The American Journal of Clinical Nutrition 119 (2024) 990–1006

The American Journal of CLINICAL NUTRITION

journal homepage: https://ajcn.nutrition.org/

Original Research Article

National taxation on sugar-sweetened beverages and its association with overweight, obesity, and diabetes

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A B S T R A C T

Background: Consumption of sugar-sweetened beverages (SSBs) has been linked to several adverse health outcomes, thus many countries introduced taxation to reduce it.

Objectives: To summarize national SSB taxation laws and to assess their association with obesity, overweight and diabetes.

Methods: We conducted a systematic scoping review up to January 2022 on PubMed, Web of Science, Embase, and Google Search to identify taxes on SSBs. An interrupted time series analysis (ITSA) was conducted on 17 countries with taxation implemented in 2013 or before to evaluate the level and slope modifications in the rate of change of standardized prevalence rates of overweight, obesity, and diabetes. Random-effects meta-regression was used to assess whether year of entry into force of the law, national income, and tax design affected observed results.

Results: We included 76 tax laws issued between 1940 and 2020 by 43 countries, which were heterogeneous in terms of tax design, amount, and taxed products. Among children and adolescents, ITSA showed level or slope reduction for prevalence of overweight and obesity in 5 (Brazil, Samoa, Palau, Panama, Tonga) and 6 (El Salvador, Uruguay, Nauru, Norway, Palau, Tonga) countries out of 17, respectively. No clear pattern of modification of results according to investigated factors emerged from the meta-regression analysis.

Conclusions: Taxation is highly heterogeneous across countries in terms of products and design, which might influence its effectiveness. Our findings provide some evidence regarding a deceleration of the increasing prevalence rates of overweight and obesity among children occurring in some countries following introduction of taxation.

PROSPERO registration number: CRD42021233309.

Keywords: health policy, sugar-sweetened beverages, taxation, diabetes, obesity, time series analysis

Introduction

Sugar-sweetened beverages (SSBs), also known as soft drinks, include carbonated and noncarbonated beverages that contain sugar-based caloric sweeteners, such as sucrose, high-fructose corn syrup, or fruit juice concentrates [1, 2].

In recent decades, the intake of SSBs has increased around the world [3–5], possibly increasing their overall burden on population's health. Indeed, the consumption of SSBs has been linked to weight gain and risk of obesity, type 2 diabetes, and heart disease [6–8]. In addition, previous research showed that long-term consumption of SSBs is associated with increased mortality, mainly due to cardiovascular disease [9]. For this reason, according to estimates from the Global Burden of Disease study, the number of deaths due to consumption of SSBs worldwide increased from 2.8 to 3.13 per 100,000 between 1990 and 2019, whereas the number of disability adjusted life years moved from 69.13 to 81.52 per 100,000, and the number of years lived with disability rose from 8.79 to 18.23 per 100,000 [10,11].

In 2009, the American Heart Association released a statement suggesting a decrease of added sugar intake to no >100 calories per day for females and 150 calories per day for males [12]. Similarly, the World Health Organization (WHO) recommends that adults and children reduce their daily intake of free sugars to <10% of their total energy intake, since free sugars, especially in the form of SSBs,

Abbreviations: ITSA, interrupted time series analysis; PPP, purchasing power parities; SSB, sugar-sweetened beverage.

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https://doi.org/10.1016/j.ajcnut.2023.12.013
Received 29 June 2023; Received in revised form 7 December 2023; Accepted 14 December 2023; Available online 26 February 2024

increase the overall energy intake and may reduce the intake of foods containing more nutritionally adequate calories, leading to an unhealthy diet, weight gain, and increased risk of noncommunicable diseases [13].

A major action for comprehensive programs aimed at reducing consumption of sugars is taxation of SSBs [14]. Although it is often introduced as a tool to generate revenue, hence not necessarily related to health [15], taxation of SSBs is an effective intervention to reduce sugar consumption, according to the WHO. Indeed, evidence shows that a 20% increase of the price can lead to a reduction of SSBs consumption of ~20%, thus potentially reducing the burden of obesity and type 2 diabetes [14]. To our knowledge, however, no previous study systematically summarized existing national policies on taxation addressing SSBs globally, as recently published reports are limited to specific regions [16, 17] or are limited to the inclusion of reports analyzing price elasticity [18, 19], thus missing information for countries where such type of studies have not been conducted. In addition, although most previous studies focused on the effect of tax implementation on purchases and SSB consumption [19–21], evidence regarding its effectiveness on population's health at the national level is lacking, with previous studies focusing on restricted study populations and limited time frames [18, 22–25], or being simulation modeling studies [24–26]. Furthermore, most previous studies focused on adults [18, 22–25], whereas just a few were conducted among children or adolescents [27–30]. However, the assessment of the impact of taxation specifically among the youth could provide useful information for policymakers regarding its effect in a context of early disease prevention.

For these reasons, the aims of our study were (1) to systematically summarize national tax legislation on SSBs worldwide and (2) to assess the association of recent taxation laws (issued after 1990) with specific indicators of population's metabolic health where possible, including national prevalence of overweight, obesity, and type 2 diabetes.

Methods

Scoping review to summarize national tax legislation on SSBs

We conducted a systematic scoping review in compliance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews [31] to summarize the landscape of national tax laws on SSBs implemented so far worldwide.

The protocol of our scoping review has been registered in the International Prospective Register of Systematic Reviews, registration number CRD42021233309.

Search strategy and eligibility criteria.

We included in the scoping review any document reporting both currently into force and past national tax laws addressing SSBs in any world country. Otherwise, when it was not possible to retrieve the text of the law, we included in our review the most salient document mentioning it and providing the details of interest, as outlined in the data extraction section of Methods.

We limited our search to policies implemented only at the national level worldwide. Thus, any local, regional, or state-level regulations (hence including those in the United States) were excluded.

The search strategy of our scoping review was formulated according to the following Population, Intervention, Comparison and Outcome model structure [32]

- P (population): worldwide countries
- I (intervention): not applicable
- C (comparator): not applicable
- O (outcome): implemented laws on taxation targeting SSBs.

In particular, 3 researchers (CC, LV, MS) carried out the search independently on PubMed, Web of Science, and Embase databases to identify relevant documents. No limits according to language, publication type, and year of publication were applied. The complete search strategy used on PubMed is reported in Supplemental Material. Due to the lack of a comprehensive legislative dataset at the worldwide level and the difficulty of retrieving the original text of several policies, such scientific search engines were used to identify any record mentioning national laws.

Subsequently, 3 researchers (CC, LV, MS) independently searched for relevant gray literature documents on Google Search engine using an adapted search string (Supplemental Material). The search terms of the string were also translated to Italian, Spanish, Portuguese, and French in order to retrieve additional documents published in languages other than English. Moreover, websites of relevant institutions, such as WHO, World Bank, and national governments and Ministries were screened to identify further documents.

The search for both scientific literature and gray literature documents was first carried out in May 2021. However, we later updated the search to identify additional documents published between May 2021 and January 2022.

Study selection process, data extraction.

As for scientific literature, after removal of duplicates, 3 researchers (CC, LV, MS) independently screened retrieved articles by title and abstract. Full texts of pertinent articles were then independently assessed for inclusion by 3 researchers (CC, LV, MS). In addition, hand search of reference lists of included articles was carried out.

Similarly, 3 researchers (CC, LV, MS) independently screened documents retrieved with the gray literature search by title, headings, summary, and abstract. An Excel spreadsheet was created with a list of potentially relevant documents from the screening phase, whose full texts or web pages were independently assessed for inclusion against our eligibility criteria by 3 researchers (CC, LV, MS). Lastly, we manually searched reference lists of included documents, if applicable.

For each document included in our scoping review, 2 researchers (CC, LV) independently extracted the following information, if applicable and available: first author, year of publication, country, type of taxation (amount-specific or ad valorem), and main characteristics of the tax law (tax amount and specific products to which it applies).

Synthesis of the results.

We summarized the results of the scoping review by performing a qualitative synthesis, focusing on differences and similarities between identified laws, such as amount of taxation, year of entry into force of the law. In addition, retrieved excise taxes were categorized according to the following types of taxation:

1. amount-specific, either based on the sugar content or on the volume of the product,
2. ad valorem, based on the value of the product and calculated as a percentage of the wholesale or retail price (e.g., 10% of producer's price) [33, 34].

Furthermore, for amount-specific taxes, we converted the amount of tax applied to SSBs from local currency to purchasing power parities (PPPs) and to US$ according to conversion and exchange rates relative

to the year of entry into force of the law and to those relative to 2020 for laws still into force (or to the closest available years if the value for the year of interest was not retrieved) as reported by the World Bank [35] in order to perform comparisons by both taking into account and ignoring the country-specific purchase power. After the conversion, we summarized findings on PPP$ and US$ values of identified amount-specific taxes based on the volume of the product using descriptive statistical measures, such as median, range, and IQR, considering median tax values for countries with tax amounts per liter varying according to the sugar content of the product or to different product types, and excluding taxes that applied to concentrated syrups or similar products. Eventually, we categorized countries having implemented SSBs taxation according to the national income, as reported by the World Bank [36]. Similarly, we summarized findings on ad valorem taxes using the same procedure described above for amount-specific taxes, overall and by national income groups.

Time series analysis for the assessment of the association of SSBs taxation implemented up to 2013 with population's health outcomes

Data sources.

Data regarding the national prevalence of obesity, overweight, and type 2 diabetes were retrieved from WHO Global Health Observatory data repository [37], where worldwide estimates for these indicators from a previously published pooled analysis of population-based studies are publicly available [38, 39]. In particular, these data derive from a global initiative aimed at providing a complete picture of trends over time of population's cardiometabolic health. Data from population-based studies and surveys (2416 studies for overweight and obesity, and 751 for diabetes) on cardiometabolic risk factors were collated by the Non-communicable Disease Risk Factor Collaboration and were thus analyzed to compute prevalence of indicators of interest using a Bayesian hierarchical model, whose resulting estimates for each country and year were informed by available data and by data from other years in the same country, as well as by data from other countries, especially those in the same region with data for similar time periods [38, 39].

We used the following indicators (rates per 1000 individuals) for the years 1990–2016:

1. Prevalence of overweight among adults (>18 y), defined as body mass index (BMI) ≥ 25 (age-standardized estimate);
2. Prevalence of overweight among children and adolescents (5–19 y), defined as BMI > +1 standard deviations above the median (crude estimate);
3. Prevalence of obesity among adults (>18 y), defined as BMI ≥ 30 (age-standardized estimate);
4. Prevalence of obesity among children and adolescents (5–19 y), defined as BMI > +2 standard deviations above the median (crude estimate).

In addition, we included in the analysis data on the following indicator for the years 1990–2014:

5. Prevalence of type 2 diabetes per 1000 individuals, defined as fasting glucose ≥ 126 mg/dL (7.0 mmol/L) or history of diagnosis with diabetes or use of antidiabetic medication, among adults (>18 y) (age-standardized estimate).

Statistical analysis.

In our analyses, the year of entry into force of the tax law was considered the intervention point. For each indicator, we included in the analysis only countries and laws with data availability for ≥3 y before and after the intervention in the years 1990–2016 (1990–2014 for the prevalence of type 2 diabetes) [40]. Thus, we included in the analysis only interventions issued in the period 1993–2013 (1993–2011 for type 2 diabetes). For countries that issued more than one law and with < 3 y interval between them, we considered only the first one as an intervention point.

In particular, we carried out a time series analysis to assess if any statistically significant change in the trends of chosen indicators occurred after the intervention, with P values < 0.05 considered statistically significant. Time series analysis has been applied in the evaluation of the real-world effects of policies, since in this context randomization is typically not feasible. Unlike pre-post studies, time series studies allow for the use of the pre-existing trend as a control, hence evaluating the potential change of the trend of a specific indicator after the introduction of an intervention (e.g., a law) using the pre-intervention trend as a comparator.

Unless otherwise specified in the results section, we applied first differencing to all indicators in order to achieve stationarity, with this prerequisite confirmed by Dickey–Fuller test. By doing so, instead of analyzing the values of the indicators (prevalence rates) over time, we evaluated the rate of change of the same indicators over the years. Data were analyzed using ordinary least square regression with standard errors computed using Newey–West method in order to take into account potential autocorrelation, and the number of lags for each country and for each indicator was chosen based on the results of Cumby–Huizinga general test for autocorrelation. ordinary least square regression was adopted for the analyses because the dependent variables in our models were represented by age-adjusted prevalence rates, since these are publicly available from the data source reported above, instead of counts (e.g., number of individuals with the condition under investigation). In particular, the regression equation was as follows: $Y = \beta_0 + \beta_1 T + \beta_2 X + \beta_3 XT$, where Y is the outcome, β_0 is the intercept, T the years since the start of the study (1990), and X a dummy variable coded as 0 before the intervention and 1 after the intervention. Thus, the coefficient β_2 represents the level change occurring at the intervention (i.e., a shift of the time series toward lower or higher values), whereas β_3 is the slope change occurring over time after the intervention (i.e., difference between slopes of the outcome before and after the intervention). Hence, we analyzed whether taxation interventions were associated with level or slope changes in the rate of change of prevalence of indicators of interest. Additionally, we evaluated any modifications occurring in the actual linear trend of the rate of change of prevalence after the intervention ($\beta_1+\beta_3$), compared with the pre-intervention trend. In particular, even a nonsignificant coefficient for the post-intervention trend (H_0: $\beta_1+\beta_3 \neq 0$) was considered as a deceleration if preceded by an accelerating pre-intervention trend, represented by a significant positive coefficient in the period before the intervention.

Eventually, we adopted a random-effects meta-regression approach, using restricted maximum likelihood method, to investigate whether the year of entry into force of the law, the national income at the year of entry into force of the law, and the tax design are associated with level or slope changes for each indicator and age group included in the analyses. In particular, these factors were included as independent variables in the meta-regression model, whereas coefficients resulting from the time series analysis described above were the dependent variable.

The statistical analyses were performed using Stata software, version 17 (StataCorp LP. College Station. TX).

Results

Scoping review

The database search, after duplicates removal, led to the retrieval of a total of 3913 records. In addition, 1301 records were identified through the gray literature search. Overall, the selection process resulted in the inclusion of 57 reports pertaining to 76 unique tax laws (Figure 1, Supplemental Table 1).

Fifty-three countries worldwide implemented SSBs taxation, of which 24 (45.3%), 18 (34.0%), and 10 (18.9%) are high-income, upper middle-income, and lower middle-income countries, respectively, and Rwanda was the only (1.9%) low-income country (Table 1). Eight laws (Finland in 1940, Chile in 1979 and in 1985, Norway in 1981, Samoa in 1984, Paraguay in 1991, Panama in 1995, and Uruguay in 1996) were introduced before 2000. Twelve laws (El Salvador, Honduras, Paraguay, Uruguay, Guatemala, Latvia, Nauru, Norway in 2008 and 2010, Samoa, Palau, and Fiji) were implemented between 2000 and 2010, whereas the remaining 56 tax laws entered into force between 2011 and 2020 (Table 1). Fifteen countries introduced more than one law over time, modifying tax amounts (Table 1). Eventually, the French tax law on SSBs also applies in Monaco (Table 1).

The range of products to which identified taxes are applied varies across countries and laws, mainly based on their sugar content; more details are reported in Table 1. Amount-specific tax was the most commonly used taxation design among taxes using a single design and was adopted in 42 cases, of which the majority (88.1%, $n = 37$) were based on the volume of the product only, whereas a minority of them (11.9%, $n = 5$) were exclusively based on the sugar content of the product (Table 1). Instead, 27 tax laws exclusively used an ad valorem tax design (Table 1). In two cases (Finland 1940 and Norway 1981) the tax design was not reported. Whereas, in France, Dominica, Ecuador, El Salvador, and Thailand the same law provided for 2 different tax designs (respectively: amount-specific volumetric and amount-specific sugar based; amount-specific volumetric and ad valorem; amount-specific sugar based and ad valorem; amount-specific volumetric and ad valorem; amount-specific volumetric and ad valorem).

As for countries with amount-specific taxes based on the volume of the product (Supplemental Table 2), Vanuatu (PPP$: 0.005) and Thailand (US$: 0.003) imposed the lowest taxes in terms of PPP$ and US$ per liter of product, respectively, at the year of entry into force of the law, whereas the highest taxation was found to be applied by Tonga (PPP$: 2.667) and Norway (US$: 2.448). Similar results were found also for currently into force laws by using 2020 conversion rates (Supplemental Table 2).

The median tax amounts per liter of product were PPP$: 0.275 (IQR: 0.295; range: 0.005–1.834) and US$: 0.161 (IQR: 0.225; range: 0.005–1.250) for all (past and currently into force) volumetric amount-specific taxes at the year of their entry into force, and PPP$: 0.250 (IQR: 0.303; range: 0.005–1.719) and US$: 0.137 (IQR: 0.216; range: 0.004–1.196) for currently into force taxes using 2020 conversion rates. In addition, such median tax values for currently into force taxes (2020 conversion rates) stratified by income group were PPP$: 0.253 (IQR: 0.190; range: 0.047–0.923) and US$ 0.203 (IQR: 0.198; range: 0.023–0.626) for high-income countries, PPP$: 0.118 (IQR: 0.308; range: 0.045–1.719) and US$: 0.074 (IQR: 0.062, range: 0.023–1.196) for upper middle-income countries, and PPP$: 0.356 (IQR: 0.447; range: 0.005–1.068) and US$: 0.165 (IQR: 0.176; range: 0.004–0.402) for lower middle-income countries.

Regarding taxes based on the sugar content of the product, Cook Islands, Ecuador, Mauritius, South Africa, and Sri Lanka imposed a tax based on the amount per gram of sugar for all SSBs, whereas France implemented a tax amount per kilogram of sugar on top of the

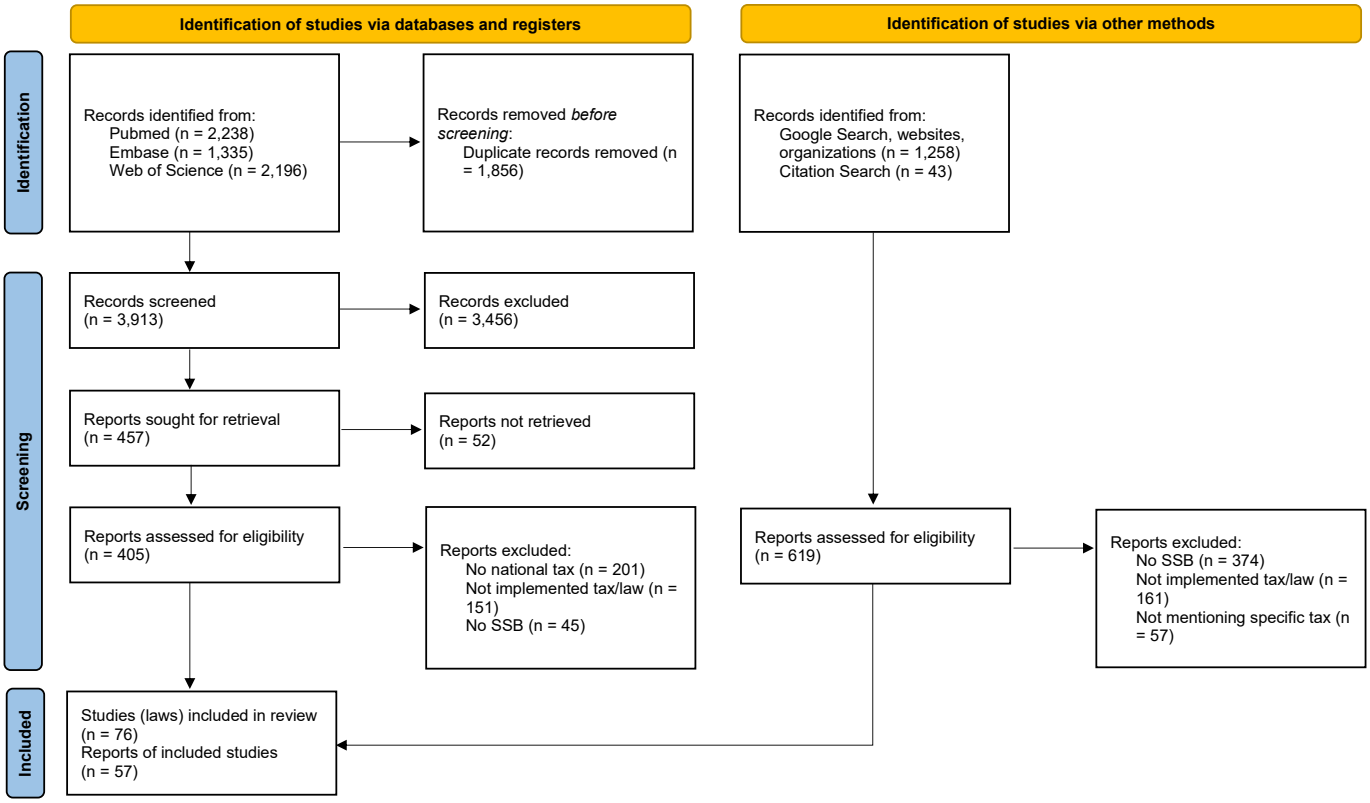

FIGURE 1. Flowchart of the report selection process.

TABLE 1
Characteristics of identified taxes that apply to sugar-sweetened beverages (SSBs)

WHO Region	Country	Current income level	Year of entry into force	Amount/percentage of the price	Products	Tax design
African Region	Mauritius	Upper middle	2016	0.03 Mauritian Rupees/g of sugar	All SSBs (juices, milk-based beverages and soft drinks), whether imported or locally produced.	Amount-specific, based on sugar content in grams
	Rwanda	Low	2015	5%	Fruit juices	Ad valorem
				39%	Lemonade, soda and other juices	
	Seychelles	High	2019	4 Seychellois Rupees/L	SSBs with sugar content > 5 g per 100 mL	Amount-specific, volumetric
	South Africa	Upper middle	2018	0.021 Rands/g of sugar	Sweetened beverages with sugar content > 4 g per 100 mL	Amount-specific, based on sugar content in grams
Eastern Mediterranean Region	Bahrain	High	2017	50%	Carbonated drinks	Ad valorem
				100%	Energy drinks	
	Oman	High	2019	50%	SSBs, energy drinks, carbonated drinks	Ad valorem
	Qatar	High	2019	50%	Carbonated drinks	Ad valorem
				100%	Energy drinks	
	Saudi Arabia	High	2017	50%	Carbonated drinks	Ad valorem
				100%	Energy drinks	
	United Arab Emirates	High	2017	50%	Carbonated drinks	Ad valorem
				100%	Energy drinks	
European Region	Belgium	High	2016	0.068 Euros/L	All soft drinks, including non-alcoholic drinks and water containing added sugar or other sweeteners or flavors.	Amount-specific, volumetric
	Estonia	High	2018	0.10 Euros/L	Only artificially sweetened drinks or products with 5–8 g sugar per 100 mL	Amount-specific, volumetric
				0.20 Euros/L	Products containing artificial sweeteners and a sugar content of 5–8 g per 100 mL	
				0.30 Euros/L	Products with sugar content of >8 g per 100 mL and on products with artificial sweeteners, sugar and sugar content of >8 g per 100 mL	
	Finland	High	1940	NR	NR	NR
			2011	0.11 Euros/L	Non-alcoholic sweetened beverages	Amount-specific, volumetric
				0.22 Euros/L	SSBs containing > 0.5% sugar	
	France	High	2012	0.0716 Euros/L	All SSBs, including sugar substitutes used in diet drinks.	Amount-specific, volumetric
			2018	3.11 Euros/100 L	SSBs with ≤ 1 Kg per 100 L	Amount-specific, volumetric
				3.63 Euros/100 L	SSBs with 1–2 Kg per 100 L	
				4.14 Euros/100 L	SSBs with 2–3 Kg per 100 L	
				4.66 Euros/100 L	SSBs with 3–4 Kg per 100 L	
				5.70 Euros/100 L	SSBs with 4–5 Kg per 100 L	
				6.74 Euros/100 L	SSBs with 5–6 Kg per 100 L	
				7.77 Euros/100 L	SSBs with 6–7 Kg per 100 L	
				9.84 Euros/100 L	SSBs with 7–8 Kg per 100 L	
				11.92 Euros/100 L	SSBs with 8–9 Kg per 100 L	
				13.98 Euros/100 L	SSBs with 9–10 Kg per 100 L	
				16.05 Euros/100 L	SSBs with 10–11 Kg per 100 L	
				18.12 Euros/100 L	SSBs with 11–12 Kg per 100 L	
				20.20 Euros/100 L	SSBs with 12–13 Kg per 100 L	
				22.27 Euros/100 L	SSBs with 13–14 Kg per 100 L	
				24.34 Euros/100 L	SSBs with 14–15 Kg per 100 L	
				+2.07 Euros/ Kg of added sugar (in addition to the value in the previous band)	SSBs with > 15 Kg per 100 L	Amount-specific, based on sugar content in grams
	Hungary	High	2011	7 Forints/L	Soft drinks	Amount-specific, volumetric
				200 Forints/L	Concentrated syrups used to sweeten drinks	
	Ireland	High	2018	0.20 Euros/L	SSBs between 5–8 g of sugar per 100 mL	Amount-specific, volumetric
				0.30 Euros/L	SSBs > 8 g of sugar per 100 mL	
	Latvia	High	2004	4 lats /100 L	Non-alcoholic beverages (water and mineral water with added sugar, other sweetener or	Amount-specific, volumetric
			2016	0.074 Euros/L	flavoring, and other non-alcoholic beverages) Drinks exempt from the tax: fruit and vegetable juice and nectar, beverages containing >90% juice (except fruit juices made of concentrate) and <10% of added sugar and which do not	Amount-specific, volumetric

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TABLE 1 (*continued*)

WHO Region	Country	Current income level	Year of entry into force	Amount/percentage of the price	Products	Tax design
					contain food additives and flavorings, natural water and mineral water, water enriched with minerals and vitamins, and without added sugar, other sweetener or flavoring	
	Monaco (French law applies)	High	2012	0.0716 Euros/L	All SSBs, including sugar substitutes used in diet drinks	Amount-specific, volumetric
	Norway	High	1981	NR	NR	NR
			2008	1.68 Norwegian kroner/L	Non-alcoholic beverages containing added sugar or artificial sweeteners	Amount-specific, volumetric
			2010	2.76 Norwegian kroner/L	Non-alcoholic beverages containing added sugar or artificial sweeteners	Amount-specific, volumetric
			2016	3.27 Norwegian kroner/L	Non-alcoholic beverages containing added sugar or artificial sweeteners	Amount-specific, volumetric
			2017	3.34 Norwegian kroner/L	SSBs	Amount-specific, volumetric
				20.32 Norwegian kroner/L	Concentrated syrups	
	Portugal	High	2017	0.082 Euros/L	Drinks with sugar content < 80 g/L	Amount-specific, volumetric
				0.164 Euros/L	Drinks with sugar content > 80 g/L	
	United Kingdom	High	2018	0.18 Pounds/L	Drinks with sugar content ranging 5–8 g per 100 mL	Amount-specific, volumetric
				0.24 Pounds/L	Drinks with sugar content > 8 g per 100 mL	
Region of the Americas	Argentina	Upper middle	2016	8%	SSBs	Ad valorem
				4%	Non-alcoholic beverages with a minimum of 10% of juice or fruit juices	
	Barbados	High	2015	10%	Locally produced carbonated soft drinks, juice drinks, sports drinks and others. Drinks exempt from the tax: 100% natural fruit juice, coconut water, plain milk and evaporated milk	Ad valorem
	Bolivia	Lower middle	2016	0.43 Bolivianos/L	Water, including mineral water and carbonated water, containing added sugar or other sweetening matter or flavored, and other non-alcoholic beverages.	Amount-specific, volumetric
				4.84 Bolivianos/L	Energy drinks, including carbonated	
			2018	0.45 Bolivianos/L	Water, including mineral water and carbonated water, containing added sugar or other sweetening matter or flavored, and other non-alcoholic beverages.	Amount-specific, volumetric
				5.10 Bolivianos/L	Energy drinks, including carbonated	
	Brazil	Upper middle	2013	27%	SSBs	Ad valorem
			2017	4%	SSBs	Ad valorem
			2018	4%	SSBs	Ad valorem
	Chile	High	1979	15%	All SSBs containing > 6.25 g of sugar/100 mL.	Ad valorem
			1985	13%	All SSBs containing > 6.25 g of sugar/100 mL.	Ad valorem
			2014	10%	All SSBs containing < 6.25 g of sugar/100 mL.	Ad valorem
				18%	All SSBs containing > 6.25 g of sugar/100 mL.	
	Colombia	Upper middle	2019	19%	All SSBs	Ad valorem
	Costa Rica	Upper middle	2018	19.15 Costa Rican colón/L	Soft drinks and soft drink concentrates	Amount-specific, volumetric
	Dominica	Upper middle	2015	0.20 East Caribbean dollars/L	Soft drinks	Amount-specific, volumetric
				10%	Energy drinks	Ad valorem
	Ecuador	Upper middle	2016	10%	Soft drinks with <25 g of sugar/L and on all energy drinks, regardless of sugar content	Ad valorem
				0.0018 US dollars/g	Beverages with >25 g sugar/L, per gram of sugar	Amount-specific, based on sugar content in grams
	El Salvador	Lower middle	2009	5%	Isotonic or sports drinks, fortifiers, juices, nectars	Ad valorem
				10%	Carbonated or soft beverages (including sugar-sweetened ones)	
				US $0.20/L	Energy or stimulant beverages only	Amount-specific, volumetric
	Guatemala	Upper middle	2002	0.18 Quetzal/L	SSBs	Amount-specific, volumetric

(*continued on next page*)

TABLE 1 (*continued*)

WHO Region	Country	Current income level	Year of entry into force	Amount/percentage of the price	Products	Tax design
	Honduras	Lower middle	2010	0.5800 Lempiras/L	SSBs	Amount-specific, volumetric
	Mexico	Upper middle	2014	1 Mexican Peso/L	All drinks with added sugar. Excluded: milks and yogurts.	Amount-specific, volumetric
	Nicaragua	Lower middle	2020	15%	SSBs, energy drinks, juices, soft drinks, carbonated drinks	Ad valorem
	Panama	Upper middle	1995	5%	Carbonated drinks	Ad valorem
			2019	7%	Carbonated drinks	Ad valorem
				5%	All other SSBs	
	Paraguay	Upper middle	1991	8%	Mineral water and non-alcoholic soft drinks, fruit juice with a maximum of 2% alcohol, and in general unspecified beverages with a maximum of 2% alcohol.	Ad valorem
			2004	5%	Sugar-sweetened non-alcoholic soft drinks, non-alcoholic fruit juice or with a maximum of 2% alcohol, and in general unspecified beverages without alcohol or with a maximum of 2% of alcohol	Ad valorem
	Peru	Upper middle	2018	25%	Drinks with sugar content > 6 g per 100 mL	Ad valorem
			2019	12%	Drinks with sugar content < 0.5 g per 100 mL	Ad valorem
	Uruguay	High	1996	22%	Non-alcoholic beverages made with ≥10% of Uruguayan fruit juice, which shall be reduced to 5% (five percent) in the case of lemon; mineral waters and sodas	Ad valorem
				30%	Other non-alcoholic beverages	
			2001	10% in the year 2001	Refined sugar in containers and/or packages of up to 10 kg	Ad valorem
				8% in the year 2002	Refined sugar in containers and/or packages of up to 10 kg	
				6% in the year 2003	Refined sugar in containers and/or packages of up to 10 kg	
				4% in the year 2004	Refined sugar in containers and/or packages of up to 10 kg	
			2019	26.30 Uruguayan Pesos/L	Freshly squeezed fruit juices, restored juices from juice concentrates, and nectars with a minimum content of 50% fruit juice. Fruit juice base with carbonation below 5.5 g/L (disposable container) and 4.3 g/L(returnable container)	Amount-specific, volumetric
South-East Asia Region	India	Lower middle	2017	40%	SSBs (28 percent GST on all goods containing added sugar or SSBs, with an additional 12% added to SSBs (for a total of 40 percent on SSBs)	Ad valorem
	Sri Lanka	Lower middle	2017	0.50 Sri Lankan rupees/g of sugar	Carbonated soft drinks and fruit juices	Amount-specific, based on sugar content in grams
			2018	0.30 Sri Lankan rupees/g of sugar	Carbonated soft drinks and fruit juices	Amount-specific, based on sugar content in grams
	Thailand	Upper middle	2017 (tax increases every 2 years)	14%	Artificial mineral water, soda water, and carbonated soft drinks without sugar or other sweeteners and without flavor; mineral water and carbonated soft drinks with added sugar or other sweeteners of flavors	Ad valorem
				10%	Fruit and vegetable juices	
				2017–2019: 0.10 Baht/L 2019–2021: 0.10 Baht/L	SSBs with sugar content 6–8 g per 100 mL	Amount-specific, volumetric
				2017–2019: 0.30 Baht/L 2019–2021: 0.30 Baht/L	SSBs with sugar content 8–10 g per 100 mL	
				2017–2019: 0.50 Baht/L 2019–2021: 1 Baht/L	SSBs with sugar content 10–14 g per 100 mL	
				2017–2019: 1 Baht/L 2019–2021: 3 Baht/L	SSBs with sugar content 14–18 g per 100 mL	
				2017–2019: 1 Baht/L 2019–2021: 5 Baht/L	SSBs with sugar content >18 g per 100 mL	

(*continued on next page*)

TABLE 1 (*continued*)

WHO Region	Country	Current income level	Year of entry into force	Amount/percentage of the price	Products	Tax design
Western Pacific Region	Cook Islands	High	2014	0.0098 New Zealand dollars/g of sugar	All beverages containing added sugars	Amount-specific, based on sugar content in grams
	Belize	Upper middle	2016	0.76 Belize Dollars/ Imperial Gallon	Waters, including mineral waters and aerated waters, containing added sugar or other sweetening matter or flavored and other non-alcoholic beverages	Amount-specific, volumetric
	Brunei	High	2017	0.40 Brunei Dollars	SSBs with > 6 g of total sugar per 100 mL, soya milk drinks with > 7 g of total sugar per 100 mL, malted or chocolate drinks with > 8 g of total sugar per 100 mL and coffee-based drinks or coffee flavored drinks with 6 g of total sugar per 100 mL. Drinks exempt from the tax: milk-based beverages and fruit juices	Amount-specific, volumetric
	Fiji	Upper middle	2006	0.10 Fijian Dollars /L	All locally produced SSBs + 5% import excise duty	Amount-specific, volumetric
			2011	0.30 Fijian Dollars/L	All locally produced SSBs + 5% import excise duty.	Amount-specific, volumetric
			2017	0.35 Fijian Dollars/L	All locally produced SSBs + 15% import duty on sweetened drinks. + 10% import duty on concentrates	Amount-specific, volumetric
	Kiribati	Lower middle	2014	40%	Drinks containing added sugar and fruit concentrates, 100% fruit juices exempt	Ad valorem
	Malaysia	Upper middle	2019	0.40 Malaysian Ringgit/L	Carbonated drinks containing added sugar or flavored and other sweetening matter which contains sugars > 5 g per 100 ml, and for fruit juices and vegetable juices which contains sugar > 12 g per 100 mL	Amount-specific, volumetric
	Nauru	High	2007	30%	Only imported sugar, confectionery, carbonated soft drinks, cordials, flavored milks and drink mixes	Ad valorem
	Palau	High	2003	0.28 USD/L	Only imported carbonated soft drinks	Amount-specific, volumetric
	Philippines	Lower middle	2018	6 Philippine Pesos/L	Products with purely caloric and purely non-caloric sweeteners or a mix of both	Amount-specific, volumetric
				12 Philippine Pesos/L	Products with purely high-fructose corn syrup or in combination with any caloric or non-caloric sweetener	
	Samoa	Lower middle	1984	0.3 Samoan Tālās/L	SSBs	Amount-specific, volumetric
			2008	0.4 Samoan Tālās/L	SSBs	Amount-specific, volumetric
	Tonga	Upper middle	2013	0.50 Tongan Pa'anga /L	Sugar- sweetened beverages	Amount-specific, volumetric
			2016	1 Tongan Pa'anga /L	Sugar- sweetened beverages	Amount-specific, volumetric
			2017	1.5 Tongan Pa'anga /L	SSBs and fruit juice with sugar content 5–20 g per 100 mL	Amount-specific, volumetric
				4 Tongan Pa'anga /L	SSBs and fruit juice with sugar content > 20 g per 100 mL	
	Vanuatu	Lower middle	2015	50 Vatu/L	SSBs	Amount-specific, volumetric

SSB, sugar-sweetened beverage.

volumetric one only for products containing >15 Kg of sugar per 100 liters (Table 1).

Eventually, identified ad valorem taxes ranged between 5% and 100% of the value of the products of interest (Table 1), whereas the median value of those currently into force was 18.5% (IQR: 40%). Additionally, median tax amounts were 50% (IQR: 70%; range: 10%–100%) for high-income countries, 10% (IQR: 7%; range: 5%–25%) for upper middle-income countries, and 28% (IQR: 29%; range: 7.5%–40%) for lower middle-income countries. The only low-income country with an ad valorem tax was Rwanda.

Time series analysis of SSB taxation implemented up to 2013

On the basis of data availability after the entry into force of the law, Brazil, El Salvador, Honduras, Paraguay, Uruguay, Hungary, France, Fiji, Samoa, Nauru, Guatemala, Latvia, Norway, Palau, Panama,

Tonga, and Finland were included in the time series analysis for each indicator, with the exception of the prevalence of type 2 diabetes in Brazil, France, and Tonga (missing data for ≥3 y after the intervention).

Prevalence of overweight, obesity, and type 2 diabetes among adults.

Overall, overweight, obesity, and type 2 diabetes prevalence rates among adults showed increasing trends over time in the countries included in the data analyses (Supplemental Figure 1).

As for overweight, the only country showing a significant slope decrease after the taxation intervention was Hungary [β = −0.227; 95% confidence interval (CI): −0.344, −0.110]. However, Paraguay also showed a decelerating post-intervention trend (Table 2).

Regarding obesity, Brazil, Hungary, and Panama had a slope reduction after the intervention, although a significant level reduction at the intervention was found for Panama and Paraguay (Table 3). El Salvador, Honduras, and France also showed a deceleration of the rates of change after the intervention, in addition to countries with significant slope decreases (Table 3).

Lastly, Hungary exhibited a level decrease of diabetes prevalence at the intervention point (β = −0.537; 95% CI: −1.030, −0.043), whereas for Finland and Guatemala, a significant slope reduction after the entry into force of taxation was observed. In addition to these two latter countries, decelerating rates of change in the post-intervention period were also found for Honduras, Hungary, and Fiji (Table 4).

Prevalence of overweight and obesity among children and adolescents.

Similarly to findings pertaining to adults, data regarding overweight and obesity prevalence among children and adolescents showed overall increasing trends over the years (Supplemental Figure 1).

Concerning overweight, Samoa (β = −1.589; 95% CI: −2.546, −0.631) was the only country with a level decrease associated with the intervention, and significant slope reductions were observed for Brazil, Samoa, Palau, Panama, and Tonga (Table 2). Although for Palau, the post-intervention trend was still similar to the pre-intervention one, decelerating trends after the intervention were found for all other countries showing significant negative slope changes and, additionally, for Honduras and Nauru (Table 2).

Analysis of data on obesity showed a level decrease at the intervention for 4 countries, namely El Salvador (β = −0.871; 95% CI: −1.525, −0.217), Uruguay (second intervention in 2001, β = −1.062; 95% CI: −1.850, −0.273), Norway (β = −0.432; 95% CI: −0.814, −0.051), and Tonga (β = −1.299; 95% CI: −2.284, −0.313). Instead, significant slope reductions associated with the intervention were found for Nauru, Palau, and Tonga. In addition to these 3 countries, decelerations in the post-intervention trends were observed for Brazil, Uruguay (first intervention in 1996), Fiji (first intervention in 2006), and Hungary (Table 3).

Factors associated with level and slope changes

Meta-regression results about the factors associated with changes after the intervention are reported in Table 5. In particular, the year of entry into force was positively associated with the slope change from the time series analysis for obesity among adults, while the tax design showed a significant association for type 2 diabetes among adults, with ad valorem taxes associated with larger slope reductions after the intervention compared with amount-specific ones. Eventually, upper middle-income countries were associated with negative slope changes compared with high-income ones for overweight among children and adolescents.

Discussion

The results of the scoping review showed that around one fourth of worldwide countries had implemented national taxation policies addressing SSBs before January 2022, most of them being high- or upper middle-income countries. In most cases, implemented taxes were amount-specific, with tax amounts greatly varying between countries.

Furthermore, through the time series analysis, we found evidence of an association between such laws targeting SSBs implemented up to 2013 and population's health in terms of prevalence of overweight, obesity, and type 2 diabetes. Although it might be limited among adults, stronger evidence was found for such association among children and adolescents, with 5 (Brazil, Samoa, Palau, Panama, Tonga) and 6 (El Salvador, Uruguay, Nauru, Norway, Palau, Tonga) countries out of those included in the analyses showing a level or slope reduction for prevalence of overweight and obesity, respectively, after the implementation of taxation. This is partly in contrast with previous studies, which reported stronger associations than those observed in our study among adults [41]. Findings from a few recent studies, instead, seem to confirm our results on children and adolescents [27–30]. Moreover, for 13 out of 17 countries (Hungary, Brazil, Samoa, Palau, Panama, Tonga, Paraguay, El Salvador, Uruguay, Nauru, Norway, Guatemala, Finland), we found evidence of an association with a level and/or slope change for at least one indicator among at least one population group included in our analysis. Furthermore, we found decelerations in the post-intervention linear trends also in some cases where no significant level or slope changes were observed. Even if these latter findings could be additionally suggestive of an effect of taxation interventions on analyzed indicators; however, they should be taken cautiously. Anyways, the results of our study suggest that SSBs taxation could be an effective policy intervention to improve population's health, especially future one by reducing health effects of SSBs among the youth, although further studies are needed to prove causality of the observed associations.

As previously suggested, the association of taxation with SSBs consumption and population's health might be influenced by other specific factors, such as the personal and country income, the consumers' behavior and educational level, and the tax design and amount [22, 41–43]. As for the quantitative assessment of factors associated with level and slope changes, and thus influencing the effectiveness of taxation, we found that national income influenced the slope change for overweight among children and adolescents after the introduction of taxation. Although this could suggest that taxation might be effective especially in settings with low income and socioeconomic status, we did not observe a clear trend according to income groups. Instead, tax design was found to be significantly associated only with the slope change for type 2 diabetes among adults, with amount-specific taxes associated with larger reductions. In this regard, however, it should be noted that the number of countries included in the analyses having the 2 different tax designed was not balanced, since amount-specific taxation was largely more common. This, together with the limited sample size, might limit the generalizability and validity of our findings. Eventually, the year of entry into force of the law showed a positive association for obesity among adults, perhaps suggesting increasing awareness of the detrimental health effects of obesity over the years, which could thus influence the results of our study.

TABLE 2
Results of the interrupted time series analysis the rate of change of overweight prevalence for countries included in the data analysis

Population, country	Trend before the intervention		Level change at intervention		Slope change after the intervention		Trend after the intervention		Number of lags
	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	
Adults									
Brazil									3
2013	−0.069 (−0.095, −0.044)	<0.001	0.153 (−0.364, 0.671)	0.545	−0.031 (−0.246, 0.185)	0.771	−0.100 (−0.313, 0.113)	0.340	
El Salvador									3
2009	−0.084 (−0.155, −0.012)	0.024	−0.650 (−1.418, 0.118)	0.093	−0.012 (−0.114, 0.091)	0.816	−0.095 (−0.159, −0.031)	0.005	
Honduras									1
2010	0.005 (−0.031, 0.042)	0.769	0.139 (−0.439, 0.718)	0.623	−0.077 (−0.190, 0.037)	0.175	−0.071 (−0.181, 0.038)	0.191	
Paraguay									3
2004	−0.045 (−0.104, 0.013)	0.122	−0.070 (−0.753, 0.613)	0.833	−0.031 (−0.099, 0.036)	0.345	−0.077 (−0.131, −0.023)	0.008	
Uruguay									3
1996	−0.500 (−0.702, −0.298)	<0.001	1.133 (0.468, 1.799)	0.002	0.500 (0.295, 0.705)	<0.001	0.000 (−0.175, 0.175)	1.000	
2001			−0.131 (−0.873, 0.611)	0.715	−0.031 (−0.197, 0.135)	0.701	−0.031 (−0.065, 0.003)	0.075	
Hungary									3
2011	0.113 (0.061, 0.164)	<0.001	0.335 (−0.284, 0.954)	0.274	−0.227 (−0.344, −0.110)	0.001	−0.114 (−0.214, −0.014)	0.027	
France									
2012	−0.022 (−0.049, 0.005)	0.104	−0.414 (−1.269, 0.440)	0.326	0.122 (−0.159, 0.403)	0.377	0.100 (−0.180, 0.380)	0.466	
Fiji									2
2006	−0.139 (−0.218, −0.061)	0.001	0.048 (−0.717, 0.813)	0.898	0.139 (−0.028, 0.306)	0.097	0.000 (−0.165, 0.165)	1.000	
2011			−0.362 (−1.245, 0.521)	0.403	−0.029 (−0.182, 0.125)	0.703	−0.029 (−0.150, 0.093)	0.629	
Samoa									2
2008	−0.076 (−0.112, −0.040)	<0.001	−0.429 (−0.967, 0.110)	0.113	0.009 (−0.060, 0.079)	0.783	−0.067 (−0.129, −0.004)	0.038	
Nauru									3
2007	−0.065 (−0.083, −0.047)	<0.001	0.432 (−0.031, 0.894)	0.066	−0.020 (−0.098, 0.057)	0.595	−0.085 (−0.163, −0.006)	0.035	
Guatemala									
2002	−0.009 (−0.114, 0.096)	0.859	−0.075 (−0.917, 0.767)	0.855	−0.037 (−0.158, 0.083)	0.526	−0.046 (−0.105, 0.012)	0.115	
Latvia									2
2004	−0.005 (−0.058, 0.047)	0.830	0.705 (0.308, 1.103)	0.001	0.002 (−0.081, 0.085)	0.961	−0.003 (−0.056, 0.049)	0.890	
Norway									3
2008	−0.066 (−0.098, −0.034)	<0.001	−0.348 (−0.776, 0.080)	0.106	0.016 (−0.046, 0.078)	0.592	−0.050 (−0.106, 0.006)	0.077	
Palau									2
2003	−0.185 (−0.273, −0.098)	<0.001	2.021 (1.126, 2.916)	<0.001	0.036 (−0.057, 0.129)	0.433	−0.149 (−0.204, −0.095)	<0.001	
Panama[1]									1
1995	−0.001 (−0.535, 0.535)	1.000	−0.424 (−1.675, 0.827)	0.488	0.000 (−0.535, 0.535)	1.000	0.000 (−0.031, 0.031)	1.000	
Tonga									2
2013	−0.087 (−0.104, −0.070)	<0.001	−0.018 (−0.394, 0.358)	0.921	−0.113 (−0.271, 0.045)	0.152	−0.200 (−0.356, −0.044)	0.014	
Finland									2
2011	−0.174 (−0.211, −0.138)	<0.001	0.265 (−0.295, 0.825)	0.338	0.174 (0.034, 0.315)	0.018	0.000 (−0.138, 0.138)	1.000	
Children and adolescents									
Brazil									2
2013	0.049 (0.028, 0.069)	<0.001	−0.122 (−0.648, 0.404)	0.635	−0.249 (−0.401, −0.096)	0.003	−0.200 (−0.356, −0.044)	0.014	
El Salvador									2
2009	−0.002 (−0.109, 0.105)	0.968	−1.008 (−2.096, 0.080)	0.068	0.085 (−0.050, 0.220)	0.203	0.083 (0.011, 0.155)	0.025	

(*continued on next page*)

TABLE 2 (*continued*)

Population, country	Trend before the intervention		Level change at intervention		Slope change after the intervention		Trend after the intervention		Number of lags
	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	
Honduras									3
2010	0.088 (0.058, 0.117)	<0.001	0.112 (−0.553, 0.776)	0.731	−0.016 (−0.135, 0.102)	0.778	0.071 (−0.048, 0.191)	0.227	
Paraguay									3
2004	0.073 (0.019, 0.126)	0.010	0.159 (−0.386, 0.704)	0.549	−0.012 (−0.075, 0.051)	0.688	0.060 (0.018, 0.103)	0.007	
Uruguay									
1996	nc		nc		nc		nc		
2001	nc		nc		nc		nc		
Hungary									3
2011	0.244 (0.221, 0.267)	<0.001	0.485 (−0.044, 1.013)	0.070	−0.101 (−0.217, 0.015)	0.085	0.143 (0.022, 0.264)	0.023	
France									2
2012	−0.074 (−0.115, −0.033)	0.001	−0.062 (−0.962, 0.838)	0.888	0.074 (−0.227, 0.375)	0.615	0.000 (−0.304, 0.304)	1.000	
Fiji									
2006	−0.036 (−0.087, 0.016)	0.165	−0.048 (−0.970, 0.875)	0.915	−0.164 (−0.403, 0.074)	0.167	−0.200 (−0.433, 0.033)	0.089	
2011			1.400 (0.845, 1.955)	<0.001	0.200 (−0.033, 0.433)	0.089	0.000 (−0.093, 0.093)	1.000	
Samoa									2
2008	0.248 (0.162, 0.333)	<0.001	−1.589 (−2.546, −0.631)	0.002	−0.148 (−0.243, −0.052)	0.004	0.100 (0.052, 0.148)	<0.001	
Nauru									2
2007	−0.029 (−0.073, 0.014)	0.174	−0.168 (−0.634, 0.297)	0.462	−0.055 (−0.129, 0.018)	0.131	−0.085 (−0.138, −0.032)	0.003	
Guatemala									2
2002	0.118 (0.065, 0.171)	<0.001	−0.083 (−0.518, 0.353)	0.698	−0.043 (−0.104, 0.018)	0.156	0.075 (0.045, 0.105)	<0.001	
Latvia[1]									1
2004	−0.003 (−0.090, 0.083)	0.934	0.670 (−0.344, 1.685)	0.183	−0.038 (−0.130, 0.053)	0.393	−0.042 (−0.105, 0.021)	0.178	
Norway[1]									1
2008	−0.022 (−0.056, 0.012)	0.192	0.242 (−0.404, 0.887)	0.445	0.055 (−0.039, 0.150)	0.237	0.033 (−0.053, 0.120)	0.430	
Palau[1]									
2003	0.091 (−0.028, 0.210)	0.126	−0.140 (−1.256, 0.976)	0.796	−0.161 (−0.310, −0.012)	0.035	−0.070 (−0.160, 0.020)	0.119	
Panama									1
1995	0.000 (−0.001, 0.001)	1.000	1.075 (0.828, 1.322)	<0.001	−0.068 (−0.091, −0.045)	<0.001	−0.068 (−0.091, −0.045)	<0.001	
Tonga									2
2013	0.092 (−0.008, 0.192)	0.070	−1.277 (−2.827, 0.274)	0.102	−0.492 (−0.630, −0.354)	<0.001	−0.400 (−0.478, −0.322)	<0.001	
Finland									3
2011	−0.245 (−0.281, −0.210)	<0.001	1.674 (1.328, 2.019)	<0.001	0.245 (0.210, 0.281)	<0.001	0.000 (-4.83×10^{-10}, 4.83×10^{-10})	1.000	

nc, not computable.
[1] Second differencing.

To our knowledge, our study is the first one attempting to systematically summarize information about the amount of national SSBs taxation for each country that implemented a related law and to assess the association of SSBs taxation with specific health outcomes through a comprehensive approach, not being limited to a single country. Among the strengths of our study there is our search strategy, that took advantage of the use of different languages, and the use of official data from the World Bank and the WHO to inform our comparisons in the scoping review. However, the omission of Asian languages from the search strategy could have led us to missing relevant information on Eastern countries. Furthermore, time series studies are subject to biases typical of ecological study designs, thus our findings might not be applicable at the individual level [44]. In addition, for some countries, the limited availability of data after the intervention point might have prevented us from detecting significant associations, thus our results might represent an underestimation of the real association of taxation with the health outcomes that we investigated at the population level. Furthermore, a latency longer than the timeframe covered by available data between the intervention and the effect could also be responsible for some of the nonsignificant results in our study. Another limitation stems from the implicit hypothesis of our time series analysis, according to which taxation was the only intervention that might have had an effect on studied outcomes in the considered time period, meaning that we did not consider other factors that might have had

TABLE 3
Results of the interrupted time series analysis the rate of change of obesity prevalence for countries included in the data analysis

Country, year of the intervention	Trend before the intervention		Level change at intervention		Slope change after the intervention		Trend after the intervention		Number of lags
	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	
Adults									
Brazil									3
2013	0.031 (0.007, 0.056)	0.015	0.143 (−0.143, 0.429)	0.312	−0.031 (−0.056, −0.007)	0.015	1.39×10^{-17} (-3.41×10^{-10}, 3.41×10^{-10})	1.000	
El Salvador									2
2009	0.067 (0.004, 0.130)	0.038	−0.415 (−1.251, 0.421)	0.315	0.004 (−0.086, 0.094)	0.921	0.071 (−0.007, 0.150)	0.071	
Honduras									2
2010	0.105 (0.068, 0.143)	<0.001	0.154 (−0.492, 0.800)	0.626	−0.034 (−0.164, 0.097)	0.596	0.071 (−0.057, 0.200)	0.263	
Paraguay									2
2004	0.109 (0.086, 0.132)	<0.001	−0.472 (−0.940, −0.003)	0.049	−0.049 (−0.102, 0.004)	0.071	0.060 (0.010, 0.111)	0.022	
Uruguay									
1996	nc		nc		nc		nc		
2001	nc		nc		nc		nc		
Hungary									3
2011	0.117 (0.072, 0.162)	<0.001	0.373 (−0.242, 0.989)	0.222	−0.146 (−0.266, −0.025)	0.020	−0.029 (−0.141, 0.084)	0.604	
France									2
2012	0.030 (0.010, 0.050)	0.006	−0.110 (−0.691, 0.472)	0.700	0.070 (−0.078, 0.218)	0.337	0.100 (−0.050, 0.250)	0.179	
Fiji									2
2006	−0.014 (−0.070, 0.041)	0.598	0.314 (−0.269, 0.898)	0.275	−0.086 (−0.316, 0.145)	0.447	−0.100 (−0.321, 0.121)	0.357	
2011			0.510 (−0.386, 1.405)	0.249	0.243 (0.005, 0.481)	0.046	0.143 (0.001, 0.285)	0.048	
Samoa									
2008	−0.015 (−0.049, 0.019)	0.378	−0.239 (−1.039, 0.561)	0.542	−0.002 (−0.146, 0.142)	0.978	−0.017 (−0.156, 0.123)	0.807	
Nauru									3
2007	−0.050 (−0.081, −0.019)	0.003	0.173 (−0.262, 0.608)	0.419	−0.011 (−0.057, 0.036)	0.638	−0.061 (−0.102, −0.019)	0.006	
Guatemala									3
2002	0.100 (0.054, 0.146)	<0.001	−0.116 (−0.517, 0.285)	0.555	−0.011 (−0.060, 0.039)	0.659	0.089 (0.065, 0.114)	<0.001	
Latvia									2
2004	0.033 (−0.017, 0.083)	0.188	0.077 (−0.495, 0.649)	0.783	0.033 (−0.022, 0.088)	0.220	0.066 (0.032, 0.101)	0.001	
Norway									2
2008	0.042 (−0.002, 0.085)	0.060	0.004 (−0.680, 0.688)	0.990	−0.042 (−0.117, 0.034)	0.266	0.000 (−0.076, 0.076)	1.000	
Palau									2
2003	−0.154 (−0.246, −0.061)	0.002	2.148 (0.602, 3.694)	0.009	0.029 (−0.085, 0.142)	0.607	−0.125 (−0.241, −0.009)	0.036	
Panama									
1995	0.600 (0.465, 0.735)	<0.001	−0.753 (−1.301, −0.205)	0.009	−0.580 (−0.719, −0.441)	<0.001	0.020 (−0.012, 0.051)	0.205	
Tonga									2
2013	−0.012 (−0.043, 0.018)	0.412	0.143 (−0.226, 0.512)	0.431	0.012 (−0.018, 0.043)	0.412	-3.47×10^{-18} (-4.83×10^{-10}, 4.83×10^{-10})	1.000	
Finland									5
2011	−0.027 (−0.042, −0.012)	0.001	−0.135 (−0.502, 0.233)	0.455	0.141 (0.064, 0.219)	0.001	0.114 (0.037, 0.192)	0.006	

(*continued on next page*)

TABLE 3 (*continued*)

Country, year of the intervention	Trend before the intervention		Level change at intervention		Slope change after the intervention		Trend after the intervention		Number of lags
	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	
Children and adolescents									
Brazil									2
2013	0.086 (0.064, 0.109)	<0.001	−0.257 (−0.923, 0.409)	0.432	0.014 (−0.225, 0.252)	0.907	0.100 (−0.146, 0.346)	0.408	
El Salvador									2
2009	0.071 (0.018, 0.124)	0.011	−0.871 (−1.525, −0.217)	0.011	0.155 (0.064, 0.246)	0.002	0.226 (0.153, 0.300)	<0.001	
Honduras									3
2010	0.114 (0.093, 0.135)	<0.001	−0.112 (−0.624, 0.400)	0.654	0.065 (−0.035, 0.164)	0.192	0.179 (0.078, 0.280)	0.001	
Paraguay									3
2004	0.091 (0.054, 0.128)	<0.001	0.148 (−0.235, 0.531)	0.430	0.008 (−0.052, 0.068)	0.784	0.099 (0.050, 0.148)	<0.001	
Uruguay									
1996	0.500 (0.214, 0.786)	0.002	−0.933 (−1.905, 0.038)	0.059	−0.300 (−0.672, 0.072)	0.107	0.200 (−0.038, 0.438)	0.094	
2001			−1.062 (−1.850, −0.273)	0.011	−0.137 (−0.382, 0.108)	0.256	0.063 (0.004, 0.122)	0.038	
Hungary									2
2011	0.153 (0.121, 0.186)	<0.001	0.647 (0.035, 1.258)	0.039	−0.096 (−0.236, 0.044)	0.168	0.057 (−0.075, 0.189)	0.380	
France									1
2012	−0.003 (−0.025, 0.020)	0.810	−0.295 (−0.825, 0.234)	0.260	0.203 (0.078, 0.327)	0.003	0.200 (0.072, 0.328)	0.004	
Fiji									3
2006	0.079 (0.035, 0.122)	0.001	−0.295 (−0.905, 0.315)	0.325	0.021 (−0.145, 0.188)	0.791	0.100 (−0.066, 0.266)	0.225	
2011			0.205 (−0.400, 0.810)	0.488	0.071 (−0.110, 0.253)	0.421	0.171 (0.113, 0.230)	<0.001	
Samoa									3
2008	0.333 (0.303, 0.364)	<0.001	−0.370 (−0.971, 0.231)	0.215	−0.117 (−0.254, 0.021)	0.093	0.217 (0.092, 0.341)	0.002	
Nauru									2
2007	0.085 (0.058, 0.113)	<0.001	−0.064 (−0.353, 0.226)	0.653	−0.116 (−0.170, −0.061)	<0.001	−0.030 (−0.078, 0.017)	0.198	
Guatemala									2
2002	0.145 (0.098, 0.193)	<0.001	−0.295 (−0.657, 0.066)	0.105	−0.038 (−0.098, 0.021)	0.197	0.107 (0.072, 0.142)	<0.001	
Latvia									3
2004	−0.016 (−0.044, 0.011)	0.234	0.526 (0.066, 0.986)	0.027	0.198 (0.149, 0.248)	<0.001	0.182 (0.134, 0.229)	<0.001	
Norway									3
2008	−0.034 (−0.065, −0.003)	0.032	−0.432 (−0.814, −0.051)	0.028	0.151 (0.089, 0.213)	<0.001	0.117 (0.066, 0.167)	<0.001	
Palau									2
2003	0.017 (−0.094, 0.129)	0.747	2.989 (1.507, 4.471)	<0.001	−0.145 (−0.269, −0.021)	0.024	−0.127 (−0.217, −0.038)	0.008	
Panama									1
1995	0.000 (−1.32 x 10^{-7}, 1.32 x 10^{-7})	1.000	0.885 (0.675, 1.095)	<0.001	0.028 (0.001, 0.055)	0.042	0.028 (0.001, 0.055)	0.042	
Tonga									3
2013	0.283 (0.221, 0.344)	<0.001	−1.299 (−2.284, −0.313)	0.012	−0.283 (−0.344, −0.221)	<0.001	0.000 (−9.66 × 10^{-10}, 9.66 × 10^{-10})	1.000	
Finland									
2011	−0.053 (−0.101, −0.004)	0.034	0.334 (−0.539, 1.206)	0.436	0.167 (−0.009, 0.343)	0.062	0.114 (−0.055, 0.283)	0.175	

nc, not computable.

TABLE 4
Results of the interrupted time series analysis on the rate of change of type 2 diabetes prevalence among adults for countries included in the data analysis

Country	Trend before the intervention		Level change at the intervention		Slope change after the intervention		Trend after the intervention		Number of lags
	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	Coefficient (95% CI)	*P* value	
El Salvador									
2009	−0.043 (−0.092, 0.005)	0.078	0.047 (−0.821, 0.915)	0.912	0.100 (−0.154, 0.355)	0.420	0.057 (−0.193, 0.307)	0.639	
Honduras									
2010	0.047 (0.015, 0.080)	0.006	−0.358 (−0.775, 0.059)	0.089	0.153 (−0.074, 0.379)	0.175	0.200 (−0.024, 0.424)	0.077	
Paraguay									1
2004	−0.027 (−0.110, 0.055)	0.497	−0.200 (−0.975, 0.575)	0.594	0.082 (−0.037, 0.201)	0.165	0.055 (−0.038, 0.147)	0.230	
Uruguay									2
1996	0.000 (−0.478, 0.478)	1.000	0.467 (−0.578, 1.511)	0.358	−0.100 (−0.625, 0.425)	0.692	−0.100 (−0.331, 0.131)	0.373	
2001			0.214 (−0.645, 1.074)	0.604	0.164 (−0.068, 0.396)	0.154	0.064 (0.019, 0.109)	0.008	
Hungary									3
2011	0.051 (0.036, 0.066)	<0.001	−0.537 (−1.030, −0.043)	0.034	0.049 (−0.165, 0.263)	0.639	0.100 (−0.116, 0.316)	0.345	
Fiji									2
2006	0.154 (0.115, 0.192)	<0.001	−0.429 (−0.989, 0.132)	0.126	−0.154 (−0.327, 0.020)	0.079	0.000 (−0.168, 0.168)	1.000	
2011			0.500 (−0.318, 1.318)	0.215	−0.100 (−0.383, 0.183)	0.467	−0.100 (−0.364, 0.164)	0.437	
Samoa									
2008	−0.027 (−0.085, 0.031)	0.346	0.035 (−0.973, 1.042)	0.944	0.063 (−0.176, 0.301)	0.590	0.036 (−0.196, 0.267)	0.751	
Nauru									2
2007	−0.228 (−0.294, −0.161)	<0.001	0.500 (−0.387, 1.387)	0.254	0.407 (0.227, 0.586)	<0.001	0.179 (0.020, 0.337)	0.029	
Guatemala									1
2002	0.091 (0.048, 0.134)	<0.001	−0.533 (−1.077, 0.011)	0.054	−0.096 (−0.174, −0.019)	0.017	−0.005 (−0.066, 0.055)	0.853	
Latvia									4
2004	0.033 (−0.011, 0.077)	0.132	−0.308 (−0.752, 0.137)	0.164	0.076 (0.032, 0.120)	0.002	0.109 (0.089, 0.129)	<0.001	
Norway									2
2008	−0.029 (−0.063, 0.004)	0.082	−0.445 (−0.964, 0.073)	0.088	0.101 (0.017, 0.185)	0.021	0.071 (−0.009, 0.152)	0.078	
Palau									2
2003	−0.203 (−0.279, −0.126)	<0.001	0.959 (0.297, 1.621)	0.007	0.056 (−0.040, 0.151)	0.236	−0.147 (−0.197, −0.096)	<0.001	
Panama									1
1995	0.100 (−0.172, 0.372)	0.453	−0.057 (−1.086, 0.972)	0.909	−0.099 (−0.364, 0.165)	0.443	0.001 (−0.029, 0.030)	0.958	
Finland									5
2011	−0.041 (−0.058, −0.023)	<0.001	0.626 (0.275, 0.977)	0.001	−0.259 (−0.415, −0.104)	0.002	−0.300 (−0.457, −0.143)	0.001	

CI, confidence interval.

a potential effect on the outcomes investigated in our study. These could include other policy interventions that national governments might have put in place in the same period of taxation, hence that could actually be responsible for some of the observed associations. Furthermore, the psychological effect of a new excise tax on consumers' behavior, even if not negligible, could not be assessed in our study, thus public perception might also be a factor affecting the effectiveness of this kind of interventions and hence our findings [45]. Moreover, we limited our study to national taxation, thus not taking into account other types of interventions, including those that might have taken place at the state, regional, or local level, potentially with similar consequences on our results as other national interventions mentioned above. Furthermore, our findings might be affected by reverse causality, since already declining SSB consumption in some settings before any intervention could perhaps have actually made the introduction of taxation more politically feasible and acceptable by the population. Additionally, owing to the heterogeneity in the characteristics of identified taxes, we did not investigate how tax amounts modify the associations of taxation with health outcomes, thus suggesting the need for further studies to evaluate which factors modify these associations, even though higher amounts of taxation could be expected to be more effective at reducing the prevalence of specific diseases. Lastly, for the present analysis we used prevalence rates from previous studies computed using statistical approaches (Bayesian hierarchical model) [38, 39], thus they represent estimates instead of being directly measured among the population, possibly limiting the generalizability of our findings. Moreover, we included in the analysis only interventions issued in 2013 or before and data on chosen

TABLE 5
Results of the meta-regression approach assessing which factors influence the effectiveness of taxation on sugar-sweetened beverages

Age group	Indicator	Variable	Level change	Slope change
			Coefficient (95% CI)	Coefficient (95% CI)
Adults	Overweight	Year of entry into force	−0.049 (−0.100, 0.003)	−0.015 (−0.031, 0.001)
		Country income	0.000 (ref)	0.000 (ref)
		High	0.343 (−0.230, 0.916)	−0.017 (−0.183, 0.149)
		Upper middle	−0.441 (−1.003, 0.122)	−0.047 (−0.196, 0.102)
		Lower middle		
		Tax design	0.000 (ref)	0.000 (ref)
		Ad valorem	0.214 (−0.322, 0.751)	0.009 (−0.137, 0.154)
		Amount-specific		
	Obesity	Year of entry into force	0.016 (−0.023, 0.056)	0.018 (0.002, 0.033)
		Country income	0.000 (ref)	0.000 (ref)
		High	0.173 (−0.209, 0.555)	0.031 (−0.135, 0.196)
		Upper middle	−0.113 (−0.514, 0.289)	0.007 (−0.153, 0.167)
		Lower middle		
		Tax design	0.000 (ref)	0.000 (ref)
		Ad valorem	0.194 (−0.130, 0.518)	0.107 (−0.040, 0.255)
		Amount-specific		
	Diabetes	Year of entry into force	0.043 (−0.053, 0.140)	0.020 (−0.008, 0.047)
		Country income	0.000 (ref)	0.000 (ref)
		High	0.514 (−0.460, 1.489)	0.123 (−0.151, 0.396)
		Upper middle	−0.050 (−0.746, 0.647)	−0.012 (−0.219, 0.195)
		Lower middle		
		Tax design	0.000 (ref)	0.000 (ref)
		Ad valorem	−0.416 (−1.233, 0.400)	−0.228 (−0.443, −0.013)
		Amount-specific		
Children and adolescents	Overweight	Year of entry into force	−0.045 (−0.154, 0.063)	−0.004 (−0.022, 0.013)
		Country income	0.000 (ref)	0.000 (ref)
		High	−0.673 (−1.918, 0.573)	−0.280 (−0.477, −0.083)
		Upper middle	−0.587 (−1.687, 0.512)	−0.086 (−0.268, 0.095)
		Lower middle		
		Tax design	0.000 (ref)	0.000 (ref)
		Ad valorem	−0.022 (−1.085, 1.041)	0.066 (−0.106, 0.239)
		Amount-specific		
	Obesity	Year of entry into force	−0.053 (−0.139, 0.032)	−0.001 (−0.018, 0.016)
		Country income	0.000 (ref)	0.000 (ref)
		High	−0.282 (−1.295, 0.732)	−0.141 (−0.333, 0.050)
		Upper middle	−0.297 (−1.223, 0.629)	−0.035 (−0.214, 0.144)
		Lower middle		
		Tax design	0.000 (ref)	0.000 (ref)
		Ad valorem	0.382 (−0.523, 1.288)	0.079 (−0.097, 0.254)
		Amount-specific		

CI, confidence interval.

indicators up to 2016, suggesting the need for updated data that could help to understand recent trends in populations' health and how these could be affected by taxation.

Even though our findings suggest that SSB taxation might be effective at reducing the prevalence of health outcomes linked to their consumption, further research in this field is warranted, with a particular attention to the confirmation of our findings at the individual level through well-designed prospective studies with accurate measurements of outcomes of interest. Indeed, the lack of data on interventions other than taxation or not implemented at the national level, and hence not included in the analysis, together with the ecological design of our study and related limitations described above, prevent us from drawing conclusions regarding causality of observed associations. In addition, great efforts should be directed toward the identification of predictors of effectiveness of taxation, both at the individual and at the population level, to guide policymakers in the design of taxes better suited at achieving the final aim of reducing SSBs consumption and related health outcomes in the national, regional, or local context where they operate.

Eventually, our study suggests that SSBs taxation may be effective, especially among the youth, and might represent an effective investment to improve population's health in the long-term, although further investigation is warranted to prove causality of observed associations. In this context, recent studies suggest that this type of interventions might also be highly cost-effective at reducing cancer burden through the reduction of the national prevalence of obesity [46], though evidence in this field is still limited. Nevertheless, although taxation might represent an effective means to reduce SSBs consumption, other types of public health interventions, such as educational initiatives aimed at raising citizens' awareness and behavioral interventions, should not be neglected [47,48].

Author contributions

All authors contributed to the study conception and design. MS, RB, and SB designed research. All authors conducted research. MS performed statistical analysis. All authors wrote the article. MS, RB,

and SB had primary responsibility for final content. All authors read and approved the final version of the manuscript.

Declaration of generative AI in scientific writing

Not applicable.

Conflicts of interest

The authors report no conflicts of interest.

Funding

This research is supported by the "Personalized CANcer Primary Prevention research through Citizen Participation and digitally enabled social innovation" project (4P-CAN) (HORIZON-MISS-2022-CANCER-01-01 no. 10110443).

Data availability

Data described in the manuscript are accessible in the manuscript itself or in sources that can be found in the reference list. Code book and analytic code will be made available upon reasonable request for research purposes.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajcnut.2023.12.013.

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