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Impact of a sugar-sweetened beverage tax on dental caries, periodontitis and edentulism in Australia: a modelling study

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ABSTRACT

Introduction Oral diseases are a growing public health challenge affecting approximately 3.5 billion people globally. Nearly 32% of Australian adults aged 15 and above have untreated dental caries. Sugar-sweetened beverages (SSBs) are a significant contributor to oral diseases such as dental caries, periodontitis and edentulism. We aimed to estimate the potential impact of implementing a 20% tax on SSBs on the burden of oral disease in Australia.

Methods A prior proportional multistate lifetable model of the 2019 Australian adult population was used. We added dental caries, periodontitis and edentulism to the model in addition to 31 non-oral health conditions to deal with competing risks. Age-specific and sex-specific mean estimates for incidence, prevalence, years lived with disability and the 2019 Australian adult population data estimates from the Global Burden of Disease 2019 study were used.

Results A 20% SSB tax is projected to add 511 thousand (95% uncertainty interval (UI) 425 to 602 thousand) health-adjusted life-years (HALYs) for the 2019 Australian population over their lifetime, of which around 24% is due to oral diseases. A total of 3.7 million (95% UI 2.3 to 5.2 million) incident cases of dental caries and 191 thousand (95% UI 147 to 237 thousand) incident cases of periodontitis would be avoided. The incidence of edentulism via dental caries would reduce by 76 thousand (95% UI 48 to 106 thousand) and edentulism via periodontitis would reduce by 39 thousand (95% UI 30 to 48 thousand) total cases. HALY results are sensitive to the degree of quality-of-life loss associated with caries and periodontitis.

Conclusions A 20% SSB tax is projected to generate substantial health gains and reduce the burden of oral diseases in Australia under the assumptions of this modelling study. This is the first study to quantify the avoidable burden of periodontitis and edentulism in addition to dental caries.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ We conducted a rapid review of literature in PubMed which revealed a strong association between sugar-sweetened beverage (SSB) consumption and prevalent oral diseases, including dental caries and periodontitis. Search terms used were related to SSBs, dental caries, periodontitis and oral diseases. These chronic oral diseases represent a significant burden on the Australian population and are among the most prevalent untreated diseases globally. Australian adults continue to suffer from poor oral health due to untreated oral diseases and a lack of timely access to dental care. The WHO in its 74th world assembly declared oral diseases as a public health priority. In 2022, there was a call on countries to implement an SSB tax due to its impact on chronic disease prevention and health promotion. A recent empirical study conducted in the United Kingdom (UK) found that the UK Soft Drinks Industry Levy led to a significant reduction in hospital admissions for carious tooth extractions in children, highlighting the potential impact of such taxes on oral health outcomes.Similarly, the Philadelphia beverage tax was associated with reductions in tooth decay measures among lower-income adults and children. Five previous modelling studies have reported substantial impacts of sugar taxes on dental caries in populations in the United Kingdom, the Netherlands, Germany, Thailand and Australia. However, there are still limited studies on how such a tax would impact other chronic oral diseases like periodontitis and edentulism over the lifetime.

INTRODUCTION

Oral diseases are a growing public health concern affecting approximately 3·5 billion people globally[1] and ranking in the top 25 contributors to disability in adults.[2] Dental caries and periodontal disease are particularly significant because they can progress to tooth loss, culminating in edentulism, a state characterised by the complete loss of teeth.[3] These conditions can significantly reduce the quality of life and overall health of affected individuals.[4] In Australia, adults continue to have poor oral health due to untreated oral diseases as many lack timely access to preventive services across various states and

WHAT THIS STUDY ADDS

⇒ Our research quantifies the potential future reduction in the burden of oral diseases in Australia, using data from the 2019 Global Burden of Disease study. We provide estimates of health-adjusted life-years (HALYs) that could be gained through the implementation of a 20% SSB tax, encompassing dental caries and the additional pathways of periodontitis and edentulism. Our study shows that a 20% SSB tax could add up to 511 thousand (95% UI 425 to 602 thousand) HALYs for the 2019 Australian population over their lifetime, of which around 24% is due to oral diseases. This highlights the significant impact of SSBs on oral diseases and the related quality of life losses.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings highlight the significant magnitude of health gains that can be achieved by addressing the burden of oral diseases through interventions such as a 20% SSB tax. This evidence increases the importance for researchers and policymakers to prioritise public health initiatives aimed at the prevention and control of oral diseases globally. Furthermore, the tax revenues generated can serve to strengthen oral health services in Australia and other countries with predominantly private oral healthcare systems, fostering support for a universal healthcare approach.

territories.[4] In 2018, oral diseases accounted for 2.4% of Australia's total health burden and 4.5% of the non-fatal burden ranking among the top 10 contributors to the overall burden of diseases.[4] There is an urgent need to focus on preventing oral diseases to reduce their contribution to the Australian burden of disease.

Sugar-sweetened beverages (SSBs) are a substantial source of dietary sugar, and their fermentation is a necessary component of the cariogenic process.[5] Studies have also shown a significant positive association between frequent free sugar intake from foods or beverages and periodontal diseases.[6] Thus reducing or eliminating sugar from diet prevents both dental caries and periodontal diseases.[7] While conclusive evidence on the direct link between SSBs and periodontitis is currently lacking, there is evidence along the causal chain. The association of diabetes with periodontitis is well-established,[8] as are the preceding links between SSB consumption, body mass and diabetes incidence.[9] Recognising the detrimental health impacts of excessive sugar consumption, the WHO recommends that added sugars should ideally be reduced to less than 5% for added health benefits.[10] The WHO has supported SSB taxes as a policy intervention to prevent diet-related non-communicable diseases (NCDs), including dental diseases.[11] Globally, more than 100 countries have implemented SSB taxes in various forms to achieve positive health objectives and increase revenue.[12] A recent empirical study conducted in the UK found that the UK Soft Drinks Industry Levy led to a significant reduction in hospital admissions for carious tooth extractions in children, highlighting the potential impact of such taxes on oral health outcomes.[13] Similarly, the Philadelphia beverage tax was associated with reductions in tooth decay measures among lower-income adults and children.[14]

The Australian Dietary Guidelines recommend limiting the consumption of beverages high in added sugars due to their limited nutritional value and risk of oral diseases.[15] However, SSB consumption remains high and in 2017–2018 approximately 9.1% of Australians aged 18 and over reported daily intake of sugar-sweetened drinks. Australia does not currently have a specific tax on SSBs. The advocacy for SSB taxation has increased over the years. Researchers have shown that increasing the prices of SSBs could reduce consumption and benefit public health.[16] The Australian public has shown high levels of support for policies to reduce sugar intake from diet.[17]

Evidence on the likely impact of SSB taxes can aid policy decision-making to tackle the burden of oral diseases in Australia.[18] This requires modelling, as the full impact of taxes on chronic disease materialises over many years.[11] Many studies have estimated the impact of SSB taxes on obesity and related diseases, but few have addressed impacts on oral diseases.[19] There are studies modelling the impact of such a tax on dental caries,[18 20] but currently there are no estimates of the potential impact on periodontitis and edentulism. This study aims to address this gap in knowledge by using a proportional multistate lifetable model to simulate the potential impact of a hypothetical 20% SSB tax on dental caries, periodontitis and edentulism for the 2019 Australian adult population, in addition to the impact via other non-oral health conditions.

METHODS

Study design and modelling framework

We expanded an existing peer-reviewed epidemiological SSB tax model to project the Australian adult population across their remaining life course in terms of their consumption of SSBs and oral health outcomes.[9] Figure 1 shows the model's logic pathway.

The proportional multistate lifetable model (PMSLT) is a macrosimulation model that simulates 5-year age and sex cohorts of the population into the future.[9] The model contains three linked parts: (1) a risk factor section, (2) disease Markov sub-models and (3) lifetables.[9] A schematic description of the model is provided in online supplemental figure 1.

Modelled intervention

The model projects the future health status of the 2019 Australian population, comparing the outcomes under an SSB tax with a 'business as usual' scenario. The differences in outcomes between both scenarios quantify the impact of the intervention. The modelled tax was a 20% ad valorem tax on SSBs, following the example of both prior modelling studies and epidemiological evidence specific to Australia.[9] A tax of at least that size is also recommended by WHO.[11 20] SSBs were defined as non-alcoholic drinks with added sugar, including carbonated

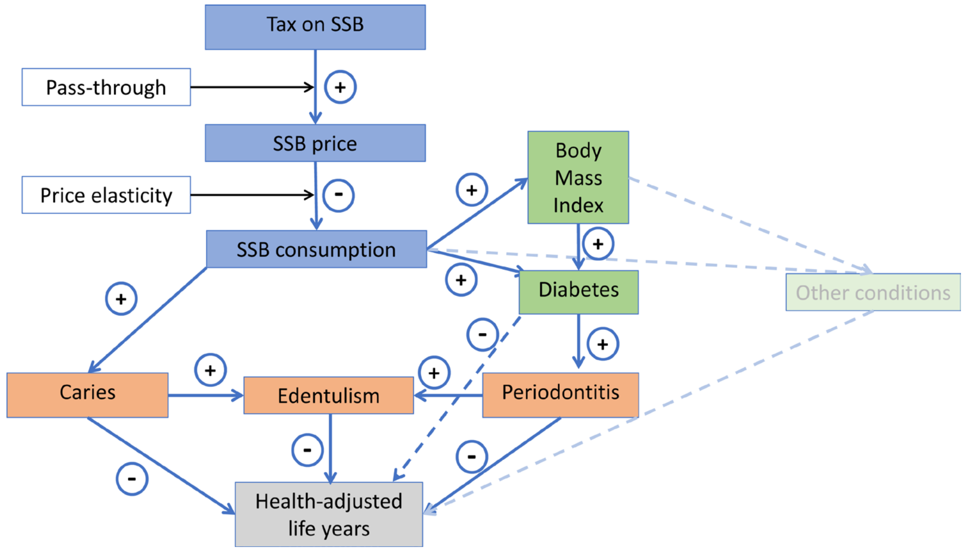

Figure 1 Logic pathway of the sugar-sweetened beverage (SSB) and oral health model. *The arrows represent the pathways analysed. Positive and negative signs indicate directionality.

soft drinks and flavoured mineral waters. This excluded 100% fruit juices and drinks, energy drinks, dairy milk (cow, sheep, goat), milk-based drinks and cordials.[9] The proportion of price increase that would be passed on to consumers (pass-through) was set at 100%.[20] Empirical evidence suggests that SSB taxes are typically passed on in full when applied to entire countries, although lower rates can occur in smaller areas.[21]

Model inputs

The rise in SSB prices and the reduction in consumption was modelled using a pooled own price elasticity estimate of −1.198 (95% CI −1.340 to −1.057) derived from a comprehensive meta-analysis of multiple studies across different contexts (online supplemental box 1). Importantly, the meta-analysis includes studies from high-income countries, ensuring relevance to the Australian context. We used previously published energy balance equations in which a change in net energy intake of 94.0 kJ per day (95% CI 88.2 to 99.8) corresponds to 1 kg change in body weight.[22] We derived the trend for mean body mass index (BMI) by age and sex, observed over the years 1975–2016 in Non-Communicable Risk Factor Collaboration (NCD-RisC) results. Following previous PMSLT modelling studies, we assumed this upward trend would continue till 2024, after which BMI would remain stable by age and sex.[23] Changes in body mass are linked to the incidence of health conditions via potential impact fraction calculations (online supplemental figure 1).[24]

Estimates for the incidence, prevalence and mortality for dental caries (permanent teeth), edentulism and periodontitis and all other BMI-related diseases were obtained from the Global Burden of Disease (GBD) 2019 study and modelled as separate diseases at the population level by age and sex (online supplemental figure 2).[25] Australian SSB consumption data were obtained from the ABS Australian Health Survey 2011/2012 (online supplemental table 3).[26] Health-adjusted life-years (HALYs) accrued over the remaining life of the Australian population were quantified by using GBD disability weights to adjust for the health-related quality of life and the life-years lived (online supplemental methods).[9] HALYs (but not disease-specific outcomes) were discounted at 3%. This discount rate is consistent with standard practice in economic evaluation. Discounting accounts for time preference whereby health gains occurring in the future are valued less than those occurring in the present and allows comparability with other modelling and cost-effectiveness studies.[27]

Modelled diseases

Dental caries in permanent teeth, periodontitis and edentulism were added to the model in addition to 31 non-oral health conditions (online supplemental box 2). The inclusion of the non-oral health conditions was informed by existing evidence on causal relationships between high BMI and respective diseases (figure 1).[13] The causal link between sugar consumption and caries and the ensuing tooth decay and missing teeth is also established and estimates of a dose–response relationship are available.[28] SSB consumption is associated with diabetes both independently and via increased body mass,[29] and diabetes is associated with periodontitis.[10] Patients with periodontitis have a higher risk of tooth loss leading to edentulism in the older and diabetic patients.[30] We used RRs from a systematic review of literature on the risk outcome pairs including SSB on dental caries, diabetes on periodontitis and edentulism due to periodontitis and dental caries (online supplemental table 4). These risk–outcome pairs were included after meeting the World Cancer Research Fund grades of 'convincing' or 'probable' evidence for a causal interpretation.[31] The current model already included body mass and diabetes,[9] which enabled us to add periodontitis as a function of diabetes prevalence. Edentulism was modelled via dental caries and periodontitis pathways. Causal pathways were added from the implementation of a tax via an increase in the price of SSBs, which leads to reductions in consumption and reductions in oral disease outcomes. We used lognormal distributions around the RRs because ratio measures such as risk ratios, ORs and HRs are usually analysed on the log scale where the sampling distribution is often more nearly normal and CIs become approximately symmetric.[32] The RRs used were obtained from systematic reviews and meta-analyses which already synthesise heterogeneity across individual studies.

The epidemiological input data on oral disease epidemiological estimates and disability weights used in our model are provided in online supplemental tables 5 and 6 and online supplemental figures 3 and 4.

Sensitivity analysis

We modelled changes to the HALYs by comparing base tax (20%) to 10% and 30% tax intervention. To explore the impact of possible industry responses, we also modelled product reformulation scenarios with 50% and 100% sugar reductions (and no consumer response) and 50% and 80% pass through scenarios. We also ran a scenario in which we used disability weights from a study on the burden of oral disease in South Australia (SA) instead of those from the GBD.[33] We varied the BMI trend by modelling two scenarios, that is, no trend (0 years) and a constant trend extending to 20 years compared with the base case assumption of BMI trends stabilising after 2024.

Uncertainty analysis

Uncertainty distributions were added to consumption of SSBs, price elasticities, energy balance and RRs for modelled diseases. Uncertainty in the outcome parameters was assessed by Monte Carlo simulation with bootstrapping using the Ersatz 1.35 program (Epigear.com, Brisbane, Australia; 2000 iterations).[9] We calculated 95% uncertainty intervals (UIs) for all outputs as the 2.5 and 97.5 percentiles.

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination of this modelling study. This study used secondary data from publicly available sources.

RESULTS

Avoidable burden of oral diseases

Table 1 shows the new cases of disease that would be avoided after the implementation of a 20% SSB tax, projected over 25 years from 2019 until 2044. A 20% SSB tax would significantly reduce the incidence of dental caries with a total of 3.7 million (95% UI 2.3 to 5.2 million) incident cases avoided, 62% of which were among males and 38% in females (table 1). A 20% SSB tax in Australia would also significantly reduce the incidence of periodontitis by 191 thousand (95% UI 147 to 237 thousand) new cases over 25 years (58% for males and 42% for females). The incidence of edentulism because of dental caries would reduce by 76 thousand (95% UI 48 to 106 thousand) total cases with 58% males and 42% females. The incidence of edentulism due to periodontitis would reduce by 39 thousand (95% UI 30 to 48 thousand) total cases with 49% males and 51% females.

Table 1 Estimated avoidable incident cases of oral diseases following the implementation of a 20% SSB tax in Australia over the first 25 years

	Number of avoidable incident cases	
Modelled pathways	**Males Mean (95% UI)**	**Females Mean (95% UI)**
Dental caries	2 330 533 (1 468 308 to 3 247 052)	1 464 167 (930 646 to 2 049 512)
Periodontitis	111 933 (80 993 to 147 030)	79 436 (56 873 to 102 282)
Edentulism via dental caries	43 999 (27 557 to 61 674)	32 383 (20 899 to 45 419)
Edentulism via periodontitis	19 239 (14 165 to 24 811)	20 008 (14 668 to 25 599)

SSB, sugar-sweetened beverage; 95%UI, 95% uncertainty interval.

Figure 2 shows that the prevalence of caries falls quite rapidly after the implementation of a 20% SSB tax, while the reductions in the numbers of people suffering from periodontitis and edentulism build up gradually over the first 25 years.

Health-adjusted life-years (HALYs)

Without the inclusion of oral diseases, the model projected that a 20% tax on SSBs could add up to 387 thousand (95% UI 323 to 456 thousand) HALYs over the lifetime of the 2019 Australian population (table 2). When oral diseases were added to the model, an additional 124 thousand HALYs (95% UI 95 to 154 thousand) were expected to be gained. Table 2 shows the effect of dental caries, periodontitis and edentulism on the lifetime HALYs.

The impact of an SSB tax at different time periods over the lifetime of the 2019 Australian population is presented in online supplemental table 7.

Sensitivity analysis

Table 3 shows that compared with the base case of 20% tax, the health impact of the tax is just over half when a 10% tax is applied and increased by 36% when a 30% tax is applied. The health impact of the SSB tax is up to three times larger with 50% reformulation as compared with the base case and nearly five times with 100% reformulation. As the pass-through rates decrease, the health impacts of the 20% SSB tax decrease. When we use the South Australian disability weights the health impacts of the SSB tax on oral diseases increases threefold. The difference was most substantial for dental caries due to the high disability weight assigned to caries (online supplemental table 8). The difference was less marked for periodontitis and edentulism. Varying the BMI trend had a modest impact on findings with the no-trend

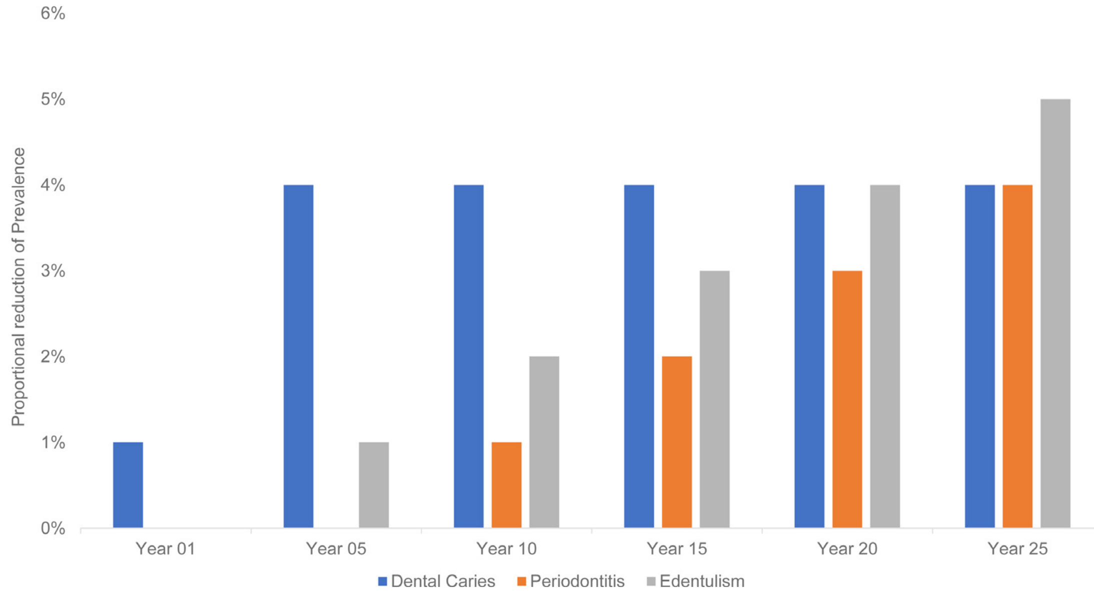

Figure 2 The avoidable prevalence of dental caries, periodontitis and edentulism (via both dental caries and periodontitis) for the Australian population after the implementation of a 20% sugar-sweetened beverage tax for years 1, 5, 10, 15, 20 and 25.

scenario producing results for oral health outcomes that are approximately 5% lower than the base case, and the 20-year-trend scenario approximately 7% higher. The impact across all health conditions is slightly larger, at −7% and +12%.

DISCUSSION

Our results show that implementation of a 20% SSB tax would lead to large reductions in the incidence of dental caries, periodontitis and edentulism among the Australian adult population.

The large number of avoided cases reflects the high baseline burden of dental caries in Australia. Dental caries is one of the most prevalent chronic conditions with a substantial proportion of adults experiencing untreated disease and ongoing incident lesions. When applied to a national population, reductions in incidence accumulate over time resulting in large cumulative effects.[6] The avoidable burden of these oral diseases is higher for males than for females. This is due to males having a higher burden of dental caries and periodontitis at baseline,[25] and a higher consumption of SSBs.[34] Over the lifetime of the 2019 Australian population, a 20% SSB tax is projected to add 511 thousand (95% UI 425 to 602 thousand) HALYs, of which approximately 24% is due to reductions in oral diseases. While the prevalence of edentulism has been steadily declining in Australia, its slow progression and irreversible nature along with its substantial impact on quality of life, accounting for 2·6% of the overall quality of life loss in our model, explain its considerable long-term impact seen on the population.[25] Our study applied disability weights from the GBD 2019 study, adjusted for the Australian population, to estimate the impact of a sugar tax on HALYs and the avoidable burden of oral diseases in Australia. This choice is grounded in the GBD's comprehensive data, which is drawn from diverse sources including national health statistics, surveys and research studies, subject to rigorous

Table 2 HALYs gained over the lifetime of the 2019 Australian population after the implementation of a 20% SSB tax

	HALYs	
Modelled pathways	**Male mean (95% UI)**	**Female mean (95% UI)**
Without oral diseases	238 688 (194 163 to 287 630)	148 445 (120 566 to 178 128)
With all conditions	306 114 (247 575 to 369 335)	204 906 (1 66 871 to 249 036)
With only oral diseases included	67 083 (50 597 to 84 982)	57 080 (42 926 to 72 233)
Dental caries	4733 (2956 to 6590)	3014 (1920 to 4219)
Periodontitis	11 214 (8128 to 14 727)	7585 (5424 to 9765)
Edentulism via dental caries (including caries)	32 041 (20 253 to 44 817)	24 728 (15 983 to 34 603)
Edentulism via periodontitis (including periodontitis)	31 702 (23 156 to 41 042)	29 580 (21 740 to 37 798)

Please note that the results for edentulism include the quality of life gains associated with caries and periodontitis, respectively.
HALYs, health-adjusted life-years; SSB, sugar-sweetened beverage; 95%UI, 95% uncertainty interval.

Table 3 Point estimate results for the lifetime HALYs in the one-way sensitivity analysis

Scenario	All diseases		All oral diseases		Males and females relative to base case
	Male	Female	Male	Female	(all oral diseases only)
Base case (20% tax, 100% pass through, 0% reformulation, GBD DWs)	304689	204517	67172	57315	1.00
10% tax	169037	113140	37392	31761	0.56
30% tax	415756	279684	91396	78279	1.36
50% reformulation	892303	605987	193433	168547	2.91
100% reformulation	1434290	985070	305052	271569	4.63
50% pass through rate	169037	113140	37392	31761	0.56
80% pass through rate	253790	170188	56023	47720	0.83
South Australia study DWs	500361	322597	262845	175395	3.52
BMI trend 0 years	287351	188295	64110	53965	0.95
BMI trend 20 years	338598	230691	71977	60813	1.07

The column males and females relative to base case presents the change in the health impact of SSB tax (on oral diseases only) for the sensitivity scenarios when compared against the base case.
BMI, body mass index; DW, disability weight; GBD, Global Burden of Disease; HALYs, health-adjusted life-years; SSB, sugar-sweetened beverage.

validation and quality control. The GBD estimates for the loss of quality of life due to edentulism considered those with severe tooth loss and no access to dentures. Since the incidence and prevalence model input data estimates from GBD account for all population, irrespective of access (or not) to dentures, our model could overestimate the impact of SSB tax on edentulism for Australians, who face fewer challenges in accessing care than the global average.[35] We found a much larger impact when using disability weights from an SA study[33] particularly for caries. Patients or cases included in that study were selected via dentists, possibly resulting in the selection of more severe cases. Furthermore, the authors did not account for disability from other chronic diseases. Thus, higher weights were assigned to oral health conditions, leading to higher estimated impacts.

The results of our study are corroborated by a modelling study which investigated the effects of implementing a SSB tax in Australia.[20] Their findings indicated that a 20% SSB tax would lead to a reduction in decayed, missing and filled teeth by 3.9 million units over 10 years.[20] However, an assumption of their model was that all carious lesions would eventually be treated. This may not be realistic; nearly one-third of Australian adults 15 years and above have untreated dental caries.[5] Assuming that all carious lesions would be treated may overestimate the impact of the SSB tax thus our model provides a more realistic interpretation of the full effect of the tax accounting for both untreated and treated dental caries. A recent study estimated a total of 254.9 DALYs averted for dental caries over the lifetime of the Australian population.[36] While this represents a significant impact, it is well over an order of magnitude lower than our estimate of 7747 HALYs for caries. This is explained by the authors' assumption of a relatively short symptomatic period of around 55 days, with no disability associated outside that time window.[36] In contrast, our study used the annualised disability estimates for oral diseases in GBD, calculated as 'years lost to disease' divided by prevalence, adjusted for other morbidity, hence our estimates appear larger. Younger age groups, particularly adolescents and young adults aged 12–24, have the highest consumption of SSBs in Australia and as individuals age, the consumption of SSBs tends to decrease.[37] At age 15, adolescents generally have a complete and mature set of permanent teeth.[38] Adolescents at this age are also approaching the end of their school years, which often coincides with greater exposure to a more independent diet, including increased consumption of SSBs.[39] The selection criteria for the population aged 15+ were set to focus on individuals with permanent dentition at higher risk of SSB consumption.

In the Australian Burden of Disease study, dental caries accounted for 52371 DALYs, periodontitis for 45274 DALYs and severe tooth loss for 30732 DALYs in 2022.[40] The 2019 GBD study estimated that in Australia, the burden of dental caries of permanent teeth amounted to 6625 DALYs, while periodontitis contributed to 18782 DALYs, and edentulism accounted for 68110 DALYs.[25] Our estimates of the lifetime oral disease burden that can be avoided by a 20% tax on SSBs are therefore in the order of 1–2 times the annual burden. Dental caries contributed to a modest loss of quality of life compared with the more significant impacts of periodontitis and edentulism, which is reflected in our health gain estimations. To the best of our knowledge, this is the first study to quantify the burden related to periodontitis and edentulism that is avoidable by the introduction of SSB taxation. Previous Australian modelling studies did not consider the burden of periodontitis and severe tooth loss.[20 36] A positive impact on oral health was anticipated in other modelling studies on the English, German, Dutch and Australian populations, all via caries.[19]

Another notable strength of this study is that we use the PMSLT model, which is a well-established approach for the estimation of long-term health outcomes allowing us to capture the cumulative effects and dynamic transitions between health states over time.[9] The lifetable approach provides estimates for changes in disease incidence and prevalence providing a comprehensive understanding of the avoidable burden related to oral diseases over the lifetime of the population under investigation. Within the PMSLT framework, each disease is modelled through separate lifetable pathways while accounting for competing risks. We also included non-oral health NCDs which allowed us to account for competing risks.[9] Our model incorporates Australian-specific inputs where possible and draws on evidence from exemplar countries, such as Mexico that has successfully implemented an SSB tax.

Some limitations of this study are that the model does not incorporate uncertainty for incidence/prevalence input data or the disability weights directly. We used DisMod II to ensure internal consistency and derive estimates of case fatality,[41] which makes it difficult to estimate the parameters for the uncertainty distributions. This means our model underestimates the uncertainty around the estimates. Additionally, the RR used in our model was taken from systematic reviews and meta-analyses of cohort studies, which may be affected by residual confounding or reverse causation. We did not model a delay in weight change after the start of implementation of the tax, and no delay between a change in BMI and the incidence of disease.[22]

The model also assumes that BMI trends stabilise after 2024 which may underestimate or overestimate future disease incidence if population BMI continues to increase or decrease over time. Sensitivity analysis testing alternative BMI trend scenarios showed this assumption has modest impact on results. Social desirability and recall bias in the ABS Australian Health Survey 2011/2012 may have led to underestimation of SSB consumption in our model.

The own price elasticities used in our model were predominantly from modelling studies with the latest dated back to 2015. Additionally, there is potential for publication bias in the effect estimates used in the model. Formal calibration against observed post-tax outcomes was not undertaken, as there is no directly comparable SSB tax implemented in Australia and differences in tax design and contextual factors limit transferability from international settings. Although formal calibration was not undertaken, the estimates are supported by GBD 2019 baseline inputs, comparable international studies and additional model testing (online supplemental methods, online supplemental figure 5). Schwendicke *et al* estimated that a tiered SSB tax in Germany would reduce caries incidence by 2.4 cases per 1000 person-years.[42] Our projected reduction of 3.7 million cases over 25 years equates to about 5.8 cases avoided per 1000 person-years in Australian adults. This is roughly twice the German estimate but remains similar in order of magnitude and may reflect differences in baseline caries burden, diet or preventive dental care access. Therefore, the model should be interpreted as a scenario analysis rather than a precise prediction of real-world effects. While our model estimates the impact of an SSB tax on direct consumption reduction some consumers may substitute tax-exempt beverages which may also contain high levels of sugar.[43] While SSBs are a major source of free sugars, other dietary sources of sugar are not explicitly modelled. Therefore, the estimated reductions in dental caries reflect the impact of changes in SSB consumption alone and should not be interpreted as all sugar-related caries being attributable to SSB intake. The extent of this effect varies across different contexts.[44] We note that an SSB tax alone is not sufficient to tackle sugar intake and future research should consider alternative policies as well. Nonetheless, this study underlines the substantial health consequences of dental caries, periodontitis and edentulism, highlighting the considerable burden they impose on health and quality of life. The reduction in the burden of the modelled oral diseases could translate not only to lower direct treatment costs but also contribute to enhanced productivity and quality of life for individuals.[45] By reducing consumption, the tax could contribute to improved oral health outcomes in populations who are at higher risk of SSB consumption and experience difficulty in accessing oral healthcare consequently addressing inequalities in oral health.[42 46] By leveraging the best available evidence to formalise the system's structure and current state in a mathematical framework, our approach facilitates forecasting likely consequences of an SSB tax in a complex system.

CONCLUSION

Our findings quantify the potential impact of an SSB tax on the oral disease burden in Australia. The evidence from this study can inform the Australian public and policymakers of the health benefits of an SSB tax intervention. Moreover, the generated tax revenue can be used for further prevention.[38] Future research should explore healthcare costs and economic consequences of an SSB tax to help in developing targeted strategies that improve and promote oral health-related quality of life over time.

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