

Systematic Review

Taxing sugar-sweetened beverages as a policy to reduce overweight and obesity in countries of different income classifications: a systematic review

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Abstract

Objective: To evaluate the potential impact of sugar-sweetened beverage (SSB) taxes on overweight and obesity prevalence in countries of different income classifications.

Design: Systematic review following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PROSPERO number CRD42020161612). Five databases (Cochrane Library, Embase, LILACS (via Virtual Health Library) and MEDLINE (via PubMed), and Web of Science were searched, from January 2009 to December 2019. Articles that reported changes in purchases, sales, intake, body weight, BMI, overweight and/or obesity prevalence due to a tax on or price change in SSB were included.

Setting: Studies conducted in countries of different income classifications.

Participants: The search yielded 8349 articles of which 21 met inclusion criteria.

Results: Among the sixteen studies selected, only two did not show that consumption, sales and purchase decreased as the price of SSB increased. In eight of the thirteen studies selected, a positive effect of an SSB tax on decreasing overweight and obesity prevalence was expected. It is estimated that a 20% taxation on SSB would result in a greater decrease in the prevalence of overweight and obesity compared to a 10% rate. Studies with no significant effect of taxing on sales, purchases, consumption and prevalence of obesity were from high-income countries, while significant effects of taxing on reducing purchase, consumption and/or obesity prevalence were found in studies from upper-middle- and middle-income countries.

Conclusion: A high SSB tax might be an effective fiscal policy to decrease purchase and consumption of SSB and reduce overweight/obesity prevalence, especially if the tax were specific for beverage volume.

Keywords
Sugar-sweetened beverage
Fiscal policy
Obesity
BMI

Current evidence from large observational studies supports a link between sugar-sweetened beverage (SSB) consumption and the development of obesity in children and adults^(1–3). Furthermore, 184 000 annual deaths worldwide were attributed to SSB consumption in 2010, mostly due to type 2 diabetes (72%) or CVD (24%), with 71%

of these deaths occurring in middle-income countries (MIC)⁽⁴⁾. Mexico, an MIC, implemented an SSB tax in 2014 and this fiscal policy was accompanied by a major mass communication strategy. Key messages were published on billboards or advertisements and posters in places such as metro stations, streets with significant foot traffic,

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of these deaths occurring in middle-income countries (MIC)⁽⁴⁾. Mexico, an MIC, implemented an SSB tax in 2014 and this fiscal policy was accompanied by a major mass communication strategy. Key messages were published on billboards or advertisements and posters in places such as metro stations, streets with significant foot traffic,

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and avenues where the soft drink industry advertised⁽⁵⁾. Two years after the introduction of a tax on sugary drinks, households showed an average reduction of 7.6% in the purchase of these drinks while households with lower incomes had a mean decrease of 11.7%⁽⁶⁾.

The WHO has endorsed taxes on SSB, and in a report on fiscal policies for the prevention of non-communicable diseases, the WHO encouraged countries to increase taxation on SSB^(7,8). The organisation asserted that 'imposing a tax on SSB is a potential strategy for increasing the price of these products and thus reducing their consumption'⁽⁹⁾. A recent review indicates that in general, taxes decrease the consumption of taxed beverages by adults, though not for all types of beverages or all groups of consumers⁽¹⁰⁾.

Previously published systematic reviews, primarily based on studies from high-income countries (HIC), indicate that taxes on SSB may reduce the consumption of these products, although there is no evidence as to whether the effect would be similar in low-income countries and MIC^(11–13). While some studies argue that the tax may work in similar ways in MIC and HIC⁽¹²⁾, other studies have predicted that the tax may be more effective in MIC, given the evidence that consumers living in these countries are more responsive to price changes, since food costs are a primary determinant of consumption patterns, especially regarding non-essential products such as SSB⁽¹⁴⁾.

Although several systematic reviews have evaluated the impact of SSB taxes on consumption^(15–17), few of them^(12,18) have evaluated the impact of SSB taxes on overweight and obesity prevalence according to the income classifications of the countries. Furthermore, an updated review is required to take account of the recent growth in the number of SSB tax assessments from around the world.

Thus, this systematic review intends to answer the following research questions: (i) Is there evidence of an effect of implemented SSB tax policies on reducing consumption, purchase and sales? (ii) Is there evidence of an effect of implemented SSB taxation on reducing overweight and obesity prevalence? and (iii) Does the evidence of an effect of these differ according to the countries' income classification?

Methods

Protocol and registration

The review was conducted following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines⁽¹⁹⁾. The full study protocol has been registered on PROSPERO (International Prospective Register for Systematic Reviews, platform protocol number: CRD42020161612).

Primary exposures and outcomes

SSB taxes were the main exposure. SSB are beverages with added energetic sweeteners, such as sucrose, high-fructose

corn syrup or fruit juice concentrates. These include non-alcoholic beverages, carbonates, fruit drinks, sports drinks, energy and vitamin water drinks, sweetened iced tea, and lemonade⁽⁷⁾. An SSB tax was defined as a tax applied to at least one category of non-alcoholic beverages containing added sugars. Taxes could comprise excise taxes, import tariffs, sales taxes or any other taxes applied⁽²⁰⁾. The main outcome was a change in overweight and obesity prevalence or change in body weight or BMI mean. We also assessed changes in the consumption of SSB, including any alteration in taxed beverage sales/purchases (as a proxy for consumption data), or dietary intake following the implementation of an SSB tax and these could be reported by volume, energies or consumption frequency.

Search strategy

Two reviewers conducted a blinded and independent literature search in December 2019. The following databases were searched: Cochrane Library, Embase, LILACS (via Virtual Health Library) and MEDLINE (via PubMed), and Web of Science. The search terms aimed to identify three domains: financial, nutritional and outcomes (Electronic Supplemental Material).

After the initial selection, reference lists from eligible studies and systematic reviews were searched for additional relevant studies. Peer-reviewed publications and grey literature (reports and self-published research) were included.

Eligibility criteria

Studies eligible for inclusion in this review were: (i) studies based on primary quantitative research, including modelling, non-experimental, quasi-experimental or experimental studies; (ii) full text published; (iii) written in English or Spanish; and (iv) published between January 2009 and December 2019. This review excluded other systematic reviews and meta-analyses as well as qualitative studies, case studies and reports, and letters to the editor. We included studies from all countries and average income of the country was classified according to World Bank definitions⁽²¹⁾.

Study selection

After searching the databases, we used a free reference manager (Mendeley Desktop – Version 1.19.5) for article sorting, duplicate documents, reference organisation and search-time optimisation. Titles and abstracts were screened to identify relevant articles. Then, the reviewers, blinded and independently, identified and excluded the studies that did not meet the inclusion criteria. Finally, the full articles were obtained, and their eligibility was confirmed by full reading. Disagreements were solved by consensus between the two reviewers; there was no need for arbitration by a third reviewer.

Assessment of study quality

Each eligible study was assessed for study quality using a critical appraisal tool (Electronic Supplemental Material) established according to previously published reviews of food and beverage pricing studies^(18,22,23).

The two reviewers applied the above quality criteria for all eligible studies and rated each of them on seven criteria, establishing for the presence of '1 point' or absence of '0 points' for each item. All articles that achieved a score equal to or higher than 4 points in these quality criteria were selected for this systematic review.

Data extraction

Using a standardised electronic form, two reviewers independently extracted the following data from the studies:

- General information: authors, year of publication, country, income classification, study design and sample size;
- Fiscal outcomes: tax rate, taxed products, year of policy sanction, consumption, purchase, sale and major findings;
- Nutritional outcomes: overweight and obesity prevalence, changes in BMI, change in body weight, and major findings.

Synthesis of the results

The effect of SSB taxes on outcomes of interest (change in overweight and obesity prevalence, body weight and BMI, consumption, sales, and purchase) were reported as difference, percentage change and tax elasticity. Tax elasticity is the percentage change in consumption for a 1 % change in tax.

Results

A total of 8338 articles were identified after the database search plus 11 additional records from the reference lists of eligible studies. After excluding 552 duplicated records, 2125 published before January 2009, 122 not written in English or Spanish (German: 34 studies; French: 20 studies; Chinese: 19 studies; Italian: 13 studies; Russian: 12 studies; Polish: 7 studies; Dutch: 5 studies; Japanese: 4 countries; Norwegian: 2 studies; and Icelandic, Danish, Bulgarian, Hungarian, Slovenian, Swiss: 1 study in each language) and 5145 due to study type, 405 records were screened by title, and 98 were selected for full-text reading. Of those, twenty-one were eligible for the review and eighteen met quality criteria. Among the eighteen articles included in this systematic review, twelve are modelling studies and six are studies that evaluated the impact of implemented real taxes. The detailed selection process is shown in Fig. 1, and the quality checklist applied to the included studies is shown in Table 1.

The quality of studies was analysed using a tool specific for outcomes of the SSB tax and the scores ranged from 4 to 5 in HIC, upper-income countries and MIC. We considered that the quality was similar among studies. Item 1 was observed only in two studies from HIC, but the objective was not to assess an SSB tax on overweight/obesity. A prospective design is better than a cross-sectional one to answer this objective. Items 2 (Q2) and 5 (Q5) were met in sixteen studies and represented that the price and consumption data of SSB or effect of SSB intake on overweight/obesity was from the same population. We considered that these aspects must be fulfilled for our analysis. Item 3 was scored in nine studies, independently of income classification. However, this is probably not a relevant limitation as the tax rate had not yet been defined in the country. Item 4 was scored in twelve studies, including upper-income countries and MIC. We assumed that in countries that included only one type of SSB, for example soft drinks, that the intake of this beverage was higher than others or the price elasticity for them was not available. Item 7 was scored in nine countries, and we considered that the effect of an SSB tax on obesity consumption could be observed⁽²⁴⁻²⁷⁾ or could be higher than we observed⁽²⁸⁻³⁰⁾, if a minimum interval between the implementation of an SSB tax and effect evaluation were considered.

Table 2 describes the sixteen studies found in this systematic review that evaluated the impact of SSB taxes on the consumption, purchase or sales of these products, and 75 % were developed in HIC. Sales and purchase were evaluated in five studies^(24,25,28,31,32). Sales decrease of 8.6 ml/capita/week after applying a 10 % *ad valorem* tax⁽³²⁾ in Barbados (time series analysis) and 9.6 % following a US\$0.67¢/oz price increase⁽³¹⁾ in California (comparison between pre-tax and first year post-tax) were found. Purchase decrease of 15 % for a 20 % sales tax in the United Kingdom⁽²⁸⁾ (theoretical simulation models) and 22 % for 1.6 % price increase in Chile⁽²⁵⁾ (comparison between pre-tax and post-tax) were found, but no statistically significant association was found in children's consumption of SSB for a 4.2 % (mean) state-level sales tax in grocery stores in the USA (comparison between pre-tax and post-tax)⁽²⁴⁾.

According to three references, consumption was reduced by approximately 13 % (20 % added tax)⁽³³⁾, 20 % (\$0.01 cent per fluid ounce excise tax)⁽³⁴⁾ and 40 % (\$0.015 cents per fluid ounce excise tax)⁽³⁵⁾, and all studies applied theoretical simulation models. Energy intake was evaluated in most of the studies and showed a reduction of 8.8 to 69.9 kJ/d/person^(28,31,33), of 25 kJ for each one percentage point increase in the soft drink tax⁽²⁶⁾, and of 150 kJ/d⁽³⁶⁾. These studies applied theoretical simulation models except for Silver *et al.*⁽³¹⁾

Three studies based on theoretical simulation models examined the effect of taxes from theoretical simulation models in upper-middle-income countries, and all of them showed an association between taxation and SSB purchase

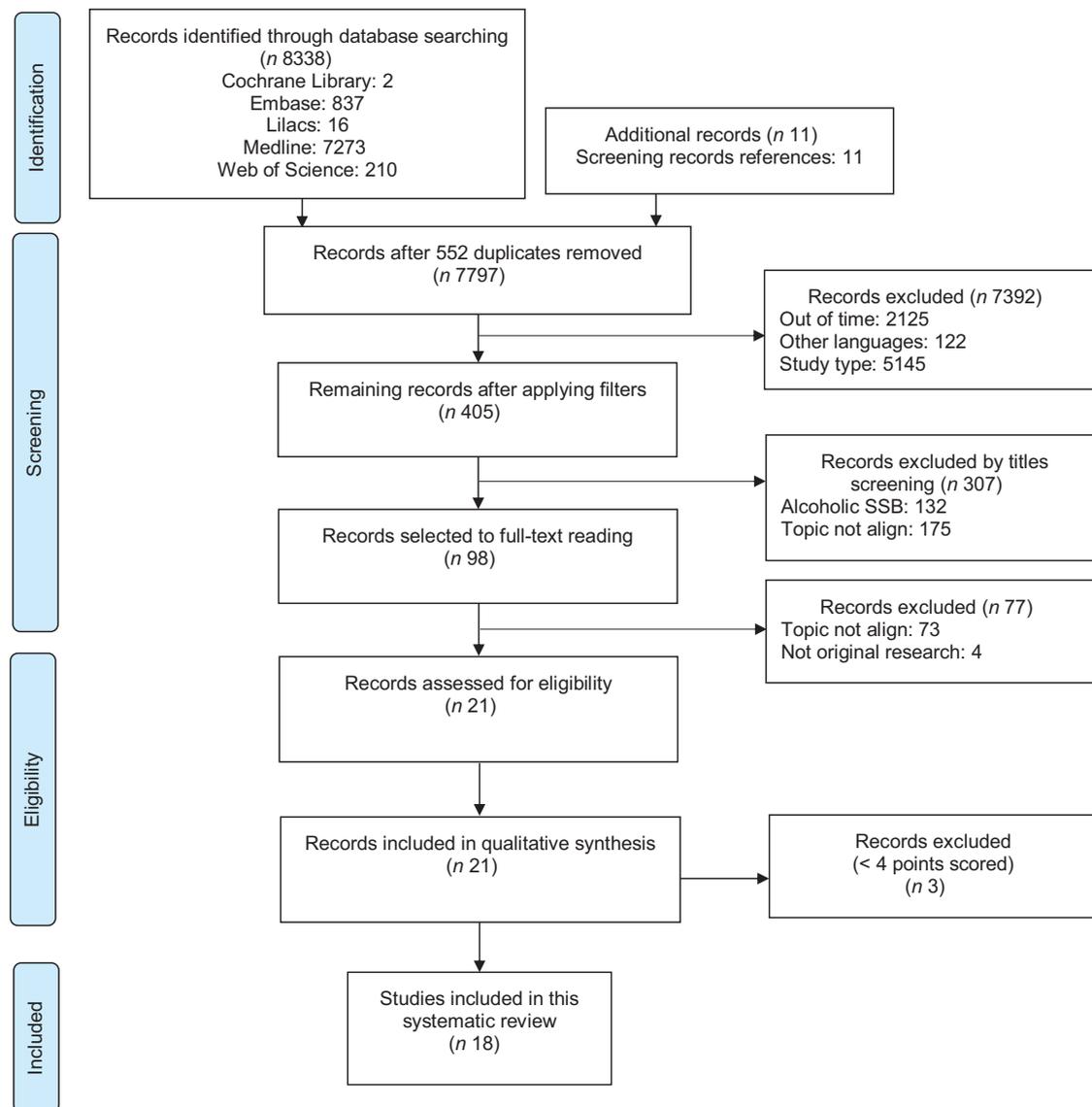


Fig. 1 (colour online) Flow chart of the selection of studies evaluating the impact of SSB tax on consumption, purchase, sale, overweight and obesity, published between 2009 and 2019. SSB, sugar-sweetened beverages

or energy intake. Reductions of 21.62 and 43.23 ml/person/d were seen for taxes of 10 and 20 %, respectively⁽³⁷⁾. An average reduction of 7.6 % in purchases⁽⁶⁾ and a reduction of energy intake by 36 kJ/d⁽³³⁾ were also found (Table 2).

Nine studies evaluated taxes applied to carbonated soft drinks or SSB^(6,24–26,28,30,31,34,38) and other studies assessed taxes applied to a broad definition of SSB (flavoured water, energy drinks and fruit juice drinks). Pan American Health Organisation recommends including all kinds of beverages with added sugar to prevent unhealthy substitutions and offering healthy options to replace SSB⁽⁵⁾. The main outcome we observed in the study was the effect of an SSB tax on the consumption of these beverages (eleven studies), only two studies evaluated SSB sales^(25,31) and two studies evaluated SSB purchases^(6,25). The main kind of SSB tax was excise tax expressed as a percentage increase

in the final product price (10 to 20 %) and five countries applied a specific tax based on the weight of the SSB (the level ranged from \$0.010 to \$0.015/ounce of SSB). One study⁽³⁷⁾ based on theoretical simulation models compared excise taxes of 10 and 20 % and the decrease in SSB consumption was twice as high for the 20 % excise tax. Only two studies^(35,39) showed that applying taxes resulted in a decreased consumption of SSB and an increased consumption of water, milk, tea or fruit juice (cross-price elasticity). One of them was based on theoretical simulation models⁽³⁵⁾ and the other evaluated the impact of an implemented tax⁽³⁹⁾.

The effectiveness of SSB taxation in reducing the prevalence of overweight and obesity is shown in Table 3. The reduction in obesity prevalence varied from 0.99 % to 2.7 % points^(3,30,33,34) and the reduction in overweight prevalence was 0.7 %⁽³⁰⁾, all of them were theoretical simulation

Table 1 Quality checklist for included studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Alvarado, 2019		✓	✓		✓		✓
Barrientos, 2017		✓		✓	✓		✓
Basu, 2014		✓		✓	✓	✓	✓
Briggs, 2013a		✓		✓	✓	✓	✓
Briggs, 2013b		✓		✓	✓	✓	✓
Colchero, 2017		✓	✓	✓	✓	✓	✓
Fletcher, 2010a			✓		✓	✓	✓
Fletcher, 2010b		✓	✓		✓	✓	✓
Fletcher, 2014			✓		✓	✓	✓
Lin, 2011		✓		✓	✓	✓	✓
Long, 2015		✓		✓	✓	✓	✓
Manyema, 2014		✓		✓	✓	✓	✓
Nakamura, 2018		✓	✓	✓	✓	✓	✓
Powell, 2009		✓	✓		✓	✓	✓
Silver, 2017	✓	✓	✓	✓	✓	✓	✓
Sturm, 2010		✓		✓	✓	✓	✓
Veerman, 2016		✓		✓	✓	✓	✓
Zhong, 2018	✓	✓	✓		✓	✓	✓

Q1. Does the study consist in a prospective evaluation of observed behaviour within the same population?

Q2. Do price and consumption data come from the same population?

Q3. Does the study assess an actual tax or subsidy rather than hypothetical measures?

Q4. Does the data include all SSB consumed?

Q5. Does the study report the effect of SSB intake on overweight or obesity within the same population?

Q6. Does the study consider potential substitution to other products?

Q7. Does the study consider a long-run input data across time with sufficient variation in prices used to estimate price elasticities? (For experimental studies: a period of at least 1 month; for studies using existing data sets on SSB price: intervals no less than 2 months apart for at least 12 months).

models. Decreases in weight and BMI were 0.97 kg⁽³⁶⁾ and 0.08 kg/m²⁽³⁴⁾, respectively (theoretical simulation models) (Table 3). Two studies^(29,37) from upper-middle-income countries using theoretical simulation models showed a positive effect of an SSB tax in decreasing obesity prevalence. Reductions of 2.5 and 5.3 % in obesity prevalence were reported for a 10 and 20 % taxation of SSB⁽³⁷⁾, respectively, and 3.8/2.4 % decreases in obesity prevalence were seen in men/women⁽²⁹⁾. The effect of an SSB tax on overweight and obesity prevalence identified from theoretical simulation models was higher in young individuals^(28–30,34,37,39).

In five studies, there was no statistically significant association between taxing SSB and changes in BMI, or overweight/obesity^(24,25,27,38,40). Most of these studies refer to modelling studies except for the Sturm *et al.*⁽²⁴⁾, Powell *et al.*⁽²⁷⁾ and Nakamura *et al.*⁽²⁵⁾ studies. Sturm *et al.*⁽²⁴⁾, using data on state sales taxes for soda and individual-level data on children, showed a non-significant association between an SSB tax and energy intake for children. However, the authors highlighted that an SSB tax could be more effective for at-risk groups such as overweight children, families with lower socio-economic status and African-American children, and for SSB sold in the school environment⁽²⁴⁾.

In studies that applied an SSB tax of 1 or 3 % from theoretical simulation models^(26,40), no effect on overweight and obesity prevalence was observed. A limitation of these two

studies is that SSB consumption information was taken from the National Health and Nutrition Examination Survey (population level) and the SSB tax was a different state-specific-tax, and the information on price and consumption was from a different population. The study developed by Powell *et al.*⁽²⁷⁾ assessed the impact of applied taxes of 4.25 % for grocery stores and 4.51 % for vending machines which was insufficient to impact on BMI values. However, the authors highlighted a weak association between increased vending machine tax rates (contextual level) and BMI for overweight adolescents (individual level)⁽²⁷⁾.

In Chile, a 13–18 % excise tax was applied to beverages with equal or higher than 6.25 g of sugar/100 ml and a parallel reduction of 3 % in the price of beverages with lower amounts of sugar. The purchase of SSB decreased after implementation of the SSB tax, but no effect of SSB tax on nutritional status was observed (comparison between pre-tax and post-tax)⁽²⁵⁾. In general, the results of the studies analysed show that a higher taxation (20 %) has a greater impact on sales, and purchase, and a decrease in overweight and obesity compared to more modest taxes (10 %).

Discussion

This systematic review covered two main aspects of SSB taxes. The first was to quantify the effect of SSB taxes on consumption, purchase or sales, and the second was to evaluate the effect of SSB taxes on body weight, BMI or overweight/obesity prevalence. In all, eighteen studies were selected; sixteen of which answered the first objective and thirteen the second. Most studies were conducted in countries with a high-income level, especially in the USA (seven studies). The effect of SSB taxes on overweight or obesity prevalence was estimated mainly from modelling studies (twelve of eighteen studies), cross-sectional data, studies conducted with adults and those conducted before the implementation of an SSB tax in the country or state (US studies) as a fiscal policy.

In this review, all studies, except two^(24,38), showed a positive effect of SSB taxation, that is, consumption, sales and purchases decreased when the price of SSB was increased in MIC, upper-income countries and HIC. Sales were assessed only in two HIC. The most common unit of assessment SSB intake was expressed as energy intake reduction (kJ/d) and ranged from 8.8 kJ to 150.6 kJ in HIC, and 36 kJ/d in one upper-income country. There was a dose–response effect for taxes of 10 and 20 % (decreased intake from 21.6 ml to 42.2 ml, respectively). The effect of SSB taxes on the estimated amount of energetic reduction depends on SSB intake as a percentage of total energy intake, that is, in countries where intake is high, the effect will be higher. For example, an SSB tax of 10 % can decrease 75.7 kJ/d/person in the USA⁽³⁶⁾;



Table 2 Summary of study findings evaluating the potential impact of sugar-sweetened beverages (SSB) taxes on dietary intake, purchase or sales

Author, year	Country	Study design	Product	Tax rates	Outcome/measure	Study population	Major findings
High-income							
Alvarado <i>et al.</i> , 2019	Barbados	Interrupted time series (uncontrolled and controlled)	Carbonated SSB and sweetened juice drinks	10% <i>ad valorem</i> tax	SSB sales (change – ml/capita/week)	All population	Sales decreased 8.6 ml/capita/week (95% CI (–10.0, –7.3))
Briggs <i>et al.</i> , 2013b	United Kingdom	Price elasticity and modelling of SSB tax	Soft drinks with added sugar	20% sales tax	SSB purchase (% change) Energy intake (kcal/person/d)	Adults aged ≥16 years old	Decrease in consumption of 15%, in energy intake of 16.7 kcal/person/d
Briggs <i>et al.</i> , 2013a	Ireland	Price elasticity and modelling of SSB tax	Soft drinks with added sugar	10% excise tax	Energy intake (kcal/person/d)	Adults	Decrease of 2.1 kcal/person/d in energy intake
Fletcher <i>et al.</i> , 2010a	USA	Price elasticity and modelling of SSB tax	Soft drinks	Soft drink tax data between 1989 and 2006	Energy intake (kcal/d)	Children and adolescents	1% increase in taxes reduced soda consumption by nearly 6 calories among the youth
Fletcher <i>et al.</i> , 2010b	USA	Price elasticity and modelling of SSB tax	Soft drinks	Soft drink tax data between 1988–1994 and 1999–2006 (mean tax 2.715%)	Consumption (% change) Energy intake (kcal/d)	Children and adolescents	No significant association between taxing soft drinks and children's weight among the full sample
Lin <i>et al.</i> , 2011	USA	Price elasticity and modelling of SSB tax	Regular soft drinks, sports and energy drinks, and fruit drinks	20% excise tax	Energy intake (kcal/d)	Adults	Decrease –36 kcal/d in energy intake
Long <i>et al.</i> , 2015	USA	Price elasticity and modelling of SSB tax	Carbonated SSB	\$0.01 cent per fluid ounce excise tax	Consumption (% change)	Youth and adults	Decrease 20% (95% CI (11, 43)) in consumption
Nakamura <i>et al.</i> , 2018	Chile	Comparison between pre-tax and post-tax	Carbonated SSB	<i>ad valorem</i> IABA* tax†	SSB purchase (% change) Price (% change)	Adults	Purchase decrease –21.6%, price increase 1.6%
Silver <i>et al.</i> , 2017	USA (California)	Association of the first penny per ounce SSB excise tax with prices, sales, SSB consumption and intake	Carbonated SSB	\$0.01 cent per fluid ounce excise tax	Price (¢/oz) SSB sales (% change) Energy intake (kcal/person/d)	Adults aged ≥18 years	Price increase +0.67 ¢/oz, sales decreased 9.6%, and –6.4 (kcal/person/d) energy intake decrease
Sturm <i>et al.</i> , 2010	USA	Association between existing state-level SSB taxes and children's cross-sectional SSB consumption and 1-year weight change	Carbonated SSB	State-level sales taxes in grocery stores (mean 4.2%)	SSB purchase (%)	Children	No significant association between variation in state-level SSB taxes
Veerman <i>et al.</i> , 2016	Australia	Price elasticity and modelling of SSB tax	Carbonated soft drinks and flavoured mineral waters	20% value added tax‡	Consumption (% change) Energy intake (kJ/d)	Adults aged ≥16 years	Consumption decreased 12.6%, average energy intake decreased 16 kJ/d for men and 9 kJ/d for women

Taxing sugar-sweetened beverages

Table 2 Continued

Author, year	Country	Study design	Product	Tax rates	Outcome/measure	Study population	Major findings
Zhong <i>et al.</i> , 2018	USA (Philadelphia)	Price elasticity and cross-sectional study of SSB tax	Soda, fruit drinks, energy drinks and bottled water	\$0.015 cents per fluid ounce excise tax	Daily consumption (% change) and 30-d consumption (% change)	Adults (18 to 64 years old)	Daily consumption of regular soda was 40 % lower (OR = 0.6, 95 % CI (0.37, 0.97)); energy drinks were 64 % lower (OR = 0.36, 95 % CI (0.17, 0.76)); bottled water was 58 % higher (OR = 1.58, 95 % CI (1.13, 2.20)); and 30-d regular soda consumption frequency was 38 % lower (ratio of consumption frequency = 0.62, 95 % CI (0.40, 0.98))
Upper-middle income Barrientos-Gutierrez <i>et al.</i> , 2017	Mexico	Price elasticity and modelling of SSB tax	Carbonated SSB, sweetened juice drinks and <i>aguas frescas</i>	1-peso/l tax (10 % taxation) and 2-peso/l tax (20 % taxation)	SSB purchase (ml/person/d)	Adults aged ≥16 years	10 % taxation decrease consumption by 21.62 ml/person/d 20 % taxation decrease consumption by 43.23 ml/person/d
Colchero <i>et al.</i> , 2017	Mexico	Price elasticity and modeling of SSB tax	Carbonated soda	1-peso/l tax	SSB purchase (% change)	Households	Average reduction of 7.6 % in purchases
Manyema <i>et al.</i> , 2014	South Africa	Price elasticity and modelling of SSB tax	Carbonated SSB, sweetened fruit juices and squash concentrates	20 % excise tax	Energy intake (kJ/l)	Youth and adults (≥15 years old)	Reduction in energy intake of 36 kJ/d (95 % CI (9, 68))
Middle income Basu <i>et al.</i> , 2014	India	Price elasticity and modelling of SSB tax	SSB	20 % excise tax	Energy intake (kcal/person/d) Consumption (% change)	Adults (25 to 65 years old)	Reduction of 0.94 % in SSB consumption for each 1 % increase in SSB price (95 % CI (0.90, 0.98)) (own-price elasticity) Substitution SSB beverage by other beverages: 0.049 % (95 % CI (0.011, 0.087)) increase in milk; 0.31 % (95 % CI (0.27, 0.35)) increase in fruit juice; 0.13 (95 % CI (0.098, 0.16)) increase in tea (cross-price elasticity)

**'Impuesto Adicional a las Bebidas Analcohólicas' or additional tax on nonalcoholic drinks.

†3 % tax for soft drinks containing low sugar levels, 18 % tax for beverages above an added sugar concentration of at least 6.25 g/100 ml and 10 % tax for those below this threshold.

‡Resulting in a percentage increase in price, as opposed to an excise tax that varies with the content of the product.



Table 3 Summary of study findings evaluating the potential impact of sugar-sweetened beverages (SSB) taxes on overweight and obesity outcomes

Author, year	Country	Study design	Product	Outcome/unit	Study population	Major findings
High income						
Briggs <i>et al.</i> , 2013b	United Kingdom	Price elasticity and modelling of SSB tax	Soft drinks with added sugar	Obesity prevalence (% change)	Adults aged ≥16 years	Expected decrease of 1.3 % in obesity prevalence
Briggs <i>et al.</i> , 2013a	Ireland	Price elasticity and modelling of SSB tax	Soft drinks with added sugar	Obesity prevalence (% change)	Adults	Expected decrease of 1.3 % in obesity prevalence and 0.7 % in overweight
Fletcher <i>et al.</i> , 2010a	USA	Price elasticity and modelling of SSB tax	Soft drinks	Overweight (% change) Body weight (kg change) Obesity prevalence (% change)	Children and adolescents	Tax influence on BMI, overweight or obesity was not significant
Fletcher <i>et al.</i> , 2014	USA	Price elasticity and modelling of SSB tax	Soft drinks	BMI (kg/m ²) Overweight prevalence (% change) Obesity prevalence (% change)	Adults	Findings suggest virtually no evidence of non-linear or threshold effects
Lin <i>et al.</i> , 2011	USA	Price elasticity and modelling of SSB tax	Regular soft drinks, sports and energy drinks, and fruit drinks	Body weight (kg change) Obesity prevalence (% change)	Adults	Expected weight reduction of 0.97 kg and obesity rate declined 30.8 % in year one of taxation
Long <i>et al.</i> , 2015	USA	Price elasticity and modelling of SSB tax	Carbonated SSB	BMI (kg/m ²) Obesity prevalence (% change)	Youth and adults	Expected BMI decrease by an average of 0.08 (95 % CI (0.03, 0.20)) in adults and 0.16 (95 % CI (0.06, 0.37)) in youths and 0.99 % decrease in obesity prevalence among adults and a 1.38 % decrease among youth
Nakamura <i>et al.</i> , 2018	Chile	Comparison between pre-tax and post-tax	Carbonated SSB	BMI (% change)	Adults	BMI changes were nonsignificant
Powell <i>et al.</i> , 2009	USA	Association between state-level SSB taxes (over 10 years) and adolescent cross-sectional BMI	Soft drinks	BMI (kg/m ²)	Adolescents aged 13 to 19 years	No significant association between state-level grocery store or soda vending machine tax and BMI of adolescents
Sturm <i>et al.</i> , 2010	USA	Association of the first penny per ounce SSB excise tax with prices, sales, SSB consumption and intake	Carbonated SSB	BMI (kg/m ²)	Children	No significant association between variation in children's BMI for any income groups
Veerman <i>et al.</i> , 2016	Australia	Price elasticity and modelling of SSB tax	Carbonated soft drinks and flavoured mineral waters	Lifetime disability-adjusted life years (DALY), incidence, and prevalence of obesity-related disease (% change)	Adults aged ≥20 years old	Expected decrease in prevalence of obesity about 2.7 %, annual gain of 112 000 DALY for men and 56 000 for women

Taxing sugar-sweetened beverages

Table 3 Continued

Author, year	Country	Study design	Product	Outcome/unit	Study population	Major findings
Upper-middle income Barrientos-Gutierrez <i>et al.</i> , 2017	Mexico	Price elasticity and modelling of SSB tax	Carbonated SSB, sweetened juice drinks and <i>aguas frescas</i>	BMI (kg/m ²) Obesity prevalence (% change)	Adults aged ≥20 years old	Expected decrease in BMI by 0.31 kg/m ² with 10 % taxation per person and obesity prevalence by 2.54 % Expected decrease in BMI by approximately 0.15 kg/m ² on average and 0.29 kg/m ² at peak monthly tax effects with 10 % excise tax. 20 % excise tax decreased BMI by approximately 0.31 kg/m ² on average and 0.57 kg/m ² at peak monthly tax effects
Manyema <i>et al.</i> , 2014	South Africa	Price elasticity and modelling of SSB tax	Carbonated SSB, sweetened fruit juices and squash concentrates	Obesity prevalence (% change)	Youth and adults (≥15 years old)	Expected decrease in prevalence of obesity by 3.8 % (95 % CI (0.6, 7.1)) in men and 2.4 % (95 % CI (0.4, 4.4)) in women Decreased number of obese women
Middle income Basu <i>et al.</i> , 2014	India	Price elasticity and modelling of SSB tax	SSB	Overweight prevalence (% change) Obesity prevalence (% change)	Adults (25 to 65 years old)	Expected decrease in prevalence of overweight by 1.6 % and obesity prevalence by 5.9 %. The expected decrease was higher for male, lower income group and rural population

35 kJ/d/person in Mexico and only 8.8 kJ/d/person in Ireland⁽³⁰⁾. The demand of SSB is sensitive to changes in price and therefore, an SSB tax affects demand⁽⁴¹⁾. For countries with higher price elasticity, the effect of an SSB tax will be higher. Barrientos-Gutierrez *et al.* (2017)⁽³⁷⁾ highlighted that it is relevant to analyse the cross-price elasticity of an SSB tax, but it depends on the availability of these data in countries. In our systematic review, only two studies included cross-price elasticity, and both showed that there was an increased consumption of bottled water⁽²⁹⁾ and milk, fruit juice and tea⁽³⁹⁾ after SSB tax implementation. A systematic review developed in MIC showed that the tax applied to soft drinks had a greater effect than sweetened fruit juices (taxation of 10 % in price contributed to a decrease of 5 to 39 kJ per capita/d in soft drink consumption). The authors observed a concurrent increase in milk consumption⁽¹⁸⁾.

We identified thirteen studies that evaluated the effect of SSB taxes on BMI or overweight and obesity prevalence, and only three studies were conducted in upper-middle-income countries (Mexico, South Africa) and MIC (India). We observed a decrease in obesity prevalence in six HIC (60 %) and in all upper-income countries and MIC (100 %). All these studies were of cross-sectional design from national surveys, one modelling study included adults and similar SSB categories, the excise tax applied was 10 or 20 % and the own-price elasticity ranged from -0.8 to -1.29. The percentage of obesity changed may be higher in MIC and upper-income countries, as it ranged from 2.54 to 5.9 % in these countries *v.* 0.99 to 2.7 % in HIC. In all countries except Chile, the studies were conducted before an SSB tax was adopted as a fiscal policy to decrease SSB consumption⁽²⁵⁾. Australia⁽³³⁾ was the only country where an SSB tax has not yet been implemented as a fiscal policy. According to Sainsbury *et al.*⁽⁴²⁾, difficulty in implementing a fiscal policy is due to influence from industry, fragmented advocacy efforts, political opposition to paternalistic policies, conflicting political agendas and inadequate pressure for change from civil society.

The models used to estimate weight change as a function of energetic intake change after an SSB tax implementation in the studies were based on a dynamic model and may contribute to avoid overestimation of the effect of SSB taxation on BMI values. These equations consider a new 'steady state' of body weight that is achieved after the change in energetic intake and is considered better than the static model⁽³⁶⁾. Four studies^(28,34,37,39) included a cross-elasticity demand together with own elasticity of SSB and observed the replacement of SSB by other beverages (milk, fruit juice, water and diet soft drinks). Cross-elasticity analysis would be relevant to prevent overestimation of the SSB tax effect on consumption, sales or purchases.

This review does not include a meta-analysis due to the heterogeneity of methods for estimating change in overweight and obesity, SSB consumption, study design, and



difficulties in controlling for income, population and other country-specific characteristics. The strengths of our study are the application of a quality checklist to include studies that specifically focus on SSB taxes, the selection of studies from different income levels and addressing the effects of SSB taxes on sales, consumption, purchase and overweight/obesity prevalence in the same review.

The limitations of our study are focused on the lack of some relevant data from selected studies to assess their quality. We applied a critical appraisal tool to assess seven topics on the quality of studies before inclusion in our systematic review. The first item on our checklist (Q1) was only met by two studies^(31,35) and these studies did not evaluate the effect of an SSB tax on overweight/obesity prevalence. Another relevant question with lower scores was question 7 (Q7: minimum interval between the implementation of an SSB tax and effect evaluation), as discussed earlier. We also highlighted the absence of an accurate definition of SSB in some studies. This term is broad and sometimes refers to soda, or soft drinks, or carbonated soft drinks.

Data about own-price and cross-price elasticities were not available in some countries and it was necessary to apply data from other countries. The studies highlighted difficulties in selecting the most appropriate model to explain weight loss and to estimate the effect of reduced SSB consumption on weight loss. The lack of information about other health policies that were carried out in these countries in addition to the SSB tax also might compromise the evaluation of the impact from fiscal policy. In Mexico, the government launched a mass-media campaign on healthy habits as well as an SSB tax implementation^(5,7). Thow *et al.*⁽²²⁾ recommended developing prospective studies and estimating the effect of SSB taxes with other interventions. Another aspect to be considered is that weight is associated with many factors of different nature so that isolated interventions would possibly not have a relevant impact on its reduction, requiring the implementation of broader intervention packages. Finally, we did not find any studies from low-income countries. One reason for this could be that *per capita* consumption is still low (0.3 portion/d), being lower than that of all the other regions⁽⁴³⁾. Also, in low-income countries, there are other serious health problems. We suggested that is relevant to estimate the price elasticity of SSB in low-income countries and MIC, because types of taxes may be different, and the characteristics of SSB sales and consumption are also different.

The results of our systematic review showed that an SSB tax could be an effective fiscal policy to decrease the purchase and consumption of SSB and reduce overweight/obesity prevalence. The effect of an SSB tax would be more powerful if the tax were higher, were specific for beverage volume and covered all kinds of SSB. Future longitudinal studies that include an SSB tax already implemented in the country as a fiscal policy and data about individual

consumption of SSB are needed for an accurate estimate of overweight/obesity prevalence.

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Supplementary material

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