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Title: How could taxes on sugary drinks and foods help reduce the burden of type-2 diabetes?

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Abstract.

Purpose of this review

Taxes on sugary drinks and foods have emerged as a key strategy to counteract the alarming levels of diabetes worldwide. Added sugar consumption from industrialized foods and beverages has been strongly linked to type-2 diabetes. This review provides a synthesis of evidence on how taxes on sugary products can influence the onset of type-2 diabetes, describing the importance of the different mechanisms through which the consumption of these products is reduced, leading to changes in weight and potentially a decrease in the incidence of type-2 diabetes.

Recent Findings

Observational studies have shown significant reductions in purchases, energy intake, and body weight after the implementation of taxes on sugary drinks or foods. Simulation studies based on the association between energy intake and type-2 diabetes estimated the potential long-term health and economic effects, particularly in low- and middle-income countries, suggesting that the implementation of sugary food and beverage taxes may have a meaningful impact on reducing type-2 diabetes and complications.

Summary

Public health response to diabetes requires multi-faceted approaches from health and non-health actors to drive healthier societies. Population-wide strategies, such as added sugar taxes highlight the potential benefits of financial incentives to address behaviors and protective factors to significantly change an individual's health trajectory and reduce the onset of type-2 diabetes worldwide, both in terms of economy and public health.

Keywords

Sugar-sweetened beverage, Added-sugar foods, Tax, Evaluation, Policy.

Statements and Declarations.

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1. Introduction

The consumption of added sugar in foods and beverages is a major public health concern worldwide. A high intake of added sugars has been linked to an increased risk of obesity, type-2 diabetes, heart disease, and other health problems.[1–5] The World Health Organization recommends limiting added sugar intake to less than 10%kcal of the total daily energy intake and ideally to less than 5%kcal for additional health benefits.[6] The energy contribution of added sugars worldwide in 2020 was heterogeneous across geographic regions, and few countries complied with the recommendation of added sugar intake (Figure 1). The excess in consumption is not exclusive of low- and middle-income countries, as it is also present in a large proportion of high-income countries such as Iceland, the United States, and the UK.[7] Worldwide, between 1990 and 2020, the energy contribution of added sugar increased in all age groups: 7 to 10%kcal in children, 8 to 12%kcal in adolescents, and 7 to 11%kcal in adults.[7] The consumption of sugar has increased rapidly in recent years, which has potentially contributed to the surge of the type-2 diabetes epidemic.

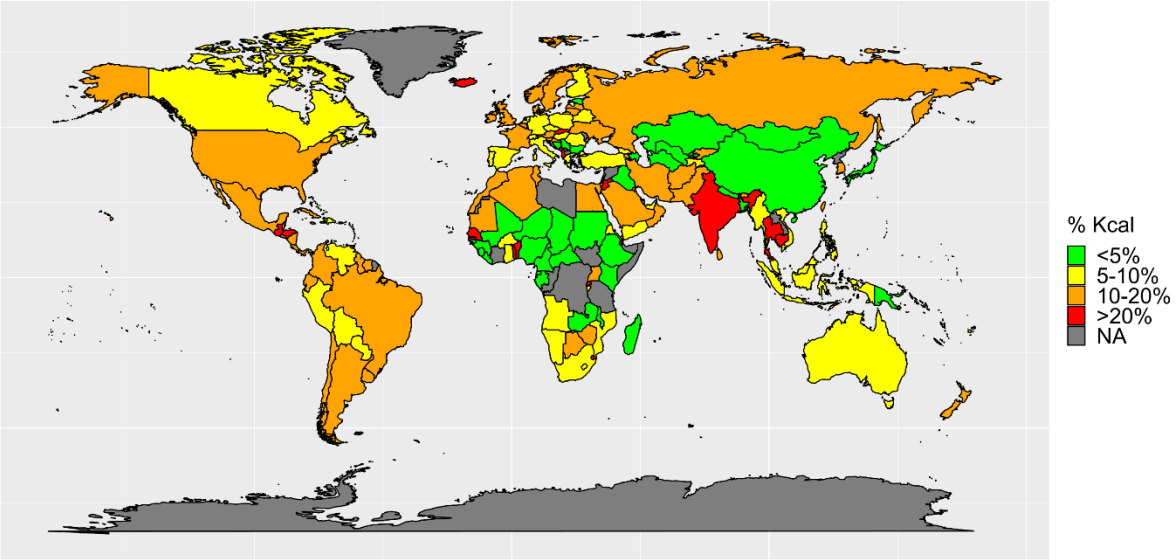

Fig. 1 Energy contribution (%kcal) of added sugar worldwide in 2020. Figure developed by authors using the final estimates from the Global Dietary Database. Tufts University, USA.[7] The production of the map was made using RStudio (Rstudio Team,2022). NA: Not available data.

Considering how ubiquitous sugary drinks are and their harmful effects on health, a potential response to the challenge of excessive sugar intake is to implement taxes on sugary products. Taxes are particular tools with population-wide reach and a potential policy response to guide healthier societies,[8–10] moving from individual-level solutions towards more structural solutions.[11] A sugar tax is a mandatory surcharge that is placed upon beverages or foods that contain added sugars. It is an important tool in the fight against type-2 diabetes, as it provides a behavioral nudge for consumers to choose healthier alternatives.[11,12] It can help reduce the consumption of non-nutritive unhealthy products and encourage consumers to choose healthier options such as fruit, plain water, milk, or other

low-sugar alternatives.[13,14] This, in turn, could potentially help reduce caloric intake and improve risk factors associated with type-2 diabetes.[15]

Sugar taxes have been implemented in multiple countries around the world, aiming to reduce the consumption of sugary drinks and high-sugar products to combat the rising rates of obesity and type-2 diabetes. Over 85 countries worldwide have implemented sugar taxes (at the national or subnational level),[16] including Mexico, Chile, the UK, South Africa, the USA, and many others are considering following suit.

Studies have shown that introducing a sugar tax can lead to a significant decrease in the consumption of sugary drinks, especially among low-income populations.[13,14,17,18] For example, two years after the introduction of a sugar-sweetened beverage (SSB) tax in Mexico, sales of sugary drinks decreased by 9.7%.[17] Other potential benefits from sugar taxes include population awareness of the negative effects of added sugars, industry response encouraging manufacturers to reformulate their products to contain less added sugar, and utilization of revenue generated from the tax to fund public health programs or to subsidize healthier food options.

In this review we aimed to synthesize the evidence on how sugar taxes can contribute towards the reduction of the burden of type-2 diabetes. We discuss the importance of social mobilization and public awareness, how the price increase may lead to reduced consumption, mainly among people of low socioeconomic status, the responses from industry to tax policies, and the possibility of using tax-generated revenues to reinvest in other obesity prevention policies. We then proceed to discuss the potential impact of sugar taxes on purchases, weight, and type-2 diabetes incidence using different epidemiological methods. This review closes with reflections on the way forward, emphasizing the opportunities of population-based approaches to counter the continuing rise of the type-2 diabetes epidemic, alongside reflections on the need to revisit and adjust sugar taxes considering that these are not one-off policies, especially considering economic aspects such as inflation and household income growth. In doing so, we contribute to the literature on the fields of public policy and population health, understanding the role of a specific policy tool, i.e. sugar taxes, in bringing desirable changes towards sustained healthier habits and healthier societies.

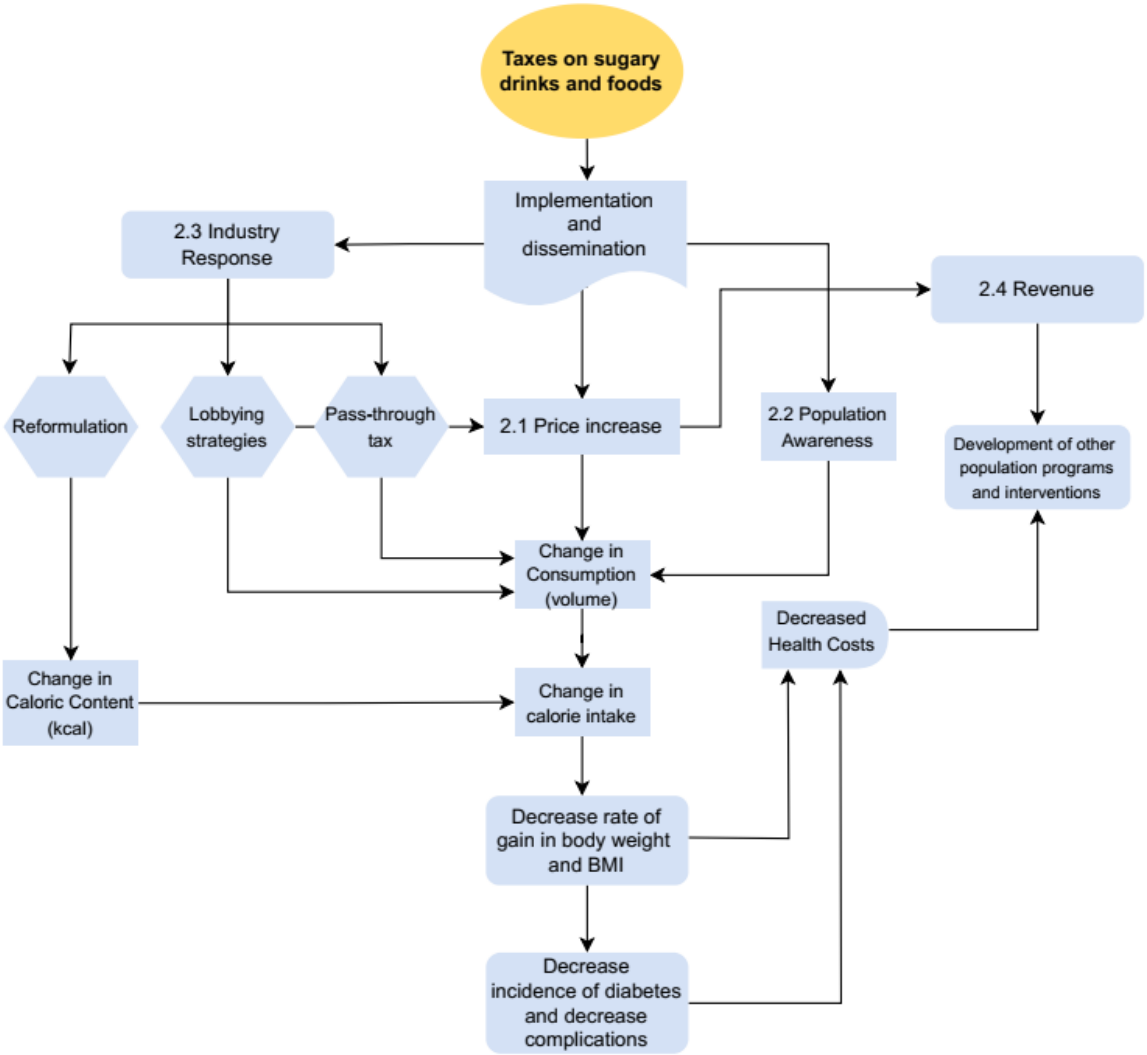

Fig. 2 Possible pathways between sugary drinks and food taxes and type-2 diabetes. Figure developed by the authors.

2. Potential pathways in which sugar taxes may reduce energy intake

The impact of sugar taxes on reducing energy intake depends on multiple factors, including how the tax was implemented, the media, non-governmental organizations' involvement, and the population's involvement. As a policy tool, the impact of these tax policies is closely related to a number of factors including, but not limited to, the amount of the tax and the increase in the price of the taxed items, the industry response, and the possibility of using the tax revenue to further support favorable health profiles. We will discuss each potential pathway, building upon the Mexican experience in which in 2014 an excise tax of ~10% to non-alcoholic sugary drinks and an ad-valorem tax of 8% to nonessential energy-dense foods were introduced.[19]

2.1. Price increase

The price increase is the first pathway for sugar taxes to reduce consumption, and this effect is a direct result of sugary drinks being elastic goods. This consumer-demand pathway is well studied from an economic perspective, in which the demand for sugary drinks is sensitive to price increases. In a recent meta-analysis using data from 10 countries, SSBs were estimated to be elastic, with a price elasticity of demand of -1.59, meaning that a 10% increase in price would be translated into a 15.9% reduction in sales of SSBs.[20] In Mexico, the price elasticity for SSBs was estimated to be -1.16, i.e, a 10% increase in price would reduce consumption by 11.6%.[21]

2.2. Public awareness

Social support and mobilization are important to enable the implementation of taxes on sugary products. By framing taxes on sugary products as a public health measure and emphasizing their health-related benefits, these policies can gain public support.[22,23] Taxes can increase public awareness of harmful products to health alongside an increased understanding of the health risks associated with excessive sugar consumption. Thus, taxes applied to sugary beverages and foods can reduce the consumption of these products through other pathways, independently of price increase. This response is called a "signaling effect" as products taxed are framed as harmful and the tax signals this information to consumers.[24,25]

In Mexico, civil society media campaigns aimed to raise public support. Campaigns focused first on illustrating the health problem, then the role of SSBs, and finally the proposed solution of taxing SSBs.[26] Furthermore, once the tax to SSBs was implemented an important part of the population was aware of it. According to the national nutrition survey two years after the implementation, 65% of the population was aware of the existence of the tax and this percentage was higher in the upper socio-economic status (74%), among those living in the country's capital Mexico City (77%), and in urban areas (68%).[27] Civil society media campaigns, as well as industry media campaigns against SSBs taxes were centered in Mexico City which could explain why the percentage of the population aware of the tax was higher in the capital. Two years after the tax implementation, those aware were 30% more likely to decrease SSBs consumption.[27] Also, in urban areas, comparing current SSBs intake, those that were aware of the tax consumed 16% less taxed SSBs than those unaware.[27] Altogether this suggests that the tax had a signaling effect among those aware of the tax contributing to reduced consumption.

2.3. Industry response

The sugary beverage and food industry is usually an opponent of the implementation of sugar taxes. Likewise, the industry can change the impact of taxation through three opposing pathways: 1) reformulation by reducing sugar content; 2) lobbying against the tax; and 3) reduction of the pass-

through of the tax, in which producers/retailers pay a portion of the tax to avoid increasing prices to the consumer.

Reformulation

A possible response of the industry is to reformulate their products to reduce or eliminate sugar content, as a way to avoid the tax. This response will positively impact obesity and type-2 diabetes by reducing the overall sugar intake of the population and providing new products for health-conscious consumers. The reformulation response of the industry depends on the tax design. For example, in South Africa, the tax implemented in 2018 was tiered, starting at 5 g per 100 ml and increasing with every extra 1 g of sugar per 100 ml.[28] This creates an incentive to reformulate, to keep reducing the imposed tax on their products. In South Africa, the average sugar content of taxed beverages fell by 12%, while the average sugar content of non-taxed beverages remained constant.[28] Beverage producers changed their products in a variety of ways, with some lowering the sugar level, some moving to non-nutritional sweeteners not subject to taxes, and others not reformulating, such as the main SSB brands.

In contrast, the SSB tax in Mexico, implemented in 2014, is a flat rate excise tax of 1 peso per liter, which implies that all products subject to the tax will have the same tax rate, regardless of their sugar content.[29] As such, the industry has no incentive to lower the sugar content of its beverages. However, the current excise SSB tax is higher for larger package sizes that were relatively less expensive (in pesos/liter). Reformulation in Mexico was limited, but sugar in most powder concentrates was removed and it was either replaced with artificial sweeteners or left to the consumer to add the sweetener. Also, new “light” versions without added sugar were observed in sports drinks and energy drinks.[30]

Lobbying and marketing strategies against the tax

The industry may lobby against the implementation of sugar taxes by arguing that they 1) are regressive, harming small businesses and low-income families and affecting employment,[16,31–35] and 2) are unnecessary because the population should be able to make their own decisions.[36–38] The first argument, regressiveness, means that tax disproportionately affects low-income individuals and families who may have limited access to healthier alternatives. This argument is often used by industry groups to garner support from politicians and the public, who may be sympathetic to concerns of negative impacts to low-income families.[38,39] Industry groups also argue that sugar taxes are unnecessary, as there are other ways to reduce the consumption of sugary foods and beverages, such as public education campaigns and voluntary reformulations of products. These arguments are used to position the industry as a proactive player in the fight against obesity and type-2 diabetes while also resisting government intervention in their businesses.[34,40] In addition to these arguments, industry groups may also use their significant financial resources to fund advertising and public relations campaigns that seek to undermine the legitimacy of sugar taxes. These campaigns may use emotional language and appeal to public concerns about government overreach and the erosion of personal choice to sway public opinion against the tax.[40] Finally, once the tax is implemented the industry can

reinforce the promotion and marketing strategies of their products to counteract the effect of price increases on consumer's choices.

In Mexico, the industry used several strategies to oppose the SSB tax implementation. For example, lobbyists from soft-drink companies met congressmen to discuss their perspectives, distributed a poster in local small stores saying "This store and its clients say NO to another tax on sodas and SSBs, our businesses are at risk", paid media to question the health effects of SSBs, warned about the negative effects on the economy and jobs and advocated instead for individual responsibility.[26] However, existing evidence shows that the SBB tax did not lead to job losses and the regressive aspect of the sugar taxes is controversial, as taxes help reduce disease and healthcare costs leading to long-term savings and revenue can be used to invest in water or food programs to benefit low-income families.[35]

Tax reflected to the consumer (pass-through)

While taxes are mandatory, the industry can implement mechanisms to reduce the amount of tax that affects the consumer. Some mechanisms of reducing the pass-through to the consumer include: 1) absorbing part of the tax as an added cost or 2) cost management measures,[41,42] 3) negotiating better prices with suppliers of raw materials and ingredients to ensure stable prices for consumers,[18] and 4) fostering collaborations for industry-retailer cost-sharing initiatives.[18] Across countries that have implemented an SSB tax, 82% of the tax passed on to consumer prices, and the remaining 18% was absorbed by the industry.[20] The absorbed proportion by the industry can vary by product or region of the same country. In Mexico, the tax pass-through was nearly 100% in urban areas but 70% in rural areas.[43,44] Passing 100% of the tax increase to the consumers is more common among larger corporations that have the market power to increase prices without losing market share.

2.4. Revenue

Revenues raised from sugar taxes can be directed to support public health initiatives aimed at enhancing healthier behavioral profiles including improved dietary habits, and in so doing to reduce the burden of type-2 diabetes. Previous evidence has shown that the revenues raised from existing SSB's tax policies worldwide have increased from 0.001 to 0.16% relative to the gross domestic product.[45] Some governments have used sugar tax revenue to fund nutrition education campaigns and community-based programs that promote healthy eating habits and physical activity.[46,47] Additionally, revenue from sugar taxes may also be used to subsidize healthier food options in areas with limited availability.

In Mexico, it was recommended by experts to use the SSB tax revenue to construct water fountains in schools, in order to further promote healthier habits.[26] Despite this, additional implementation challenges were identified as fiscal revenues could not be earmarked despite the recommendation from Congress when the taxes were approved in 2014.[34]

3. Evidence of the expected impact of sugar taxes on type-2 diabetes

Evidence about the biological plausibility of the impact of sugar reduction on type-2 diabetes is extensive.[48,49] Reducing energy from added sugar, reduces the glycemic load in the diet, reduces weight,[48,49] and increases beta-cell function that helps to normalize hyperglycemia (**Fig. 2**).[50] Diverse studies have demonstrated the association between a higher glycemic load and an increased risk of weight gain and type-2 diabetes onset.[51–54] Also, weight loss enhances insulin sensitivity and improves beta-cell function, ultimately leading to better glucose homeostasis.[50,55–58] This is particularly relevant in the context of type-2 diabetes, where impaired beta-cell function and insulin resistance contribute to the development and progression of the disease.[59] By lowering the glycemic load and facilitating weight loss, sugar taxes offer a mechanism to address these underlying factors and reduce the risk of hyperglycemia and type-2 diabetes.

Despite the biological plausibility, to our knowledge, no study has estimated the observed impact of sugar taxes on type-2 diabetes. This could be because diabetes onset takes time and most imposed taxes have been implemented for less than 10 years. However, by reducing energy intake from sugary sources, taxes should contribute to modest but meaningful weight loss at the population level and, in turn, help lower the risk of developing type-2 diabetes and improve glycemic control. In the next subsections, we will describe the observed impact of sugar taxes on purchases and weight, and the simulated impact of sugar taxes on type-2 diabetes.

3.1. Observed impact of sugar taxes on energy intake

The impact of taxes on sugary beverages and foods on the reduced consumption of taxed products has been well established with observational studies. Recently, results from a meta-analysis evaluating the impact of SSB tax policies on purchases at the national- and state-level estimated reductions of 10% in purchases and dietary intake for a 10% tax.[60] A systematic review with data from six middle-income countries found slight decreases in energy intake from 5 to 39 kJ/person/day after a 10% increase in SSB prices.[61] In both studies increases in milk intake was observed as a substitute after a tax was implemented.[60,61] Estimating the effects of a tax from heterogeneous populations with diverse data sources is challenging, so these results are key to establish the impact of taxes on consumption changes in societies with different socioeconomic background, considering different price elasticities and the effect of substitution by other food or beverage sources.

In Mexico, observational studies have shown that the ~10% SSB tax and the 8% *ad valorem* tax on junk food lead to reductions in household purchases of these products, with larger effects among low-income households and high consumers. Up to three years after implementation, a decrease of 7.6% in SSBs purchases and of 6.0% in junk food purchases were observed.[17,62–64] In a longitudinal study in Mexican adults, three years after the tax implementation the probability of being a non-consumer of SSBs increased by 5 percentage points and of being a low consumer increased by 8 percentage points.[65] Evidence from national representative surveys in Mexico also found decreases in the intake of taxed products using 24-hour dietary recalls and Food Frequency Questionnaires of -

0.23% ml of SSBs and -3%kcal of taxed foods before and after the tax of these products was implemented.[66] Although some increases occurred in some unhealthy untaxed items, such as homemade SSBs, processed meats, and desserts, the total content of added sugars in beverages and foods consumed did decrease after the tax was implemented.[66]

3.2. Observed impact of sugar taxes on weight

Meta-analytic evidence about the effect of sugar taxes on body weight is scarce. A study considering US population described heterogenous results, using different units of analysis (households or individuals), heterogeneous populations, and tax types and magnitudes. Still, they described that a 1% price increase in sugary beverages could lead to a change in BMI of -0.003 and -0.015 kg/m2 among adults and children respectively, and a change of -0.065 kg/m2 for a 20% increase in prices at household level.[67] Additionally to these results, observational studies have shown that sugar taxes can help to reduce body weight and obesity. A retrospective cohort study of 11,861 individuals aged 14 to 32y-old conducted in the USA from 1992 to 2003, showed that a US$1 price increase in a 2-L SSB was linked to a decrease in the probability of having obesity by 28.1% among women, and by 10.8% among men.[68] Recent evidence from the UK shows an absolute reduction of obesity of 1.6 percentual points among girls aged 10 to 11 years 19 months after the implementation of the soft drink levy.[69] Similarly, in Mexico, using longitudinal individual-level yearly data (height and weight) from 2012 to 2017, two years after the implementation of the SSB tax, an absolute decrease in obesity prevalence of 1.3 percentual points was observed among adolescent girls (10-18 years), but no effect for boys.[70]

3.3. The potential impact of sugar taxes on type-2 diabetes

Simulation studies have estimated the potential impact of sugar taxes on type-2 diabetes. Worldwide it has been estimated that 132,500 type-2 diabetes deaths could be avoided by eliminating the consumption of sugary beverages.[71] The burden is unequal by country income level: most attributable deaths (76%) occur in low- and middle-income countries.[71] Worldwide**,** a 20% tax on sugary beverages was estimated to reduce obesity rates and save billions in healthcare costs.[72] The estimated cost-saving generated from an SSB tax was also found to be substantial, with estimates ranging from US$87 to US$167,799 million.[73] In Mexico, simulation studies have shown that the country has one of the highest burdens of type-2 diabetes attributable to sugary beverages (24,000 diabetes deaths).[71,74] The tax on sugary beverages was projected to prevent 239,900 cases of obesity and 61,340 cases of type-2 diabetes, over 10 years, generating savings of US$ 91.6 million in healthcare costs.[75]

4. The way forward

4.1. Galvanizing population-based approaches

Much of the public responses to specific health conditions, including type-2 diabetes, tend to focus on the identification of individuals at risk and focusing efforts to target these groups. Yet, type-2 diabetes

is a social disease with well-established social drivers and social determinants.[76] Interventions beyond the health sector, for example, improvements in housing or urban health-related policies, are closely linked with reductions in the burden of type-2 diabetes.[77,78] These society-wide experiences, in a similar fashion as SSB taxes, are in line with the call for attention on the upstream determinants of type-2 diabetes.

As chronic noncommunicable diseases (NCDs) have risen up the global agenda, population-wide interventions merit attention.[79] As proposed by Rose decades ago, tackling major risk factors can be done through the individual high-risk approach and population-based interventions.[80] Population-wide preventive strategies focus on intervening upon the determinants of health in large groups, with the aim of shifting the whole population's distribution of a given risk factor.[80–82] There are multiple examples in the field of non-communicable diseases where turning to population-wide efforts contribute to improvements on the disease burden of entire populations.[83–85] For example, reducing sodium intake and eliminating the intake of artificial trans fatty acids has been proposed to delay 94 million deaths worldwide within 25 years.[83] This concept of achieving population-wide benefits has been recently applied in Peru, where a pragmatic population-based approach using a salt substitution strategy has shown community-wide reductions in levels of blood pressure as well as reductions in the incidence of hypertension.[85]

Another key aspect of population-wide policies, closely related to their wide reach to entire populations, is the unique opportunity to strategically reach those groups when they can accrue the most benefits. In other words, we have to ask and understand the timing and sustained impact of these policies, when these policies exert the most impact in the life course of a given individual. Preventing the onset of type-2 diabetes in early adulthood is better than later in life due to the gains in healthy years of lives and the avoidance of complications, and it would be even better to avoid the onset of childhood and adolescent type-2 diabetes, considering the cumulative organ damage and complications over the years. In that regard, multi-faceted intersectoral efforts that seek to intervene appropriately over a long-time period are crucial to reducing NCDs. This is particularly vital in considering strategies that target young people for the primary prevention of cardiometabolic disease. Introducing healthier behaviors and protective factors during childhood and adolescence can significantly change an individual's health trajectory into adulthood.[86,87] Another potential effect of sugar taxes is their contribution to support disease-free life trajectories.

5. Conclusions

As with any other policy, sugar taxes are but one of multiple policy tools introduced in complex heterogeneous environments.[8] It follows that the evaluation of the impact of taxes on type-2 diabetes poses several challenges. First, we would not expect any significant change in type-2 diabetes in the short term. Second, taxes may be too low or insufficient to have a detectable impact. Third, the evaluation of sugar taxes on type-2 diabetes would require robust designs and large sample sizes. Despite the insufficient evidence with observational studies demonstrating the direct link between sugar tax and type-2 diabetes, the short-term impact of taxation should be recognized now.

Sugar taxes may be more effective to reduce type-2 diabetes if they are not implemented in isolation but as part of a comprehensive policy approach to redirect consumers away from non-nutritional and high-caloric food and beverages, and towards more healthful alternatives such as water or food without added sugar. Aspects such as public campaigns to increase awareness of the harmful effect of sugary food and beverages, the industry response, and finding a way to employ part of the revenue to support health promotion initiatives[88] and further transform the food environment, such as subsidizing fruit and vegetables or investing in a healthier school environment are thus essential.[88,89]

The rapid surge of type-2 diabetes throughout the world, a change that has occurred in a relatively short span in recent decades,[90,91] calls for multi-pronged approaches from health and non-health actors to drive healthier societies.[92] Population-wide approaches with wide and sustained reach, particularly those generated and promoted 'outside' the health sector, will be essential to complement existing clinical and healthcare-delivered interventions. Sugar taxes are, therefore, a suitable policy tool to consider in the arsenal of policies to counter type-2 diabetes worldwide.

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Human/Animal Studies informed consent statement.

This article does not contain any studies with human or animal subjects performed by any of the authors

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