The impact of a tax on sugar-sweetened beverages according to socio-economic position: a systematic review of the evidence

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The impact of a tax on sugar sweetened beverages according to socioeconomic position: A systematic review of the evidence

ABSTRACT

Objective: A tax on sugar sweetened beverages (SSBs) has been proposed to address population weight gain but the effect across socioeconomic position (SEP) is unclear. This study aimed to clarify the differential impact(s) of SSB taxes on beverage purchases and consumption, weight outcomes and the amount paid in SSB taxes according to SEP.

Design: Databases (OVID and EMBASE) and grey literature were systematically searched in June 2015 to identify studies that examined effects of a SSB price increase on beverage purchases or consumption, weight outcomes or the amount paid in tax across SEP, within high income countries.

Results: Of the 11 included articles, three study types were identified – those that examined the association between variation in SSB taxes and SSB consumption and/or body weight (n=3), price elasticity estimation of SSB demand (n=1) and modelling of hypothetical SSB taxes by combining price elasticity estimates with population SEP-specific beverage consumption, energy intake or body weight (n=7). Few studies statistically tested differences in outcomes between SEP groups. Nonetheless, of the seven studies that reported on changes in weight outcomes for the total population following an increase in SSB price, all reported either similar reductions in weight across SEP groups or greater reductions for lower compared to higher SEP groups. All studies that examined the average household amount paid in tax (n=5), reported that a SSB tax would be regressive, but with small differences between higher and lower income households (0.10% - 1.0% and 0.03% - 0.60% of annual household income paid in SSB tax for low and high income households, respectively).

Conclusions: Based on the available evidence, a tax on SSBs will deliver similar population weight benefits across socioeconomic strata or greater benefits for lower SEP groups. A SSB tax is shown to be consistently financially regressive, but to a small degree.

Keywords: sugar sweetened beverage; socioeconomic inequalities; obesity; policy

Introduction

The prevalence of obesity follows a socioeconomic pattern. In high income countries, individuals with a lower income, education or who live in more disadvantaged areas are at a higher risk of excess weight gain and obesity (1, 2) . Accordingly, it was recommended, in the 2010 UK 'Fair Societies, Healthy Lives' report, that evidence based, universal interventions that address the causes of obesity across the socioeconomic gradient be implemented (3). However, very few obesity prevention interventions are evaluated according to their impact across socioeconomic strata (4-7).

A tax on sugar sweetened beverages (SSBs) features prominently in the suite of recommended regulatory approaches to address population weight gain (8-11). Evidence demonstrates that regular consumption of SSBs is associated with excess weight gain and a number of co-morbid conditions (12), including diabetes, cardiovascular disease and dental caries (13). Moreover, SSBs lack nutritional value, and in the absence of satiety signals, commonly represent excess calories in the daily diet (14, 15). Individuals from lower socioeconomic groups commonly consume more SSBs than their higher socioeconomic counterparts (16, 17), potentially contributing to the observed inequalities in excess weight and associated disease. Finally, SSBs are consumed at relatively high quantities (in 2012 26.3% of US adults consumed SSBs ≥ 1 times daily (18)) leading to greater price sensitivity compared to products consumed at low frequencies and volumes (19).

Although several high-income countries around the world already have a tax on SSBs, these are often small in magnitude (for example, across all US states, SSB taxes average approximately 4% (11)) and are implemented for revenue, rather than health related reasons. The latter is important as a tax implemented for health-related is likely to additionally act as a health communication campaign. In 2014, Mexico became the first country to impose a national health-related excise tax on beverages with added sugar of 1 peso-per-litre (approximately a 10% price increase). Recent evaluation of the tax revealed a reduction in the purchase of sugary drinks of 12%, 12-months post policy implementation, compared to the counterfactual scenario based on pre-tax trends (20). In this study, the

greatest declines were observed among households of a lower SEP, with a 12-month decline in sugary drinks of 17% compared with pre-tax trends (20).

Price elasticity estimates of SSB demand suggests that a 10% tax on SSBs could lead to an 8-10% reduction in purchase of these beverages (21). Modelling studies further predict that a 20% tax on SSBs in the US could reduce the prevalence of obesity by 3.5 %-points (22). However, one of the major concerns of a tax on SSBs is that it will be financially regressive, whereby those with a lower income would pay a greater proportion of their income in tax compared to higher income earners (23). Proponents, on the other hand, argue that this financial regressivity would be justified by the progressive health benefits (greater for those with a lower SEP) given the higher obesity prevalence and greater consumption of SSBs among lower socioeconomic groups (23).

Although several studies have synthesised the impacts of a SSB tax according to SEP, these studies are usually limited to include specific-study designs, single outcomes and do not consider the differential amounts paid in SSB tax as a proportion of income. Understanding the health equity impact of a SSB tax is essential if we wish to prioritise obesity prevention interventions that are most likely to be effective across all socioeconomic strata. The aim of this work was to systematically review the literature for studies (of any study design) conducted in high-income countries that examined the effect of a SSB price increase on beverage purchase or consumption and/or weight outcomes according to an indicator of SEP. Where possible we additionally aimed to examine the average amount paid in SSB tax across socioeconomic strata (as a percentage of income).

Methods

We conducted a systematic review of the literature to identify studies from high-income countries that reported on one or more of the following outcomes: beverage purchases, beverage consumption (and/or total energy intake), and/or weight outcomes following a change in SSB price according to a marker of socioeconomic position (SEP). Low and middle income countries were excluded due to the relationship between SEP and SSB intake and/or obesity being the reverse (or varying relationship as a result of undergoing nutritional transition) of that which is consistently observed in high income countries. From these studies, we were additionally interested in the data pertaining to the amount paid in tax for

each SEP group. Because a regressive tax is one where the poor pay a higher percentage of their income in tax compared to the rich, we intended to only included studies where the proportion of income paid in SSB tax across SEP was reported. However, we were also able to include studies that only reported on the absolute amount paid in SSB tax across income groups as these studies reported a greater absolute amount paid in tax among lower income households, which necessarily equates to a greater proportion of household income.

A protocol was developed for the selection, analysis and reporting of articles in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Equity (PRISMA-Equity) guidelines (24) (see appendix table 1 fro PRISMA checklist). Relevant information was extracted from all included studies, including the impact of a SSB price change on beverage purchase and consumption and weight outcomes, as well as the amount paid in tax for all socioeconomic groups. Finally, the overall quality of the study was assessed (see below) and the robustness of conclusions evaluated. Due to the heterogeneity in the outcome reported across studies, and therefore a small number of studies for each outcome, we did not examine risk of publication bias.

Search strategy

Electronic data bases (Medline via OVID and EMBASE) and grey literature (System for Information on Grey Literature in Europe, the Virtual Library for Public Health, Google Scholar, plus websites and reports from relevant organizations, including those with a health equity focus) were systematically searched from data base inception through to June 2015 to identify studies (any study design) that included terms for SSBs, taxation and SEP. Each hedge (SSBs, taxation and SEP) was combined with the operator 'AND' and within each hedge, search terms were combined using the operator 'OR'. Specific search terms were as follows (used as key words unless otherwise stated): SSBs (soda, soft drink, carbonated beverage*, sugar-sweetened*, beverage*, beverages/economics (Medical Subject Heading (MeSH)); taxation (price*, subsid*, cost*, tax*, demand elast*, taxes/economics (MeSH)); SEP (income, education*, disadvantage, disparit*, equit*, inequal*, inequit*, occupation, socio*, socioeconomic factors (MeSH), social class (MeSH)). Use of an asterix denoted an open ended search term. No limits were placed on the basis of language, country or

publication date. The reference lists of all relevant original research and review articles were scanned to capture citations missed by electronic searches. Authors were contacted for missing information.

All retrieved articles were independently scanned in three stages by two reviewers (KB and VL). First, studies were assessed for relevance of title. If the title appeared relevant, or if authors were unsure, the abstract was next assessed to determine if the study satisfied the inclusion criteria. Included or unclear articles then proceeded to the full manuscript stage to be formally assessed against the inclusion criteria.

Inclusion criteria and data extraction

Studies were included if they reported on the impact of a change in SSB price on beverage purchase or consumption, energy intake and/or body weight outcomes (or another marker of adiposity) according to any marker of SEP (individual or area based) within a high-income country.

A matrix table of study characteristics was compiled and the relevant information was extracted from the included articles by two independent authors with disagreements resolved by consensus with other authors. In the few instances where relative consumption or weight outcomes (% reduction) were reported we also calculated absolute effects (percentage-point reduction) and present both. Where possible we also converted units of results to the most commonly reported unit for consistency across studies. Study authors were contacted where relevant information was missing.

Quality of studies

We assessed the quality of all studies using a checklist derived from two recent reviews of food and beverage pricing studies (25, 26). The quality criteria assessed were: (i) prospective study of observed behaviour; (ii) evaluation of an actual tax (rather than a hypothetical tax); (iii) price linked directly to purchase within same population; (iv) consideration of product compensation (cross-price elasticity); (v) long-run input data across time with sufficient variation in prices used to estimate price elasticities (for experimental studies this included data collected over a period of at least one month, for studies using existing data sets on SSB price this included data collected at intervals no less than two months apart for at least

12 months), (vi) valid and appropriate country specific data (vii) reporting of uncertainty around price elasticity estimates. We report on all quality criteria for all studies and rate each study out of seven reflecting one point for each quality measure. A sensitivity analysis was performed on studies that scored ≥4.

Results

Study characteristics

The literature search identified 270 articles in total. After screening for inclusion criteria, eleven articles were selected to be included in the synthesis of evidence (see figure for flow chart of search strategy). A Summary of the study characteristics and the likely effect of a SSB price change on differences by SEP in SSB purchase, consumption or weight outcomes and the tax burden as a result of a SSB tax is presented in table 1. Briefly, seven studies used data from the USA, with one study from each of the UK, Ireland, Australia and New Zealand. Ten studies used income as an indicator of SEP (nine of these used household income and one used individual income) and one study in adolescents used parental education. Three principle study types were identified – those that examined the association between variation in SSB taxes across US states and individual SSB consumption and/or body mass index (n=3 (27-29)), price elasticity estimation of SSB demand from household food and beverage price and expenditure data (n=1 (30)) and the modelling of a hypothetical SSB tax by combining price elasticity estimates with population data on the SEP-specific patterning of beverage consumption, net energy intake or body weight outcomes to simulate the impact of a hypothetical SSB tax (n=7 (22, 31-36)). Four of the seven modelling studies used similar data from the USA (with some overlap of sampling period) (22, 31, 32, 36), however model specifications and input parameters differed markedly between studies. Six of the 11 included studies received a score of four or higher (out of seven) for quality appraisal (22, 31-33, 35, 36)(table 3). Few studies statistically tested differences in outcomes between SEP groups.

Results (point estimates, variance and when tested, significance) are outlined below and in table 2 for all eleven of the included studies (analysis of only studies scoring >4 in quality

appraisal revealed similar conclusions). Details of the data sets used and the general methods employed for each study can be found in the appendix.

Beverage purchase, consumption and weight impacts of a SSB tax according to socioeconomic position

Studies evaluating existing SSB taxes

Three studies examined the association between variation in state level SSB taxes (average 4%) across the US and individual level SSB consumption and/or BMI according to a marker of SEP.

Powell et al (27) reported no relationship between variation in SSB taxes and adolescents' BMI for any parental education group. In the study by Sturm et al (28) associations between variations in existing SSB tax rates and SSB consumption and BMI were examined for the entire population and for children from low income households. For the whole population, no association was observed between SSB taxes and overall SSB consumption or mean BMI change. However, among children from low income families, a one percentage-point increase in the SSB tax rate (in excess of other food items) resulted in a significant reduction in the total number of SSBs consumed of 0.142 SSBs per week. A one percentage-point higher differential SSB tax rate was also associated with a significant reduction in BMI of 0.013kg/m^2 between the third and fifth grades for the total population, but this did not hold up under all statistical analyses. For low income populations higher tax rates were not associated with a significant reduction in BMI, however the authors note that reduced statistical power limited the results from sub-group analyses. Fletcher et al (29) reported a stronger relationship between variation in SSB taxes and weight outcomes for lower (compared to higher) income adults and for those with a higher (compared to a lower) education level. Between 1990 and 2006, a one percentage-point increase in existing SSB tax rates was associated with a significant 0.015kg/m^2 reduction in BMI for low income adults and a 0.008kg/m^2 decrease in BMI for high income adults. When using education as the SEP indictor, a one percentage-point increase in the SSB tax rate was associated with a significant 0.0031kg/m^2 and 0.0076kg/m^2 reduction in BMI for high school graduates and college graduates, respectively.

Studies where the primary result was estimated price elasticities

One study estimated the income specific change in SSB demand following a change in SSB price (own price elasticity (OPE)) in New Zealand (30). In this study, lower income households were generally more responsive to an increase in the price of SSBs compared to high income households, with price elasticities (and standard errors) reported as -2.20 (1.16), -3.47 (0.99), -0.14 (0.43), -2.95 (0.52), -1.27 (0.44) for Q1 (lowest income quintile) to Q5 (highest income quintile), respectively, however the difference between quintiles 1 and 5 was not statistically significant (difference in OPEs was 0.07 (95% CI, -4.71 to 4.84)). Income-specific cross price elasticities were not reported.

Modelling studies

Seven studies used price elasticity estimates to model the impact of a SSB tax on total energy or weight outcomes (with one of these studies modelling the effect of a SSB tax on total beverage consumption (32)). It is important to note, that such modelling allowed for possible differences in baseline SSB consumption and in the prevalence of unhealthy weight across SEP groups (both of which were generally higher for lower income groups). Consequently, differences in price elasticity estimates across socioeconomic strata did not necessarily translate to similar differences in SSB consumption, net energy intake and/or adiposity outcomes following the examination of a hypothetical SSB tax. For example, a lower price elasticity for SSB demand among groups with a lower SEP (compared to higher SEP groups) may nevertheless result in a similar or greater decline in SSB consumption, net energy intake and/or adiposity outcomes for lower SEP strata, simply because baseline SSB consumption and the prevalence of excess weight is greater in this population. Six of the seven modelling studies estimated OPE in addition to an estimate of the change in demand of a related food/beverage following a change in SSB price (cross-price elasticity; CPE) (22, 31-33, 35, 36). One study used existing OPE estimates from the literature to inform their modelling analysis and did not take into account CPEs (34). The responsiveness to a change in SSB price was variable among the six studies that estimated OPEs, with three studies reporting high income households to be more price elastic (22, 32, 33), two studies reporting similar price elasticity across household income categories (31, 36) and one study reporting low income households to be more price elastic (35). Income specific substitution

effects to related products (CPEs) were similarly variable across studies. All six modelling studies that reported on energy intake or body weight outcomes and the one modelling study that reported on SSB purchases, consistently reported similar (n=5)(22, 31-34) or greater (n=2)(22, 35, 36) impact of a SSB tax for lower income groups.

Finklestein et al (31) modelled the impact of a 20% and 40% sales tax on either carbonated beverages or all SSBs in the US. Across all households the estimated OPE (and standard errors) were significant and similar across income groups. OPEs for carbonated beverages were −0.73 (0.09), with estimates ranging from −1.02 (0.17) for households in the 50% to 75% income quartile to −0.49 (0.20) for households in the 0% to 25% income quartile. The modelled tax on carbonated SSBs significantly reduced the mean per capita beverage kilocalories purchased across the entire population by 4.2 and 7.8 kilocalories per day following a 20% and 40% SSB tax, respectively (taking into account both OPE and CPEs), which was driven entirely by middle-income households, with no statistical change reported for low or high income households. When extrapolating a reduction in kilocalories purchased to annual weight loss (using a static calorie-to-weight relationship), taxes on carbonated SSBs of 20% and 40% generated significant annual weight losses (standard errors) of 0.20kg (0.07) and 0.37kg (0.13) per person, respectively. Expanding the tax to include all SSBs, it was estimated that a 20% and 40% tax would result in significantly annual weight losses of 0.32kg (0.09) and 0.59kg (0.16), respectively. Again, this was driven by the middle two quartiles, with changes for households in the lowest and highest income quartiles not statistically significant.

Lin et al (22) modelled the impact of a 20% excise tax on SSBs on changes in beverage consumption, net calorie intake, weight loss, and body weight status in the US. OPE estimates were significant for both income groups, however high income demand for SSBs was more price elastic than low-income demand (OPE (standard error), -1.29 (0.096) and -0.95 (0.082) for high and low income groups, respectively). When the price of SSBs increased, individuals from high income households were likely to substitute SSBs for skim milk, bottled water or juice, whereas low income households were likely to substitute to juice only. A 20% tax on SSBs translated to a larger reduction of SSB calorie intake among adults from low income households compared to adults from high income households (a

reduction of 38 and 35 kilocalories per day for low and high income households, respectively). For children, a 20% tax on SSBs translated to reduction 33 and 45 kilocalories per day for children from low and high income households, respectively. Simulating a 20% SSB tax resulted in a 1 year weight loss of 0.95kg (1.8kg at 10 years) and 1.04kg (1.96kg at 10 years) for high and low income groups, respectively (predictions not made for children).

Zhen et al (32) simulated the impact of 0.5c per ounce excise tax on SSB consumption in the US, taking into account habit formation (estimating a myopic and rational model to account for beverage addiction). Demand for SSBs was less elastic for low income households compared to high income households (OPE, -1.06 (rational) and -1.22 (myopic) for low income households and -1.54 (rational) and -1.44 (myopic) for high income households), however high income households were found to substitute SSBs more readily than low income households (predominantly with sports and energy drinks). This combined with a greater baseline consumption of SSBs for lower SEP groups, resulted in a similar reduction of regular carbonated SSB consumption for both income strata (low income: 82.81 (rational) and 102.68 (myopic) ounce per household per month, high income: 88.92 (myopic) and 92.23 (rational) ounce per household per month).

Briggs et al (33) modelled the impact of a 20% sales tax on any soft drinks with added sugar in the UK. The OPE (standard error) for non-concentrated SSBs were −0.79 (0.044), −0.80 (0.038) and −0.85 (0.040) for low, middle and high income groups, respectively. For non-concentrated SSBs, relatively large substitution effects occurred for non-concentrated diet soft drinks, concentrated SSBs, milk, fruit juice, tea and coffee. Substitution patterns were similar across all income thirds with a trend towards larger substitution effects in the lowest income third. The tax reduced consumption of non-concentrated SSBs by 15.2% (17.1kj/day), 15.9% (12.4kj/day) and 16.8% (18.1kj/day) for the lowest, middle and highest income groups, respectively. Daily net energy intake was reduced by 19.2kj (-29.3, -7.6), 13.4kj (-21.2, -4.8) and 23.2kj (-31.3, -15.0) per person for low, middle and high income groups, respectively. The smaller reductions in energy intake for the low and middle income groups compared with the highest income group were partly due to a greater substitution with high fat milk, however the confidence intervals for these estimates were wide and overlap. Corresponding reductions in mean population BMI were 0.08 kg/m^2 (-0.13, -0.03),

0.06 kg/m^2 (-0.09, -0.02) and 0.1kg/m^2 (-0.13, -0.06), with no significant difference across income groups.

Briggs et al (34) estimated the effect of a 10% SSB excise tax on SSB purchases and consumption in Ireland. OPEs were derived from the literature and were assumed to be -0.9 across all income groups. The estimated daily reduction in SSB energy intake (kilocalories per person) following a 10% SSB excise tax was 2.2 (women) and 1.6 (men) for the lowest income group, 1.9 (women and men) for the middle income group and 1.9 (women) and 2.6 (men) for the highest income group. This resulted in a similar percentage reduction in the prevalence of obesity across income groups, which were 1.4 (1.0, 1.9) for women and 0.7 (0.5, 1.0) for men in the lowest income group, 1.2 (0.8, 1.6) for women and 1.0 (0.7, 1.3) for men in the middle income group and 1.2 (0.8, 1.6) for women and 1.5 (1.0, 1.9) for men in the highest income group.

Sharma et al (35) modelled the effect of a 20% sales tax and a 20c/L excise tax on SSB consumption, net energy reduction and body weight by household income level in Australia. Following a 20% SSB sales tax, the demand for regular soft drinks was estimated to be slightly less responsive for high income households (a significant per capita reduction of 13.10% (35.17ounce/quarter), 14.92% (50.7ounce/quarter) and 15.05% (52.1ounce/quarter) for high, middle and low income households, respectively; significant differences between income groups not tested). Differences across income groups were more pronounced for fruit drinks (a significant reduction of 11.82%, 36.61% and 3.08% for high, middle and low income households, respectively) and cordial (45.55%, 35.63% and 29.98% for high, middle and low income households, respectively). A 20% sales tax resulted in a reduction in body weight for all income groups, which was significantly greatest for those with the lowest compared to highest incomes (0.40kg compared to 0.37kg for middle income and 0.23kg for high income groups). This was a result of a greater price elasticity and a greater baseline consumption of SSBs for lower income groups. A 20c/L tax resulted in a reduction in weight of 0.56kg, 0.69kg and 0.35kg for low, middle and high income households, respectively.

Zhen et al (36) estimated the impact of a 0.5c per ounce SSB excise tax (approximating an average increase in retail SSB price of 26%) on US household purchases of calories and on the nutrients fat and sodium. OPEs for regular carbonated soft drinks for high and low

income households were similar (-1.03 and -1.04 for low and high income households, respectively). CPEs were also broadly similar across income groups. Across all households, Zhen et al estimated that this tax would reduce per capita daily calorie intake by 13.2kilocalories for low income households and by 5.6kilocalories for high income households. Using a dynamic energy-weight loss model, these reductions in energy intake were estimated to translate to reductions in weight of 0.37 and 0.16kg/person in one year and 0.70 and 0.31kg/person in 10 years for low and high income households, respectively (the significance of these estimates was not tested).

Amount paid in SSB tax according to socioeconomic position following an increase in SSB price

Five of the studies included in this review examined the amount paid in tax following an increase in the price of SSBs by SEP (22, 32, 33, 35, 36). All of these studies reported the tax to be financially regressive whereby lower income households would pay a greater proportion of their income in additional tax. Results for each study are described below. For comparison across studies, the difference in SSB tax paid between the highest and lowest income households are also presented annually and in US dollars using 2015 conversion rates.

Lin et al (22), reported across all household income groups, that the tax burden following a 20% SSB excise tax would represent a small share of the total food and beverage budget, at less than 1% of annual food and beverage spending. Low income households, who consume more SSBs, would pay slightly more in annual tax (US$19.97; 1% of annual food budget) compared to high income households (US$18.84; 0.6% of annual food budget). Zhen et al (32) estimated that low income households would pay an annual tax of between US$17.64-US$18.60 (approximately 0.1% of annual household income) and high income households an annual tax of US$15.84 - US$16.92 (approximately 0.03% of annual household income) following 0.5c per ounce excise tax on SSBs. Following a 20% sales tax on SSBs, Briggs et al (33) reported the greatest increase in beverage expenditure for the lowest income group (increase of 9.4p per person per week (6.2, 13.4); 2.1% increase (1.4, 3.0)) compared with the middle income group (increase of 9.1p per person per week (6.6, 11.9); 1.7% (1.2, 2.2)) and the high income group (6.0p per person per week (3.2, 8.8); 0.8% (0.4, 1.2)). This

represented a difference in the annual amount paid in SSB tax of less than US$2.5 between high and low income households. Sharma et al (35) estimated that following a 20% sales tax, low income households would pay approximately AU$20.89 per capita per year in SSB tax (0.22% of annual household income) compared to AU$17.74 (0.07% of annual household income) and AU$16.60 (0.02% of annual household income) for middle and high income households, respectively, with significant differences between the highest and lowest income groups. The tax burden would be lower for a 20c/L excise tax, at AU$19.00, AU$14.77 and AU$13.81 per annum, representing 0.15%, 0.05% and 0.04% of annual household income for low, middle and high income households, respectively. When converted to US dollars, for both of the modelled taxes, the difference in the annual amount paid in SSB tax between high and low income households was less than US$4. Zhen et (36) estimated that a 0.5c per ounce increase in SSBs would result in low-income households paying approximately US$5 per household per year more in SSB tax compared to high income households, with an average of US$20 paid in SSB tax per household per year.

Discussion

The current review synthesises all existing literature on beverage purchase, consumption and weight outcomes, and the amount paid in SSB tax, following an increase in SSB price or a SSB tax across socioeconomic strata within high-income countries. We found consistent evidence that a tax on SSBs is likely to lead to improvements in population weight of a similar magnitude across SEP groups or of a greater magnitude for lower compared to higher SEP groups. Our review reinforces the regressive financial nature of a SSB tax, whereby lower income households would pay a greater proportion of their income in additional tax, however the monetary burden across all households is small, with relatively minor differences between higher and lower income households (0.10% - 1.0% and 0.03% - 0.60% of annual household income paid in SSB tax for low and high income households, respectively, equating to less than US$5 per year). This challenges the significance of the financial regressivity argument commonly put forth to oppose such a tax (23).The findings from this review are important as countries begin to consider, and indeed implement, this policy around the world.

Our results corroborate those of a 2012 systematic review of simulation studies examining the association between food and beverage pricing strategies and changes in purchase or consumption of food and beverage items and health related outcomes (25). Similarly, our results align with those of Thow et al (2014)(26) who systematically reviewed the literature for studies that reported the effect of food and beverage taxes and subsidies on food and beverage consumption. When extracting the data pertaining to SSBs, both these reviews concluded that the relative health benefits inferred following a price increase on SSBs, or a tax on SSBs, was greater for lower (compared to higher) income consumers. Our review updates and extends these reviews by including studies of all designs and reporting on all differential impacts of a SSB tax or price change for a range of outcomes across the intended policy pathway of effect according to SEP (rather than including it as a small sub-section within a broader review). We additionally summarise the amount paid in SSB tax for each SEP group, which has not been reported in prior reviews. Whilst the variation in outcomes reported within our review and the differences in the type and size of tax (or price increase) examined precluded synthesis to a single summary effect, it allowed the inclusion of a much broader range of studies, all of which were able to contribute to our conclusion that a SSB tax is likely to have a similar effect on population weight across socioeconomic strata or a greater impact for lower SEP groups.

The recent evaluation of the national SSB tax policy in Mexico on the purchase of SSB across different socioeconomic groups, supports the conclusions from this review. One year post implementation of the policy in January 2014, which required an increase in the price of SSBs at a rate of one peso per litre (roughly equivalent to a 10% increase in price), there was a reduction in mean SSB purchases across all socioeconomic groups, with the greatest reduction among households with the lowest resources (SSB purchases reduced by 17% one year after policy implementation in this group compared to 12% overall) (20). In the current review we excluded low to middle income countries due to the varied and often reverse relationship between SEP and SSB consumption and/or obesity prevalence (37), and thus the likelihood that the equity impact of a tax on SSBs may also differ. Whilst Mexico is considered a middle income country, and data from the 2006 Mexican Household Income and Expenditure Survey indeed reveals a positive relationship between SEP and energy

intake from soda (38), these recent results of the impact of the national SSB tax policy are nonetheless congruent with results in our review on high-income countries, where the relationship between SEP and SSB purchase and consumption is reversed.

Own price elasticities, and the difference across income groups, were variable across the eight studies that reported income specific estimates. This variation in own price elasticity estimates across different studies is likely to result from methodological variations (including data sources used, beverage grouping and/or model specifications used to estimate price elasticities) or real country and contextual differences in response to a SSB price change. Understanding the exact sources of variation will be important to inform the evidence base on the likely impact of a SSB tax on population weight. Nevertheless, when studies used price elasticity estimates to simulate the effect of a hypothetical SSB tax on total energy intake and/or health outcomes, results were remarkably consistent across studies, with all studies demonstrating either a similar benefit across households with differing income levels or a greater impact for households with a lower compared to higher income. The impact of a SSB tax on population weight results from a delicate balance between own-price elasticities, cross-price elasticities (product substitution), and the distribution of SSB consumption and weight within a population. Whilst modelling studies have their limitations, they are able to account for these determinants (to a greater or lesser degree, depending on the study). Eight of the eleven studies included in our review reported greater SSB consumption and higher weight and/or obesity prevalence for lower income households, with mixed reports of differential product compensation across income groups. These results highlight that caution should be taken when concluding on the health equity impact of a SSB tax based on price elasticity data alone.

The strengths of the current study include the comprehensive systematic search of both academic and grey literature and extraction of all relevant data by at least two authors.

Limitations

The major limitation relates to the limited variability in study types identified. Only three studies evaluated the association between existing real-world SSB taxes and SSB consumption or weight outcomes, and these studies were all limited by the relatively small

tax rates (average of approximately 4%) and the limited variability in taxes across US states. The remaining eight studies estimated price elasticities of SSB demand and seven of these simulated the effects of a SSB tax on total SSB consumption, total energy intake or weight outcomes using econometric modelling methods. These latter studies are reliant on household survey or scanner data and a number of assumptions, which may not have been empirically tested. These studies do not consider 'real world' dynamics, such as the interaction of pricing strategies with other population or individual level interventions, the impact on social norms as a result of implementing a 'health related' tax, possible unintended consequences and the response from the beverage industry, all of which could have a differential impact according to socioeconomic position. Furthermore, only six of studies considered the differential impact of substituting SSBs with other beverages and only one considered substitution to food products. As the overall health impact of a SSB tax depends on the net change in energy intake from all foods and beverages it is important to consider all possible substitutions, which may differ according to socioeconomic group. For example, Zhen et al (2014) estimated that almost half of the reduction in SSB calories caused by an increase in its price could be offset by an increase in calories from other foods, with a probable increase in sodium and fat intake (36) . This highlights the complexity of evaluating the impact of tax on SSBs and the need to consider possible unintended effects across all socioeconomic groups. Whilst our conclusions herein remain robust, it is essential that they are confirmed with other study designs. For this reason, as SSB taxation policies are implemented around the world, as they have been recently in Mexico and St Helena, it is important that they are rigorously evaluated with the data disaggregated by socioeconomic position. Nevertheless, whilst real world evaluations have great external validity, internal validity is difficult to manage. It may therefore also be important that experimental studies be conducted and the conclusion on the health equity impact of a tax on SSBs be based on the totality of evidence, as recommended by the US body, the Institute of Medicine (39).

A further limitation is that many of the included studies did not evaluate if the differences in outcomes were significantly different between groups of differing SEP. Whilst this is unlikely to alter our conclusions that a SSB tax is unlikely to increases socioeconomic inequalities in

weight, we recommend future studies statistically test differences across socioeconomic groups.

SSBs have been linked to a number of non-communicable diseases, including cardiovascular disease (13) and diabetes (40) as well as dental caries (41), all of which are more prevalent among lower SEP groups in high income countries (42-44). Thus, it is likely that the health equity benefits of a tax on SSBs extend beyond the weight outcomes described in this review. Furthermore, if the revenue generated from the tax was directed towards targeted interventions that improved health among more disadvantaged groups, then the health equity impact of a SSB tax may be greater. A tax on SSBs should be considered as just one strategy among many to address the unequal burden of excess weight and health across socioeconomic groups.

Conclusion

Current evidence suggests a tax on SSBs is likely to be an effective policy to reduce SSB consumption (25, 26). Here we additionally demonstrate that, within the current evidence base, a tax on SSBs is also likely to have a similar impact on consumption and weight outcomes for high and low income households or a greater impact among those with a lower SEP. Our evidence synthesis further challenges the relevance of the argument pertaining to financial regressivity. Careful health equity evaluations of real world SSB taxation policies and well controlled experimental studies are required to broaden and strengthen the evidence base in this area.

1. Backholer K, Mannan HR, Magliano DJ, Walls HL, Stevenson C, Beauchamp A, et al. Projected socioeconomic disparities in the prevalence of obesity among Australian adults. Australian and New Zealand journal of public health. 2012;36(6):557-63.
2. Ball K, Crawford D. Socioeconomic status and weight change in adults: a review. Soc Sci Med. 2005;60(9):1987-2010.
3. Marmot M AJ, Goldblatt P, Boyce T, McNeish D, Grady M, Geddes I. Fair Society, Healthy Lives. 2010.
4. Beauchamp A, Backholer K, Magliano D, Peeters A. The effect of obesity prevention interventions according to socioeconomic position: a systematic review. Obes Rev. 2014;15(7):541-54.
5. Magnee T, Burdorf A, Brug J, Kremers SP, Oenema A, van Assema P, et al. Equity-specific effects of 26 Dutch obesity-related lifestyle interventions. Am J Prev Med. 2013;44(6):e57-66.
6. Hillier-Brown FC, Bambra CL, Cairns JM, Kasim A, Moore HJ, Summerbell CD. A systematic review of the effectiveness of individual, community and societal level interventions at reducing socioeconomic inequalities in obesity amongst children. BMC Public Health. 2014;14:834.
7. Hillier-Brown FC, Bambra CL, Cairns JM, Kasim A, Moore HJ, Summerbell CD. A systematic review of the effectiveness of individual, community and societal-level interventions at reducing socio-economic inequalities in obesity among adults. Int J Obes (Lond). 2014;38(12):1483-90.
8. IOM (Institute of Medicine). Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation. Washington, DC: The National Academies Press., 2012.
9. National Preventive Health Taskforce. Australia: the healthiest country by 2020. Australia: 2009.
10. Brownell KD, Frieden TR. Ounces of prevention--the public policy case for taxes on sugared beverages. The New England journal of medicine. 2009;360(18):1805-8.
11. Brownell KD, Farley T, Willett WC, Popkin BM, Chaloupka FJ, Thompson JW, et al. The public health and economic benefits of taxing sugar-sweetened beverages. The New England journal of medicine. 2009;361(16):1599-605.
12. Vartanian LR, Schwartz MB, Brownell KD. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. Am J Public Health. 2007;97(4):667-75.
13. Malik VS, Popkin BM, Bray GA, Despres JP, Hu FB. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. Circulation. 2010;121(11):1356-64.
14. Mourao DM, Bressan J, Campbell WW, Mattes RD. Effects of food form on appetite and energy intake in lean and obese young adults. Int J Obes (Lond). 2007;31(11):1688-95.
15. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity. 2000;24(6):794-800.
16. Mullie P, Aerenhouts D, Clarys P. Demographic, socioeconomic and nutritional determinants of daily versus non-daily sugar-sweetened and artificially sweetened beverage consumption. European journal of clinical nutrition. 2012;66(2):150-5.
17. van Ansem WJ, van Lenthe FJ, Schrijvers CT, Rodenburg G, van de Mheen D. Socio-economic inequalities in children's snack consumption and sugar-sweetened beverage consumption: the contribution of home environmental factors. The British journal of nutrition. 2014;112(3):467-76.
18. Kumar G, Pan L, Park S, Lee-Kwan SH, Onufrak S, Blanck HM. Sugar-Sweetened Beverage Consumption Among Adults — 18 States, 2012 2014. Available from: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6332a2.htm.
19. Kim B, Rossi P. Purchase Frequency, Sample Selection, and Price Sensitivity: The Heavy-User Bias. Marketing letters. 1994;5(1):57-67.
20. Colchero MA, Popkin BM, Rivera JA, Ng SW. Beverage purchases from stores in Mexico under the excise tax on sugar sweetened beverages: observational study. BMJ. 2016;352:h6704.

21. Andreyeva T, Long MW, Brownell KD. The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food. Am J Public Health. 2010;100(2):216-22.
22. Lin BH, Smith TA, Lee JY, Hall KD. Measuring weight outcomes for obesity intervention strategies: the case of a sugar-sweetened beverage tax. Economics & Human Biology. 2011;9(4):329-41.
23. Mytton OT, Clarke D, Rayner M. Taxing unhealthy food and drinks to improve health. BMJ. 2012;344:e2931.
24. Welch V, Petticrew M, Tugwell P, Moher D, O'Neill J, Waters E, et al. PRISMA-Equity 2012 extension: reporting guidelines for systematic reviews with a focus on health equity. PLoS medicine. 2012;9(10):e1001333.
25. Eyles H, Ni Mhurchu C, Nghiem N, Blakely T. Food pricing strategies, population diets, and non-communicable disease: a systematic review of simulation studies. PLoS Medicine / Public Library of Science. 2012;9(12):e1001353.
26. Thow AM, Downs S, Jan S. A systematic review of the effectiveness of food taxes and subsidies to improve diets: understanding the recent evidence. Nutrition reviews. 2014;72(9):551-65.
27. Powell LM, Chriqui J, Chaloupka FJ. Associations between state-level soda taxes and adolescent body mass index. The Journal of adolescent health : official publication of the Society for Adolescent Medicine. 2009;45(3 Suppl):S57-63.
28. Sturm R, Powell LM, Chriqui JF, Chaloupka FJ. Soda taxes, soft drink consumption, and children's body mass index. Health Affairs. 2010;29(5):1052-8.
29. Fletcher JM, Frisvold D, Tefft N. Can Soft Drink Taxes Reduce Population Weight? Contemporary economic policy. 2010;28(1):23-35.
30. Ni Mhurchu C, Eyles H, Schilling C, Yang Q, Kaye-Blake W, Genc M, et al. Food prices and consumer demand: differences across income levels and ethnic groups. PloS one. 2013;8(10):e75934.
31. Finkelstein EA, Zhen C, Nonnemaker J, Todd JE. Impact of targeted beverage taxes on higher- and lower-income households. Archives of Internal Medicine. 2010;170(22):2028-34.
32. Zhen C, Wohlgenant M, Karns S, Kaufman P. Habit formation and demand for sugar-sweetened beverages. The American Journal of Agricultural Economics. 2011;93(1):175-93.
33. Briggs AD, Mytton OT, Kehlbacher A, Tiffin R, Rayner M, Scarborough P. Overall and income specific effect on prevalence of overweight and obesity of 20% sugar sweetened drink tax in UK: econometric and comparative risk assessment modelling study. BMJ. 2013;347:f6189.
34. Briggs AD, Mytton OT, Madden D, O'Shea D, Rayner M, Scarborough P. The potential impact on obesity of a 10% tax on sugar-sweetened beverages in Ireland, an effect assessment modelling study. BMC Public Health. 2013;13:860.
35. Sharma A, Hauck K, Hollingsworth B, Siciliani L. The effects of taxing sugar-sweetened beverages across different income groups. Health Econ. 2014;23(9):1159-84.
36. Zhen C, Finkelstein EA, Nonnemaker J, Karns S, Todd JE. Predicting the Effects of Sugar-Sweetened Beverage Taxes on Food and Beverage Demand in a Large Demand System. American journal of agricultural economics. 2014;96(1):1-25.
37. Peeters A, Walls HL, Backholer K, Sacks G, Abdullah A. Welcome from the policies, socio-economic aspects, and health systems research section. BMC Obes. 2015;2:23.
38. Barquera S, Hernandez-Barrera L, Tolentino ML, Espinosa J, Ng SW, Rivera JA, et al. Energy intake from beverages is increasing among Mexican adolescents and adults. J Nutr. 2008;138(12):2454-61.
39. IOM (Institute of Medicine). Bridging the Evidence Gap in Obesity Prevention: A Framework to Inform Decision Making. Washington, DC: The National Academies Press; 2010.

40. Malik VS, Popkin BM, Bray GA, Despres JP, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. Diabetes care. 2010;33(11):2477-83.
41. Moynihan PJ, Kelly SA. Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. J Dent Res. 2014;93(1):8-18.
42. Williams ED, Tapp RJ, Magliano DJ, Shaw JE, Zimmet PZ, Oldenburg BF. Health behaviours, socioeconomic status and diabetes incidence: the Australian Diabetes Obesity and Lifestyle Study (AusDiab). Diabetologia. 2010;53(12):2538-45.
43. Beauchamp A, Peeters A, Wolfe R, Turrell G, Harriss LR, Giles GG, et al. Inequalities in cardiovascular disease mortality: the role of behavioural, physiological and social risk factors. Journal of epidemiology and community health. 2010;64(6):542-8.
44. Capurro DA, Iafolla T, Kingman A, Chattopadhyay A, Garcia I. Trends in income-related inequality in untreated caries among children in the United States: findings from NHANES I, NHANES III, and NHANES 1999-2004. Community Dent Oral Epidemiol. 2015.

Figure: Search strategy

Study	Country	Study type	SEP measure	SSB definition	size and type of tax	Outcome reported	Own price elasticity	Modelled effect	Tax burden
Studies evaluating existing SSB taxes									
Powell et al (2009)(27)	USA	Association between existing state level SSB taxes (over 10 years) & *adolescent* cross-sectional BMI	Parents education	Soft drinks	State level sales taxes in grocery stores (mean 4.25%) and vending machines (mean 4.51%) between 1997-2006	BMI	Similar*	n/a	n/a
Sturm et al (2010)(28)	USA	Association between existing state level SSB taxes & *children's* cross-sectional SSB consumption and 1-year weight change	Family income	Carbonated beverages	State level sales taxes in grocery stores in 2004 (mean 4.2%)	SSBs purchased BMI	Progressive*	n/a	n/a
Fletcher at al (2010)(29)	USA	Association between existing state level SSB taxes & *adult* cross-sectional BMI	Individual income; educational attainment	Soft drinks	State level sales taxes between 1990-2006 (range 3-5%)	BMI	Progressive*	n/a	n/a
Studies where the primary result was estimated price elasticities									
Ni Mhurchu et al (2013)(30)	New Zealand	Price elasticites	Household income	Carbonated soft drinks	n/a	SSB Purchase	Progressive	n/a	n/a
Summary of modelling studies									
Finklestein et al (2010)(31)	USA	Price elasticities & modelling of SSB tax	Household income	Regular soda, fruit drinks, sports energy drinks	20% and 40% sales tax	Energy intake Body weight	Similar	Similar	n/a
Lin et al (2011)(22)	USA	Price elasticities & modelling of SSB tax	Household income	Regular soft drinks, sports and energy drinks, and fruit drinks	20% excise tax	Energy intake Body weight	Regressive	Similar	Regressive
Zhen et al (2011)(32)	USA	Price elasticities & modelling of SSB tax	Household income	Carbonated soft drink	0.5c per ounce excise tax	SSBs purchased	Regressive	Similar	Regressive
Briggs et al (2013;a)(33)	UK	Price elasticities & modelling of SSB tax	Household income	Soft drinks with added sugar	20% sales tax	SSB purchase Energy intake Obesity prevalence	Regressive	Similar	Regressive
Briggs et al (2013;b)(34)	Ireland	Price elasticities & modelling of SSB tax	Household income	Soft drinks with added sugar	10% excise tax	Energy intake Obesity prevalence	n/a	Similar	n/a
Sharma et al (2014)(35)	Australia	Price elasticities & modelling of SSB tax	Household income	Regular soft drink, cordial and fruit drink	20c/L excise tax 20% sales tax	Body weight	Progressive	Progressive	Regressive
Zhen (2014)(36)	USA	Price elasticities & modelling of SSB tax	Household income	Regular carbonated soft drinks, sports/energy drinks & juice drinks	0.5c per ounce excise tax	SSBs purchased Total energy intake Body weight	Similar	Progressive	Regressive

Table 1: Summary of the study characteristics and the likely effect of a sugar sweetened beverage (SSB) price change on differences in overall SSB consumption or weight benefits and the tax burden as a result of a SSB tax. BMI: Body Mass Index. NOTE: Progressive refers to when the effect sizes are greater for lower socioeconomic groups compared to higher socioeconomic groups. Regressive refers to when the effect sizes are greater for higher socioeconomic groups compared to lower socioeconomic groups. n/a: not applicable. * These studies did not estimate own price elasticities: Powell et al reported no association between state level SSB taxes and adolescent BMI across income categories; Sturm et al reported that lower existing SSB tax rates were associated with less SSB consumption for children from low income households, which was not observed for children overall; Fletcher et al reported that increases in state level SSB tax rates were associated with decreases in state level BMI over time.

Study	Price elasticities	Size and type of tax	Modelled effects of hypothetical SSB tax or relationship with existing state level SSB taxes				
			Consumption	Energy intake	Weight or BMI	Obesity prevalence	Tax burden
Studies evaluating existing SSB taxes							
Powell et al (2009)(27)	n/a	State level SSB sales taxes in grocery stores (mean 4.25%) and vending machines (mean 4.51%).	n/a	n/a	No significant association between variation in state level SSB taxes and adolescent BMI across any parental education categories.	n/a	n/a
Sturm et al (2010)(28)	n/a	State level SSB sales taxes in grocery stores (mean 4.2%).	No significant association between existing state level SSB taxes and children's SSB consumption for the total population. For children from low income families, for every 1% higher tax rate across states (over and above the tax on other foods within the state) there was a 0.142* and 0.039* reduction in the total drinks/week consumed and drinks/week consumed at school, respectively.	n/a	No significant association between variation in state level SSB taxes and children's BMI for any income groups.	n/a	n/a

Fletcher et al (2010)(29)	n/a	State level SSB sales taxes (range 3-5%)	n/a	n/a	A 1%-point increase in existing SSB tax rates was associated with a 0.015kg/m^2* reduction in BMI for low income adults and a 0.008kg/m^2* decrease in BMI for high income adults. The corresponding reductions were 0.0031kg/m^2 *and 0.0076kg/m^2* for high school graduates and college graduates, respectively.	A 1%-point increase in existing SSB tax rates was associated with a 0.08%-point* reduction in obesity and a 0.1%-point* reduction in overweight for low income adults and a 0.05%-point* and 0.08%-point* reduction in obesity and overweight, respectively, for high income adults. The corresponding reductions were 0.02* and 0.02%-points* for high school graduates and 0.04* and 0.04%-points* for college graduates, respectively.	n/a
Studies where the primary result was estimated price elasticities							
Ni Mhurchu et al (2013)(30)	OPE Carbonated soft drinks (SE): Q1: -2.20 (1.16) Q2: -3.47 (0.99) Q3: -0.14 (0.43) Q4: -2.95 (0.52) Q5: -1.26 (0.44) (No statistically significant difference in OPEs between Q1 & Q5)	n/a	n/a	n/a	n/a	n/a	n/a
Summary of modelling studies							

Finkelstein et al (2010)(31)	Carbonated SSBs: Across all households the OPE (SE) was −0.73 (0.09)*, with estimates ranging from −1.02(0.17)* for households in the 50% to 75% income quartile to −0.49 (0.20)* for the 0% to 25% income quartile of households All SSBs: Income specific OPEs not reported CPE: Examined but not reported	20% or 40% sales tax on carbonated SSBs 20% or 40% sales tax on all SSBs	n/a	*20% tax on carbonated SSBs,* kcal/day No statistically significant reduction in beverage calories for households in the lowest and highest income quartiles. Across all households beverage purchases reduced by a mean of 4.2*, which was entirely driven by the middle income households *40% tax on carbonated SSBs*, kcal/day: Across all households beverage purchases reduced by a mean of 7.8*, which was entirely driven by middle-income households	BMI change, kg/m^2 (SE) 20% Tax on carbonated SSBs: Q1, 0.01 (0.20); Q2, −0.37* (0.14); Q3, −0.36*(0.14); Q4, 0.03 (0.13) 40% Tax on carbonated SSBs: Q1, −0.004 (0.36); Q2, −0.68* (0.26); Q3, −0.65* (0.25); Q4, 0.04 (0.24) 20% Tax on all SSBs: Q1, -0.12 (0.23); Q2, −0.46* (0.17); Q3, −0.68* (0.15); Q4, 0.07 (0.15) 40% Tax on all SSBs: Q1, −0.23 (0.43); Q2, −0.83* (0.30); Q3, −1.20* (0.26); Q4, 0.13 (0.28)	n/a	n/a
Lin et al (2011)(22)	OPE (SE) High income: -1.29 (0.096)* Low income: -0.95 (0.082)* CPE High income: significant substitution for skim milk, low-fat milk, juice, bottled water and significant complementary reduction in diet drinks Low income: significant substitution for juices and complementary reduction in diet drinks, skim milk, low fat milk and whole milk	20% excise tax	n/a	Change in energy intake, kcal/day High income Adults: -37 from all beverages, -38 from SSBs Children -45 from all beverages, -50 from SSBs Low income Adults: -33 from all beverages, -35 from SSBs Children -33 from all beverages, -36 from SSBs	10 year weight change, kg; adults only High income: -1.80 Low income: -1.90	10-year % change in prevalence of obesity (%-points; adults only) High income: -10.5 (3.46) Low income: -10.2 (3.58)	Annual tax burden attributable to SSB tax Low income: US$19.97 High income: US$18.84 SSB tax as a percentage of all food and beverage spending Low income: 1% High income: 0.6%

Zhen et al (2011)(32)	OPE for regular carbonated soft drink Low income households: -1.22 (mypoic), -1.06 (rational) High income households: -1.44 (myopic), -1.54 (rational) CPE High income households substitute SSBs more readily than low income households (predominantly with sports and energy drinks)	0.5c per ounce excise tax	% Long run household change in monthly demand of regular carbonated soft drinks (reduction in oz) Low income: -27.4,-33.9 (-82.81,-102.62) High income: -34.4, -35.6 (-88.92,-92.23)	n/a	n/a	n/a	Annual tax burden (% of annual income) Low income: US$17.64 - US$18.60 (0.1) High income: US$15.84 - US$16.92 (0.03)
Briggs et al (2013;a)(33)	OPE (SE) for non-concentrated SSBs Lowest income third: −0.79* (0.044) Middle income third: −0.80* (0.038) highest income third: −0.85* (0.040) CPE For non-concentrated SSBs, relatively large substitution effects occurred for non-concentrated diet soft drinks, concentrated SSBs, milk, fruit juice, tea and coffee. Substitution patterns were similar across all income thirds with a trend towards larger substitution effects in the lowest income third.	20% sales tax on all SSBs (concentrated and non-concentrated)	% change in non-concentrated SSB consumption (change in kj/day) Low income: -15.2 (-18.1) Middle income: -15.9 (-12.4) High income: -16.8 (-17.1)	Change in energy intake per person, kcal/day (95% CI) Lowest income third: -4.6* (-7.0, -1.8) Middle income third: -3.2* (-5.1, -1.1) Highest income third: -5.5* (-7.5, -3.6) The smaller reductions in energy intake for the two lowest income thirds compared with the highest third are primarily due to a greater substitution with high fat milk (from both concentrated and non-concentrated SSBs)	Change in mean BMI, kg/m^2 (95% CI) Lowest income third: -0.08* (-0.13, -0.03) Middle income third: -0.06* (-0.09, -0.02) Highest income third: -0.10* (-0.13, -0.06)	% change in prevalence of obesity (95% CI) Lowest income third: -1.3* (-2.0, -0.3) Middle income third: -0.9* (-1.6, -0.1) Highest income third: -2.1* (-2.9, -1.3) *No significant difference between income groups*	Increase in expenditure, in pounds sterling, on all beverages per person per year (95% CI), % increase (95% CI) Lowest income third: 4.9* (3.2, 6.9), 2.1%* (1.4, 3.0) Middle income third: 4.7* (3.4, 6.2), 1.7%* (1.2, 2.2) Highest income third: 3.1* (1.7, 4.6), 0.8%* (0.4, 1.2)

Briggs et al (2013;b)(34)	OPE -0.9 (derived from literature and assumed to be the same across income groups)	10% excise tax	n/a	Change in energy intake per person, kcal/day Lowest income group: -2.2 (women), -1.6 (men), -1.9 (overall) Middle income group: -1.9 (women), -1.9 (men), -1.9 (overall) Highest income group: -1.9 (women), -2.6 (men), -2.3 (overall)	n/a	% Change in prevalence of obesity (95% CI) Lowest income group: -1.4* (-1.0, -1.9) for women, -0 .7* (-0.5, -1.0) for men, -1.1* (-0.7, -1.4) overall Middle income group: -1.2* (-0.8, -1.6) for women, -1.0* (-0.7, -1.3) for men, -1.1* (-0.7, -1.4) overall Highest income group: -1.2* (-0.8, -1.6) for women, -1.5* (-1.0, -1.9) for men, -1.4* (-0.9, -1.8) overall	n/a
Sharma et al (2014)(35)	Income specific OPEs and CPEs estimated but not explicitly reported, however it is noted that high-income households had the least elastic demand for regular soft drinks	20% sales tax 20c/L excise tax	% Change in SSB consumption per capita (reduction in Oz/quarter) 20% sales tax: Low income: -15.05 (-52.1)* Middle income: -14.92 (-50.7)* High income: -13.10 (-35.17)* 20c/L excise tax: not reported by income	n/a	Weight change, kg 20% sales tax: low income: -0.40, middle: -0.37, high income: -0.23 20c/L excise tax: low income: -0.56, middle income: -0.69 and high income: -0.35 *Differences between high and low income groups significant**	n/a	Annual per capita tax burden, in AUD, attributable to SSB tax (% of annual income) 20% sales tax: Low income pay: $20.89 (0.22%) Middle income: $17.74 (0.07%) High income: $16.60 (0.03%) 20c/L excise tax: Low income pay: $19.00 (0.15%) Middle income: $14.77 (0.05%) High income: $13.81 (0.04%) *Differences between high and low income groups significant**

Zhen et al (2014)(36)	OPE Low income households: -1.03* High income households: -1.04* CPE broadly similar across income groups	0.5c per ounce excise tax	Change in regular carbonated soft drink consumed per capita, reduction in Oz/quarter low income: -65.8 high income: -49.3	Change in energy intake per person, kcal/day low income: -13.2 high income: - 5.6	Change in weight, kg low income: -0.37 in 1 year and -0.70 in 10 years high income: -0.16 in 1 year and -0.31 in 10 years	n/a	Average tax burden of approximately US$20 per year per household with a difference of approximately US$5 per household per year between high and low income households

Table 2: Price elasticity estimates and likely impact of a sugar sweetened beverage (SSB) tax on socioeconomic inequalities in SSB consumption, energy intake, population levels of mean body mass index (BMI) and/or obesity prevalence and the associated tax burden. Q: Quintile. SE: Standard error *Significant effect size Note: Significance of point estimates and differences between SEP groups are stated, otherwise significance not reported. Values in parentheses represent 95% confidence (or credible) intervals. For a given outcome, all values are converted to the most common unit reported across studies for comparison.

Study	All studies							
	Prospective study of observed behaviour	Evaluation of actual tax (rather than hypothetical)	Price linked directly to purchase in same population	Consideration of product compensation	Long-run input data	Valid and appropriate country specific data	Reporting of uncertainty around outcome estimates	Quality score (out of 7)
Powell et al (2009)(27)	×	✓	×	✓*	×	✓	×	3
Finklestein et al (2010)(31)	×	×	✓	✓	×	✓	✓	4
Sturm et al (2010)(28)	×	✓	×	✓*	×	✓	×	3
Fletcher et al (2010)(29)	×	✓	×	✓*	×	✓	×	3
Lin et al (2011)(22)	×	×	✓	✓	✓	✓	✓	5
Zhen et al (2011)(32)	×	×	✓	✓	✓	✓	✓	5
Briggs et al (2013;a)(33)	×	×	✓	✓	×	✓	✓	4
Briggs et al (2013;b)(34)	×	×	✓	×	×	×	✓	2
Ni Mhurchu et al (2013)(30)	×	×	✓	×	×	✓	✓	3
Sharma et al (2014)(35)	×	×	✓	✓	×	✓	✓	4
Zhen et al (2014)(36)	×	×	✓	✓	✓	✓	✓	5

Table 3: Quality checklist for included studies. * These studies examined the association between variations in state level sugar sweetened beverage (SSB) taxes and cross-sectional body mass index (BMI), which therefore implicitly took into account product substitution.