BMJ Open

Health and economic burden of disease of sugar-sweetened beverage consumption in four Latin American and Caribbean countries: a modelling study

Andrea Alcaraz ,[1] Ariel Esteban Bardach,[1,2] Natalia Espinola,[1] Lucas Perelli,[1] Federico Rodriguez Cairoli ,[1] Althea La Foucade,[3] Cid Manso de Mello Vianna,[4] Giovanni Guevara,[5] Kimberly-Ann Gittens-Baynes,[3] Paula Johns,[6] Vyjanti Beharry,[3] Darío Javier Balán,[1] Alfredo Palacios,[1] Federico Augustovski,[1,2] Andres Pichon-Riviere[1,2]

To cite: Alcaraz A, Bardach AE, Espinola N, *et al*. Health and economic burden of disease of sugar-sweetened beverage consumption in four Latin American and Caribbean countries: a modelling study. *BMJ Open* 2023;**13**:e062809. doi:10.1136/bmjopen-2022-062809

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-062809).

Received 15 March 2022
Accepted 11 January 2023

For numbered affiliations see end of article.

Correspondence to
Dr Andrea Alcaraz;
aalcaraz@iecs.org.ar

ABSTRACT

Objective Overweight and obesity are important contributors to the non-communicable disease burden. The consumption of sugar-sweetened beverages (SSBs) has been associated with an increased risk of type 2 diabetes mellitus (T2DM), cardiovascular disease, cancer and other conditions. The objective of this study was to estimate the burden of disease attributable to the consumption of SSBs and the costs to the healthcare systems in Argentina, Brazil, El Salvador, and Trinidad and Tobago.

Design Following a systematic review of models, a comparative risk assessment framework was developed to estimate the health and economic impact associated with the consumption of SSBs.

Setting Argentina, Brazil, El Salvador, and Trinidad and Tobago.

Participants Overall population.

Primary and secondary outcome measures The model estimated the effects of SSB consumption on health through two causal pathways: one mediated by body mass index (BMI) and health conditions associated with BMI and another that reflected the independent effects of SSB consumption on T2DM and cardiovascular diseases.

Results The model results indicated that for all four countries, in 1 year, SSB consumption was associated with 18 000 deaths (3.2% of the total disease-related deaths), seven million disease events (3.3% of the total disease-related events), a half-million DALYs and US$2 billion in direct medical costs. This included 1.5 million cases of overweight and obesity in children/adolescents (12% of the excess weight cases) and 2.8 million cases in adults (2.8%); 2.2 million cases of type 2 diabetes (19%); 200 000 cases of heart disease (3.8%); 124 000 strokes (3.9%); 116 000 cases of musculoskeletal disease (0.2%); 102 000 cases of kidney disease (0.9%); and 45 000 episodes of asthma (0.4%). The Trinidad and Tobago population were the most affected by disease events.

Conclusions The study results indicate that the consumption of SSBs is associated with a significant burden of disease and death in Latin America and the Caribbean.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is the first study to assess the disease burden of sugar-sweetened beverage (SSB) consumption in Latin America and the Caribbean (LAC) with a simulation model tailored for the region and capable of estimating attributable multidisease events, deaths, disability-adjusted life years and direct medical costs predictions, including the whole population of the evaluated countries.

⇒ LAC is a region that suffers a disproportionate burden of disease and death attributable to SSBs with lack of quality sources of information.

⇒ There are several natural targets for policy-driven interventions: the low price of SSB, lack of regulation of advertising and/or suboptimal implementation of existing policies; lack of awareness in the population about the risks associated with SSB; and no food warning labels in many countries.

⇒ This study can be a valuable contribution to draw the attention of the population and decision makers to this critical public health problem and provide support to the policy interventions that many countries are struggling to implement.

INTRODUCTION

Globally, non-communicable diseases (NCDs) are the leading cause of mortality, accounting for more than 70% of deaths, with 77% of deaths occurring in low-income and middle-income countries.[1] It also imposes a significant economic burden on health systems and societies at large.[2] The Sustainable Development Goals, defined by the United Nations in

2015, identify the prevention and control of NCDs as core priorities.[3]

Overweight and obesity are critical determinants of the burden of disease and death currently attributable to NCDs. High body mass index (BMI) was responsible for more than eight million deaths worldwide in 2019.[4] The global prevalence of obesity has tripled over the past few years, with nearly 1.9 billion adults estimated to be overweight and 650 million obese.[5] The prevalence of excess weight among children and adolescents has increased worldwide and is alarming. In Latin America and the Caribbean (LAC), it is estimated that over 3.8 million children under 5 years and more than 40 million school-aged children and adolescents are overweight or obese.[6] Additionally, multiple studies have demonstrated the high economic burden of overweight and obesity, both in developed and developing countries.[7]

Sugar-sweetened beverages (SSBs) are high in calories, low in nutritional value and are the leading source of added sugars in the diet.[8–11] Consumption of SSBs promotes weight gain and increases the risk of other metabolic disorders, such as type 2 diabetes mellitus (T2DM) in adults. Reducing the consumption of SSBs reduces the risk of overweight and obesity and lowers the risk of obesity-related diseases such as cardiovascular and cerebrovascular disease, cancer, musculoskeletal disorders, asthma, depression, social isolation and dental caries, among others.[12–14] The evidence confirms the link between SSB consumption and weight gain in children and adolescents along with greater risk of insulin resistance, high blood pressure and dental caries, among others.[15 16]

SSB consumption varies considerably according to sociodemographic characteristics, with consumption being higher in younger people, males and in LAC in relation to other regions.[17] In LAC, Trinidad and Tobago has the highest consumption of SSBs among adults, while Argentina has the highest SSB consumption among children in the region.[18 19]

Estimating the burden of disease and the economic burden derived from the consumption of SSBs can provide valuable information for policy makers in the region. This information allows for the estimation of the potential impact of interventions like taxes, front of package labelling, advertising restrictions or school environment modifications on SSB consumption.[20 21]

The objective of this study was to estimate the burden of disease attributable to the consumption of SSBs and the costs to the healthcare systems in Argentina, Brazil, El Salvador, and Trinidad and Tobago.

METHODS

Model structure

A comparative risk assessment framework was used to estimate the health and economic impact of SSB consumption. The conceptualisation of the model and the selection of outcomes was carried out after a systematic review of the existing models for SSBs[22] and a Policy Dialogue held in Buenos Aires in 2018 that brought together 35 experts and decision makers from seven countries in LAC.[23] These activities were used to inform the development of the model so that it could adequately respond to the information needs of decision makers and contribute to the design and implementation of effective public policies for the control of SSB consumption in the region. Following these activities, the use of a comparative risk approach was prioritised[24] taking into account the feasibility of obtaining the necessary inputs to execute this approach in Latin America.

The model estimates the effects of SSB consumption on health through two main causal pathways. One path is mediated through the effects of SSBs on BMI and the effect of BMI on the risk of health conditions associated

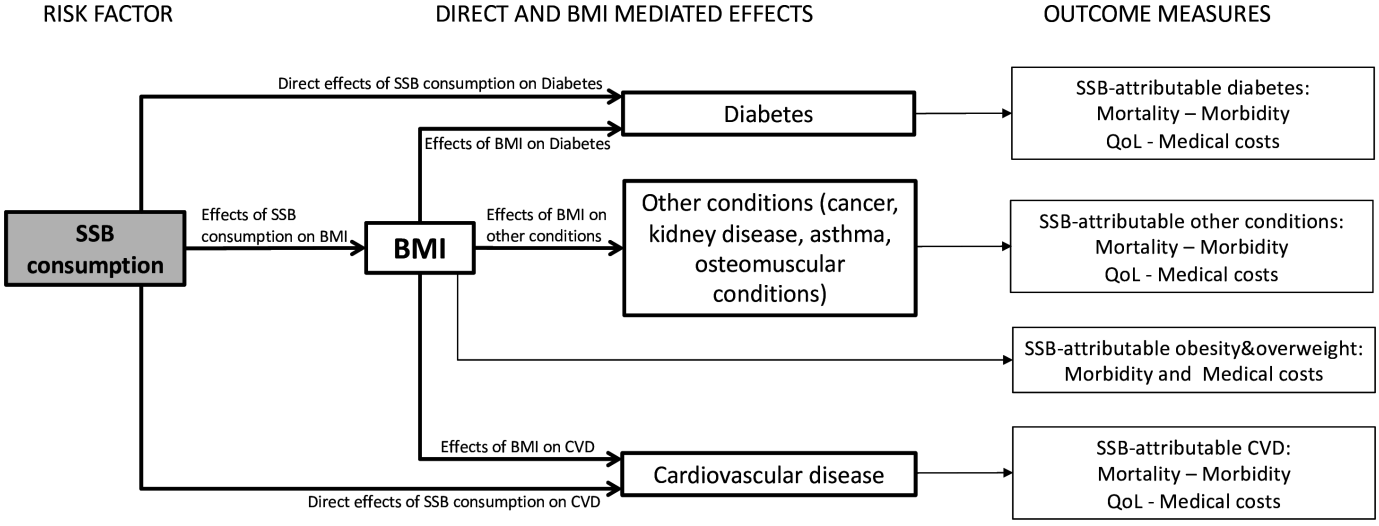

Figure 1 Model framework. BMI, body mass, index; SSB, sugar-sweetened beverag;CVD, cardiovascular disease; QoL, quality of life.

with overweight and obesity. The other causal path reflects the independent effects of SSB consumption on T2DM and cardiovascular diseases (figure 1).[25 26] In children and adolescents, the model estimates only the effects of SSB consumption on overweight and obesity prevalence.

The comparative risk approach was used to determine the Population Attributable Fraction (PAF) for each targeted disease. The PAF is the proportion of cases that can be attributed to a particular exposure (see online supplemental material). The model was developed in three stages to estimate the impact of SSB consumption. First, changes in SSB consumption distribution between baseline (current behaviour) and selected scenarios were estimated. Second, changes in T2DM, CVD and BMI caused by changes in SSB consumption were calculated. Third, changes in disease burden were estimated using the PAF and applied to baseline levels of each selected disease in the population.

The model measures the number of prevented incident and prevalent cases, the number of deaths prevented, the years lost due to ill health and total healthy years and the economic burden associated with these diseases. The disease burden was estimated as the difference between the results predicted by the model for each country under current SSB consumption prevalence and a counterfactual scenario of no SSB consumption without caloric compensation.

To incorporate uncertainty in the health and economic outcomes attributable to SSB consumption, a second order Monte Carlo simulation was used. The sensitivity analyses explored the potential effect on results attributable to uncertainty about SSB consumption as well as the strength of the association (relative risk, RR or hazard ratio, HR) linking SSB consumption with BMI, T2DM and CVD. One thousand iterations were done fitting distributions from the parameters of SSB consumption (mean and SE) and from relative risks (considering a normal distribution, where the SD were obtained from the reported 95% CIs), for each country, gender and age group. The mean and 95% uncertainty intervals were reported. The analysis was performed using Stata software, V.14.0, and Visual Basic Excel.

The model was calibrated using national vital statistics. A variation of plus or minus 10% in the results is considered acceptable; if it was not achieved, a modification of ±20% was made in the lethality or incidence risk equations to adjust the results.

Epidemiological data

The selection of data sources and parameters for the four countries was based on a joint decision rule that was defined in order to establish a priority among the different possible sources of data that stated: (1) use good quality local information when available, (2) use international sources when local information was not available or considered to be of poor quality and (3) use the best estimate from the author group when data were not considered 'transferable', to derive or estimate the parameter based on best data available locally.

The following beverages were defined as SSBs: sugar-sweetened sodas, sugar-sweetened fruit juices, energy drinks, sports drinks and sugar-sweetened flavoured waters. One hundred per cent homemade natural juices and sugar-sweetened dairy products like coffee or tea were not included. Population-based surveys were the preferred data sources for SSB consumption; where such data were unavailable, consumption was estimated from international studies. A serving of a SSB was defined as 240 mL.

Each serving of a SSB per day was associated with a 0.10 (95% CI 0.05 to 0.15) kg/m^2 of increase in BMI in individuals with BMI <25 and with 0.23 (95% CI 0.14 to 0.32) kg/m^2 of increase in BMI in individuals with BMI ≥25 in adults.[27] In children, a BMI reduction of 0.33 kg/m^2 for a serving of SSB was use.[28]

Prevalence of overweight and obesity was obtained from the last available risk factor survey in each country. Data on the general population structure, incidence, prevalence and mortality of the different conditions for age and gender were also included. The DISMOD II software was used to pool data from multiple sources, model missing data and check the consistency of estimates of incidence, prevalence, duration and case fatality for diseases.

The relative risks of diseases associated with SSB consumption were obtained through a comprehensive review of the literature. T2DM and cardiovascular diseases—including cerebrovascular disease, ischaemic heart disease, atrial fibrillation and hypertensive heart disease—were directly associated with daily consumption of SSB. For T2DM, an RR of 1.37 (95% CI 1.15 to 1.63) per serving per day was used considering the systematic review of Imamura *et al*.[25] For the association of SSB consumption with mortality and incidence of cardiovascular events, an RR of 1.08 (95% CI 1.04 to 1.13) and 1.08 (95% CI 1.02 to 1.14) per serving per day respectively were considered from a systematic review of Yin *et al*.[26]

For the other diseases included in the model, the increased risk was mediated by increased BMI. The relative risks of developing each condition for different BMI were obtained from the Global Burden of Disease study (Institute for Health Metrics and Evaluation, IHME), including only the BMI-related diseases with the highest disease burden. Also included were oncological like oesophageal cancer, colon-rectum, uterine body, kidney and gallbladder and biliary tract cancer, and non-oncological diseases like osteoarthritis, lower back pain, biliary tract, gallbladder diseases, asthma, dementia, Alzheimer's disease and chronic kidney disease.[4]

Total disability-adjusted life years (DALYs) were calculated from the years of life lost due to premature death (YLLs) and the years lost due to a disability (YLDs). YLLs and YLDs were estimated for each of the diseases considered in the model (not for overweight/obesity conditions). Life expectancy tables were used when estimating YLLs, for each country using the WHO online

Global Health Observatory data repository.[29] YLDs were calculated from the prevalence values of each disease multiplied by its weight of disability. The weighting for disability data was obtained from the Global Burden of Disease study for each disease.[4]

Direct medical costs

The direct medical costs (including diagnosis, treatment and follow-up) were estimated for each condition included in the model. For Argentina and El Salvador, the direct medical costs represent a weighted average of the costs of the three main healthcare subsectors (public, social security and private). For Brazil and Trinidad and Tobago, the direct medical costs were estimated from the perspective of the public health system.

In each country, the research team developed a standard costing approach (microcosting or macrocosting) depending on the availability and quality of the information. For the microcosting approach, a Microsoft Excel spreadsheet was designed to estimate the direct medical cost of the following health conditions: T2DM (with and without complications), overweight, obesity types 1, 2 and 3, acute myocardial infarction and its follow-up, heart failure, kidney insufficiency (with and without dialysis) and stroke. These microcosting spreadsheets were developed based on previous cost estimation projects, clinical guidelines and communications with local experts in each country.

When adequate local information was unavailable to estimate the direct medical cost of a specific event in a particular country, a two-stage indirect estimation approach was used. First, for each country with information on the cost of a particular health event, the ratio between the cost of the health event and the country's gross domestic product (GDP) per capita was calculated. Second, for each country with missing cost data, the average of these ratios (calculated for countries with cost data) was applied to the GDP per capita of the country without cost data, in order to estimate (indirectly) the cost of the health event of interest.

All direct medical costs were estimated in local currency units and then converted to US dollars using the exchange rates of 2020, published by the central banks of each country.

Patient and public involvement

Patients were not involved directly in the design and implementation of this research. The results to be developed by this study were prioritised in a dialogue of decision makers and key actors on the subject, including civil society actors who presented perspectives from the general population. The main study results were presented in infographic pieces written in plain language for patients and the general population and presented in two webinars open to the public. The material is available in the language of the four study countries at the following link www.iecs.org.ar/sugar.

RESULTS

Epidemiological and economic data were obtained for each country. The main parameters included in the model are shown in table 1 and online supplemental file 1.

The average consumption of SSBs at the population level ranged from 0.78 servings per day in Brazil to 1.21 servings in Argentina, with considerable variation by gender and age groups (see table 1). The country with highest consumption in children was Argentina, and the country with highest consumption in adults was Trinidad and Tobago. The estimated cost of treating each SSB consumption related disease by country is available in the online online supplemental file 1.

An estimated 1.5 million cases of obesity and overweight in children and adolescents (<18 years) were attributable to SSB consumption in 2020, which represented 12% of the total of obesity cases in this population. In the adult population (18 years or older), 2.8 million cases of obesity and overweight were attributable to SSB consumption representing 2.8% of the total cases of overweight and obesity in this population (table 2). The 18–44 years age group was the most affected in all countries. Generally, men were more affected than women except in the 18–44 years age group in El Salvador and the 45–64 years age group in Trinidad and Tobago. The number of cases of overweight and obesity was strikingly high in the 5–17 years age group in Argentina (figure 2). In terms of direct medical costs, it was estimated that US$18 million was expended in 1 year to treat obesity and overweight attributable to SSB consumption in children and adolescents, while US$80.7 million was spent to treat obesity and overweight in adults.

The effect of SSB consumption on T2DM was markedly strong. A total of 2.2 million cases of T2DM, 265 994 DALYs and 7000 deaths were attributable to SSB consumption in 2020 in these countries, which represents approximately 19% of total T2DM cases and 23% of deaths. Of all the direct medical costs estimated to be associated with SSB consumption in the four countries, T2DM was responsible for 76% of these costs.

As can be seen in table 2, in the four countries, the number of events of other diseases that can be attributed to the consumption of SSB is also high, representing close to 200 000 cases of heart disease; 124 000 strokes; 116 000 musculoskeletal diseases – mainly low back pain; 102 000 kidney disease events; and 45 000 episodes of asthma. Also 225 360 DALYs and 11 000 deaths were caused by these conditions in 1 year. This resulted in a cost to the health system of US$481.1 million.

Overall, for 2020, SSB consumption was associated with 18 059 deaths (3.2%), 7 139 560 disease events (3.3%), 491 354 DALYs and US$2010.2 million in direct medical costs for these four countries.

Figure 3 provides a breakdown of deaths and events in adults attributable to SSB consumption per million adults to make countries more comparable. Among the four countries, the Trinidad and Tobago population was the

Table 1 Key epidemiological model parameters by age and gender in Argentina, Brazil, El Salvador, and Trinidad and Tobago

	Argentina				Brazil				El salvador				Trinidad and Tobago				
	Children (females) (<18 years)	Children (males) (<18 years)	Adult (females) (>18 years)	Adult (males) (>18 years)	Children (females) (<18 years)	Children (males) (<18 years)	Adult (females) (>18 years)	Adult (males) (>18 years)	Children (females) (<18 years)	Children (males) (<18 years)	Adult (females) (>18 years)	Adult (males) (>18 years)	Children (females) (<18 years)	Children (males) (<18 years)	Adult (females) (>18 years)	Adult (males) (>18 years)	References
Total population (millions)	6.7	7.0	15.5	14.3	28.7	29.9	76.0	70.4	1.1	1.1	2.3	1.9	0.17	0.18	0.01	0.01	(1, 2, 3, 4)
Overweight (percentage of the total population)	17%	14%	30%	39%	7%	8%	34%	42%	8%	9%	34%	38%	14%	16%	30%	36%	(5, 6, 7, 8, 9, 10)
Grade 1 obesity (percentage of the total population)	10%	13%	22%	24%	5%	6%	14%	15%	2%	3%	20%	13%	12%	13%	22%	15%	(7. 8. 9, 10)
Grade 2 obesity (percentage of the total population)			9%	8%			4%	3%			7%	3%			11%	6%	(7, 8, 9, 10)
Grade 3 obesity (percentage of the total population)			7%	3%			1%	1%			4%	3%			7%	2%	[7](7, 8, 9, 10)
Average body mass index value (Mean)	NA		28.4	28.3	NA		26.0	26.6	NA		27.6	25.8	NA		29.0	26.4	(9, 11, 12, 13)
Average daily SSB consumption in serving per day (mean)	1.4	1.6	0.8	1.1	1.0	1.1	0.5	0.6	1.3	1.1	0.6	0.8	1.1	1.1	1.1	1.2	((9, 11, 12, 13)

Note: NA: not applicable in the model since the burden of other diseases secondary to obesity were not modeled in children and adolescents.

References
1. INDEC, Instituto Nacional de Estadística y Censos de la República Argentina. INDEC: Instituto Nacional de Estadística y Censos de la República Argentina. [cited 19 Feb 2021]. Available: https://www.indec.gob.ar/indec/web/Nivel4- Tema-2-24-84"
2.Projeções da População. Available: https://www.ibge.gov.br/estatisticas/sociais/populacao/9109-projecao-da-populacao.html.
3. Ministerio de Salud, Gobierno de El Salvador. Demografía. Available: https://www.salud.gob.sv/demografia/
4. Official Website of the Government of Trinidad & Tobago. Available at: https://cso.gov.tt
5. WHO. Global School-based Student Health Survey. Available: https://www.who.int/teams/noncommunicable-diseases/surveillance/systems-tools/global-school-based-student-health-survey
6. Unicef. Encuesta de Indicadores Múltiples por Conglomerados (MICS) MICS-2014. Available at: https://www.unicef.org/elsalvador/informes/encuesta-nacional-de-salud-mics-2014
7. Ministerio de Salud. Cuarta Encuesta Nacional de Factores de Riesgo. Available at: https://bancos.
8.Ministerio da Saúde. POF 2008 (Brazilian Family Income Survey 2008–9. Available at: https://www.ibge.gov.br/en/statistics/social/social-protection/17387-pof-2008-2009-en.html?=&t=o-que-e.
9. Ministerio de Salud, Gobierno de El Salvador. ENECA-ELS, 2015. Available at: http://w5.salud.gob.sv/archivos/comunicaciones/archivos_comunicados2017/pdf/presentaciones_evento20032017/01-ENECA-ELS-2015.pdf
10. Pan American STEPS 2012, Trinidad and Tobago. Chronic non-communicable disease. Available at: https://www.psi.org/wp-content/uploads/2018/02/TT-STEPS-Survery.pdf
11.Instituto Brasileiro de Geografia e Estatística. POF 2017–2018. Available at: https://www.ibge.gov.br/en/statistics/social/population/25610-pof-2017-2018-pof-en.html?=&t=o-que-e.
12. Local expert estimates from Primer Encuesta Nacional de Nutrición y Salud (ENNYS). Available at: http://www.extensioncbc.com.ar/wp-content/uploads/ENNyS-2007.pdf)
13.Singh GM, Micha R, Khatibzadeh S, Shi P, Lim S, Andrews KG, Engell RE, Ezzati M, Mozaffarian D; Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE). Global, Regional, and National Consumption of Sugar-Sweetened Beverages, Fruit Juices, and Milk: A Systematic Assessment of Beverage Intake in 187 Countries. PLoS One. 2015 Aug 5;10(8):e0124845. doi: 10.1371/journal.pone.0124845. Erratum in: PLoS One. 2019 Mar 27;14(3):e0214344. PMID: 26244332; PMCID: PMC4526649.

Table 2 Annual sugar-sweetened beverage consumption burden attributable in adults: mortality, disease events, disability-adjusted life years and direct medical costs, by cause, country and gender

Condition	Argentina		Brazil		El Salvador		Trinidad and Tobago	
	Total (%*)	95% CI	Total (%*)	95% CI	Total (%*)	95% CI	Total (%*)	95% CI
Obesity and overweight (<18 years)								
Events	774 018/4 305 048 (18%)	(372 839 to 1 223 565)	722 639/6 383 714 (11.3%)	(381 499 to 1 006 604)	21 432/244 015 (8.8%)	(11 291 to 31 182)	11 455/110 663 (10.4%)	(6704 to 17 693)
Direct medical cost, US$ (million)	$13.1/$65.4 (20%)	($6 to $21.5)	$3.8/$36 (11%)	($1.3 to $6.2)	$0.42/$4.8 (8.8%)	($0.15 to $0.65)	$0.24/$1.9 (13%)	($0.18 to $0.33)
Obesity and overweight (adults)								
Events	520 762/20 109 746 (2.6%)	(361 044 to 890 222)	2 219 168/81 905 595 (2.7%)	(1 6 47 187 to 2 907 689)	94,893/2 687 020 (3.5%)	(60,731-141,390)	15,034/5 98 522 (2.5%)	(9,772-23,303)
Direct medical cost, US$ (million)	$47.3/$969.8 (4.8%)	($45.5 to $83.2)	$28.6/$586.5 (4.9%)	($21.3 to $42.1)	$ 3 / $ 68.1 (4.4%)	($ 3 - $ 6)	$ 1.8 / $ 40.3 (4.5%)	($ 1.2 - $ 3.3)
Diabetes								
Deaths	1317/7021 (18.8%)	(592 to 1970)	5179/43 831 (11.8%)	(2181 to 8511)	234/1477 (15.8%)	(101 to 359)	233/1046 (22.3%)	(106 to 342)
Events	638 871/2 755 090 (23.2%)	(296 851 to 922 944)	1 386 228/8 457 936 (16.3%)	(624 131 to 2 129 006)	83 597/401 140 (20.7%)	(37 996 to 123 420)	44 125/158 805 (28%)	(21 215 to 62 083)
DALYs	61 932	(29 901 to 94 542)	187 209	(84 532 to 306 445)	10 412	(4799 to 16 166)	6441	(3104 to 9530)
Direct medical cost, US$ (million)	$903/$3896 (23%)	($420 to $1305)	$575.3/$3510.3 (16.4%)	($259 to $884)	$43.8/$ 210.2 (20.8%)	($19.9 to $64.7)	$5.3/$19.2 (27.8%)	($2.6 to $7.5)
*Cardiac diseases***								
Deaths	1801/36 997 (4.8%)	(858 to 2759)	3590/1 22 465 (2.9%)	(1654 to 5910)	170/3910 (4.2%)	(81 to 265)	102/1680 (5.9%)	(48 to 154)
Events	53 575/1 025 944 (5%)	(25 612 to 81 840)	137 440/4 088 529 (3.4%)	(65 165 to 217 649)	3797/87 249 (4.3%)	(1796 to 5854)	1974/31 500 (6.2%)	(948 to 3000)
DALYs	20 091	(9817 to 31 540)	72 892	(33 998 to 120 730)	3672	(1750 to 5725)	1566	(750 to 2407)
Direct medical cost, US$ (million)	$97.7/$ 1845.9 (5.3%)	($47 to $ 149)	$53.1/$1592.8 (2.9%)	($25 to $85)	$10.2/$232.2 (4.4%)	($4.8 to $15.6)	$6.8/$108 (6.3%)	($3.3 to $10.4)
Cerebrovascular diseases								
Deaths	1056/21 155 (5%)	(504 to 1616)	3414/115 383 (3%)	(1568 to 5593)	58/1314 (4.4%)	(27 to 89)	42/701 (6%)	(20 to 64)
Events	29 031/515 296 (5.6%)	(13 935 to 44 171)	91 411/2 590 589 (3.5%)	(43 293 to 143 770)	2086/45 685 (4.6%)	(1002 to 3210)	1116/16 765 (6.7%)	(539 to 1689)
DALYs	18 724	(9157 to 29 284)	76 907	(36 165 to 127 389)	1528	(732 to 2398)	781	(380 to 1210)
Direct medical cost, US$ (million)	$57.5/$1008.3 (5.7%)	($28 to $87)	$53.1/$1473.9 (3.6%)	($25 to $84)	$7.4/$159.2 (4.6%)	($3.5 to $11.4)	$5.9/$88.9 (6.6%)	($ 2.8 to $ 8.9)
Musculoskeletal diseases								
Deaths	0	(0 to 0)	0	(0 to 0)	0	(0 to 0)	0	(0 to 0)
Events	33 777/9 457 267 (0.4%)	(22 230 to 53 137)	79 433/40 335 594 (0.2%)	(51 466 to 123 449)	1671/653 980 (0.3%)	(1112 to 2585)	651/160 853 (0.4%)	(428 to 1027)
DALYs	2397	(2111 to 5045)	5926	(5147 to 12 345)	117	(105 to 245)	43	(37 to 89)

Continued

Table 2 Continued

Condition	Argentina		Brazil		El Salvador		Trinidad and Tobago	
Direct medical cost, US$ (million)	$1.6/$520.3 (0.3%)	($1 to $3)	$1.3/$726.7 (0.2%)	($1 to $2)	$0.18/$78.2 (0.2%)	($0.1 to $0.3)	$0.05/$13.1 (0.4%)	($0 to $0.1)
Chronic kidney disease								
Deaths	90/7181 (1.3%)	(60 to 145)	209/27 156 (0.8%)	(136 to 320)	30/2770 (1.1%)	(21 to 48)	7/341 (1.8%)	(4 to 10)
Events	21 428/1 669 691 (1.3%)	(14 395 to 33 962)	74 725/9 659 638 (0.8%)	(48 059 to 114 729)	3997/370 933 (1.1%)	(2677 to 6134)	1535/82 290 (1.9%)	(1018 to 2413)
DALYs	1671	(1132 to 2723)	5180	(3406 to 8037)	738	(498 to 1137)	118	(78 to 194)
Direct medical cost, US$ (million)	$ 18.6 / $ 1451.4 (1.3%)	($ 13 - $ 30)	$ 28.5 / $ 3689 (0.8%)	($18-$44)	$1.5/$138.3 (1.1%)	($1 to $2.3)	$2.8/$149.6 (1.9%)	($1.9 to $4.4)
Asthma								
Deaths	4/486 (0.9%)	(3 to 7)	12/2471 (0.5%)	(7 to 18)	0/99 (0%)	(0 to 1)	0/42 (0%)	(0 to 1)
Events	15 989/1 594 510 (1%)	(10 581 to 25 097)	27 333/10 090 834 (0.3%)	(17 717 to 42 324)	1879/414 877 (0.5%)	(1252 to 2931)	77/9260 (0.8%)	(49 to 120)
DALYs	675	(472 to 1116)	1244	(854 to 2070)	74	(49 to 138)	14	(2 to 26)
Direct medical cost, USD (million)	$ 13.9 / $ 1386 (1%)	($ 9- $ 22)	$ 10 / $ 3723.4 (0.3%)	($7-$16)	$ 2.3 / $ 513.4 (0.5%)	($ 1.5 - $ 3.5)	0.05 / $ 5.7 (0.8%)	($ 0 - $ 0.1)
*Other diseases****								
Deaths	157/32 061 (0.5%)	(106 to 253)	343/124 691 (0.3%)	(216 to 529)	4/841 (0.5%)	(3-6)	4/528 (0.8%)	(3-6)
Events	9181/861 525 (1%)	(6159 to 14 421)	14 262/2 717 004 (0.5%)	(9155 to 22 052)	730/69 952 (1%)	(480-1,126)	244/16 952 (1.4%)	(161 to 382)
DALYs	2003	(1382 to 3290)	6048	(3870 to 9464)	103	(78-158)	53	(42 to 84)
Direct medical cost, US$ (million)	$6.9/$1042 (0.7%)	($5 to $11)	$4.6/$1355.4 (0.3%)	($3-$7)	$0.68/$126.3 (0.5%)	($0.5 to $1)	$0.19/$21.9 (0.9%)	($0.1 to $0.3)
Total								
Deaths	**4425**/105 799 (**4.2%**)	**(2773 to 6146)**	**12 749**/436 183 (**2.9%**)	**(8070-18 500)**	**499**/10 414 (**4.8%**)	**(333 to 677)**	**386**/4340 (**8.9%**)	**(243 to 522)**
Events	**2 096 631**/42 294 119 (**5%**)	**(1 361 844 to 3 3132 030)**	**4 752 639**/166 229 433 (**2.9%**)	**(3 254 303-6 391 220)**	**214 082**/4 974 851 (**4.3%**)	**(129 500 to 309 552)**	**76 208**/1 185 609 (**6.4%**)	**(43,836 to 112 565)**
DALYs	**11 029**	**(53 972 to 167 540)**	**355 405**	**(167 972 to 586 480)**	**16 643**	**(8011 to 25 967)**	**9016**	**(4393 to 13 540)**
Direct medical cost, US$ (million)	**$1159.3**/$12 185.1 (**9.5%**)	**($687.2 to $1633.6)**	**$758.3**/$16 694 (**4.5%**)	**($362.3 to $1171.7)**	**$69.5**/$1530.7 (**4.5%**)	**($43.6 to $96.3)**	**$23.1**/$448.6 (**5.1%**)	**($12 to $ 35.3)**

US$ exchange rate. Argentina: 48.14; Brazil: 3.94; El Salvador: 1; Trinidad and Tobago: 6.75. Source: https://data.worldbank.org/indicator/PA.NUS.FCRF.
*Percentage indicates the proportion of all cases of X disease (ie, diabetes) that could be attributable to SSBs consumption; for example, in Argentina, 513 958 cases of overweight+obesity in adults could be attributable to SSBs consumption; it represents 2.5% of all cases of overweight+obesity in Argentina.
†Includes: atrial fibrillation, ischaemic heart disease and hypertensive heart disease.
‡Includes: cancer, Alzheimer's disease and dementias, gallbladder and biliary disease.
.DALYs, disability-adjusted life years.

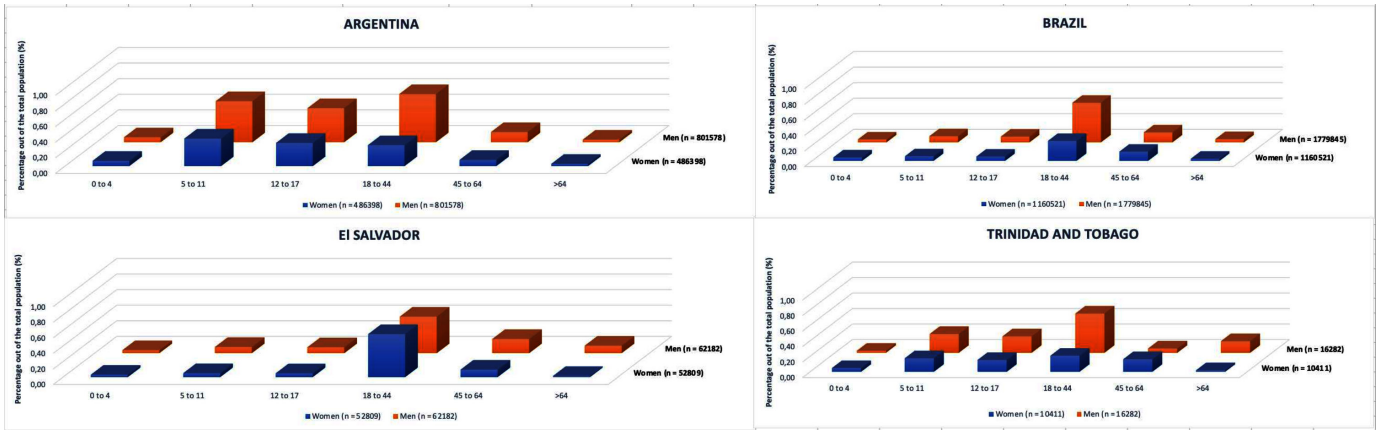

Figure 2 Overweight and obesity total events attributable to SSBs consumption by gender and age group in Argentina, Brazil, El Salvador, and Trinidad and Tobago. SSBs, sugar-sweetened beverages.

most affected, with 50 000 SSB-attributable events and close to 400 SSB-attributable deaths per million adults.

DISCUSSION

This is the first study to assess the disease burden of SSB consumption in LAC with a simulation model tailored for the region and capable of estimating attributable disease events, deaths, DALYs as well as direct medical costs predictions. Our findings show that SSB consumption is associated with a substantial health and economic burden in Argentina, Brazil, Trinidad and Tobago, and El Salvador. For 1 year, SSB consumption was associated with 18 000 deaths, seven million disease events, a half million DALYs and US$2 billion in direct medical costs in these four countries. Furthermore, more than 4.3 million cases of obesity and overweight and 2.2 million cases of diabetes could be attributed to SSBs consumption. Twelve per cent of all obesity cases in children and adolescents and 19% of the total cases of T2DM in adults was associated with SSBs consumption.

The study's findings are consistent with previous studies, both on the direction and magnitude of effects. As part of a global disease burden study, Singh *et al*[16] considered only the BMI-mediated effects of SSB intake on CVD and found for 2010 a substantial absolute and proportional burden in SSB-related mortality and morbidity in LAC as compared with other regions. These findings were interpreted in the context of the low cost of SSBs in the region, as well as the suboptimal implementation of taxes and regulation of advertising and limited access to clean drinking water, all conditions that remain almost unchanged in most LAC countries.

In line with our findings, a study conducted in Argentina estimated that over the 2015–2024 period, a realistic 10% reduction in SSB consumption with a caloric compensation of 39% was projected to reduce incident

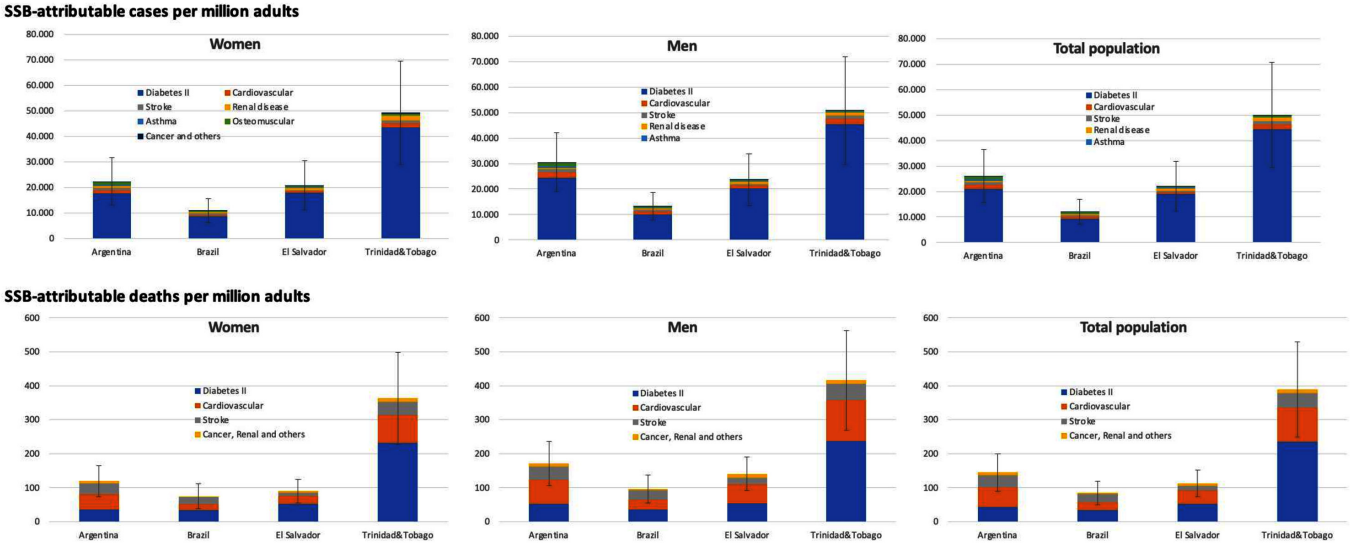

Figure 3 SSB-attributable events and deaths per million adults in Argentina, Brazil, El Salvador, and Trinidad and Tobago. SSB, sugar-sweetened beverage.

diabetes cases by 13 300–27 700 and myocardial infarction events by 2500–5100 compared with a scenario of no change in SSB consumption, with the largest reductions in the youngest and in males.[30]

We found a markedly higher SSB attributable burden in Trinidad and Tobago, a finding also observed in previous studies.[18] This is not explained by consumption—which is just slightly higher in Trinidad and Tobago—but it could be attributable to the higher incidence and prevalence rates of SSB-related diseases, such as diabetes and cardiovascular disease, which was more than twice that of the other countries in the study.

One strength of this study is that a model adapted to the availability and quality of epidemiological and cost information data in LAC was developed. We also incorporated the best available evidence for the direct effects of SSBs on BMI, diabetes mellitus, cardiovascular disease and on the diseases associated with overweight and obesity. The additional inclusion of recent evidence on the direct effect of SSBs on cardiovascular disease independent of BMI constitutes an innovation and has contributed to the achievement of results that more accurately reflect the prevailing epidemiological reality. We performed sensitivity analyses, which also contribute to a more contextualised interpretation of the results and their uncertainty. The inclusion of four countries, with diverse socioeconomic and epidemiological realities, provide elements for a more informed extrapolation of the results to other countries and regions. The early involvement of decision makers and key leaders in this study allows us to have the information they prioritised to promote change in public policies.

One of the main limitations of our study is that the results are highly dependent on the information from epidemiological parameters, SSB consumption and costs, whose quality and availability may be limited in many LAC countries. Our analysis considered the most important set of health outcomes linked to SSBs but may represent an underestimation of the real burden given that we did not include other important dimensions such as dental decay, or the social and psychological impact on children and adults of being obese. Additionally, we only considered the direct medical costs generated by SSBs, which are only a portion of the total financial burden if other dimensions such as productivity losses or caregivers' burden are included.

The countries of our region have a high consumption of unhealthy products, including SSBs, and this consumption is partly responsible for the epidemic of chronic diseases that have impacted LAC in recent decades and has been invisible for years. The information generated could be used by the Ministries of Health of the participant countries for the design of evidence-based public policies.

It is important to implement healthy taxes in LAC countries to achieve decreases in consumption. There is evidence that increasing taxes can produce important public benefits, with Mexico being the first country that successfully promoted this type of change in the region.[20] Also, in Brazil, Claro *et al*[31] reported that a 1% increase in the price of SSBs could led to a 0.85% reduction of SSB calories consumed (1.03% reduction for the poor and 0.63% for the non-poor).

Likewise, reformulation of SSBs to reduce sugar content could produce measurable reductions in consumption for populations in LAC countries.[32]

Furthermore, the beneficial effect that warning labels could have on public health and in effectively reducing obesity and its associated costs was studied in Mexico. The expected impact of beverage labelling could lead to a 10.5% reduction in calories consumed.[33] Mexico, Chile, Peru, Uruguay and recently Argentina have already implemented labelling for ultra-processed foods and are beginning to benefit from these changes.

Remaining research gaps include the analyses of direct/indirect costs of the burden of SSBs in LAC, and the determination of the expected impact on SSB consumption of bans on formal media and social network advertising, regulation of SSBs in the school environment and the exploration of the joint effect of various food policies.

LAC is a region that suffers a disproportionate burden of disease and death attributable to consumption of SSBs. It is also a region in which there are several natural targets for policy-driven interventions: the low price of SSBs, lack of regulation of advertising and/or suboptimal implementation of existing regulations; the lack of awareness in the population about the risks associated with the consumption of SSBs; and the absence of food warning labels in many countries. This study can make a valuable contribution to draw the attention of the population and decision makers to this important public health problem, as well as to provide support to the policy interventions that many countries are struggling to implement.

Author affiliations
[1]Health Techonology Assessment and Economic Evaluation Department, Institute for Clinical Effectiveness and Health Policy, Buenos Aires, Argentina
[2]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Buenos Aires, Argentina
[3]Centre for Health Economics, The University of the West Indies at St Augustine, St Augustine, Tunapuna-Piarco, Trinidad and Tobago
[4]Health Economics Department, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil
[5]Universidad Católica de El Salvador, Santa Ana, El Salvador
[6]ACT Promoção da Saúde, Sao Paulo, Brazil

Twitter Andrea Alcaraz @AndrealECS and Alfredo Palacios @AlfrePalacios13

Contributors AA: guarantor, project administration, research conceptualisation, research design, modelling, analysis, discussion and writing. AEB: research conceptualisation, research design, modelling, analysis, discussion and writing. NE: modelling lead, research conceptualisation, research design, discussion and writing. LP, FRC, AP and FA: research conceptualisation, research design, analysis, discussion and writing. ALF, CMdMV, GG, K-AG-B, PJ, VB and DJB: research conceptualisation, research design, analysis, review and editing. AP-R: modelling lead, research conceptualisation, research design, analysis, discussion and writing.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

ORCID iDs
Andrea Alcaraz http://orcid.org/0000-0002-4260-8239
Federico Rodriguez Cairoli http://orcid.org/0000-0002-3029-4439

REFERENCES

1 Noncommunicable diseases. Available: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases [Accessed 5 Jan 2022].
2 Murphy A, Palafox B, Walli-Attaei M, *et al*. The household economic burden of non-communicable diseases in 18 countries. *BMJ Glob Health* 2020;5:e002040.
3 Transforming our world: The 2030 agenda for sustainable development. In: *A New Era in Global Health*. New York, NY: Springer Publishing Company, 2018.
4 Murray CJL, Aravkin AY, Zheng P. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the global burden of disease study 2019. *Lancet* 2020;396:S0140-6736(20)30752-2:1223–49.:.
5 Vardell E. Global health observatory data Repository. *Med Ref Serv Q* 2020;39:67–74.
6 Rivera JÁ, de Cossío TG, Pedraza LS, *et al*. Childhood and adolescent overweight and obesity in Latin America: a systematic review. *Lancet Diabetes Endocrinol* 2014;2:S2213-8587(13)70173-6:321–32.:.
7 Tremmel M, Gerdtham U-G, Nilsson PM, *et al*. Economic burden of obesity: a systematic literature review. *Int J Environ Res Public Health* 2017;14:435.
8 Malik VS, Popkin BM, Bray GA, *et al*. Sugar-Sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. *Circulation* 2010;121:1356–64.
9 Malik VS, Hu FB. Sugar-Sweetened beverages and cardiometabolic health: an update of the evidence. *Nutrients* 2019;11:1840.
10 Valenzuela MJ, Waterhouse B, Aggarwal VR, *et al*. Effect of sugar-sweetened beverages on oral health: a systematic review and meta-analysis. *Eur J Public Health* 2021;31:122–9.
11 Bomback AS, Derebail VK, Shoham DA, *et al*. Sugar-Sweetened soda consumption, hyperuricemia, and kidney disease. *Kidney Int* 2010;77:609–16.
12 Mekonnen TA, Odden MC, Coxson PG, *et al*. Health benefits of reducing sugar-sweetened beverage intake in high risk populations of California: results from the cardiovascular disease (CVD) policy model. *PLoS One* 2013;8:e81723.
13 Chen L, Caballero B, Mitchell DC, *et al*. Reducing consumption of sugar-sweetened beverages is associated with reduced blood pressure: a prospective study among United States adults. *Circulation* 2010;121:2398–406.
14 Chen L, Appel LJ, Loria C, *et al*. Reduction in consumption of sugar-sweetened beverages is associated with weight loss: the premier trial. *Am J Clin Nutr* 2009;89:1299–306.
15 Bleich SN, Vercammen KA. The negative impact of sugar-sweetened beverages on children's health: an update of the literature. *BMC Obes* 2018;5:6.
16 Gui Z-H, Zhu Y-N, Cai L, *et al*. Sugar-Sweetened beverage consumption and risks of obesity and hypertension in Chinese children and adolescents: a national cross-sectional analysis. *Nutrients* 2017;9:1302.
17 Sandoval RC, Roche M, Belausteguigoitia I, *et al*. Excise taxes on sugar-sweetened beverages in Latin America and the Caribbean. *Rev Panam Salud Publica* 2021;45:e21.
18 Singh GM, Micha R, Khatibzadeh S, *et al*. Global, regional, and national consumption of sugar-sweetened beverages, fruit juices, and milk: a systematic assessment of beverage intake in 187 countries. *PLoS One* 2015;10:e0124845.
19 encuesta-nac-nutricion-salud_resumen-ejecutivo.pdf. Available: https://bancos.salud.gob.ar/sites/default/files/2020-01/encuesta-nac-nutricion-salud_resumen-ejecutivo.pdf
20 Barrientos-Gutierrez T, Zepeda-Tello R, Rodrigues ER, *et al*. Expected population weight and diabetes impact of the 1-peso-per-litre Tax to sugar sweetened beverages in Mexico. *PLoS One* 2017;12:e0176336.
21 Basto-Abreu A, Braverman-Bronstein A, Camacho-García-Formentí D, *et al*. Correction: expected changes in obesity after reformulation to reduce added sugars in beverages: a modeling study. *PLOS Med* 2019;16:e1002743.
22 Alcaraz A, Pichon-Riviere A, Palacios A, *et al*. Sugar sweetened beverages attributable disease burden and the potential impact of policy interventions: a systematic review of epidemiological and decision models. *BMC Public Health* 2021;21:1460.
23 Alcaraz A, Jones D, Rodriguez B, *et al*. Decision makers dialogue: empowering decision makers to meet regional information needs to promote public policies on sugar-sweetened beverages in latin america and the caribbean. *Instituto de Efectividad Clínica y Sanitaria* 2019.
24 Ananthapavan J, Jan Berendregt VB, *et al*. Assessing cot-effectiveness of obesity prevention policies in australia. *ACE-OBESITY POLICY* 2018. Available: http://www.aceobesitypolicy.com.au
25 Imamura F, O'Connor L, Ye Z, *et al*. Consumption of sugar sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review, meta-analysis, and estimation of population attributable fraction. *BMJ* 2015;351:h3576.
26 Yin J, Zhu Y, Malik V, *et al*. Intake of sugar-sweetened and low-calorie sweetened beverages and risk of cardiovascular disease: a meta-analysis and systematic review. *Adv Nutr* 2021;12:89–101.
27 Micha R, Shulkin ML, Peñalvo JL, *et al*. Etiologic effects and optimal intakes of foods and nutrients for risk of cardiovascular diseases and diabetes: systematic reviews and meta-analyses from the nutrition and chronic diseases expert group (nutricode). *PLoS One* 2017;12:e0175149.
28 Ebbeling CB, Feldman HA, Chomitz VR, *et al*. A randomized trial of sugar-sweetened beverages and adolescent body weight. *N Engl J Med* 2012;367:1407–16.
29 GHO | by category | life tables by country - argentina. Available: https://apps.who.int/gho/data/view.main.60050?lang=en [Accessed 5 Jan 2022].
30 Salgado MV, Penko J, Fernandez A, *et al*. Projected impact of a reduction in sugar-sweetened beverage consumption on diabetes and cardiovascular disease in Argentina: a modeling study. *PLoS Med* 2020;17:e1003224.
31 Claro RM, Levy RB, Popkin BM, *et al*. Sugar-Sweetened beverage taxes in Brazil. *Am J Public Health* 2012;102:178–83.
32 Basto-Abreu A, Braverman-Bronstein A, Camacho-García-Formentí D, *et al*. Expected changes in obesity after reformulation to reduce added sugars in beverages: a modeling study. *PLoS Med* 2018;15:e1002664.
33 Basto-Abreu A, Torres-Alvarez R, Reyes-Sánchez F, *et al*. Predicting obesity reduction after implementing warning labels in Mexico: a modeling study. *PLoS Med* 2020;17:e1003221.