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Research Article

Population health and health sector cost impacts of the UK Soft Drinks Industry Levy: a modelling study

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Abstract

Background: The United Kingdom Soft Drinks Industry Levy was introduced in April 2018, resulting both in changes in sugar levels in drinks and purchases of drinks. Both mechanisms could impact on the incidence and prevalence of raised body weight, diabetes and diet-related diseases, and therefore, have implications for economic costs to the health sector.
Objectives: To model future impacts of the Soft Drinks Industry Levy on population health and health sector costs and to estimate net monetary benefit to the health system.
Design and methods: Proportional multistate lifetable modelling study – open and closed cohort analyses.
Setting and population: All children and adults in the United Kingdom.
Intervention: The Soft Drinks Industry Levy is a two-tier levy of £0.18/l on drinks with between 5 and 8 g of total sugars/100 ml and of £0.24/l on drinks with ≥ 8 g of total sugars/100 ml.
Main outcome measures: We evaluated impact of the sugar reduction on: (1) prevalence of overweight and obesity, obesity-related diseases and dental health out to 2050 and (2) lifetime population health (measured in quality-adjusted life-years), change in costs to the health sector and the resulting net monetary benefit.
Data sources: We estimated a per person reduction in sugar from a previously published interrupted time series analysis, which found an 8.0 g/household/week (95% confidence interval 2.4 to 13.6) reduction in sugar at 1 year after implementation. Our multistate lifetable model is parameterised using data from population health monitoring surveys, the Global Burden of Disease project, the Human Mortality Database and the Office for National Statistics. Health sector costs were obtained from Department of Health and Social Care budget allocations.

Results: The model predicts that the Soft Drinks Industry Levy will reduce the prevalence of overweight and obesity in the United Kingdom by 0.18% points (95% uncertainty interval: 0.059 to 0.31) for males and by 0.20% points (0.064 to 0.34) for females. In the first 10 years of implementation, the reductions in sugar and overweight/obesity are predicted to prevent 270,000 (35,000–600,000) dental caries, 12,000 (3700–20,000) cases of type 2 diabetes, 3800 (1200–6700) cases of cardiovascular diseases and 350 (110–590) cases of obesity-related cancer. For the current United Kingdom population, it is estimated that the Soft Drinks Industry Levy will add 200,000 quality-adjusted life-years (63,500–342,000) over their lifetime and avert £174 million (£53.6–319) in their costs of health care (discounted at United Kingdom Treasury rates). At a United Kingdom Treasury value of £60,000 per quality-adjusted life-year, it is estimated that the Soft Drinks Industry Levy will produce a net monetary benefit of £12.2 billion (£3.88–20.8) for the health system.
Limitations: Modelled results assume that the effect of the Soft Drinks Industry Levy remains constant into the future. The longevity of the effect of the Soft Drinks Industry Levy has not been tested.
Conclusion: This study of the United Kingdom Soft Drinks Industry Levy tiered tax on sugar content provides further evidence that sugar-sweetened beverage taxes have the potential to achieve meaningful improvements in population health and reduce health sector spending.
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Introduction

In 2016, the UK Chancellor of the Exchequer announced that the UK Government would implement incentives for soft drink manufacturers, importers and bottlers to reduce the amount of sugar in soft drinks in the UK.[1] The Soft Drinks Industry Levy (SDIL) was implemented in 2018 as a two-tier levy of £0.18/l on drinks with between 5 g and 8 g of total sugars/100 ml and of £0.24/l on drinks with ≥ 8 g of total sugars/100 ml.[2] The levy targets soft drinks where sugar or similar sweeteners, such as honey, are added during the manufacturing process. Fruit or vegetable juices with no added sugar, and drinks that are at least 75% milk, among others, are excluded.

Sugar-sweetened beverages are a rational target for a levy, since they provide no nutritional benefit in the diet. Experimental studies have shown that they are associated with weight gain in children.[3,4] Those who regularly consume these drinks are more likely to have overweight or obesity and experience type 2 diabetes and cardiovascular disease.[5–9] The low impact of these drinks on feelings of satiety and subsequent overconsumption of calories are understood to be key mechanisms underlying these effects, although there is also emerging evidence of other adverse metabolic mechanisms.[10] Oral health is also affected, with greater consumption of sugar-sweetened beverages being associated with an increased risk of dental caries.[11]

Previous modelling analyses predicted that a sugar-sweetened beverage tax in the UK would improve population health by reducing the prevalence of obesity and rates of cardiovascular disease, diabetes, cancer and dental caries.[12,13] But these studies relied on speculation of the likely effects on product reformulation and changes in the market share of products with different levels of sugar content and relied on price elasticities to estimate consumer responses to potential changes in price. Following implementation of the SDIL in the UK, we now have the opportunity to examine the population health and healthcare cost implications of the tax based on real-world evaluation of the effects on sugar content and drink purchasing. Many countries have now implemented sugar-sweetened beverage taxes,[14] and evidence from Mexico from a real-world evaluation has been used to examine the future consequences for population health and healthcare expenditure. In the first 2 years after implementation of a $1 (conversion of peso to GBP: £0.04; $1 = £0.04, date of conversion 12 August 2025) per litre tax in Mexico in 2014, purchases of sugar-sweetened beverages reduced by an average of 7.6%.[15] Health economic modelling estimated that the tax would be cost-effective from a health sector perspective, predicting significant reductions in the prevalence of obesity and cases of diabetes, cardiovascular disease and cancers, and would reduce healthcare expenditure.

In this study, we model the health implications of the SDIL in the UK based on real-world evaluation of its effects on the sugar content and purchasing of soft drinks. Interrupted time series analyses of purchasing trends before and after the announcement and implementation of the SDIL found that at 1 year after implementation, the purchased volume of soft drinks had increased by 188.8 ml/household/week [95% confidence interval (CI) 30.7 to 346.9] but that the amount of sugar in purchased drinks had decreased by 8.0 g/household/week (13.6 to 2.4 g).[16] In a previous study, we modelled the health implications for children and adolescents, focusing on the social gradient in effect and the potential reductions in health inequalities that could result.[17] In this paper, we model the future impacts of the sugar reduction on obesity, diabetes, cardiovascular disease, cancer and dental health in the whole of the UK population and of the cost implications of these changes for the health sector.

Methods

We modelled the health and healthcare cost impacts of the SDIL using PRIMEtime,[18] a proportional multistate lifetable model developed in the UK for simulating population health and cost impacts of public health interventions and scenarios. PRIMEtime simulates the changing health of a population through time. From changes in prevalence of behavioural risk factors, such as obesity, the model can simulate impacts on incidence, prevalence and mortality of non-communicable diseases, including cardiovascular diseases, diabetes and cancers. These changes in disease influence both the years of life that are lived by the population and their quality of life, from which we can estimate the impact of an intervention or scenario on life expectancy, quality-adjusted life-years (QALYs) and health sector costs (*Figure 1*). A full description of the PRIMEtime input data for these analyses is shown in *Report Supplementary Material 1*.

Soft Drinks Industry Levy effect on sugar purchased in drinks

We derived the effect of the SDIL on purchased sugar in drinks from the results of an interrupted time series analysis.[10] This evaluation study analysed commercial household purchasing panel data from before announcement of the SDIL (March 2014–March 2016) to 1 year post implementation (April 2018–March 2019). The data included purchases of drinks eligible for the levy (e.g. soft drinks) and drinks that were exempt (e.g. milk, milk-based drinks, alcoholic drinks, no-added-sugar fruit juices and drinks sold as powders) to capture potential substitution effects. The panel data only included purchases for consumption at home; drinks purchased and consumed outside the home (e.g. as part of a meal, on a journey or at a restaurant) were excluded. The study found a net reduction in purchased sugar of 8.0 g/household/week (13.6–2.4 g).[16] From this, we estimated an average per person reduction in sugar consumption, assuming an average of 2.4 people per household[19] and assuming that changes in purchases translate directly into changes in dietary sugar intake.[20,21] This equated to a mean sugar reduction of 0.48 g/person/day. We did not assume any variation in modelled consumption by age or sex in the household, since examination of National Diet and Nutrition Survey data in the years before the announcement of the SDIL did not indicate any observable variation by age or sex in the consumption of sugar from across the range of included drinks (soft drinks, bottled water, milk and milk-based drinks, no-added-sugar juices and drinks sold as powders).[22]

Body mass index

We estimated the effect of sugar reduction on body mass index (BMI) using energy balance equations for children and adults,[23,24] assuming 3.75 kcal per gram of sugar[25] and no compensatory changes in energy expenditure or substitution of calories from other foods or drinks. For a child:

$$\Delta\ \text{BMI} = \Delta s \times 3.75 \times \frac{1}{\beta - (2.5 \times \text{age})} \times \frac{1}{\text{height}^2} \qquad (1)$$

where Δs is the change in sugar in g/day, age is the child's age in years, height is the child's height in metres, and β takes a value of 68 for a boy or 62 for a girl.

For an adult:

$$\Delta\ \text{BMI} = \Delta s \times 3.75 \times \frac{4.184}{100} \times \delta \times \frac{1}{\text{height}^2} \qquad (2)$$

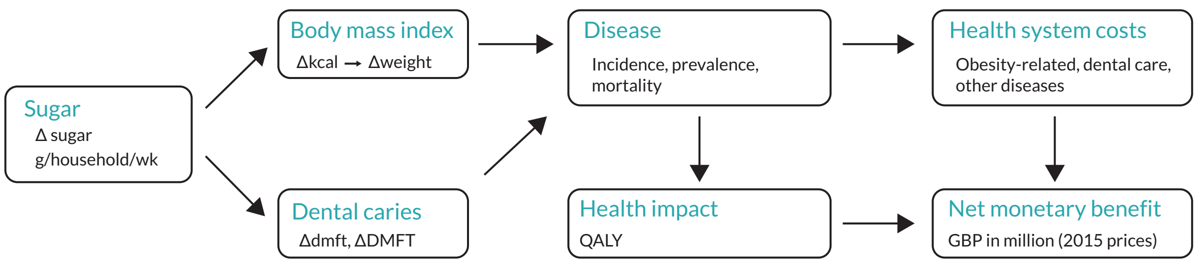

FIGURE 1 Modelling the effects of the SDIL on population health and health system costs. Note: dmft/DMFT, decayed missing and filled deciduous/permanent teeth. GBP, Great British pounds.

where Δs is the change in sugar in g/day, height is the adult's height in metres and δ is the proportion of the full effect (0.5 in year 1, 0.75 in year 2, 0.95 in year 3 and 1 from year 4 on).

Carbohydrates consumed in liquid form do not have the same effects on feelings of satiety that they do when consumed in solid food.[26,27] The lack of impact on satiety may lessen the desire to increase consumption and calorie intake from other foods or drinks.[28,29] In the evaluation of the SDIL, there was evidence of increases in purchasing of low or no sugar drinks, due to reformulation (which are accounted for in our modelling), but there was no evidence of an increase in purchasing of confectionery (a potential substitute for sugar and/or calorie intake) over the time period of announcement and implementation of the SDIL.[16] Additionally, studies of sugar-sweetened beverage taxes in the USA and the Netherlands do not indicate compensatory increases in calories from food purchasing.[28,29]

We modelled the SDIL effect on BMI as a change in trajectory of the shape and scale of the log-normal distribution of BMI, by age and sex, based on prediction models developed and validated on 27 years of Health Survey for England data.[30] For the main analyses, we used non-linear prediction models that forecast mean BMI heading towards an asymptote. In sensitivity analyses, we used linear prediction models that forecast mean BMI, reaching a peak within the next decade and declining thereafter. Prevalence of overweight and obesity was defined using BMI thresholds from the International Obesity Taskforce.[31]

Dental caries

We defined dental caries by the number of decayed, missing and filled permanent (DMFT) or deciduous (dmft) teeth. In the absence of UK-specific data, we estimated the effect of the sugar reduction on dental caries based on the results of a longitudinal analysis of sugar consumption and dental caries in three national surveys (2000, 2004 and 2011) in Finland.[12,32] In this study, Bernabé *et al.* found an increase of 0.09 DMFT (95% CI 0.02 to 0.15) for each additional 10 g of sugar consumed each day over the 11-year period in the study population aged 30+ years. Given a substantial body of evidence demonstrating a relationship between the amount of sugar consumed and development of dental caries in both children and adults,[33] we assumed that the dose–response relationship applied equally to dmft.

For children, we determined current dmft and DMFT rates from the Children's Dental Health Survey 2013.[34] For adults, we derived DMFT rates from separately measured numbers of decayed, missing and filled teeth reported in the Adult Dental Health Survey 2009,[35] adjusting for congenital tooth absence, tooth extraction from causes other than dental decay (e.g. periodontal disease and trauma) and edentulism.[36–38]

Disease modelling

We evaluated the impact of BMI changes on the incidence of five cardiovascular and metabolic diseases (ischaemic heart disease, ischaemic stroke, intracerebral haemorrhage, hypertensive heart disease atrial fibrillation/flutter and diabetes mellitus type 2) and eight obesity-related cancers (colorectal cancer, post-menopausal breast cancer, uterine cancer, oesophageal cancer, kidney cancer, pancreatic cancer, liver cancer and multiple myeloma).[39–42] We estimated the impact of changes in the distribution of BMI on the incidence of disease by calculating population impact fractions (PIFs).[43] A PIF is an estimate of the percentage reduction in rate of disease in a population and is a function of the baseline distribution of a risk factor, the scenario distribution of a risk factor and the dose–response relationship between the risk factor and a disease. Dose–response relationships were defined by relative risks from meta-analyses of prospective cohort analyses (see *Report Supplementary Material 1*).

For PRIMEtime analyses, we derived the baseline incidence, prevalence and case fatality rates for each of the modelled diseases in the UK using incidence, prevalence and mortality data from the Global Burden of Disease (GBD) and the disbayes R package to derive epidemiologically consistent rates of case fatality, which are not explicitly reported in the GBD reports (see details in *Report Supplementary Material 1*).[44,45] To estimate background trends in disease incidence and case fatality rates, we estimated rates for 2015 (the baseline year) and 2005 and allowed a linear annual progression between these years to continue into the forecast range for 10 years at which point incidence and case fatality rates remain constant.

Quality-adjusted life-years

From simulation of the obesity-related diseases, PRIME time estimates the impact of the SDIL on population mortality and life expectancy. We determined QALYs by adjusting the predicted years of life lived by disease-specific utility weights (see *Report Supplementary Material 1*), which reflect quality of life associated with diseases at each age and sex.[46]

Health system costs

We derived healthcare costs (see details in *Report Supplementary Material 1*) for the 2018–9 budget year and adjusted to the 2015 modelling baseline year using the Consumer Price Index.[47] NHS costs of treating disease were derived from Department of Health and Social Care budget allocations to: (1) clinical commissioning groups, which are responsible for hospital and community healthcare services in England; (2) primary care and (3) specialised services, which focus on conditions that are particularly expensive or have a small patient population. From the total costs of treating each modelled disease, we estimated an average cost per prevalent case by dividing by the average number of prevalent cases in 2018–9. From the total costs of treating all other diseases that were not explicitly modelled in PRIMEtime, we estimated an average cost per person in the population in 2018–9. For dental caries, where outcomes are modelled in units of decayed, missing or filled teeth, rather than population cases, we estimated the average cost of treatment from the total value of NHS dental contract payments, the total Units of Dental Activity that were carried out and the number of Units of Dental Activity associated with dental clinic fillings and extractions. The general practitioner–patient survey on dental care suggests that around 42% of all dental patients opt for private rather than NHS dental care, which is typically associated with higher fees than those charged by a NHS provider.[48] Thus, our estimates of healthcare cost impacts for dental care are likely to be conservative.

Net monetary benefit

Net monetary benefit (NMB) is a measure favoured by the UK Treasury. It reflects the value of an intervention in monetary terms and can be derived from the net intervention impacts on costs to the health sector and population health, assuming a willingness-to-pay threshold for health.[49] We determined the NMB of the SDIL policy from PRIMEtime estimates of the lifetime health (QALY) and cost impacts. A QALY was valued at £60,000 as recommended by UK Treasury,[50] and healthcare costs were fixed at 2015 prices. Both QALYs and costs were discounted using declining long-term discount rates, as recommended by UK Treasury, to capture both social time preferences and intergenerational transfer of wealth: 3.5% costs and 1.5% health (0 to 30 years), 3% costs and 1.29% health (31–75 years) and 2.5% costs and 1.07% health (76–125 years).[51]

PRIMEtime simulation

We ran both open and closed cohort simulations with the PRIMEtime model. To report changes in prevalence of overweight/obesity and rates of disease, we ran the PRIMEtime model until 2055, while continuing to add new birth cohorts to the simulation, so that the denominator for estimating rates would remain representative of the whole population (open cohort simulation). Estimates of future births in the UK were based on population projections from the Office for National Statistics.[52] To estimate lifetime impact of the SDIL on QALYs and costs to the health sector, we ran the PRIMEtime model until everyone in the 2015 UK population had died (a closed cohort analysis).

Uncertainty analyses

We estimated 95% uncertainty intervals around all model outputs, by repeating the simulations 3000 times, iteratively drawing from uncertainty distributions around PRIMEtime inputs, including the SDIL effect on sugar, relative risks of obesity-related diseases, the sugar–DMFT dose–response relationship, disease utility weights and healthcare costs. For healthcare costs, we were only able to derive point estimates for unit costs, so for uncertainty analyses, we assumed that the cost followed a log-normal distribution with the point estimate as mean and standard deviation (SD) as 20% of the point estimate. Contribution of these parameters to the uncertainty in model outputs was assessed in univariate analyses and displayed in a tornado diagram.[53] The total number of iterations (3000) was sufficient to report stable outcomes to three significant figures.

Sensitivity analyses

We examined the sensitivity of the modelled estimates of QALYs, costs and NMB to a number of factors, including the addition of diseases not included in the study protocol, but with evidence of an association with obesity, alternative discount rates, variations in background trends in BMI and disease rates and the rate at which change in obesity is assumed to have an impact on disease incidence (*Table 1*). We also evaluated NMB at a range of willingness-to-pay values for the QALY, ranging from zero to double the UK Treasury rate.

Results

Overweight and obesity

Assuming the sugar reduction effects of the SDIL are sustained to 2055, the model predicts that the SDIL will lead to a reduction in the prevalence of both overweight and obesity in the UK population (*Figure 2*). The combined prevalence of overweight and obesity is reduced by 0.18% points (95% uncertainty interval 0.059 to 0.31) for males and by 0.20% points (0.064 to 0.34) for females.

Obesity-related disease and dental health

In the first 10 years after implementation of the SDIL, it is estimated that there will be 12,000 (3700–20,000) fewer cases of type 2 diabetes, 3800 (1200–6700) fewer cases

TABLE 1 Sensitivity analyses

Sensitivity analysis	Base-case scenario	Sensitivity scenario
Added diseases	Ischaemic heart disease, ischaemic stroke, intracerebral haemorrhage, hypertensive heart disease atrial fibrillation/flutter, diabetes mellitus type 2, colorectal cancer, post-menopausal breast cancer, uterine cancer, oesophageal cancer, kidney cancer, pancreatic cancer, liver cancer and multiple myeloma	As for base-case scenario + asthma, low back pain, osteoarthritis of the hip and knee, depression and gallbladder and biliary diseases[54–60]
BMI linear trend	Non-linear background trend in BMI (model predicts that slowing rates of increase in BMI will ultimately reach an asymptote – see *Report Supplementary Material 1*, *Figure S2*)[30]	Linear trend (model predicts that slowing rates of increase in BMI will peak and then decrease – see *Report Supplementary Material 1*, *Figure S2*)[30]
BMI no trend	Non-linear background trend in BMI (model predicts that slowing rates of increase in BMI will ultimately reach an asymptote – see *Report Supplementary Material 1*, *Figure S2*)[30]	No background trend in BMI, i.e. prevalence of overweight and obesity remain stable at 2015 levels
No disease trends	Trends in disease incidence and case fatality applied for 10 years and then remain stable	No background trends in disease rates; rates remain stable at 2015 levels
No effect lags	Linear increase to full effect of BMI changes on disease incidence at 5 years for cardiovascular and metabolic diseases and 20 years for cancers	Immediate effect of BMI changes on disease incidence
NICE discount rates	UK Treasury tiered rates (0–30, 31–75, 76+ years):[51] 3.5%, 3%, 2.5% for health 1.5%, 1.29%, 1.07% for costs	NICE flat rate of 3.5% for costs and health outcomes[61]
Undiscounted	UK Treasury tiered rates (0–30, 31–75, 76+ years):[51] 3.5%, 3%, 2.5% for health 1.5%, 1.29%, 1.07% for costs	No discounting of costs or health outcomes (i.e. 0%)

NICE, National Institute for Health and Care Excellence.

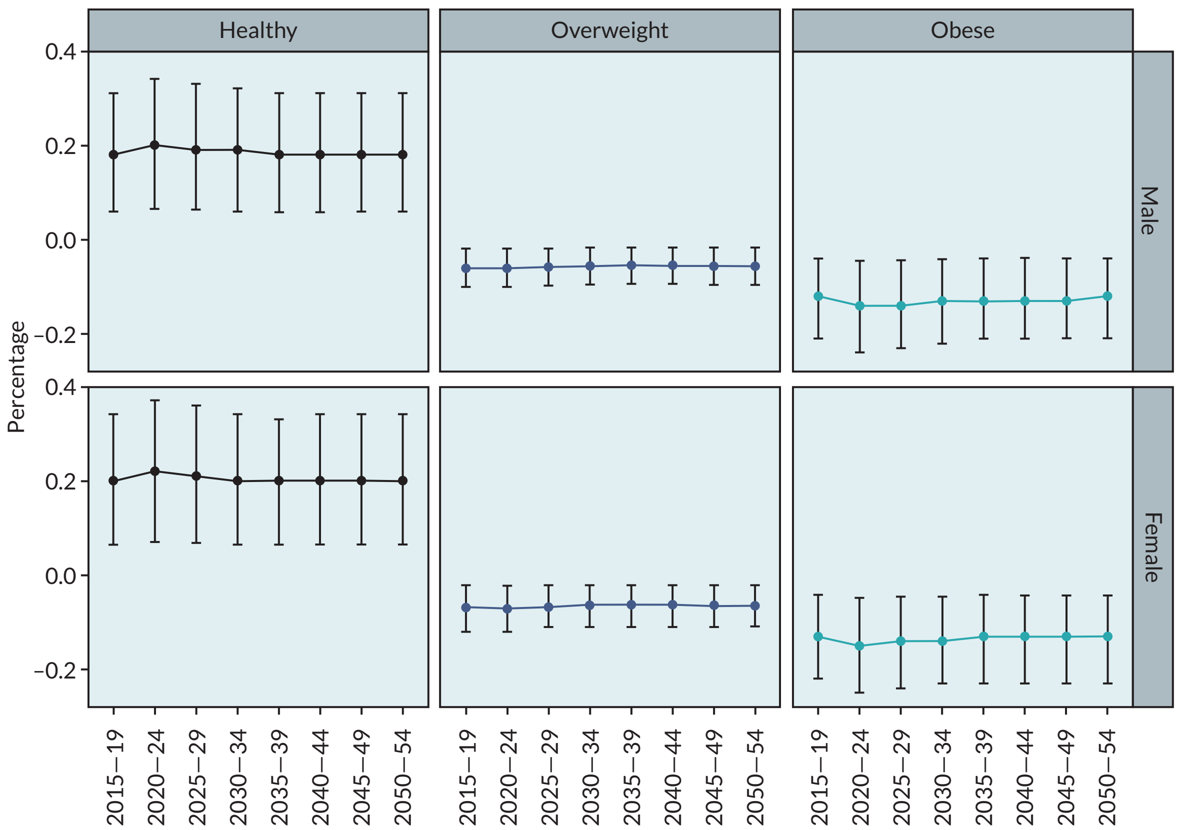

FIGURE 2 The SDIL impact on prevalence of healthy weight, overweight and obesity in the UK population over time. The *y*-axis ('Percentage') refers to percentage point changes in prevalence.

of cardiovascular diseases, 350 (110–590) fewer cases of obesity-related cancers and 270,000 (35,000–600,000) fewer dental caries. *Table 2* shows the predicted impact on each of the modelled causes for males and females.

Quality-adjusted life-years and healthcare costs

The model predicts that the SDIL will lead to a population health gain of 200,000 QALYs (63,500–342,000) over the lifetime of the 2015 UK population (*Table 3*). It is estimated that there will be a £174 million (£53.6–320) reduction in costs to the health service for treatment of dental caries and obesity-related diseases, which will be countered by a small £94.6 thousand (£30.6–162) increase in costs of treatment for other diseases (e.g. injuries, dementia and so on) that occur due to additional years of life lived. This leads to a net cost saving of £174 million (£53.6–319). At the UK Treasury value of £60,000 per QALY, the net effect of these modelled lifetime impacts on health and healthcare costs is a NMB of £12.2 billion (£3.88 to £20.8). NMB is linearly related to the willingness-to-pay value for the QALY: different values can be estimated from *Report Supplementary Material 2*, *Figure S2*.

Uncertainty analyses

Examination of the tornado diagram (*Figure 3*) shows that the majority of uncertainty in the magnitude of the health gains, net costs and NMB is due to the wide CI around the effect of the SDIL on sugar in purchased drinks. The uncertainty in the unit costs of disease, which we estimated as a SD equal to 20% of the point estimate cost, also has sizeable impact on the net healthcare costs.

Sensitivity analyses

In sensitivity analyses, the health gains, net cost savings and positive NMB remained significant under all scenarios evaluated, although the magnitude of the estimates varied (*Figure 4*). Modelled estimates were most sensitive to the discount rates chosen for analysis. For example, the NMB of the SDIL was 37% lower if discounted using NICE rates of 3.5% for both QALYS and costs but was 79% higher with no discounting of QALYs or costs. The addition of potential BMI-related changes in asthma, depressive disorders, gallbladder and biliary diseases, low back pain and osteoarthritis of the hip and knee increased cost savings (+62%) more than it increased QALYs (+12%), which led to a 13% higher NMB. The choice of background trend

TABLE 2 Soft Drinks Industry Levy impact on incident cases of disease and dental caries in the 10 years following SDIL implementation

Cases	Male	Female	Total
Ischaemic heart disease	−1400 (−2400 to −440)	−620 (−1100 to −200)	−2000 (−3500 to −640)
Ischaemic stroke	−190 (−340 to −59)	−200 (−370 to −63)	−390 (−700 to −120)
Intracerebral haemorrhage	−100 (−190 to −29)	−110 (−210 to −29)	−210 (−400 to −58)
Hypertensive heart disease	−130 (−260 to −28)	−150 (−300 to −36)	−280 (−560 to −65)
Atrial fibrillation and flutter	−520 (−960 to −160)	−440 (−820 to −140)	−970 (−1800 to −300)
Diabetes mellitus type 2	−6300 (−11,000 to −2000)	−5300 (−9000 to −1700)	−12,000 (−20,000 to −3700)
Breast cancer	–	−85 (−150 to −26)	−85 (−150 to −26)
Colon and rectum cancer	−15 (−30 to −4.1)	−14 (−28 to −3.9)	−29 (−58 to −8)
Oesophageal cancer	−39 (−72 to −12)	−22 (−40 to −6.6)	−61 (−110 to −18)
Kidney cancer	−18 (−33 to −5.5)	−13 (−24 to −4)	−32 (−57 to −9.5)
Liver cancer	−21 (−41 to −5.6)	−16 (−32 to −4.3)	−37 (−73 to −9.9)
Multiple myeloma	−5.4 (−9.5 to −1.7)	−4.8 (−8.4 to −1.5)	−10 (−18 to −3.1)
Pancreatic cancer	−9.2 (−18 to −2.7)	−11 (−22 to −3.2)	−20 (−40 to −5.9)
Uterine cancer	–	−72 (−120 to −23)	−72 (−120 to −23)
Dental caries[a]	−130,000 (−290,000 to −17,000)	−140,000 (−300,000 to −18,000)	−270,000 (−600,000 to −35,000)

a Dental caries are measured as the number of decayed, missing and filled teeth.

TABLE 3 Lifetime population health and healthcare cost impacts and NMB of the SDIL

Sex	QALY (years)	Costs of health care for dental caries and obesity-related diseases (£ million)	Costs of health care for all other diseases in added years of life (£ million)[a]	NMB (£ million)
Female	98,600 (31,500–168,000)	−100 (−186 to −31)	0.0476 (0.0154–0.0811)	–
Male	101,000 (32,100–174,000)	−73.9 (−138 to −21.9)	0.047 (0.0152–0.0808)	–
Total	200,000 (63,500–342,000)	−174 (−320 to −53.6)	0.0946 (0.0306–0.162)	12,200 (3880–20,800)

a Difference in costs of health care for diseases not explicitly modelled, in added years of life.

Note
Values are modelled using point estimate and 95% uncertainty interval based on 3000 iterations of a Monte Carlo analysis. All results are presented to three significant figures. Values are discounted using UK Treasury tiered discount rates and a QALY is valued at the UK Treasury rate of £60,000 in calculating the total NMB.

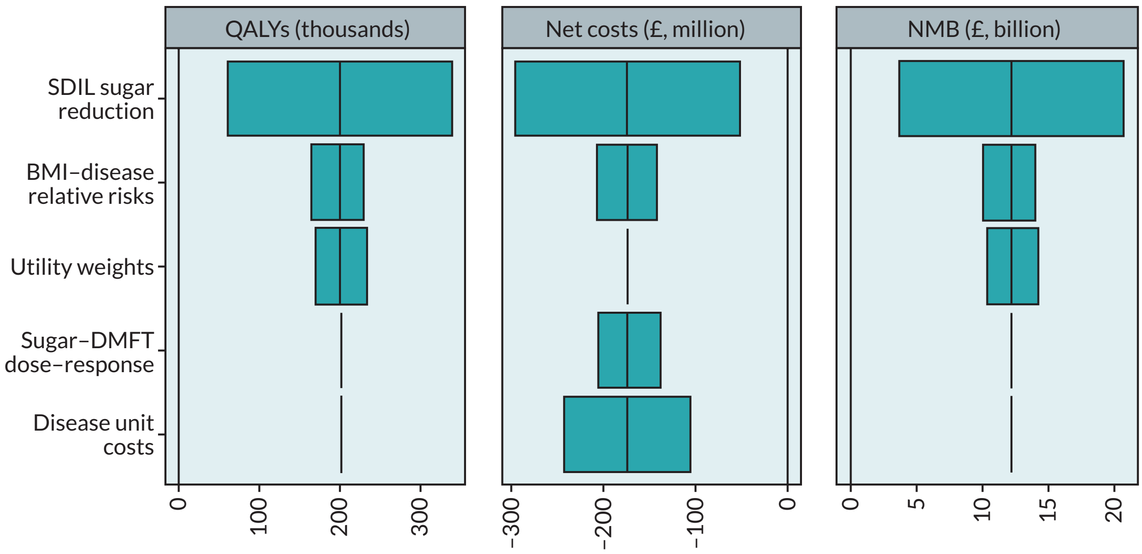

FIGURE 3 Tornado plots illustrating the contribution of uncertainty around model input parameters to the uncertainty in model outputs – QALYs, net costs and NMB. In each case, the *x*-axis shows the variation around the central estimate (measured in units shown in the header of the plot) if only uncertainty from the parameters shown on the *y*-axis are included in the model.

model (linear vs. non-linear) had relatively little impact on health economic outcomes (< 1% change in NMB), but the NMB was 8.9% higher when assuming no background trends at all in BMI (see *Report Supplementary Material 2*, *Figure S1* for comparison of the impact on prevalence of overweight and obesity). Removing the assumed lags in effect of changes in BMI on disease incidence (5 years for cardiovascular disease and 20 years for cancer) increased NMB by 6.5% while removing background trends in diseases reduced NMB by 2.9%.

Discussion

Statement of principal findings

We evaluated the population health and health sector impacts of the SDIL by using the PRIMEtime model to simulate the likely impact on obesity, disease and healthcare costs from the observed effects on sugar purchased in drinks for in-home consumption. The model predicts that the reductions in sugar will reduce the prevalence of overweight and obesity in the UK, preventing type 2 diabetes, cardiovascular disease and obesity-related cancers, and it will improve dental health. For the current UK population, it is estimated that the SDIL will add 200,000 QALYs (63,500–342,000) over their lifetime and avert £174 million (£53.6–£319) in their costs of health care, producing a NMB of £12.2 billion (£3.88–£20.8) for the health system. There are wide uncertainty intervals around the model predictions, which chiefly reflect the wide uncertainty in the effect of the SDIL on sugar purchased in drinks [−8.0 g/household/week (95% CI −13.6 to −2.4)].[16] Nevertheless, the beneficial impacts of the SDIL are robust to variations in modelling assumptions around background trends in BMI and disease rates, lags in the effect of the SDIL on disease and discount rates.

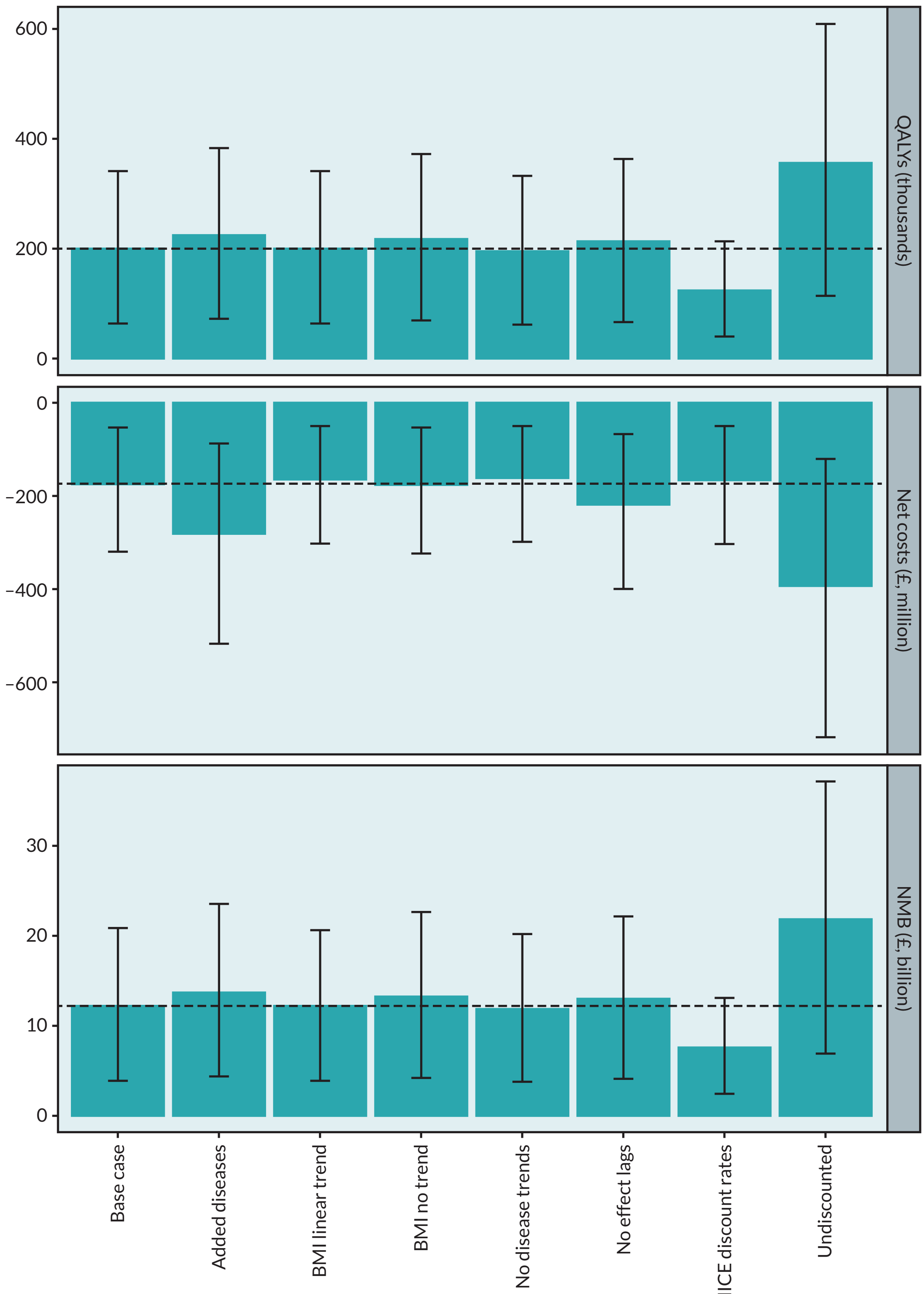

FIGURE 4 Sensitivity of NMB to a range of modelling assumptions. The *y*-axis is measured in units shown on the right-hand side of each plot.

Comparison with other literature

Our results are consistent with previous modelling studies, which have predicted health and monetary benefits of a tax targeting sugar-sweetened beverages in the UK.[12,13] The potential reductions in disease modelled in these previous studies are larger than we have predicted from the effects of the SDIL. For example, Briggs *et al.*[12] estimated that 19,094 cases of diabetes could be prevented annually;

Collins *et al.*[13] estimated that 2432 cases of diabetes could be prevented annually, whereas our model estimated that the SDIL could prevent an average of 1200 cases of diabetes. Our result is an average derived from the modelled effects over the first 10 years (*Table 2*) and is in part lower than previous modelled estimates, because we more conservatively assumed that the changes in sugar intake would take time to reach full effect (5 years for diabetes). However, the chief reason for our lower estimates of disease prevention is that the 1.8 kcal/person/day reduction attributed to the SDIL is much lower than the 10 kcal/person/day reduction modelled by Briggs *et al.*[12] and the 6.5 kcal/person/day reduction modelled by Collins *et al.*[13] Since the previous modelling studies preceded implementation of the SDIL, they relied on price elasticity and other data to estimate the likely consumer response to a hypothetical tax on sugar-sweetened beverages. Such studies cannot directly capture potential supply-side responses, such as reformulation, or consumer responses to the signalling of health concerns potentially associated with a government initiating an intervention targeting sugar-sweetened beverages.[62] By drawing on real-world evaluation of the SDIL, our modelling study provides stronger evidence of the likely health and health sector benefits of implementing a tax targeting sugar-sweetened beverages in the UK.

As of December 2021, 40 countries are reported to have announced or implemented some form of sugar-sweetened beverage tax.[14] There is a growing body of evidence demonstrating the effectiveness of taxes in reducing purchasing or consumption of sugar-sweetened beverages,[62] but, to date, only, in Mexico, has this evidence from real-world evaluation been used to examine the future consequences for population health and healthcare expenditure. Like our study, modelling of the sugar-sweetened beverage tax implemented in Mexico[55] estimated that the tax would be a cost-effective intervention for improving population health from a healthcare perspective.[63] There are differences in the design of the taxes between the two countries: Mexico implemented a $1 (conversion of peso to GBP: £0.04; $1 = £0.04, date of conversion 12 August 2025) per litre excise tax, which raised the retail price of drinks, whereas the UK implemented a tiered levy on drinks as an incentive for drink manufacturers to reduce the sugar content of drinks. But overall, the results of the modelling analyses were relatively similar: predicting small reductions in obesity prevalence (i.e. 0.21% point reduction from a baseline prevalence of 32%[64] in Mexico, and 0.13% point reduction from a baseline prevalence of 29% in the UK) leading to significant reductions in cases of diabetes, cardiovascular disease and cancers and reduced healthcare expenditure.

Strengths and weaknesses of the study

A key uncertainty in modelling the population health impacts of sugar-sweetened beverage taxes is the pathway by which the change in drink consumption or sugar content of drinks influences disease. The evaluation of the UK SDIL found a reduction in sugar purchased in drinks.[16] In our modelling analyses, we estimated the equivalent reduction in calories and simulated effects of reduced energy intake on BMI and obesity-related disease. We assumed that there would be no substitution for the calorie effect from increased consumption of other foods. There was no evidence of an increase in purchasing of confectionery over the time period of announcement and implementation of the SDIL.[16] Analysis of Homescan data from the USA,[28] which considered compensation from a wider variety of sugary foods, and a virtual supermarket randomised controlled trial in the Netherlands,[29] support the assumption that calorie reduction associated with taxing sugar-sweetened beverages is unlikely to be compensated for with increases in purchasing of other foods, but the true long-term effects of the SDIL are unknown.

There is a wealth of observational and trial evidence supporting the causal relationship between the intake of sugar and sugar-sweetened beverages and obesity.[9,65] But there is also a growing body of evidence, including lab studies and prospective cohort studies, suggesting that the metabolism of sugars in sugar-sweetened beverages may have cardio-metabolic effects that are over and above the impacts on energy intake that we have accounted for in our modelling.[66] By restricting our cardiovascular disease and cancer modelling to the direct calorific impact on body weight, we may have underestimated the full impact of the SDIL.

We also did not evaluate the effect of any change in the consumption of non-sugar sweeteners that may have occurred in the reformulation of drink products with the SDIL. Randomised controlled trials suggest that people consuming non-sugar sweeteners as a replacement for sugars have a lower body weight or BMI at the end of the trial, but longer-term prospective cohort studies suggest that there will be an increased risk of diabetes and cardiovascular disease with consumption of non-sugar sweeteners.[67] It is possible that these observed associations with harmful effects are due to reverse causation and/or residual confounding. We did not model the effects, if any, of possible increases in the consumption of non-sugar sweeteners on population health due to the SDIL.

The interrupted time series analysis of the SDIL was based on household-level purchasing data; hence we were not able to determine how the changes in household sugar purchasing may have impacted differently on individuals within the household (e.g. adults vs. children). Additionally, the interrupted time series analysis only included data on the products brought into the home.[16] Out-of-home purchases account for around 10–12% of expenditure on cold non-alcohol beverages in the UK.[68] If the SDIL has a similar impact on sugar in drinks' purchases out-of-home, then the SDIL may have had a larger impact on health than we have modelled here, but further work is needed to understand the impacts of the SDIL on out-of-home purchases.

Additionally, we do not know the impact of product wastage within the home. The reduction in sugar that we have modelled is a net effect of changing sugar content and changing purchase volume of taxed and untaxed products. Analyses of UK household waste in 2012 estimated volumetric wastage proportions of 5.2% for bottled water, 7.2% for carbonated soft drink, 8.6% for squash, 12.0% for fruit juices and smoothies and 7.0% for milk.[69] This suggests that waste may vary by drink type, but the net waste effect due to changing proportions of different product purchasing was not estimated in the time series analyses of the SDIL effect. Further, we do not know if product wastage is influenced by possible taste changes due to product reformulation.

Implications

Sugar-sweetened beverage taxes are among the suite of 'best buy' interventions recommended by the World Health Organization (WHO) for addressing childhood obesity and preventing non-communicable diseases.[70,71] From an economic perspective, the costs of treating dental caries and obesity-related diseases that stem from drinking sugar-sweetened beverages are a negative externality, and taxes are a potential way of internalising these costs. Our modelling of the UK SDIL and the modelling of the sugar-sweetened beverage tax in Mexico indicate that these interventions are likely to both improve population health and reduce health sector expenditure.

Children and adolescents are heavy consumers of sugar-sweetened beverages.[72,73] Consumption is frequently higher in those from lower-income or lower socioeconomic households,[73,74] which contributes to the socioeconomic differences in body weight that begin in early life.[75] Interrupted time series analyses suggest that lower-income households have benefited the most with reductions in purchasing of sugar from beverages with the SDIL,[76] and analyses of surveillance data of obesity in school-aged children suggest that there has been an associated reduction in the prevalence of obesity in girls and in both boys and girls from schools in the most deprived areas of England.[77] Our modelling shows that the SDIL is likely to achieve small but significant reductions in inequality in the life expectancy of English children.[17]

The WHO recommends limiting free sugar consumption to a maximum of 10% of energy intake.[78] The high levels of potential harm, low nutritional benefit and discretionary nature of sugar-sweetened beverages make them an ideal target for reducing free sugar intake. In the UK, however, the SDIL on its own will not be enough to reduce free sugar consumption to the levels recommended by the WHO. In the UK, non-alcoholic beverages account for a large proportion of free sugar intake, particularly in teenagers (34%), but across all ages, the majority of free sugars are consumed in foods such as cereal and cereal products (e.g. cakes and pastries),discretionary sugars (e.g. in tea and coffee), preserves and sweet spreads, confectionery and dairy products (e.g. yoghurt and dairy desserts).[79] Widening the remit of food taxes to include free sugar from all sources could be a useful tool to prompt both reformulation and reduce purchasing of high sugar foods.[80,81] Such a tax was proposed in the National Food Strategy review commissioned by the UK Government.[82] Estimates suggest that this tax may reduce (free) sugar consumption by as much as 4–10 g/person/day,[83] which is substantially more than the sugar reduction associated with the SDIL (approximately 0.48 g/person/day, assuming an average household size of 2.4 people), but further modelling of the National Food Strategy tax scenarios is needed to fully account for the changes in demand across the food system. Studies from Australia and New Zealand suggest that there are likely to be population health benefits from combining food and drink taxes and/or subsidies, such as a tax on sugar-sweetened beverages and a subsidy on fruits and vegetables.[84,85] But further work exploring the public acceptability of fiscal policies in the food system, and working with the public to design food tax and subsidy scenarios, may also help to build trust and political support for new interventions in the UK.

Unanswered questions and future research

In this study, we examined the impacts of the SDIL on population health and costs of health care, but there are also likely to be broader societal impacts stemming from reductions in obesity-related diseases, such as increased productivity in working-age adults and reduced costs of social care at older ages. We determined NMB of the SDIL from the averted healthcare costs and by applying a value of statistical life to the QALY gain, but we did not include costs of delivering the intervention. However, in ongoing macroeconomic work, we are examining a much wider range of impacts on UK Treasury, industry and consumers (e.g. changes in revenue, employment, GDP and household spending), and in forthcoming assessment, we will be presenting a wider range of both health and economic indicators. Further ongoing research is exploring the potential for extension of the SDIL to other health-related food taxes and subsidies in the UK and modelling their long-term impact on health and health inequalities. This research includes the COPPER,[86] FINCH[87] and HEALTHEI[88] projects, all funded by NIHR.

Patient and public involvement in the study

This study was one part of the NIHR-funded 'Evaluation of the health impacts of the UK Treasury Soft Drinks Industry Levy'. The project was supported by a steering committee with a lay member, who provided feedback on project aims and methods throughout. The aim of the lay member on the steering committee was to provide input into both direction of research strategy and scrutiny of research outputs. The results of this study were presented to the steering committee and feedback was provided to improve the understandability of the reporting.

Conclusion

The UK SDIL is a tiered levy designed to encourage drink manufacturers to reduce sugar content. Analysis at 1 year after implementation in April 2018 found that it had reduced sugar in drinks purchased for home consumption by 8.0 g/household/week (95% CI 2.4 to 13.6). Population health modelling suggests that these changes in sugar consumption, if sustained, will reduce prevalence of overweight/obesity and related diseases and will improve dental health in the UK. Health economic analysis indicates that, over the lifetime of the current UK population, the SDIL could add 200,000 QALYs (63,500–342,000) and avert £174 million (£53.6–319) in healthcare costs, leading to a NMB of £12.2 billion (£3.88–20.8) for the health sector. This study provides further evidence that sugar-sweetened beverage taxes have the potential to achieve meaningful improvements in population health and reduce health sector spending.

Additional information

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Patient data statement

This work uses data provided by patients and collected by the NHS as part of their care and support. Using patient data is vital to improve health and care for everyone. There is huge potential to make better use of information from people's patient records, to understand more about disease, develop new treatments, monitor safety and plan NHS services. Patient data should be kept safe and secure, to protect everyone's privacy, and it is important that there are safeguards to make sure that they are stored and used responsibly. Everyone should be able to find out about how patient data are used. #datasaveslives You can find out more about the background to this citation here: https://understandingpatientdata.org.uk/data-citation.

Data-sharing statement

All data used to support the PRIMEtime model and the analyses conducted in this paper are available in the public domain, some with licensed agreements from relevant data archives (e.g. the UK Data Archive: www.data-archive.ac.uk/).

Ethics statement

This study used publicly available secondary data and did not involve collecting primary data from human participants. Ethical approval was therefore not required.

Information governance statement

This study did not handle any personal information.

Disclosure of interests

Full disclosure of interests: Completed ICMJE forms for all authors, including all related interests, are available in the toolkit on the NIHR Journals Library report publication page at https://doi.org/10.3310/GJMW1501.

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List of supplementary material

Report Supplementary Material 1
PRIMEtime data inputs

Report Supplementary Material 2
Additional analyses and results

Supplementary material can be found on the NIHR Journals Library report page (https://doi.org/10.3310/GJMW1501).

Supplementary material has been provided by the authors to support the report and any files provided at submission will have been seen by peer reviewers, but not extensively reviewed. Any supplementary material provided at a later stage in the process may not have been peer reviewed.

The supplementary materials (which include but are not limited to related publications, patient information leaflets and questionnaires) are provided to support and contextualise the publication. Every effort has been made to obtain the necessary permissions for reproduction, to credit original sources appropriately, and to respect copyright requirements. However, despite our diligence, we acknowledge the possibility of unintentional omissions or errors and we welcome notifications of any concerns regarding copyright or permissions.

List of abbreviations

BMI	body mass index
DMFT	decayed, missing and filled permanent teeth
DMFT	decayed, missing and filled permanent deciduous teeth
GBD	Global Burden of Disease
NICE	National Institute for Health and Care Excellence
PIF	population impact fraction
QALY	quality-adjusted life-year

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