, disease incidence, prevalence, and mortality, and a different approach to healthcare costing and cost offsets than those used in ACE. The emphasis was changed from a focus on DALYs over the lifetime of	For SBB tax ∆ Excise Tax on Sugar-Sweetened Beverages (SSB) to ∆ SSB price to change in SBB consumption to change in BMI . BMI then leads to Change in DALYs and QALYs and associated health care costs. (Long 2015), and For TV AD Elimination of tax subsidy of advertising to reduction of exposure to ads for unhealthy foods/hr of TV watched linked to reduction in energy intake to reduction in BMI to reduction in Obesity related healthcare costs and QALYS. The model calculated costs and effectiveness of the interventions through their impact on BMI changes and cost per BMI change in the cohort in the short term (over a two year period Model assumed no effect in year one and full effect in year two -thus a 'conservative' approach for adults and children For all interventions, effects on BMI change were assumed to occur after 1 year. This assumption approximates the time to full effect following changes in energy balance in children. Costs of the intervention	year period 2015-2025 the model calculates intervention costs, BMI change, obesity prevalence, costs per BMI change, obesity-related health care costs, net costs, and in the case of the SSB intervention, obesity-related disease incidence, disability adjusted life years (DALYs), and QALYs (also for the TV-AD).	steady state."Costs for advocating for the passage of a given policy were not included, but costs of policy dissemination were included. Intervention costs- both SSB and TVAD interventions were assumed to be in effect (and incurring costs) throughout the 10 year period. Obesity Related Health Care Costs were included. Estimates of health care costs relied on analyses by Finkelstein and Trogden 2008 that indicated higher health care costs for obese children and youth (compared to non-obese), and steadily increasing excess rates associated with obesity as age increases. For ages below six no extra health care costs were associated with obesity. For ages 6-19 there were added health care costs per year if the child is obese, compared to non-obese; inflated to 2014 U.S. dollars the difference is $282.31 Larger differences are observed for ages 20 and above. Medical Expenditure Panel Survey data for the years 2001-2003 were the source for these estimates, Further analyses of these data indicated that excess costs were	evidence reviews, and based on RCT evidence linking the primary behaviour to changes in BMI, additionally, SBB also rely on change and change longitudinal observational studies as well. This included extensive literature reviews, with the goal of identifying the best evidence for use in CHOICES cost effectiveness modeling. Typically this meant that studies were identified that were high quality, and did not include other behavioural components that might confound the effect estimate. Details of the evidence reviews are provided with each of the papers. The **SSB study** included an extensive review of literature (including 13 reviews) linking SSB intake to change in BMI. This review identified one double blind RCT of children, SSB intake and BMI, and four quality longitudinal change in SSB and change in BMI studies in adults that were used for effect estimates in the model. The **TV AD** paper relied on a recent systematic evidence review including 49 studies by the Guide to Community Preventive Services that recommended behavioural interventions to reduce recreational sedentary screen time among children, finding evidence for significant reductions	from published estimates of obesity related QoL among adults aged ≥ 18 years.(Muenning 2006) DALY weights appear to have used the assumption that Australian data can be applied to the USA. ? Future outcomes discounted at 3% annually.	dollars per year for TV AD and SSB tax resp. The corresponding per person BMI unit reduction was a change of 0.028 (95% UI: 0.011, 0.046) 0.08 (95% UI: 0.03, 0.20) resp., and cost per unit BMI reduction of $1.16 (95% UI: $0.51, $2.63) and $3.16 (95% UI: 1.24, $8.14) resp. for the first 2 years. At 10 years the SSB tax and TV AD would save net costs (health care cost savings included), SSB intervention had net total cost savings of $23.2 (95% UI: $8.88, $54.5) billion and the TV AD intervention total savings of $343 (95% UI: $129, $572) million. The SSB and TV AD would save an estimated $55 (95% UI: $21, $140) and $35 (95% UI: $14, $74) for every dollar spent. The SSB excise tax would advert 101,000 DALYs (95% UI: 35,000, 249,000) and both SSB and TV AD would increase QALYs: 871,000 (95% UI: 342,000, 2,030,000) and 4,540 (95% UI: 1,750, 7,500) resp. Both SSB ($12.5 billion) and TV AD ($80 million) would produce yearly tax revenue (excluded from the net societal costs of the intervention). The authors stated that cost-effectiveness of these interventions is greater than that seen for published clinical interventions to treat obesity. Both the SSB and TV AD interventions are cost saving within a 10 year period.	sampling all parameters values from predetermined distributions. Results are reported as 95% uncertainty intervals (around point estimates). To estimate costs per BMI units reduced over two years, @Risk software (Version 6.0. Ithaca, NY: Palisade Corporation; 2009) was used to calculate 95% uncertainty intervals from 10,000 iterations of the model. In estimating 10 year healthcare costs, net costs, net cost saved per dollar spent, and DALY and QALY outcomes, uncertainty intervals were calculated using Monte Carlo simulations programmed in JAVA and 1,000,000 iterations of the model. Model uncertainty was also assessed by modifying the primary scenario with alternative logic pathways. Further details for the different scenarios are provided in the individual papers In uncertainty analysis, the likelihood of cost savings at 10 years was quite high (99% following the first 2 years) for both the SSB and TV AD interventions. No additional sensitivity analysis results were reported, e.g. one or two-way	effects/benefits of childhood interventions persist over decades may be unrealistic. – e.g. reduction in morbidity are minimal until decades later at age 35 years and older, when obesity-related diseases become more prevalent. The ACE-Prevention model may be modifiable to the Scotland setting, given the fact it has already been adapted from one country setting (Australia) to another country (US) setting. In general, high quality evidence links the key behaviours with the outcome of BMI – but many possible key uncertainties regarding implementation of the interventions, including their feasibility and acceptability to stakeholders (e.g. opposition from beverage, food, and advertising industries) Also less is known about how to effectively translate and scale these interventions in community settings through the nation. The impact of interventions may also be underestimated, in part because only a limited set of outcomes was examined. The SSB model likely	The details of the four studies reported in Gortmaker 2015a are reported in separate papers (Long 2015, Sonnevilled 2015, Barrett 2015, Wright 2015) An important key assumption of the modelling approach is that interventions have the effect of accumulating cost offsets with interventions that lower short term BMI and obesity rates in childhood and that these lower rates in turn will persist into adulthood. In this way the growth of obesity and excess health care costs can be reduced. As with the framework adopted in the ACE studies, the CHOICES work incorporated a stakeholder group and was engaged in reviewing findings in light of implementation and equity issues, including quality of evidence, equity, acceptability, feasibility, sustainability, side effects, and social and policy norms. These implementation issues combined with cost effectiveness results provide a more complete picture for decision makers.

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	disease, diabetes mellitus, osteoarthritis, post-menopausal breast cancer, colon cancer, endometrial cancer, and kidney cancer using relative risks linking changes in BMI to disease incidence (BMI in adults or BMI z-score in children).	a population cohort, to shorter term changes in population health, including the outcomes of cost per BMI unit change for 2 years following an intervention, and 10-year healthcare costs, net costs, DALYs, and QALYs. These changes aligned the modelled results with the timeframe of intervention studies used for evidence, make findings more relevant to concerns of U.S. policymakers, and avoid the need to assume sustained intervention effect over individuals' lifetimes.	implementation during this first year of the modelling timeframe were included. Estimates of intervention costs did not include one-time start-up costs, and yearly costs were those incurred when the intervention was fully operational.		related to outpatient visit, prescription drug and emergency room expenditures. The assumption was not made, as in the ACE studies (Haby 2006 Vos 2010) that healthcare cost offsets occur only after obesity-related disease onset. Rather, excess healthcare costs linked to obesity at all ages, including childhood and adolescence, were taken into account. All costs were expressed in 2014 US Dollars. Unclear if future costs were discounted at 3% in the same way as outcomes?	in BMI and obesity prevalence. This finding was similar to that of two recent meta-analyses, as well as a systematic review among young children. The authors reviewed all studies in the systematic reviews, looking for RCTs of screen time interventions that manipulated only screen time (e.g., not diet), included ages 2-18; measured change in weight, BMI z-score or BMI, demonstrated significant change in screen time and lasted six months or more. Two RCTs met these criteria, and these found similar effects so this effect estimate was used. Other evidence from these studies indicated the relationship between TV and BMI was mainly due to increased energy intake and in particular commercial TV viewing, as well as the large number of hours of TV still watched by children and the focus of TV advertising on junk foods and beverages. The baseline national population came from the U.S. Census middle series 2012 National Population Projections for 2015 by sex and five-year age groups (2 years and older). Baseline and age-related increases in BMI by age and sex were based on NHANES data for 2009-2012 The Dismod II software program, which was developed for the Global Burden				underestimates effects on outcomes because direct effects of changes in SSB on both diabetes and cardiovascular disease independent of BMI are not modelled. The model also excludes potential health gains from earmarking tax revenues for health promotion. Limiting the evaluation to a 10-year time horizon may underestimate the long-term healthcare cost savings and reduction in morbidity and mortality associated with childhood obesity prevention efforts. The findings from these four studies resonate with a number of the results from the ACE modeling efforts in Australia.6,7,9,11,13 ForFor example, some of the most costeffective strategies were found to be policy interventions, in part because of their relatively low cost, broad population reach, and potential for sustainability. In the present study, the SSB, TV AD, and ECE policy interventions all show good cost effectiveness and potential to demonstrate substantial cost savings. These policy and preventive interventions may	

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						of Disease 2000 study, was used to model the incidence and case fatality of the nine obesity-related diseases. For all the modelled interventions there was direct evidence linking behaviour change to BMI. The SSB intervention also required additional econometric evidence linking increased price to lower consumption.				also produce changes in BMI at much lower cost than some commonly reimbursed clinical interventions. Uncertainty over the population reach of the interventions due to the lack of implementation research.	
Gortmaker et al. (2015b) USA CEA Fundng: supported in part by grants from The JPB Foundation; Robert Wood Johnson Foundation (Grant No. 66284); the Donald and Sue Pritzker Nutrition and Fitness Initiative; and the Centers for Disease Control and Prevention (Grant No. U48/DP001946),inc luding the Nutrition and Obesity Policy Research and Evaluation Network	**Aim:** To estimate the cost-effectiveness of a number of policy interventions for addressing childhood obesity **Population:** Children and adolescents targeted (various population reaches were modelled) **Intervention(s) included:** - an excise tax of one cent per ounce on sugar-sweetened beverages, applied nationally and administered at the state level - the elimination of the tax deductibility of advertising costs for television ads seen by children and adolescents for nutritionally poor foods and beverages -restaurant menu calorie labeling, modeled on the federal menu regulations to be implemented under the Affordable Care Act. **Comparator:** not explicitly stated, but	A stochastic, discrete-time, individual-level microsimulation model of the population in the United States was developed to simulate the experience of the population in the United States from 2015-2025. Modelling framework build on the Australian Assessing Cost-Effectiveness approach in obesity and prevention studies (but using a MS approach as opposed to Markov cohort model as in previous work, see Gortmaker 2015a) Model incorporated US population, mortality, and health care cost data **Perspective:** modified societal (excluded were productivity losses associated with obesity or patient costs for items such as transport to clinic visits or the value of time spent seeking or	The impact of each of the modelled interventions on individual BMI was estimated based on the best available evidence linking the policy or program to change in BMI, weight, daily energy intake (or physical activity) using a logic model developed for each intervention. Assumption that the effects of the interventions were sustained over the model's time frame (that is, eight years after two start-up years).	Implementatio n of the interventions over 10 years (2015-25) 3% discount rate	Intervention implementation costs, and obesity-related disease medical costs were included based on best available data on costs E.g. for TV AD tax deduction costs related to processing and auditing were included for the, but not for enacting. Overhead costs of the tax system included administrative costs (e.g., tax audits, litigation) and personnel responsible for these undertakings. The estimated effects of the interventions on health care costs were based on national analyses that indicated excess health care costs associated with obesity among children and adults (published 2001-2003 Medical Expenditure Panel data) All costs were reported in 2014 US dollars, and discounted at 3% annually.	Estimates of the effectiveness of the interventions were based on systematic evidence reviews process (consistent with the GRADE approach, and guidelines from the Cochrane Collaboration). Key epidemiological and clinical data came from a variety of sources including the Census Bureau, American Community Survey, Behavioural Risk Factor Surveillance System, National Health and Nutrition Examination Surveys (NHANES), and National Survey of Children's Health. It also used longitudinal data about weight and height from the National Longitudinal Survey of Youth, National Longitudinal Study of Adolescent to Adult Health, Early Childhood Longitudinal Study—Kindergarten, Panel Survey of Income Dynamics, and NHANES I Epidemiologic Followup Study. Smoking initiation and cessation rates from the National Health Interview Surveys and	Cost per BMI unit change at 2 years, 10 years changes in obesity (cases prevented/ childhood obesity prevalence), health care costs and net costs**.** LYRs gained?	The annual intervention costs were driven by both the cost per person and the population reach ($ millions): SSB tax 47.6 (31.0, 63.8), excise tax elimination 0.82 (0.82, 0.82) and restaurant menu calorie labelling 95.5 (82.7, 108.50 The associated cost per unit of BMI reduced ($) were 2.49 (0.62, 10.59), 0.66(0.27, 1.13) and 13.09 (-122.61, 154.42) resp. SSB tax, excise tax elimination, and restaurant menu calorie labelling prevented 575,936 (131,794, 1,890,715) 129,061 (48,200, 212,365) and 41,015 (-41,324, 122,396) cases of childhood obesity in 2025 resp. SBB tax and excise tax elimination for advertising unhealthy food to children were found to be cost-saving across the range of modelled uncertainty (i.e. the interventions saved more in reduced health care costs over 10 years, than the interventions would cost to implement). The net savings to society for each dollar spent were estimated to be $30.78 (6.07, 112.94) and 32.53 (12.42, 53, 35) resp. Restaurant menu calorie labelling was also found to be cost-saving. 5.90 (-5.06, 18.00)	Probabilistic sensitivity analyses was performed by simultaneously sampling all parameter values from predetermined distributions. These results were presented as point estimates with their 95 percent uncertainty intervals based on Monte Carlo simulations The authors also estimated that the SBB tax and the elimination of the tax subsidy for advertising unhealthy food to children would lead to substantial yearly tax revenues ($12.5 billion and $80 million, respectively). These revenues were not included in the calculations of net costs	The authors stated that in their previous publications (Gortmaker 2015a, Long 2015, Sonneville 2015) a Markov cohort simulation model to estimate the impact of two of the interventions modelled (the sugar-sweetened beverage excise tax and the elimination of the tax subsidy for advertising was used). They stated that the cohort model was limited in its ability to model heterogeneity of individual differences, exposure to the intervention, and trajectories of BMI over the life course, and it could not calculate population estimates for specific years. With the microsimulation model, they were able to estimate the number of cases of obesity prevented. For both of these interventions, the estimated costs per BMI unit reduction were similar under	The study comes with an 89 page supplementary Appendix available online with further details about the interventions, data sources used, key input parameters, parameter' distributions and assumptions, evidence on interventions effectiveness, and Microsimulation Model Description As with the ACE approach an important element was the creation of a stakeholder group of thirty-two US policy makers, researchers, and nutrition and physical activity experts to provide advice concerning the selection of interventions, evaluation of data, analyses, and implementation and equity issues. This group advised looking broadly for interventions to evaluate across settings and sectors.

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	appears to be that of no intervention **Outcomes:** obesity prevalence, BMI	receiving medical care)				mortality rates by smoking status and BMI from the NIH AARP Diet and Health Study.		Net costs saved over the decade 2015-25 were $14.2 billion for the beverage excise tax, $260 with elimination of the tax subsidy for adverting unhealthy food to children/		both modelling approaches, and both interventions were shown to be cost-saving. Impact of simultaneous implementation of multiple interventions? Limited evidence exists that directly links the interventions to change in population-level obesity prevalence. Rather existing evidence on effectiveness is supported by randomized trials or natural or quasi-experimental evaluations that linked the intervention or behavioural mechanism targeted by the intervention directly to reductions in BMI for recipients of each intervention. Excluded were the additional health improvements and health care cost reductions due to improvements in diet and physical activity that were independent of reductions in BMI (e.g. reductions in diabetes and heart disease)	
Magnus et al 2009 Australia CEA/CUA Funding: The Assessing Cost-Effectiveness in Obesity (ACE-Obesity) project was funded	**Aim:** To model the health benefits and cost-effectiveness of government intervention banning television (TV) advertisements in Australia for energy-dense, nutrient-poor food	ACE-Obesity Markov model (Change) in EDNP food consumption, energy intake and energy balance, were converted to (change) in body weight using a validated equation	Changes in BMI, and disability-adjusted life years (DALYs) saved. Changes in BMI (benefit) maintained to adulthood	lifetime, 100 years	Intervention costs, health-care costs associated with obesity-related health conditions. Intervention related costs appear to come from author's own assumptions.	Effectiveness data were from various sources including: a randomized controlled trial of food consumption (behaviour change), together with modelled behavioural change to BMI change, using a mix of	DALYs saved	The intervention had an incremental cost-effectiveness of AUD$ 3.70 (95% uncertainty interval (UI) $2.40, $7.70) per DALY. Total DALYs saved were 37 000 (95% UI 16 000, 59 000). Total intervention cost	2 scenario analyses (30 staff monitoring compliance, Swinburn method used for both food and beverages) The intervention remained dominant. Restricting TV advertising of EDNP food and beverages seems to be	A main limitation could be the fact that effectiveness was based on a single RCT. Parallel evidence of behavioural change measured with reductions in advertising of other	

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by the Victorian Government Department of Human Services, Australia.	and beverages during children's peak viewing times. **Population:** children (5 to 14 years?) in 200, 2.4 million1 **Intervention:** Removing advertising on energy-dense nutrient poor (EDNP) food and beverages from TV during peak child viewing times in the morning for 1 to 2h, and in the afternoon/evening for 5h (up to 2100 hours). **Comparator:** current practice/ regulation in place in 2001 **Outcomes:** BMI, DALYs	(from Swinburn 2006). Every 1% change in energy intake led to a 1.4% change in weight. Weight reduction was then converted to a reduction in BMI units. Change in (sweetened) beverage intake was directly linked to change in BMI using a published relationship from a prospective observational study (Ludwig et al RCT data of the direct effect of advertising on BMI and DALYs were not available, so modelling was used to create a mathematical depiction of relationships between known data and likely associated future costs and health outcomes. Few details provided on how BMI was linked to obesity-related diseases, or which conditions were included. **Cost perspective:** Public health sector/ societal?			Disease costs were from a single published Australian study Haby et al. 2006 (ACE model project) Price year AUS$ 2001, annual discount rate 3%	cross-sectional and longitudinal evidence (Swinburn 2006, Gorn 1982, Ludwig 2001) reduction in consumption then linked to reduction on energy intake and energy balance and was based on previously analysed dietary data from the 1995 National Nutrition Survey in Australia. Change in energy balance on body weight was then assessed using the validated equation from Swinburn et al., and weight reduction converted to a reduction in BMI units. Impact of reduced sweetened beverages intake on BMI change came from a prospective observational study (Ludwig et al. Average consumption of grams of sweetened beverages per day from the National Nutrition Survey 1995 as current practice in 2001, and calculated the reduction in grams by applying the relative risks derived from the Gorn and Goldberg trial results. The change in grams was converted into servings per day. The reduced consumption of sweetened drinks observed in the trial converted into (fewer) servings per day and then generated a reduction in BMI units (effect of reduced beverages was assumed to occur within 12 months)		$130000 ($120 000, $140 000). Savings in future health-care costs was (AUD$ 300m (95% UI $130m, $480m), the intervention was 'dominant', because it resulted in both a health gain and a cost offset compared with current practice. The variables that most strongly correlated with the ICER were the relative risks of a reduced consumption of EDNP food, followed by the effectiveness under Australian conditions assumption and the relative risk of reduced beverages consumption.	extremely cost effective in reducing unhealthy weight gain in children aged 5–14 years Threshold analysis identified that BMI benefit could be almost completely eroded over time, and that this intervention would remain dominant because of its modelled very low cost. PSA/ Monte Carlo simulation was the main analysis performed	products, such as toys, tobacco and alcohol, supported the conclusions reached in this analysis for EDNP foods. Cross-sectional studies used for evidence of impact of food choice on BMI. Assumptions on maintenance of BMI benefit through time in children, implementation costs possible revenue impacts on the advertising industry or on producers of EDNP foods Advertising in Australia today, compared with the period covered by Gorn and Goldberg, takes a multitude of forms in addition to TV advertising whether the potential lost sales would be replaced by diversification within the food industry into adult food products or into healthier foods for children, assumed that not only was the cost of other food that was substituted for the EDNP food removed from the diet of equal dollar value, but the food preparation time component was also equivalent. If this were not the case, the intervention would become less	

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										acceptable to parents. Supportive evidence is also gained from the evaluation of other products (toys in children, tobacco products and alcohol in adults) for which reduced exposure to advertising has been evaluated Costs are likely to vary depending on the degree of current regulation of advertising in place in other settings..	
Sacks et al. 2011 Australia CEA/CUA Funding: MRC Health Service Grant (no.31558), this study forms part of the ACE-Prevention project	**Aims:** To compare the potential cost-effectiveness of ("conservative scenarios") for mandatory, front-of-pack traffic light nutrition labelling in selected food categories, and a tax on a range of unhealthy foods. **Population:** Australian adult population (aged ≥ 20 years) in 2003. The model divides the population into 5-year age and gender cohorts **Intervention:** - traffic light labelling intervention, junk food tax (and includes a social marketing component – to educated and inform the population on how it interpret the labels) - a 10% tax on unhealthy/ non-core food categories (biscuits, cakes, pies, snack,	Logic pathway used to identify/ model the steps in estimating the impact of each intervention on BMI and health outcomes. **TLL:** reduction in consumption (g) of targeted foods and beverages + replacement of targeted foods and beverages with equal weight of substitute (with lower energy densities) **Tax:** change in consumption (g) of targeted foods and beverages in response to price increase (using *own-price elasticities*) + change in consumption (g) of related foods and beverages in response to price increases (using *cross-price elasticises*) **Perspective**: Health sector (with some industry costs included, e.g.	Change in food purchasing behaviour leads to a reduction in energy intake (kJ/day) with no compensatory changes in PA, leads to changes in weight/BMI, then to changes in obesity related diseases (stroke, IHD, hypertensive disease, DM, osteoarthritis, 4 cancers) and ultimately DALYs Both interventions assumed permanent. I.e. Weight loss effect assumed to be maintained for the cohort lifetime.	Life time (100 years) Disease and non-disease mortality rates applied Costs and benefits discounted at 3% p.a. Baseline population based on existing levels of morbidity and mortality in 2003 and the exposed population which is identical expect it receives the intervention. Owing to lower body weights, the exposed population has a lower risk of each of the diseases, and the model calculates the effect that this has on	Costs of implementing the legislation based on estimates for Australia by the WHO-CHOICE project (Chisolm 2004) Cost of social marketing for TLL (Carter 2000) based on the reference to the Victorian '2 fruit and 5 veg' campaign. Costs to industry changing product labels based on a 'benefit-cost' analysis – on estimated costs of implementing 'county of origin' labelling in Aust. Report the for Food Standards Australia and NZ, 2005) – conservative assumption used the full costs of changing the labelling of all pre-packaged food items in Aust. Interventions assumed to be operating under steady state conditions – so	**TLL:** Changes in energy intake – assumed (10) % shift in consumption to healthier food options (hypothetical scenario examined) in (10) % adults (conservative assumption). **Tax:** changes in energy intake - estimated using price elasticities from a 10% price increase in 7 junk foods (UK NFS estimates of price elasticities were used to model changes in food consumption in response to the tax intervention, MAFF 2000). The tax intervention was assumed to raise consumer-end prices of the targeted products by 10%, and elasticities of demand were used to calculate the resultant change in consumption of each food category, For both interventions, using the new average energy densities for each food category, and assuming that	DALYs averted (used for calculating the ICERs: including the cost outlay only, and including the cost outlay for the interventions less the healthcare costs saved as a result of the interventions)	Mean DALYs averted were 45 100 (95% UI: 37 000; 60 100) with TLL and 559 000 (UI: 459 500; 676 000) with the 'junk-food' tax. Mean cost outlays were AUD$81 million (95% UI: 44.7; 108.0) and AUD18 million (95% UI: 14.4; 21.6) respectively. Total cost offsets were AUD$455 (385;560) and AUD$5550 (4700;6370) The bulk of the cost of the TLL intervention (75%) falls on industry, and it is likely that these costs would be passed on to the consumer. Both interventions were shown to be 'dominant' (effective and cost-saving).	The estimates for each cost element and the changes in mean weight resulting from the interventions include 95% Uncertainty intervals (UIs). The model then calculated 95% UIs for DALYs, net costs and ICERs using Monte Carlo simulations (2000 iterations) with the Excel add-in Ersatz (http://www.epigear.com). In scenario analysis the effect of the intervention was assumed to progressively decay down to know effect after 10 years (and impact 2.5% of the adult population for TLL; the price elasticities was 20 times less). The median ICERs (with cost offsets) would increase to AUD$540 000 per DALY averted for TLL, and would remain dominant for the tax intervention.	As with similar economic evaluation studies – quite a lot of modelling assumptions were needed (due to) the absence of direct evidence/ weak effectiveness data from RCTs (on how the interventions will influence consumer behaviour). => so 'best available evidence was used to model ∆s in BMI and DALYS (plus supplemented with 'reasoned assumptions where necessary) to estimate the potential effect of the intervention Analyses were conducted at the food category (not product) level. The study results were comparable to similar policy based obesity prevention CE studies (whole population target) in the Australian setting.(i.e. with	All modelling was implemented in Microsoft Excel 2003 Note. TLL intervention was modelled to have an impact on the purchases of only 10% of the adult population, whereas the tax intervention impacts on the total adult population. Swinburn et al. Estimating the changes in energy flux that characterize the rise in obesity prevalence. Am J Clin Nutr 2009; 89: 1723–1728. Swinburn B et al. . Reply to KD Hall and CC Chow. Am J Clin Nutr 2010; 91: 817-a.

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	confectionary, and soft drinks) **Comparator:** current practice of mandatory inclusion of the nutrient information panel on the back of each product sold, no requirement for front-of-pack nutrition labelling,) pastries, **Outcome:** impact of the interventions on BMI, DALYs	cost of changing food labels).		prevalence and disease-specific mortality and morbidity.	setup, R&D of the intervention costs were excluded), but implementation costs (e.g. social marketing campaign re. TLL included Resource use/costs based on pathway analysis. Limited details on the methods used to assess healthcare disease specific costs	average weight of foods consumed at a category and a total level remained unchanged, the change in total energy consumed per person per day was calculated separately for males and females. Food consumption: (data from the 1995 National Nutrition Survey) Equations by Swinburn et al. were used to model a change in energy balance at the individual level (by sex) to a change in mean population body weight and BMI at the population level. DALYs averted as a result of the changes in BMI were modelled by applying a multistate life table Markov model (and compares 2 populations in separate life tables).(Forster et al 2010).				fiscal measures being CE or cost saving) Acceptability to different groups (e.g. TLL, private industry might protest about the cost of changing food labels – pass this cost on to consumers; widespread opposition of the tax, operationalisation on food products etc...)	
An 2015 USA CUA Funding: University of Illinois Urbana-Champaign Research Board Award (RB15126)	**Aims:** to evaluate the cost effectiveness of a nationwide expansion of a USDA pilot financial incentive program on fruit and vegetable purchases (HIP- the Healthy Incentives Pilot (HIP) trial to all Supplemental Nutrition Assistance Program (SNAP) households (low-income). – A financial incentive program piloted/ administered by the US. Department of	A decision Markov model was constructed (in TreeAge Pro) **Perspective:** societal stated by the author (from the viewpoint of the US/federal government) Diet behaviour modification is proportional to price change The incidence of specific obesity related diseases or health states (and related mortality) not explicitly / separately	In the model the level of fruit and vegetable consumption is directly linked to age specific all-cause mortality rate A key assumption is that the health benefit of fruit/vegetable intake is fully captured by reduced all-cause mortality. The model assumed the age-specific all-cause mortality rate among HIP incentive recipients to be 0.95 that of the corresponding	Lifetime, aged 100 years 3% discount rate applied to future costs, life years, and QALYs	Costs came from the USDA final report (Bartlett et al 2014) and (limited to) including a one-time (nonrecurring) implementation cost and an annual cost of incentive payments. Implementation costs were estimated from pilot implementation expenses and input from industry experts, including managing the implementation of the HIP within a state, modifying EBT and other systems/terminals	Effectiveness estimates came from a large-scale US randomized trial (Bartlett et al., 2014) – the trial that provided 30% rebate on targeted fruits and vegetables to 7500 study participants enrolled in the Supplemental Nutrition Assistance Program (SNAP). Among HIP participants, program participation increased daily consumption of targeted fruit and vegetable by 0.48 servings (95% CI: 0.26;0.69) ~ or an increase in daily fruit/vegetable	QALYs A nonparametric locally weighted regression was performed to estimate the age-specific HRQL scores based on the EQ-5D index administered in the 2003 wave of the Medical Expenditure Panel Survey, a nationally representative health survey (http://meps.ahrq.gov/mepsweb/)	The estimated life-time per capita costs to a HIP recipient is $1323 (control group zero cost). The number of QALYs were 20.083 with HIP ad 20.001 with no HIP. The average gains in quality-adjusted life expectancy to a SNAP participant is 0.082 QALYs, resulting in an incremental cost-effectiveness ratio of $16,172 per QALY gained.	One-way, two-way and probabilistic sensitivity analysis using Monte Carlo simulation was undertaken to explore uncertainty. The PSA showed a 94.4% and 99.6% probability that the estimated ICER would be lower than the cost-effective threshold of $50,000 and $100,000 per QALY gained, resp. The authors reported that study findings were robust to reasonable variations in variable values and distribution assumptions (the all-cause mortality risk	The model relies on key assumptions due to lack of data (e.g. assuming a permanent price effect on fruit/vegetable intake among HIP incentive recipients. It is unclear whether increasing demand for targeted fruit s and vegetables from a nationwide expansion of the HIP would affect market equilibrium and lead to price increase. A dose-response relation between fruit/vegetable	No schematic of the model structure provided

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		Model structure, perspective, and scope (basic structure, and key assumptions)	Modelling of obesity progression and complications (yes/no; key assumptions used)	Time horizon and mortality (how mortality changes were calculated)	Costs (types of direct and indirect resource use included, and measurement methods)	Clinical, Effectiveness data	Outcomes (types of outcomes reported and measurement / extrapolation methods)	Findings ("headline" results of the base-case analysis, "headline" results from sub-group analyses)	Sensitivity analysis (types of sensitivity analysis conducted, and sensitivity of headline findings to these analysis)		
	Agriculture (USDA) **Population:** adults ≥16 years (average number of people in SNAP household =2.1, average age since earning HIP incentive and age since fruit/ vegetable effect on mortality emerges = 30 years old) **Intervention**: HIP participating households received on their SNAP Electronic Benefit Transfer (EBT) card an incentive of 30 cents for every dollar of SNAP benefits that they spent in participating retailers on targeted fruits and vegetables, including fresh, canned, frozen, and dried fruits and vegetables without added sugars, fats, oils or salt, but excluding white potatoes, mature legumes, and 100% fruit juice. The monthly incentive was capped at $60 per household mainly to prevent misuse. **Comparator:** non-HIP participating households continued to receive their SNAP benefits as usual **Outcome:** QALYs	modelled Impact of the HIP initiative on fruit/vegetable consumption remains stable over time, i.e. response is immediate and permanent to the price effect Market prices are not affected due to increasing demand for targeted fruits and vegetables Dose-response relationship between all-cause mortality rate and daily fruit/vegetable intake	rate among people receiving SNAP benefits as usual. This assumption was from a meta-analysis of 16 prospective cohort studies, in response to an additional serving of daily fruit and vegetable intake (Wang et al 2014) The national age-specific all-cause mortality rate from United States Life Tables, 2010 was used to approximate the rate among people receiving SNAP benefits as usual.		for HIP transactions, and training SNAP staff and retailers (totalling $89,776,395 or about $5 per SNAP Household). HIP incentive payments to SNAP households will be an ongoing expense and by far the largest cost of a nationwide expansion of the HIP to the Federal government. The HIP final evaluation report determined $3.65 per SNAP household per month to be an adequate indicator of incentive payment for extrapolating to a nationwide expansion of the HIP. This payment amount captured the monthly average incentive earned per household in the pilot study from March to October 2012, but excluded the periods of phase-in and phase-out of incentives. In the decision model, we assumed a nationwide one-time implementation cost of $5 per SNAP household incurred within the first year and an annual cost of incentive payments of $44 ($3.65 per month by 12 months) All costs were in 2012 US dollars.	consumption by 26%.			ration of fruit/vegetable intake has the largest impact on the ICE, then the effect of HIP on daily fruit/vegetable consumption).	consumption and risk of all-cause mortality (base on meta-analysis, Wang et al 2014), but this relationships could be nonlinear and heterogeneous across subgroups. All health benefits may not be fully captured by reduced all-cause mortality. For instance impact ton QoL through improved brain and musculoskeletal system not accounted for. Total spend with HIP might be underestimated (no/limited data available), e.g. excluded were miscellaneous costs such as program support system update and modification, participants' effort on activating and learning about the HIP, and time spent on purchasing additional fruit/vegetable products and corresponding transportation costs. Diet behaviour modification is proportional to price change – the authors concluded that when people's actual eating behaviours and what dietary guidelines recommend differ by several fold, even a 30% rebate closes just a small fraction of that gap and has limited beneficial impact	

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		Model structure, perspective, and scope (basic structure, and key assumptions)	Modelling of obesity progression and complications (yes/no; key assumptions used)	Time horizon and mortality (how mortality changes were calculated)	Costs (types of direct and indirect resource use included, and measurement methods)	Clinical, Effectiveness data	Outcomes (types of outcomes reported and measurement / extrapolation methods)	Findings ("headline" results of the base-case analysis, "headline" results from sub-group analyses)	Sensitivity analysis (types of sensitivity analysis conducted, and sensitivity of headline findings to these analysis)		
										on participants weight management chronic disease prevention, and HRQoL.	
Veerman et al. 2016 Australia CEA/CUA Funding: the Obesity Policy Coalition and by NHMRC funding for the Centre for Research Excellence in Obesity Policy and Food Systems (APP1041020).	**Aims:** to estimate the consequences of an additional 20% (valoric) tax on SSBs on health and health care expenditure, using the latest dietary intake date for the Australian population. **Population:** 2010 adult population (aged ≥ 20 years) **Intervention:** additional 20% tax on sugar sweetened beverages **Comparator:** no intervention "business-as-usual scenario" **Outcome:** DALYs**,** incidence, prevalence and mortality of 9 obesity-related disease (4 cancers, osteoarthritis, IHD, hypertensive HD, stroke, type II diabetes) health care expenditure.	A lifetable-based epidemiological model developed in Microsoft Excel (a "proportional multi-state life table model") by age-sex group to simulate the effects and costs of weight change on obesity related diseases incidence (based on using PIF calculations + continuous risk functions) Main analysis implemented as a Monte Carlo simulation (~PSA) Same model used in Sacks et al.2011 **Perspective:** health sector	Consumption of SBBs (and change in response to the tax) is translated to energy intake (by age/sex group), then to body weight, (estimated from Hall 2011, whereby every change in energy intake of 100 kJ per day results in and eventual body weight change of approx. 1kg), then converted to change in BMI (by age/sex) using mean heights and weights from the AHS. Changes in BMI translated to changes in obesity related disease incidence and mortality Changes in disease incidence resulted in changes in prevalence at higher ages and later in time, and ultimately disease-specific mortality followed. Changes in disease-related quality of life at every age were calculated using disease-specific disability weights (Forster et al. 2011) Disease-specific changes fed into a life table to calculate the number of DALYs.	lifetime	Health care expenditure (from the Australian Institute of Health and Welfare Disease costs and Impact Study 2001) and the cost of implementing, administering and enforcement of legislation (government) from the most likely value base on WHO estimate for Australia of cost of changing legislation regarding alcohol abuse (assumed 30 years of monitoring, Level 4 admin officer, annuitized with 3% discounting ",,Healthcare costs for non-obesity related disease were included in the model so 'unrelated' healthcare costs in added years of life are accounted for.." All costs were in AUS$, price year 2010	Epidemiology and clinical effectiveness data were from a variety of different published studies and sources. Sugar drinks consumption, population numbers, overall mortality rates (Australian Health Survey 2011-2013) kJ / g of soft drink (CalorieKing.com.au) Australia-specific price elasticities, own-price elasticity (regular soft drinks) from (Sharma et al 2014) BMI (predictions developed by Haby et al based on 11 cross-sectional national or state population surveys conducted in Australia between 1969-2004 disease epidemiology (Australian Burden of Disease 2003 with trends extrapolating to 2010, Vos et al. 2010) RR of obesity related disease per BMI unit increase (RR by age from WHO's comparative risk assessment project, Ezzati 2003)	DALYs, LYs Disability weights were from another Australian economic modelling study (Forster et al, 2011).which sources them from the Australian Burden of Disease 2003 Study.	Main analysis (undiscounted) The SBB tax intervention (to government) was estimated to cost AUD 27.6 million and generated health care sector cost savings in overall of AUD609 million (95%UI: 368 million– 870 million). Healthcare savings rise over the first 20 years and then stabilise at around AUD29 million. Government revenue generated by the 20% tax was estimated at AUD400 million The SBB tax showed gains of 112,000 DALYs for men (95% UI: 73,000-155,000) and 56,000 P95% UI: 36,000-76,000) for women over the population lifetime SSB tax generated health care sector costs savings in overall of AUD609 million (95%UI: 368 million– 870 million). The average lifetime impact for a hypothetical cohort of 20 to 24 year old Australians. Was also estimated: males equivalent of about 7.6 days in full health, of which 4.9 in life extension and 2.7 in improved quality of life; . females the model predicts 3.7 health-adjusted days gained, of which 2.2 from increased longevity The 20% tax would reduce the number of type 2 diabetes cases, with incidence down by approximately 800 per year After 25 years there would be 16,000 less prevalent cases of diabetes, 4,400 fewer cases of IHD and	Uncertainty was assessed by Monte Carlo simulation using the Ersatz program (Epigear.com, Brisbane, Australia; 2000 iterations), incorporating uncertainty in intervention effect on mean BMI, relative risks of incident disease and intervention costs One-way sensitivity analysis conducted (and compared to the bases case) on the impact of the expected BMI trend, the duration of the effect on body mass, the pass-on rate, and discounting of future health gains and costs: -if body mass across the ages were to remain as in 2010 rather than continue to increase until 2023, the lifetime (DALYs) health benefits would be 10% lower - Limiting the effect of the tax on body mass to the first 10 years reduces the health impact by 75%. - The degree to which producers pass on the tax linearly relates to the size of the health benefits. - Discounting future lifetime health gains by 3% has a relatively large impact, since the gains materialise over the course of several decades. The results for health care costs are in the same direction, but proportionally more modest in size.	The methods + data sources used appear to be appropriate, and the results adequately reported (an appendix provides more details on the data sources) Some study limitations include -A restricted definition of SSBs and/or the nature of the Australian Health survey data we used, where recall bias may have led to underestimation of the consumption of unhealthy foods [- the study assumes that the only cross-price elasticity that was statistically significant for Australia related to artificially sweetened drinks (based on Sharma 2011) -no analysis of the differential impacts on different socio-economic groups Conclusions appear to be valid (and conservative estimates – i.e. valoric tax vs. volumetric may have less impact on weight change)., given the scope of the analysis and the data available. Many of data sources used (clinical and costs) were specific to the Australia setting	A copy of the EXCEL Obesity model SBB tax Australia and related files are available as supporting files (input parameters, RRs of disease per 1 unit increase of BMI, results of 9 disease over the first 25 years following the tax introduction. # pages

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								1,100 of stroke. In total, an estimated 1600 fewer deaths will occur by year 25, with heart disease accounting for the largest share of this postponed mortality.	In all scenarios, the policy was likely to be cost-saving from a health sector perspective.	and therefore may not be generalizable to Scotland.	
Wang et al. 2012 USA CEA Funding: The study was partially supported by a grant-in-aid from the American Heart Association Western States Affiliate and by a grant from the Robert Wood Johnson Foundation	**Aim:** To examine the potential impact on health and heath spending of a nationwide penny-per ounce excised tax on sugar sweetened beverages **Population:** adults aged 25-64 years **Intervention:** a penny-per ounce excised tax imposed on SSB **Comparator:** no SBB tax **Outcomes:** reductions in obesity, diabetes, cardiovascular disease, and associated (downstream) medical costs	(a validated) State transition (Markov cohort) model, the Coronary Heart Disease Policy Model (e.g. Weinstein 1987, Pletcher 2009) that simulates CHD and stroke based on risk factors in the US adult population **Perspective:** health care system (appendix) The CHD Policy Model (33-36) is a computer-simulation, statetransition (Markov cohort) model of CHD incidence, prevalence, mortality, and costs among persons older than 35 years in the United States adult population ages 35-84 years (e.g. Pletcher 2009 Weinstein 1987)	reduction in the consumption of SSB were linked to health benefits via two pathways: weight reduction (BMI ?) and reduction in the risk of type 2 diabetes, both of which reduce cardiovascular disease risk over time.	10 years (over the period 2010-2020)	Health care costs (diabetes CHD) came from published national data sources. (Centers for Medicare & Medicaid Services the mean annual cost of diabetes was based on a Report from the American Diabetes Association, based on multiple data bases. Total health care costs estimated using national data. CHD cost component by using California data), deflated by using cost-to-charge ratios. and the ratio of the U.S. national average costs to the California average and then inflated to 2010 dollars by using the Bureau of Labor Statistics Consumer Price Index for Medical Care Costs(Discounted 3% per year All costs in US dollars (price year, 2010, in appendix)	The authors stated that a sound knowledge base exists to inform projections of consumers' likely behaviour and impacts on disease risks in this population as a result of such a tax Baseline consumption of SBB was estimated from the National Health and Nutrition Examination Survey (2003-2006). The extent to which the proposed tax could reduce consumption was estimated using the average price of these beverages and published estimates of the price elasticity of demand, • Reduction in the risk of diabetes was estimated by applying the relative risk estimates reported by Mathias Schulze (2004) to the baseline individual intake levels from the National Health and Nutrition Examination Survey data for 2003–06. Potential differences in calorific intake with and without the tax were calculated. • The authors stated that consistent with previous studies, the base case assumed that the tax-induced reduction in SSB intake was likely to be replaced by a combination of water, diet drinks, and other nutritious caloric	reductions in diabetes, cardiovascular diseases, and associated (downstream) medical costs (savings)	The tax would reduce consumption of SSB by 15%.(95% CI:6,24) The net caloric saving would be 9 calories per day (95% CI: 3,16) the tax induced net reduction in calories results in a net reduction of 0.9 pound (95% confidence interval: 0.4, 1.5) in mean weight at the population level. The tax would have a greater impact on consumption and weight among younger adults and men, who consume more sugar-sweetened beverages at baseline, than among older adults and women. The resulting modest decline in expected BMI would result in approximately 867,000 fewer obese adults ages 25–64—a 1.5 percent reduction. In addition, the shift in SSB consumption would reduce new cases of diabetes by 2.6 percent over-all from 1.6 percent in in women age fortyfive and older to 3.4 percent in men under age forty-five. The tax was estimated was estimated to prevent 2.4 million diabetes person-years, 95,000 coronary heart events, 8,000 strokes, and 26,000 premature deaths, while avoiding more than $17 billion in medical costs over 10 years. In addition to generating approximately $13 billion in annual tax revenue, a modest tax on SSB could reduce the adverse health and cost burdens of obesity, diabetes, and cardiovascular diseases.	Probabilistic sensitivity analysis was undertaken (and Confidence intervals were calculated using the Monte Carlo method, which repetitively ran the model (for 1,000 repetitions) using different parameter values drawn from predetermined distributions based on published ranges. A one-way sensitivity analysis was conducted on the extent to which a reduction in calories from SSB leads to a compensatory increase in calories from food or beverages that are not taxed (base case 40% compensation). This parameter was varied over the full range—that is, from 0 percent (most optimistic) to 100 percent (most pessimistic, with no change in net calorie intake and thus no impact on body mass index). If 100 percent of the tax-induced reduction in calorie intake from sugar-sweetened beverages was replaced by equivalent caloric intake from other beverages and foods, there would be no impact on population body weight, and only about half of the diabetes risk reduction expected at the 40 percent replacement	The authors stated that a limitation of their study was that the National Health and Nutrition Examination Survey sample, may over represent lower income people in the community. Also the self-reported food consumption patterns in its food frequency questionnaire are also subject to recall bias. Other relevant disease outcomes are excluded such as osteoarthritis, some cancers, and dental caries. Overall the analysis produced conservative estimates of the full impact of the proposed SBB tax. The authors highlighted key areas of uncertainty including - how much consumers would reduce their purchasing in response to each 1 percent increase in price (or "price elasticity"). In the base-case the assumptions was that each 10 percent increase in price results in an 8 percent reduction in consumption (a price elasticity of−0:8), and was based on the most recent meta-analysis. (Andreyeva 2010) However, a wide range in elasticity	More details on the the Coronary Heart Disease Policy Model (CHDPM) model, summary of the evidence are available in an online Appendix (42 pages)

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						beverages (such as milk and juice) in equal measure.30 This pattern of replacement assumes that approximately 40 percent of the calories "saved" by reducing SSB intake are compensated for, producing a net reduction of 60 calories for every 100 calories of SSB not consumed. • Reduction energy intake (calories) were then converted to reduction in body weight using a validated conversion rule • The estimated reduction in diabetes and mean BMI associated with the reduction in weight were then entered into the Coronary Heart Disease Policy Model to predict downstream reductions in CVD (2010-20)			level would be realized. As a result, the health care savings would be reduced to $6.7 billion (approximately 40 percent of the base case). If none of the calories avoided by reducing SSB consumption were replaced by increases in other caloric beverages, the resulting medical savings would increase to $20.1 billion. Varied the discount rate, % SSB calories compensated	estimates (−0:13 to −3:18) exists in the literature. (Andreyeva 2010) Inevitably, there is also a wide range in price elasticity among consum What consumers substitutes in place of SSB is a key determinant of the net impact of the tax. Whether a sugar-sweetened beverage tax would disproportionately affect low-income consumers is uncertain. More evidence and attention in policy discussions should be devoted to the size of downstream health benefits to lower-income consumers and racial and ethnic minorities.	

Appendix 5

Summary of the main outcomes from the 10 studies included in the review of economic evaluations

Economic evaluation study	**Intervention(s)**	**Target population/cohort, and size/number modelled**	**Time horizon, cost perspective, and discount rate**	**Main outcomes reported (point estimates with confidence intervals, (CI) or uncertainty intervals (UI))***
Cecchini et al 2010 (England)	Food advertising regulation	Population aged 2-18 years. Size not reported	50 years Health service and programme costs 3% per year	2,179 DALYs per million population; US$ 4,278 per DALY averted
	Compulsory food labelling	Population aged ≥ 0 years. Size not reported		4,019 DALYs per million population; US$ 5,268 per DALY averted
	Fiscal measures	Population aged ≥ 0 years. Size not reported		6,049 DALYs per million population; US$ 52.5 million cost savings
Collins et al 2015 (England)	20% sugary drinks duty	Population of 41 million adults in 326 lower tier local authorities in England	20 years Health care costs Future costs and benefits appear not be discounted	Mean (2.5%, 97.5% percentile): 40,908 (6,923, 81,816) QALYs gained per year across England; £14,811,121 total health care cost savings per year across England
Veerman et al 2016 (Australia)	Additional 20% tax on the price of SSBs	Adult population aged >= 20 years Total size not reported	Lifetime Costs of legislative intervention and health care costs 3% per year	Mean (2.5%, 97.5% percentile): 167,993 DALYs averted; AUD$ 609 million (95% UI: 368-970) health care cost savings over the lifetime of the population aged > = 20
Wang et al 2012 (US)	Penny-per ounce excise tax on sugar sweetened beverages	Adult population ages 25-64 years. Total population size not reported.	10 years Health care costs 3% per year	Mean (95% CI): **Reduction** in: 2,377,000 diabetes person years; 95,000 incidence of CHD; 30,000 MIs; 8,000 strokes and 26,000 premature deaths; US$ 17.1 billion (10.6-23.5) savings in medical costs

Economic evaluation study	Intervention(s)	Target population/cohort, and size/number modelled	Time horizon, cost perspective, and discount rate	Main outcomes reported (point estimates with confidence intervals, (CI) or uncertainty intervals (UI))*
Gortmaker et al 2015a (US)	Excise tax of one cent per ounce on sugar-sweetened beverages	US population, all ages **reach 313 million** (≥ 2 years of age).	10 years "modified" societal (health care and intervention costs) 3% annually	Mean (95% UI): **Reduction** in 101,00 (35,000, 249,000) DALYs averted; 871,000 (342,000, 2,030,000) QALYs gained; US$ 23,200 million (54,500, 8,880) cost savings
	Elimination of the tax deductibility of TV advertising costs seen by children and adolescents	Population **reach 74 million** Ages 2–19 years only 74 million	As above	Mean (95% UI) 4,540 (1,750, 7,500) QALYs gained; US$ 343 million (572, 129) costs savings
Gortmaker et al 2015b (US)	Excise tax of one cent per ounce on sugar-sweetened beverages	Population reach 306.6 million	As above	Mean (95% UI) 575,936 (131,794, 1,890,715) cases of childhood obesity prevented US$ 14,169 million (47,119, 2,645) cost savings
	Elimination of the tax deductibility of advertising costs	As above	As above	Mean (95% UI): 129,061 (48,200, 212,365) cases of childhood obesity prevented US $260 million (431,94) cost savings
	Restaurant menu calorie labelling	Population reach 72.3 million	As above	Mean (95% UI): 41,015 (-41,324, 122,396) cases of childhood obesity prevented US $4,675 million (16,010, +6,284) cost savings to additional cost
Basu et al 2013 (US)	SSB ban	Target Population: US 2011 adults aged 25 to 64 y. Total population size not reported.	10 years Governmental. Medical costs and intervention - cost of subsidies or taxes	Mean (95% CI): 99,000 (82,000, 121,000) QALYs gained; US $0.285 billion (0.223, 0.373) cost savings
	SSB tax			Mean (95% CI): 26,000 (20,000, 33,000) QALYs gained; US

Economic evaluation study	Intervention(s)	Target population/cohort, and size/number modelled	Time horizon, cost perspective, and discount rate	Main outcomes reported (point estimates with confidence intervals, (CI) or uncertainty intervals (UI))*
			3% annually	$13.106 billion (11.286,15.226) cost savings
	Veg subsidy			Mean (95% CI): 7,700 (6,400, 9,500) QALYs gained; US$ 6.777 (5.845, 7.857) billion cost savings
An 2015 (US)	Monetary incentive of 30 cents for every dollar spent in participating retailers on fruits and vegetables	30-year-old SNAP participants receiving the HIP incentive.	Lifetime Societal (intervention and health care costs) 3% annually	US$ 1,323 additional cost per person; 0.083 QALYs gained per person; US$ 16,172 per QALY gained. 94.4% and 99.6% probability that the estimated cost per QALY gained would be lower than the cost-effective threshold of $50,000 and $100,000 per QALY gained, respectively.
Sacks et al 2011 (Australia)	Front-of-pack traffic light nutrition labelling in selected food categories	Affected population were 10% of adults (≥20 years) in Australia in 2003, 1.5 million.	Lifetime Health sector perspective (with some industry costs included). 3% annually	Median estimates (95% UI): 45,100 (37,700, 60,100) DALYs averted; AUD$ 455 (385, 560) million total cost offsets
	Tax on a range of unhealthy foods	Affected population were all adults ≥20 years in Australia in 2003, 14.5 million	As above	Median estimates (95% UI): 559,000 (459,500, 676,000) DALYs averted; AUD$ 5,550 (4,700, 6,370) million total cost offsets
Magnus et al 2009 (Australia)	Banning TV advertisements for energy-dense, nutrient-poor food and beverages	Target population were all children aged 5–14 years in Australia in 2001. Number 2..4 million	Lifetime Health care and interventions costs 3% annually	Median (95% uncertainty interval): 37 000 (16,000, 59,000) total DALYs saved AUD$ 300 (130, 480) million total cost offsets