

# Taxation of Sugar-Sweetened Beverages and its Impact on Dental Caries: A Narrative Review

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## Abstract

Dental caries is one of the largest health concerns worldwide, and a key causative factor is excess sugar intake. Sugar-sweetened beverages (SSBs) are one of the largest sources of added sugars, which significantly contribute to adverse oral and general health. To reduce SSB consumption and its consequent impact on health, including dental caries, several interventional measures have been implemented; sugar taxation is one such measure. This review aimed at understanding the current knowledge available regarding the effect of sugar taxation on dental caries. Accordingly, PubMed, the Cochrane Library, Web of Science, and Scopus were searched with relevant keywords and findings from the identified studies are discussed in this review article.

**Keywords:** Dental caries, oral health, sugar consumption, sugar sweetened beverages, sugar tax

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**Submitted:** 22-Jan-2021 **Revised:** 16-Mar-2021 **Accepted:** 18-Mar-2021 **Published:** 29-Apr-2021

## INTRODUCTION

Dental caries is one of the largest health concerns worldwide, and it poses an economic burden for the public and governments.<sup>[1,2]</sup> Excessive sugar intake is the main causative factor for caries initiation and progression. The optimal pH of oral cavity is 6.7 to 7.2, the threshold for dental caries development is pH 5.5 and dentine erosion occurs at pH 6.0. However, after sugar consumption, the pH in plaque can fall rapidly to <5.0 through production of acids (predominantly lactic acid) by bacterial metabolism. The percentage of tooth material loss in enamel and dentine erosion increases with exposure time and frequency of consumption.<sup>[3]</sup>

Sugar sweetened beverages (SSBs), which comprise energy drinks, soda and fruit juices, are primary sources of added sugars. Aggressive marketing, wide availability and affordability of SSBs have led to their increased consumption worldwide.<sup>[4-6]</sup> In Saudi Arabia, about 17% and 56% of 7–12-year-old children consume carbonated beverages daily and weekly, respectively.<sup>[7]</sup> In Kuwait, a neighboring Gulf Cooperation Council (GCC) country, 72% of children consume soft drinks or sweets at least once a day. This was the highest consumption level among 34 countries that participated in the Health Behaviour in School-aged Children study.<sup>[8]</sup> Most SSBs are acidic, with their pH ranging from 2.5 to 3.3,<sup>[9,10]</sup> and numerous studies have demonstrated an association between SSB

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**How to cite this article:** Alhareky M. Taxation of sugar-sweetened beverages and its impact on dental caries: A narrative review. Saudi J Med Med Sci 2021;9:113-7.

### Access this article online

#### Quick Response Code:



#### Website:

www.sjmms.net

#### DOI:

10.4103/sjmms.sjmms\_54\_21

consumption and dental caries.<sup>[2,10-21]</sup> In fact, longitudinal studies have also found increased likeliness between SSB intake during infancy/early childhood and dental caries later in life.<sup>[20,21]</sup>

Considering its adverse effects, several interventions have been proposed to reduce SSB consumption, including ban on its sale in schools/ colleges, limiting its advertisements, altering the composition and introducing tax against it.<sup>[22-25]</sup> In fact, many countries, including most GCC countries, have already introduced some form of taxes on SSBs.<sup>[26]</sup> The impact of sugar tax on dental caries remains unclear, and thus this review explores the existing evidence in literature to assess this impact.

For this narrative review, MEDLINE/PubMed, the Cochrane Library, Web of Science and Scopus were searched for relevant articles published between January 2011 and October 2020 using the following keywords: “sugar-sweetened beverages”, “added sugar and dental caries”, “sugar tax” and “sugar consumption”.

### Impact of taxation on SSB consumption trends

A common intervention for reducing SSB consumption is levying tax based on per calorie value/gram of added sugar or per unit sale. Such taxes have usually been implemented as excise or sales tax by various countries worldwide. Several studies across countries have found that levying such taxes has a deterrent effect on SSB consumption trends [Table 1].<sup>[27-40]</sup> Therefore, given the association of added sugars with various health issues, including dental caries, reductions in SSB consumption due to taxation is suggestive of having a positive impact on health and in reducing the economic burden of countries.

### Impact of SSB taxation on dental caries

A total of five simulation-based studies were identified that evaluated the likely impact of SSB taxation on dental caries [Table 2]. Four studies<sup>[25,41-43]</sup> found that such an intervention would result in reduction in DMFT (decayed, missing or filled teeth) and caries incidence, whereas one study<sup>[44]</sup> found that implementing SSB tax alone will not achieve the desired oral health outcomes.

In 2016, Schwendicke *et al.*<sup>[41]</sup> conducted a model-based study to estimate the effect a 20% SSB sales tax would have on caries and treatment cost in a German population aged 14–79 years over a 10-year period. They found that such measures would prevent 0.75 million caries lesions and save €0.08 billion in treatment costs over the estimated timeframe. The study also found that the benefits (dental

caries and cost reduction) would be higher among younger and lower income population than the older and higher income population. The greatest reduction in caries increment (>10%) was observed in males from low- or middle-income backgrounds. Finally, the benefits of taxation were noted across all age groups of males, but surprisingly, in females, both increase in caries and treatment costs were observed. This was attributed to the fact that females had low SSB consumption, but high juice consumption, which contributed to caries and negated the effects of the taxation.

In the United Kingdom, following the Government’s initiative of levying a tax on SSBs from 2016, a study assessed the impact of the possible industry responses on obesity, diabetes and dental caries. The authors modelled three possible responses, namely, reformulation with lower sugar content, increase in the product price or introduction of higher number of mid- to low-sugar drinks, and modelled the best–worst case scenarios for each.<sup>[25]</sup> Of the six possible scenarios, except the worst case scenario for larger market share of mid- to low-sugar drinks, all other scenarios showed that industry response to SSB taxation would result in reducing dental caries, with best-modeled scenario resulting in 269,375 fewer DMFTs (range: 82,211–470 928; incidence reduction of 4.4 per 1000 person-years). The study also found that those in the 11–18 years age group are likely to have the highest relative benefit, as they have the greatest baseline SSB consumption. A more recent study found that the UK industry response was primarily to reduce the amount of sugar added in SSBs and pass a proportion of the additional costs to consumers, both of which reduces the exposure of sugar for the public.<sup>[45]</sup> Collectively, this indicates that SSB taxation may be beneficial for health, including in reducing caries.

In a cohort model designed by Sowa *et al.*<sup>[42]</sup> to predict the implication of SSB taxes on dental caries and utilization of dental care services in Australian settings, it was shown that 3.9 million units of DMFT can be prevented and €405 million would be saved over a 10-year period. This study and that of Briggs *et al.*<sup>[25]</sup> used different tax definitions, and thus the findings cannot be compared. Nonetheless, when compared with the findings of Schwendicke *et al.*,<sup>[41]</sup> it was shown that in Australia, SSB tax implementation would lead to 0.21 DMFT units/person (treatment cost savings of about €21/person) compared with 0.46 DMFT units/person (treatment cost savings of about €14/person) in Germany.

Using a tooth-level Markov model, Jevdjevic *et al.*<sup>[43]</sup> estimated that implementing a 20% sales tax on SSBs in

**Table 1: Studies on impact of sugar sweetened beverages taxes on sales, purchases and consumption**

Jurisdiction	Year of tax introduction	Tax increase	Outcome	Reference
US state-level analysis	Varied between states	Average 4%	1 percentage point increase in the softdrink tax rate reduces the amount of calories consumed by soda by nearly 6 calories	Fletcher <i>et al.</i> <sup>[27]</sup>
Cleveland, US	2003	5%	2% decline with a standard error of 0.04	Colantuoni and Rojas <sup>[28]</sup>
Portland, US	1991	5.5%	2% decline with a standard error of 0.04	Colantuoni and Rojas <sup>[28]</sup>
Berkeley, US	2015	US\$ 0.01/oz (0.34/L)	1-year post-tax, 9.6% decline in SSB sales (ounces/transaction) in Berkeley stores Consumption of SSBs decreased 21% in Berkeley and 4% increase in comparison cities	Silver <i>et al.</i> <sup>[29]</sup> Falbe <i>et al.</i> <sup>[30]</sup>
Philadelphia, US	2017	US\$ 0.015/oz (0.51/L)	30-day regular soda consumption frequency was 38% lower	Zhong <i>et al.</i> <sup>[31]</sup>
Chile	2014	Increased from 13% to 18%, for drinks containing ≥6.25g added sugar per 100ml	Households decreased monthly per capita purchase volumes of (high sugar) SSBs by 3.4% and 4.0% by calories. 21.6% reduction in high tax soft drink volumes purchased	Caro <i>et al.</i> <sup>[32]</sup>
Mexico	2014	1 peso/L	Pre vs both years posttax: decline of 7.3%. 6.3% decrease in sugar drink consumption	Nakamura <i>et al.</i> <sup>[33]</sup> Colchero <i>et al.</i> <sup>[34-36]</sup> Aguilar <i>et al.</i> <sup>[37]</sup>
France	2012	0.0716 Euros/L	Taxed drinks consumption decreased by 9 centiliters per week per person	Capacci <i>et al.</i> <sup>[38]</sup>
Catalonia, Spain	2016	0.12 Euros/L if >8 g sugar/100 mL	Purchases of SSBs reduced by 4.7 L per product, a reduction by 15.4% with respect to the mean of SSB purchases before the reform	Vall Castello <sup>[39]</sup>
Saudi Arabia	2017	Soda 50% and energy drinks 100%	Annual purchases of soda and energy drinks reduced by 41% and 58%, respectively in 2018 as compared to 2016	Alsukait <i>et al.</i> <sup>[40]</sup>

**Table 2: Studies on SSB taxations and its effect on caries incidence and/or treatment cost**

Title of the study	Author, Year, Location	Age group	Study type	Outcome
Effects of Taxing Sugar-Sweetened Beverages on Caries and Treatment Costs	Schwendicke <i>et al.</i> 2016 <sup>[41]</sup> Germany	14-79 yrs	Model-based approach	20% sales tax on SSBs will result in reduction 0.75 million of caries lesions and treatment costs of 0.08 billion Euro over a 10-y period. Greater benefit for low income, younger males.
Health impact assessment of the UK soft drinks industry levy: a comparative risk assessment modelling study	Briggs <i>et al.</i> 2017 <sup>[25]</sup> United Kingdom	4-≥65 yrs	Comparative risk assessment model	In the best model scenario, an increase in the price of SSBs would result in 269 375 (82 211-470 928; incidence reduction of 4.4 per 1000 person-years) fewer DMFT annually. The greatest benefit for oral health would be among individuals aged younger than 18 years
The impact of a sugar-sweetened beverages tax on oral health and costs of dental care in Australia	Sowa <i>et al.</i> 2019 <sup>[42]</sup> Australia	Adults	Cohort model	Tax of 20% would lead to a reduction in DMFT by 3.9 million units, savings of A\$666 million over a 10-y period.
The caries-related cost and effects of a tax on sugar-sweetened beverages	Jevdjevic <i>et al.</i> 2019 <sup>[43]</sup> Netherlands	6-79 yrs	Tooth-level Markov model	20% sales tax on SSBs would result in an average of 2.13 caries-free tooth years per person and around 1.03 million caries lesions prevented and avoiding treatment costs of 159 million euro. Greater benefit for males and younger age group.
Impact of sugar-sweetened beverage tax on dental caries: A simulation analysis	Urwannachotima <i>et al.</i> 2020 <sup>[44]</sup> Thailand	Adults	Qualitative system dynamics model	Implementing SSB tax alone will not achieve the desired oral health outcomes, until it is implemented along with oral health education and improved access to oral health services

the Netherlands would lead to 2.13 caries-free tooth years per person, prevent 1.03 million new caries lesions and avoid treatment costs of €159 million. Boys aged 6–12 years would benefit the most in terms of caries-free tooth years per person.

Although the above-mentioned studies<sup>[25,41-43]</sup> found an association between levying SSB tax and reduction in dental caries and the cost of dental care, it should be noted they all were modeling and simulation-based studies. This is attributed to the relatively recent implementation of the tax policy as well as direct studies of dental caries and

SSB taxation may not be able to account for the complex nonlinear relationship between the variables. These studies also showed that dental benefits vary based on age and income levels, with the impact being greater among those who are younger<sup>[41,43]</sup> and with low-income levels.<sup>[41]</sup> This is an important factor to consider when planning similar studies, as the information about consumption patterns, population income, price elasticity and data about dental caries status must be available. However, all four studies were conducted in high income countries, and may have limited generalizability to developing and low-income countries, as both dental caries and SSB

consumption are sensitive to the disparity in the income of the consumers.

More recently, Urwannachotima *et al.*,<sup>[44]</sup> using the system dynamics modelling, showed that in Thailand, a middle-income country, implementing SSB tax alone would likely not achieve the desired oral health outcomes. The authors suggested that in Asian countries, majority of the sugar consumed is from non-tax sugary food and beverages due to widely practiced street food culture which may contribute to unequal sugar intake. Therefore, they recommend that to maximize the benefits, the SSB tax implementation should be supplemented with oral health education and improved access to oral health services.

For Arabian Gulf countries, which are high-income countries, the introduction of SSB taxation may provide beneficial effects similar to that observed in the four high-income studies. However, given that culture and consumption trends vary across population, there is a need for similar studies in the Arab countries to analyze the effect levying SSB tax has on its consumption and, consequently, on dental caries.

## CONCLUSIONS

The impact of SSB on dental caries is well established, and taxation of SSBs has consistently been shown to lower its consumption. In addition, modelling studies from developed and high-income countries have shown that SSB taxation would result in significant reductions in dental caries and its treatment costs; however, these findings were not corroborated in the only study from a developing middle-income country. As different countries have adopted different taxation structures for SSBs and were conducted over different time periods, findings from one country cannot be generalized to another. Therefore, there is a need for each country with such implementation to study the impact of SSB taxation on dental caries and its treatment costs.

## Peer review

This article was peer-reviewed by two independent and anonymous reviewers.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

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