The equitable impact of sugary drink taxation structures on sugary drink consumption among Canadians: a modelling study using the 2015 Canadian Community Health Survey-Nutrition

Brendan T Smith [1,2], Christine M Warren [1], Laura N Anderson [3,4], David Hammond [5], Douglas G Manuel [6,7,8], Ye Li [1,2], Alessandra T Andreacchi [1,2], Laura C Rosella [2,9,10], Sze Hang Fu[1], Erin Hobin [1,2]

[1]Public Health Ontario, 480 University Avenue, Suite 300, Toronto, ON M5G 1V2, Canada
[2]Dalla Lana School of Public Health, University of Toronto, 155 College St Room 500, Toronto, ON M5T 3M7, Canada
[3]Department of Health Research Methods, Evidence, and Impact, McMaster University, 1280 Main Street West, Hamilton, ON L8S 4L8, Canada
[4]Child Health Evaluative Sciences, Sickkids Research Institute, 686 Bay St, Toronto, ON M5G 0A4, Canada
[5]School of Public Health Sciences, University of Waterloo, 200 University Avenue West, Waterloo, ON N2L 3G1, Canada

This is an Accepted Manuscript for Public Health Nutrition. This peer-reviewed article has been accepted for publication but not yet copyedited or typeset, and so may be subject to change during the production process. The article is considered published and may be cited using its
DOI 10.1017/S1368980024000545
Public Health Nutrition is published by Cambridge University Press on behalf of The Nutrition Society.

[6]Ottawa Hospital Research Institute, Clinical Epidemiology, 501 Smyth Box 511, Ottawa, ON K1H 8L6, Canada

[7]Department of Family Medicine, and School of Epidemiology and Public Health, University of Ottawa, 600 Peter Morand Crescent Room 101, Ottawa, ON K1H 8L6, Canada

[8]Bruyère Research Institute, 85 Primrose Ave, Ottawa ON K1R 6M1, Canada

[9]Institute for Better Health, Trillium Health Partners, 100 Queensway West, Mississauga ON L5B 1B8, Canada

[10]Department of Laboratory Medicine and Pathobiology, Temerty Faculty of Medicine, University of Toronto, 1 King's College Circle, Toronto ON M5S 1A8, Canada

Corresponding author: Brendan Smith, PhD, Public Health Ontario, 480 University Avenue, Suite 300, Toronto, ON M5G 1V2 Canada, Tel: 647 260-7446 , Email: brendan.smith@oahpp.ca

Short title: Impact of a sugary drink tax in Canada [not exceeding 45 characters]

Acknowledgements: We thank Salma Hack for providing nutrition-related analytical support using the Canadian Community Health Survey – Nutrition 2015.

Financial Support: This research was funded by the Canadian Institutes of Health Research (CIHR Project Grant #391602). CIHR had no role in the design, analysis or writing of this article.

Conflict of Interest: None

Authorship: BTS, EH contributed to the conception and design of this work. BTS and DGM acquired funding for this work. CMW and SHF contributed to the formal analysis. BTS, CW and SHF contributed to the interpretation of data and results; BTS, CMW, LNA, DH, DGM, YL, ATA, LCR, SHF and EH contributed to this study's methodology. BTS led this works' supervision. BTS and CW contributed to the writing of the original draft. All authors contributed to review and editing of this work, and have read and approved the final manuscript.

Abstract

Objective: Estimate the impact of 20% flat-rate and tiered sugary drink tax structures on the consumption of sugary drinks, sugar-sweetened beverages, and 100% juice by age, sex, and socioeconomic position.

Design: We modelled the impact of price changes –for each tax structure– on the demand for sugary drinks by applying own- and cross-price elasticities to self-report sugary drink consumption measured using single day 24-hour dietary recalls from the cross-sectional, nationally-representative 2015 Canadian Community Health Survey-Nutrition. For both 20% flat-rate and tiered sugary drink tax scenarios, we used linear regression to estimate differences in mean energy intake and proportion of energy intake from sugary drinks by age, sex, education, food security and income.

Setting: Canada.

Participants: 19,742 respondents aged 2 and over.

Results: In the 20% flat-rate scenario, we estimated mean energy intake and proportion of daily energy intake from sugary drinks on a given day would be reduced by 29 kcal/day (95%UI: 18, 41) and 1.3% (95%UI: 0.8, 1.8), respectively. Similarly, in the tiered tax scenario, additional small, but meaningful reductions were estimated in mean energy intake (40 kcal/day, 95%UI: 24, 55) and proportion of daily energy intake (1.8%, 95%UI: 1.1, 2.5). Both tax structures reduced, but did not eliminate, inequities in mean energy intake from sugary drinks despite larger consumption reductions in children/adolescents, males and individuals with lower education, food security and income.

Conclusions:

Sugary drink taxation, including an additional benefit of taxing 100% juice, could reduce overall and inequities in mean energy intake from sugary drinks in Canada.

Keywords: sugary drinks; sugar-sweetened beverages; taxation; policy; health equity, socioeconomic factors

Introduction

Sugary drinks, defined as beverages with added sugars (e.g., sugar-sweetened beverages (SSB), a subset of sugary drinks) and beverages with natural intrinsic sugars (e.g.,100% juice), are associated with increased chronic disease risk in children and adults, including obesity, type 2 diabetes and cardiovascular disease[1,2]. Excise taxation of sugary drinks, levied at the point of manufacturing or distribution, is well-established to reduce population-level intake, and related health, economic and social costs[3]. Evidence from real-world SSB taxation policies suggests that excise taxes result in higher prices, reduced sales and increased revenue for investment in public heath priorities[4]. A systematic review and meta-analysis of high quality international studies found that excise SSB taxes had an average pass-through rate (defined as the proportion of the excise tax that is reflected in the retail price of the product) of 79% (95%CI: 60, 97) which increased the overall SSB prices, and was associated with a corresponding 13% (95%CI: 6, 20) mean reduction in SSB sales (a price elasticity of demand of −1.39 (95%CI: -1.86, -0.91))[5]. Sugary drinks taxes are considered a World Health Organization (WHO) 'best-buy' intervention, recommended as part of a suite of population-level interventions to reduce sugar consumption, including: financial (e.g., excise taxation, incentives), advertising, health beverage defaults, and restricted availability[4].

Internationally, SSB taxes have been implemented in 105 jurisdictions, covering 51% of the world's population[6]. The targeted beverages, tax rate, and tax structure are important considerations for the development of sugary drink taxes. To date, existing sugary drink taxes have overwhelmingly targeted SSBs, omitting important sources of free sugar consumption from 100% juice. Further, on average, implemented SSB tax rates have been 10% or less[5], falling below the WHO recommended 20% flat excise tax[2]. The structure of existing sugary drink taxation policies also vary, targeting the overall price of the product (e.g., flat-rate), the amount of volume of beverage purchased, or the concentration of sugar (e.g., tiered tax design) or other tax instruments that apply to a broad range of goods and services (e.g., import taxes or sale taxes)[7], which can lead to heterogeneous effects of SSB taxation. Flat-rate tax structures aim to shift individual consumer behaviour away from sugary drinks. Tiered tax structures can additionally incentivize sugary drink reformation by manufacturers to reduce sugar content under tax thresholds, which can indirectly reduce sugar consumption through reduced sugar content of

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

sugary drinks[8]. A recent global review of SSB taxes found that only 18% (18 of 104) of SSB taxes worldwide apply a tiered tax structure[6]. Tiered SSB taxes were predominant identified in high income countries, as they can be more burdensome to implement than flat-rate structures due to their contingency on sugar concentrations of each product[9].

In Canada, a national sugary drink tax has not been adopted, despite these beverages contributing 21% (aged 9-18) and 17% (aged 19+) of Canadians' total sugar consumption[10,11] and a higher prevalence of consumption and mean energy intake from sugary drinks among individuals with low compared to high socioeconomic position (SEP)[12]. A recent Canadian study estimated that total free sugar consumption above 10% of total energy intake, WHO's benchmark for total free sugar intake, cost Canada's healthcare system 2.5 billion CAD in 2019 from direct (1.1 billion CAD) and indirect (1.4 billion CAD) costs[13]. Subnational SSB taxes exist in the Canadian provinces of Newfoundland and Labrador (a 20cent/L sugary drink tax levied on manufacturers since September 2022[14]) and in British Columbia (where soda beverages are no longer exempt from the 7% Provincial Sales Tax applied to food products for human consumption as of April 2021[15]). The impact of these sugary drink taxes have not yet been evaluated, however their introduction suggests sugary drink taxes are an acceptable policy option for reducing the health and economic burden associated with sugary drink consumption in Canada.

Additional evidence is required to inform the development of a national sugary drink tax in Canada. First, while tiered taxes have been implemented across jurisdictions, the potential impact of this taxation structure has not been examined in Canada. Second, natural and added sugars are indistinguishable through the metabolic process in humans[2], therefore despite containing essential nutrients and possibly contributing to a healthy diet in moderation, it is important to consider 100% juice in potential taxation scenarios which are often omitted from SSB taxes. Third, evidence regarding the extent to which SSB tax outcomes are heterogeneous across sociodemographic factors is limited[5], with evidence from a systematic review suggesting the tax would deliver similar if not greater benefits for individuals with lower SEP[16]. Studies modelling the potential impact of sugary drink taxes across SEP have focused on income (individual or ecological) as the sole indicator of SEP[17–19]. It is important to understand the impact of such policies across additional indicators of SEP to fully reflect social pathways

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

associated with consumption and health[20]. Modelling studies are useful to estimate and compare the impact on consumption under multiple potential implementation scenarios[9]. Our study objective was to estimate the impact of implementing 20% flat-rate and separately, tiered sugary drink tax structures on consumption of sugary drinks, SSB, and 100% juice across age, sex, and SEP in Canada using the most recent population representative dietary intake data available in Canada.

Methods

Data source

We conducted a modelling study using data from the 2015 Canadian Community Health Survey-Nutrition (CCHS-N)[21]. The cross-sectional CCHS-N is the most recent nationally-representative assessment of Canadians' dietary intakes since 2004. The CCHS-N, administered by Statistics Canada, used interviewer-administered 24-hour dietary recalls adapted from the Automated Multi-Pass Method from the United States Department of Agriculture[22]. A multi-stage, cluster sampling approach was used to secure a sample of 20,487 Canadians aged 1 and older living in private dwellings across the 10 provinces (61% response rate)[21].

We included single day 24-hour dietary recalls among Canadians aged 2 and older (n=20,115). We excluded respondents if they were breastfeeding or reported no energy intake (n=200), or were missing information on income (n=22), education (n=41) or food security (n=110). The final analytic sample included 19,742 respondents.

Modelled interventions: Flat-rate and tiered sugary drinks tax

Tax structures

We modelled two sugary drink taxation structures: 1) a 20% flat-rate tax, the most commonly advocated tax by public health experts[3]; and, 2) a tiered tax that applied 10% (2-4.9 g/100ml), 20% (5-7.9 g/100ml), or, 30% (≥ 8 g/100ml) tax based on the amount of sugar per volume. Tiers were defined based on the UK Sugar Drinks Industry Levy[23], with tax levels matching a previous Canadian experimental study[24] (tax assumptions and beverages list available in **Supplementary Table 1**).

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

Beverage tax base options

We examined three potential beverage tax bases: sugary drinks (all beverages containing free sugars, which includes both added and natural sugars), SSB (beverages containing added sugars only) and, 100% juice (beverages containing natural sugars only). Sugary drinks included both SSB and 100% juice[12]. Briefly, we estimated per-capita energy intake (kcal) on a given day from each beverage category by applying Health Canada's sugary drinks definition[25] to Nutrition Survey System (NSS) codes linked to Canadian Nutrient File (CNF) descriptions (sugary drinks = 249 codes, SSB = 190 codes, 100% juice = 59 codes). For each beverage category, we estimated their relative proportion of daily energy intake from all food and beverages consumed (%).

Model inputs – price to demand

We modelled the impact of price changes – for each tax scenarios– on the demand for sugary drinks using price elasticities. Own-price elasticities (OPE) represent the responsiveness of demand for a product to a percentage change in the price of that product. Cross-price elasticities (CPE) represent responsiveness of demand for one product to a percentage change in the price of another product. Price elasticities for sugary drinks were derived from a recent meta-analysis which estimated a -1.39 (95%CI: -1.86, -0.91) OPE of sugar-sweetened beverages from high quality studies and 0.42 (95%CI: -0.52, 1.35) CPE for beverage substitutions (e.g., milk, diet beverages) at an average pass-through of taxation from manufacturer to consumer of 79%[5]. To estimate the impact of taxation by SEP, we applied the percentage change of income-specific price elasticities from a Canadian study[17], assuming that the OPE and CPE from the meta-analysis[5] represented the average of the middle income quintile (Q3). Detailed methods for parameters are available in **Supplementary Table 2**. Each CCHS-N respondent was assigned price elasticities for 1% increase in price for each beverage type based on reported household income-quintile[17].

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

Model inputs – demand to energy intake from sugary drinks

We modelled the impact of the demand on energy intake from sugary drinks by multiplying income-specific OPE and CPE by the modelled tax amount (e.g., 10%, 20% or 30%) for each respondent, beverage, and tax scenario. Energy intake from taxed beverages and CPE-impacted beverages was estimated by taking the product of the expected demand change for each tax scenario and reported energy intake from each beverage type. Energy estimates from all other food/beverages items were unchanged. For each respondent, we summed modelled energy intake for each beverage type and from all sources for each tax scenario.

Primary outcomes

Our primary outcomes were per-capita mean energy intake (kcal) and proportion of daily energy intake (%) – i.e., the ratio of energy intake from taxed beverages to all food/beverage items – from sugary drinks, SSB, and 100% juice on a given day.

Exposures

We examined study outcomes across a sociodemographic characteristics. We categorized sex as female or male and age into children/adolescents (aged 2-18) or adults (aged 19+). We categorized highest level of household education into four groups: “less than high school”, “high school diploma”, “certificate below bachelor’s degree” (e.g., a trade, college, or non-bachelor certificate), or “bachelor degree or above”. Household food security status was assessed by eight questions for children/adolescents (aged 2-18) and ten for adults (aged 19+) with responses classified as either food secure (i.e., answered “yes” to 0-1 questions about difficulty with income-related food access) or food insecure (i.e., answered “yes” to two or more questions about compromised quality/quantity or reduced food intake due to disrupted eating patterns)[22]. Household income adequacy quintiles were derived based on the adjusted ratio of the respondents’ total household income reported in the previous 12 months to the low income cut-off corresponding to their household and community size[22].

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

Statistical Analysis

We estimated means, mean differences and corresponding 95% confidence intervals (CI) using ordinary linear regressions (OLS) and the least-squared means procedure for per-capita mean energy intake and proportion of daily energy intake on a given day, for sugary drinks, SSBs, and 100% juice overall and across sociodemographic characteristics measured in the 'no tax' scenario (i.e., CCHS-N) and for each modelled taxation scenario. In addition, we used OLS regressions to estimate the change in per-capita mean energy intake (change in kcal) and proportion of daily energy intake (change in percentage-points) measured in the 'no tax' compared to each modelled taxation scenario across sociodemographic characteristics. All models were unadjusted to estimate actual intake in population representative surveys[26].

We derived 95% uncertainty intervals (UI) using a probabilistic approach. We selected 20 OPE and 20 CPE values based on their probability distributions. For the per-capita mean energy intakes, we fit 20 regression models since the energy intake from sugary drinks is only affected by OPE but not CPE; while for the proportion of daily energy intake, we fit 400 regression models based on the 400 pairs of OPE-CPE values. Each model was bootstrapped (500 repetitions) following Statistics Canada procedures to account for the CCHS-N's complex survey design[21]. Survey sample weights were applied to all analyses to produce population representative estimates[21]. We applied Rubins' Rules, designed for pooling repeated parameter estimates that are normally distributed from multiple imputation, to derive pooled estimates and uncertainty intervals from the regression models[27]. We used the "miceadds" R package to obtain the pooled estimates. Statistical analyses were conducted using R v4.3.1.

We explored several deterministic sensitivity analyses to assess the robustness of our findings. Specifically, we varied the following model inputs: 1) applied a consistent own price elasticity of -1.39 (95%CI: -1.86, -0.91) [5] assuming similar price responses across income[19]; 2) applied a smaller own price elasticity -1.00 (95% CI: -1.47, -0.50) from an earlier systematic review and meta-analysis[28]; and, 3) for both taxation scenarios, assumed 100% pass-through rate from manufacturer to consumer.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

Results

We estimated mean per-capita energy intake and proportion of daily energy intake from sugary drinks, on a given day, across sociodemographic characteristics measured in the CCHS-N (**Table 1)**. Overall, Canadians consumed on average 127 kcal (95%CI: 122, 132) from sugary drinks, which was 6.7% (95%CI: 6.4, 7.0) of daily energy intake. Mean per-capita energy intake and the proportion of daily energy intake from sugary drinks was 57 kcal (95%CI: 46, 68) and 3.4% (95%CI: 2.8, 3.9) higher in Canadians aged 2-18 compared to 19+. Mean energy intake from sugary drinks was 47 kcal (95%CI: 38, 56) higher in males compared to females. Sugary drink consumption on a given day was higher among individuals with 'high school diploma' (18 kcal, 95%CI: 4, 32) and 'certificate below bachelor's degree' (17 kcal, 95%CI: 4, 29) compared to 'bachelor's degree or above', in food insecure compared to the food secure group (43 kcal, 95%CI: 15, 70) and in the lowest compared to the highest income quintile (15 kcal, 95%CI: -5, 35).

We modelled the difference in sugary drinks, SSB and 100% juice consumption from the 'no tax' scenario for both 20% flat-rate tax and tiered tax scenarios (**Figure 1 and Supplementary Table 3 and 4)**. In the 20% flat-rate tax scenario, we estimated mean per-capita energy intake from sugary drinks would decrease 29 kcal (95%UI: 18, 41) on a given day, a 1.3% (95%UI: 0.8, 1.8) reduction of daily energy intake from sugary drinks. In the tiered tax scenario, we estimated that mean energy intake from sugary drinks would decrease by 40 kcal (95%UI: 24, 55) and 1.8% (95%UI: 1.1, 2.5) reduction of daily energy intake from sugary drinks. Similar trends were observed for reductions in energy intake and the proportion of daily energy intake for SSB and 100% juice. Although SSBs accounted for the majority of reduced energy intake from sugary drinks, including 100% juice as part of each sugary drink tax scenario resulted in an additional 28% reduction in mean energy intake from sugary drinks compared to a SSB-only tax in both 20% flat-rate tax and tiered tax scenarios.

We estimated the difference in sugary drink consumption across sociodemographic characteristics from baseline for each tax scenario on sugary drink consumption (**Figure 2 and Supplementary Table 3 and 4)**. Baseline inequities in energy intake and the proportion of daily energy intake from sugary drink consumption across age, sex, and socioeconomic indicators

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

were reduced but not eliminated in each modelled taxation scenarios, with additional small but meaningful reductions in the tiered tax scenario across subgroups.

Further, for each modelled taxation scenario, we assessed whether reductions in sugary drink consumption were differential across sociodemographic characteristics (**Table 2)**. Both tax structures reduced absolute energy intake from sugary drinks by a larger degree among individuals aged 2-19 compared to 19+ (20% flat tax: -13 kcal, 95%UI: -19, -8; tiered tax: -17 kcal, 95%UI: -25, -9), males compared to females (20% flat tax: -11 kcal, 95%UI: -16, -6; tiered tax: -15 kcal, 95%UI: -21, -8) and food insecure compared to secure (20% flat tax: -10 kcal, 95%UI: -18, -3; tiered tax: -13 kcal, 95%UI: -23, 1), with smaller reductions across education and income quintiles. These trends were mirrored across the proportion of daily energy intake from sugary drinks, with additional reductions ranging between 0.1-0.9%.

We assessed per-capita mean energy intake from sugary drinks targeted by each tier (tier 1 – lowest, tier 2, tier 3 – highest) in the tiered tax scenario by sociodemographic characteristics (**Figure 3).** Across sociodemographic characteristics, groups who consumed more energy from sugary drinks overall consumed more energy from beverages with higher sugar concentration and were estimated to reduce energy intake by a larger scale under a tiered tax scenario.

Sensitivity analyses

Analyses using a homogenous own price elasticity across income groups did not change our results (**Supplementary Table 5)**. Using a lower own price elasticity (-1.00) reduced the benefit of the modeled taxation scenarios compared to the estimates used in our main result (-1.39), however, the overall patterns of sugary drink consumption across sociodemographic characteristics remained (**Supplementary Table 6)**. Assuming a 100% pass-through of both a flat rate tax and tiered tax resulted in further reductions of overall intake and inequities across equity groups (**Supplementary Table 7)**.

Discussion

Using the most recent Canadian nationally representative dietary intake survey, we modelled the impact of implementing a sugary drink tax – a widely implemented policy internationally that is under consideration in Canada - on energy intake from sugary drinks. We estimated a sugary drink tax would reduce both mean energy intake and the proportion of daily

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

energy intake from sugary drinks, with the tiered tax associated with a potential small additional but meaningful reductions in energy intake compared to the 20% flat-rate tax scenario. Additionally, we estimated both taxation structures would reduce inequities in mean energy intake from sugary drinks measured in the CCHS-N, through greater reduction in energy intake in children/adolescents, males, lower education, food insecure and the low income quintile groups. However, in each sugary drink taxation scenario, inequities in sugary drink consumption remained after modelled tax implementations. In addition, 100% juice contributed an additional 34 kcal to per-capita or 1.9% of daily energy intake, demonstrating the potential benefit of considering policies that reduce the consumption of beverages containing both added and natural sugars[8,17]. Overall, our study highlights the potential of sugary drink taxation, including additional benefit of taxing 100% juice, for reducing overall and inequities in energy intake from sugary drinks in Canada.

Our findings from Canada add to the emerging international literature suggesting that tiered tax structures may be more effective than flat-rate taxes for reducing SSB consumption. For example, a US modelling study estimated a tiered tax to be more cost-effective than a flat-rate tax, with nearly double the health gains and savings[9]. In our study, reductions in mean per-capita energy from sugary drinks were greater in the tiered compared to the 20% flat-rate scenarios (40 vs. 29 kcal, respectively), with greater per capita mean energy intake from beverages with higher sugar concentration (Tier 2 and 3 tax targets), however 95% uncertainty intervals were overlapping after incorporating uncertainties related to OPE and CPE values. Additionally, our estimates are likely conservative, as shifts in consumer choice to lower sugar products and incentivized manufacturer product reformulation to reduce sugar content observed in real world tiered sugary drink taxes were not modelled. For example, following the implementation of the two-tiered United Kingdom (UK) soft drinks industry levy [high tier: £0.24/L in the high tier (≥ 8 g/100ml) and £0.18/L in the low tier (5-7.9 g/100ml)], the purchased volume of drinks in the high levy tier decreased 44% (95%CI: 29-60) and the percentage of drinks with sugar in the high tier was reduced by 30% [9,30]. Similarly, in Portugal, product reformulation following the introduction of a two tiered SSB tax in 2017 (<8 g/100ml: €0.08/L, and ≥8 g/100ml: €0.17/L) decreased the average energy density of SSBs by 3.1 kcal/100ml[30,31]. Tiered tax structures are consistent with public health rationale for the implementation of sugary drink taxation, in that it can target both specific beverages and sugar content of these

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

beverages[6]. However, their limited implementation outside of high income economies highlight potential implementation barriers, for example the challenges in verifying and monitoring sugar content of SSBs[6].

Our findings suggest the introduction of a sugary drinks tax in Canada could reduce sugary drink consumption with the potential to reduce inequities in energy intake from sugary drinks. These findings are consistent with the international literature from empirical studies in the US[32] and Mexico[33] as well as modelling studies from Canada[17] and Australia[18] which suggest that SSB taxes reduce SSB purchases more among individuals with lower incomes and educational attainments. Further, sugary drink taxes have the potential to reduce social inequities in the prevalence and healthcare costs of associated health conditions. Modelling studies in Canada and elsewhere estimate larger potential health benefits among lower SEP groups with minimal additional financial burden concentrated among lower income groups[17–19,34–36]. For example, a Canadian study modelling estimated the annual financial burden associated with the implementation of a 20% flat-rate sugary drink tax would be larger in the lowest income quintiles ($43.52 CAD) compared to the highest income quintile ($38.74 CAD) [17]. While this suggests the sugary drink tax was regressive, because price increases would represent a larger percentage of income from low compared to high income earners, the tax difference was offset by the increase in averted DALYs (156,000 vs.125,000 DALYs) and increased lifetime healthcare savings ($2.27 vs. $1.98 billion) in the lowest compared to highest income quintile, respectively[17].

Although our study estimated a sugary drink tax would reduce inequities sugary drink consumption in Canada, it is critical that policy-makers consider the wider impacts of the design and implementation of a sugary drink tax. While from a public health perspective implementing a sugary drink tax can have health benefits and generate revenue, critics have argued these taxes can be paternalistic and regressive, unfairly and disproportionately impacting lower income consumers [37,38]. Appropriately balancing the ethical concerns raised by proponents and critics alike is important to the design of a sugary drink tax[39]. Transparency about the rationale for and anticipated benefits of the tax – health benefit, revenue generation, countering manipulation of consumers by sugary drink manufacturers[7,39] - and how tax revenues will be equitably invested to balance the unfair tax burden for low SEP sugary drink consumers are critical considerations

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

for assessing the degree to which a sugary drink tax is *just*[3,40]. For example, the 7 US cities with a SSB taxes raise $134 million annually from SSB taxes and contributed 85% of revenues towards supporting projects and program in impacted communities, for example early childhood programs ($58 million), community improvements including recreation centres and libraries ($21M) and increasing healthy food and beverage access ($17 million)[41]. Considerations for the design, implementation and evaluation of a *just* sugary drink tax go beyond 'to tax or not to tax', and require insights from multiple disciplines and stakeholders, including constructive collaboration between finance and health policy makers[42].

Sugary drink taxation policies are an important first step for reducing sugar consumption and related adverse health conditions. However, no single policy will reduce sugary drink consumption to healthy levels and additional interventions should be considered[43,44]. A recent Canadian study estimated that targeting SSBs with taxation would be insufficient on its own to effectively reduce the health and economic burden of chronic diseases associated with excess sugar consumption from additional products[13]. Moreover, it is imperative to consider taxation in the context of an embodied policy approach, with additional considerations for improving access (i.e., availability and affordability) to safe nutrient-dense items[43] and reducing health inequities associated with material deprivation[45]. A recent systematic review found that food subsidy programs are associated with increased purchasing of subsidized goods however there was uncertainty around associated shifts in consumption[44]. Moreover, food subsidy programs[46] have existed for decades but are inadequate in alleviating material deprivation (food insecurity) in Canada[45], where in 2022, 6.9 million Canadians in the ten provinces lived in a food-insecure households, with further inequities across geography, race/ethnicity, and income[47]. Recent economic shifts associated with reductions in food access (among other necessary goods and services)[48] reflect a timely need for broad policy action. Comprehensive monetary policies such as guaranteed annual income may provide autonomy in regards to accessing healthy and safe food options and reduce barriers associated with targeted food subsidy programs, such as enrollment criteria and longevity[46]. Further research on this topic should be considered in Canada.

This study is not without limitations. Social desirability bias in self-reported data may have attenuated inequities towards the null as lower compared to higher SEP groups may be

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

more likely to underreport the unfavourable consumption of sugary drinks[49]. However, our previous analysis of sugary drink consumption in the CCHS-N found minimal impact on outcomes when adjusting for energy misreporting[12]. We utilized single-day 24-hour dietary recalls which are prone to random error associated with within-person variation. However single-day 24-hour dietary recalls are sufficient for estimating mean intake on a given day[11]. Our analyses required several assumptions for modelling inputs. Price elasticity estimates vary across modelling studies[5,17,28]. For example, a recent systematic review estimated average SSB price elasticity estimates of -1.00 (95% CI: -1.47, -0.50)[28] while income-specific price elasticities utilized in previous Canadian research ranged from -0.87 to -0.92[17]. We leveraged the most recent meta-analysis which estimated a larger price elasticity of -1.39 from high-quality studies[44]. Despite the variability in price elasticities, our estimates align with other studies[17]. We assumed consistent price elasticities for all sugary drinks and the tax effect on different beverage types (e.g., soft drinks vs. 100% juice) may differ overall and across equity stratifiers. However, due to the heterogeneity of beverage options included in modelling price elasticity estimates, we assumed that the average impact represents an appropriate measure for our study. For the tiered taxation scenario, we assumed that cross-price elasticities would be reflected by a 20% price increase which may not directly reflect the replacement related to low and high sugar beverage products.

Our study has several strengths. We leveraged the most recent population-representative nutrition survey, which contains the only data on consumption, to estimate the impact of sugary drink taxation on intake in the population and across equity stratifiers. Our comprehensive list of sugary drinks included traditional and novel types, including 100% juice[50]. We estimated the impact of two taxation structures in Canada, both of which have been implemented in real-world policies[7]. We tested the robustness of including both income-specific (primary analysis) and homogenous price elasticity estimates and found similar impacts of both taxation scenario across equity stratifiers. Finally, our sociodemographic-specific trends highlight the importance of population-level interventions to consider differential impacts across important equity stratifiers.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

Conclusion

We estimated that sugary drink taxation would reduce overall intake from sugary drinks, SSB, and 100% juice and would reduce, but did not eliminate, inequities in energy intake across age, sex and SEP among Canadians. The tiered tax scenario was estimated to a have small but meaningful reduction in mean energy intake from sugary drinks compared to a 20% flat-rate scenario. Future research should consider how best to design and implement a sugary drinks tax in Canada that both maximizes the health benefits and reduces social inequities in consumption.

Ethical Standards Disclosure: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Ethics Review Board at Public Health Ontario (Protocol Code: 2018-046.01)**. The project involved the secondary use of non-identifiable data, therefore consent was not required as per Canada's Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans – TCPS 2 (2022) Article 5.5B, which states that "Researchers shall seek REB review, but are not required to seek participant consent, for research that relies exclusively on the secondary use of non-identifiable information."**

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

References

1. Global Burden of Disease (GBD) 2017 (2018) Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **392**, 1923–1994.

2. World Health Organization (WHO) (2015) *Guideline: Sugars intake for adults and children*. Geneva: World Health Organization.

3. World Health Organization (2016) *Fiscal policies for diet and prevention of noncommunicable diseases: technical meeting report, 5-6 May 2015, Geneva, Switzerland*. Geneva: World Health Organization.

4. Krieger J, Bleich SN, Scarmo S, et al. (2021) Sugar-Sweetened Beverage Reduction Policies: Progress and Promise. *Annu. Rev. Public Health* **42**, 439–461.

5. Andreyeva T, Marple K, Marinello S, et al. (2022) Outcomes Following Taxation of Sugar-Sweetened Beverages: A Systematic Review and Meta-analysis. *JAMA Netw Open* **5**, e2215276.

6. Hattersley L & Mandeville KL (2023) Global Coverage and Design of Sugar-Sweetened Beverage Taxes. *JAMA Netw Open* **6**, e231412.

7. Backholer K, Vandevijvere S, Blake M, et al. (2018) Sugar-sweetened beverage taxes in 2018: a year of reflections and consolidation. *Public Health Nutr* **21**, 3291–3295.

8. Popkin BM & Ng SW (2021) Sugar-sweetened beverage taxes: Lessons to date and the future of taxation. *PLoS medicine* **18**, e1003412.

9. Lee Y, Mozaffarian D, Sy S, et al. (2020) Health Impact and Cost-Effectiveness of Volume, Tiered, and Absolute Sugar Content Sugar-Sweetened Beverage Tax Policies in the United States: A Microsimulation Study. *Circulation* **142**, 523–534.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

10. Langlois K, Garriguet D, Gonzalez A, et al. (2019) *Change in total sugars consumption among Canadian children and adults*. Ottawa: Statistics Canada.

11. Garriguet D (2019) *Changes in beverage consumption in Canada*. 20–30. Statistics Canada.

12. Warren C, Hobin E, Manuel DG, et al. (2022) Socioeconomic position and consumption of sugary drinks, sugar-sweetened beverages and 100% juice among Canadians: a cross-sectional analysis of the 2015 Canadian Community Health Survey–Nutrition. *Can J Public Health*.

13. Liu S, Munasinghe LL, Maximova K, et al. (2022) The economic burden of excessive sugar consumption in Canada: should the scope of preventive action be broadened? *Can J Public Health*.

14. Government of Newfoundland and Labrador. Sugar Sweetened Beverage Tax Information Circular [cited 2023 Apr 10]. Available from: https://www.gov.nl.ca/fin/files/Information-Circular-Sugar-Sweetened-Beverage-Tax-Dec-2022.pdf. .

15. Government of British Columbia. Notice to Sellers of Soda Beverages Provincial Sales Tax Act.[cited 2023 Apr 10]. Available from: https://www2.gov.bc.ca/assets/gov/taxes/sales-taxes/publications/notice-2021-002-sellers-soda-beverages.pdf. .

16. Backholer K, Sarink D, Beauchamp A, et al. (2016) The impact of a tax on sugar-sweetened beverages according to socio-economic position: a systematic review of the evidence. *Public Health Nutr* **19**, 3070–3084.

17. Kao K-E, Jones AC, Ohinmaa A, et al. (2020) The health and financial impacts of a sugary drink tax across different income groups in Canada. *Economics & Human Biology* **38**, 100869.

18. Lal A, Mantilla-Herrera AM, Veerman L, et al. (2017) Modelled health benefits of a sugar-sweetened beverage tax across different socioeconomic groups in Australia: A cost-effectiveness and equity analysis. *PLoS medicine* **14**, e1002326.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

19. Briggs AD, Mytton OT, Kehlbacher A, et al. (2013) Overall and income specific effect on prevalence of overweight and obesity of 20% sugar sweetened drink tax in UK: econometric and comparative risk assessment modelling study. *Bmj* **347**, f6189.

20. Braveman PA, Cubbin C, Egerter S, et al. (2005) Socioeconomic Status in Health Research: One Size Does Not Fit All. *JAMA* **294**, 2879.

21. Health Canada (2017) *Reference Guide to Understanding and Using the Data 2015 Canadian Community Health Survey—Nutrition*. Health Canada.

22. Statistics Canada (2018) *2015 Canadian Community Health Survey (CCHS) – Nutrition User Guide*. Statistics Canada.

23. Pell D, Mytton O, Penney TL, et al. (2021) Changes in soft drinks purchased by British households associated with the UK soft drinks industry levy: controlled interrupted time series analysis. *BMJ*, n254.

24. Acton RB & Hammond D (2018) The impact of price and nutrition labelling on sugary drink purchases: Results from an experimental marketplace study. *Appetite* **121**, 129–137.

25. Health Canada (2019) *Canada's dietary guidelines for health professionals and policy makers*. .

26. Conroy S & Murray EJ (2020) Let the question determine the methods: descriptive epidemiology done right. *Br J Cancer* **123**, 1351–1352.

27. Enders CK (2022) *Applied missing data analysis*. Second Edition. New York London: The Guilford Press.

28. Teng AM, Jones AC, Mizdrak A, et al. (2019) Impact of sugar-sweetened beverage taxes on purchases and dietary intake: Systematic review and meta-analysis. *Obesity reviews : an official journal of the International Association for the Study of Obesity*.

29. Scarborough P, Adhikari V, Harrington RA, et al. (2020) Impact of the announcement and implementation of the UK Soft Drinks Industry Levy on sugar content, price, product size and number of available soft drinks in the UK, 2015-19: A controlled interrupted time series analysis. *PLoS Med* **17**, e1003025 [Popkin BM, editor].

30. Goiana-da-Silva F, Cruz-e-Silva D, Gregório MJ, et al. (2018) The future of the sweetened beverages tax in Portugal. *The Lancet Public Health* **3**, e562.

31. Goiana-da-Silva F, Severo M, Cruz E Silva D, et al. (2020) Projected impact of the Portuguese sugar-sweetened beverage tax on obesity incidence across different age groups: A modelling study. *PLoS Med* **17**, e1003036 [Popkin BM, editor].

32. Bleich SN, Lawman HG, LeVasseur MT, et al. (2020) The Association Of A Sweetened Beverage Tax With Changes In Beverage Prices And Purchases At Independent Stores: Study compares changes in sweetened beverage prices and purchases before and twelve months after tax implementation, at small, independent stores in Philadelphia. *Health Affairs* **39**, 1130–1139.

33. Ng SW, Rivera JA, Popkin BM, et al. (2018) Did high sugar-sweetened beverage purchasers respond differently to the excise tax on sugar-sweetened beverages in Mexico? *Public health nutrition*, 1–7.

34. Andreyeva T, Chaloupka FJ & Brownell KD (2011) Estimating the potential of taxes on sugar-sweetened beverages to reduce consumption and generate revenue. *Prev Med* **52**, 413–6.

35. Barrientos-Gutierrez T, Zepeda-Tello R, Rodrigues ER, et al. (2017) Expected population weight and diabetes impact of the 1-peso-per-litre tax to sugar sweetened beverages in Mexico. *PloS one* **12**, e0176336.

36. Caro JC, Ng SW, Bonilla R, et al. (2017) Sugary drinks taxation, projected consumption and fiscal revenues in Colombia: Evidence from a QUAIDS model. *PloS one* **12**, e0189026.

37. Grignon M (2022) Taxing free sugar: the devil is in the resulting distribution of gains and pains. *Can J Public Health* **113**, 327–330.

38. Riediger ND & Bombak AE (2018) Sugar-sweetened beverages as the new tobacco: examining a proposed tax policy through a Canadian social justice lens. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne* **190**, E327–E330.

39. Mackay D & Huber-Disla A Designing a Just Soda Tax. *Economics and Philosophy* **Forthcoming**.

40. Petimar J, Gibson LA & Roberto CA (2022) Evaluating the Evidence on Beverage Taxes: Implications for Public Health and Health Equity. *JAMA Netw Open* **5**, e2215284.

41. Krieger J, Magee K, Hennings T, et al. (2021) How sugar-sweetened beverage tax revenues are being used in the United States. *Prev Med Rep* **23**, 101388.

42. Ng SW, Colchero MA & White M (2021) How should we evaluate sweetened beverage tax policies? A review of worldwide experience. *BMC Public Health* **21**, 1941.

43. Valizadeh P, Popkin BM & Ng SW (2021) Linking a sugar-sweetened beverage tax with fruit and vegetable subsidies: A simulation analysis of the impact on the poor. *The American Journal of Clinical Nutrition*, nqab330.

44. Andreyeva T, Marple K, Moore TE, et al. (2022) Evaluation of Economic and Health Outcomes Associated With Food Taxes and Subsidies: A Systematic Review and Meta-analysis. *JAMA Netw Open* **5**, e2214371.

45. Kirkpatrick SI, Dodd KW, Parsons R, et al. (2015) Household Food Insecurity Is a Stronger Marker of Adequacy of Nutrient Intakes among Canadian Compared to American Youth and Adults. *The Journal of nutrition* **145**, 1596–603.

46. Niebylski ML, Redburn KA, Duhaney T, et al. (2015) Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence. *Nutrition* **31**, 787–95.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

47. Statistics Canada Table 13-10-0834-01. [cited 2023 Apr 10]. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310083401. .

48. PROOF (2022) What does record inflation mean for household food insecurity in Canada? University of Toronto: .

49. Garriguet D (2018) *Accounting for misreporting when comparing energy intake across time in Canada*. Ottawa, ON: Statistics Canada.

50. Czoli CD, Jones AC & Hammond D (2019) Trends in sugary drinks in Canada, 2004 to 2015: a comparison of market sales and dietary intake data. *Public health nutrition*, 1–6.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

Table 1: Descriptive statistics and weighted mean per-capita energy intake from sugary drinks on a given day by sociodemographic characteristics, Canadian Community Health Survey-Nutrition (n=19,742)

Sociodemographic characteristics	N	%	Absolute Energy Intake (kcal)		Relative Contribution (%)	
			Mean (95%CI)	Mean Difference (95%CI)	Mean (95%CI)	Mean Difference (95%CI)
Sugary drinks	19,742	100	127 (122, 132)		6.7% (6.4, 7.0)	
Sugar-sweetened beverages	19,742	100	93 (88, 98)		4.8% (4.6, 5.1)	
100% juice	19,742	100	34 (32, 36)		1.9% (1.7, 2.0)	
Age (years)						
2-18 years	6,114	31	173 (163, 184)	57 (46, 68)	9.4% (8.9, 10.0)	3.4 (2.8, 3.9)
19 years or older	13,628	69	116 (111, 121)	Ref	6.1% (5.8, 6.3)	Ref
Sex						
Male	9,473	48	151 (143, 159)	47 (38, 56)	7.0% (6.7, 7.4)	0.6 (0.1, 1.1)
Female	10,269	52	104 (99, 109)	Ref	6.4% (6.0, 6.8)	Ref
Education						
Less than high school	1,748	9	117 (94, 140)	-1 (-24, 22)	6.5% (5.6, 7.4)	0.2 (-0.8, 1.1)
High school	3,668	18	136 (123, 149)	18 (4, 32)	7.4% (6.7, 8.0)	1.0 (0.2, 1.8)
Certificate below bachelor's degree	7,429	38	135 (126, 143)	17 (4, 29)	6.9% (6.5, 7.3)	0.5 (0.0, 1.1)
Bachelor's degree or higher	6,897	35	118 (110, 126)	Ref	6.3% (6.0, 6.7)	Ref
Food Security						
Food insecure	2,056	10	166 (141, 191)	43 (15, 70)	9.0% (7.9, 10.1)	2.5 (1.2, 3.7)
Food secure	17,686	90	124 (118, 129)	Ref	6.5% (6.2, 6.8)	Ref
Income						
Quintile 1 (low)	4,035	20	137 (123, 151)	15 (-5, 35)	7.7% (7.0, 8.3)	1.9 (0.8, 3.0)
Quintile 2	4,044	20	122 (107, 137)	0 (-16, 17)	6.6% (6.0, 7.3)	0.9 (0.2, 1.5)
Quintile 3	4,287	22	129 (118, 139)	7 (-9, 23)	6.8% (6.4, 7.3)	1.1 (0.1, 2.0)
Quintile 4	3,678	19	126 (114, 139)	4 (-10, 19)	6.6% (6.0, 7.2)	0.9 (0.0, 1.7)
Quintile 5 (high)	3,698	19	122 (111, 133)	Ref	5.8% (5.1, 6.5)	Ref

Footnotes: 'Absolute energy intake (kcal)' refers to the mean per-capita energy intake from sugary drinks on a given day. 'Relative contribution (%)' refers to the mean per-capita proportion of energy intake from sugary drinks relative to all food and beverages consumed on a given day.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

Table 2: Difference of reduction in per-capita energy intake and proportion of daily energy intake from sugary drinks between sociodemographic groups for each modelled taxation scenario , Canadian Community Health Survey-Nutrition (n=19,742)

	Flat-rate (20%) Tax		**Tiered Tax**	
	Absolute Energy reduction (kcal)	**Relative Contribution Reduction (pct-age points)**	**Absolute Energy Reduction (kcal)**	**Relative Contribution Reduction (pct-age points)**
	Mean Difference (95%UI)	**Mean Difference (95%UI)**	**Mean Difference (95%UI)**	**Mean Difference (95%UI)**
Age				
2-18 years	-13 (-19, -8)	-0.7 (-0.9, -0.4)	-17 (-25, -9)	-0.9 (-1.2, -0.5)
19 years or older	Ref	Ref	Ref	Ref
Sex				
Male	-11 (-16, -6)	-0.1 (-0.2, -0.0)	-15 (-21, -8)	-0.2 (-0.3, -0.0)
Female	Ref	Ref	Ref	Ref
Education				
Less than high school	0 (-6, 5)	-0.0 (-0.2, 0.1)	-1 (-8, 6)	-0.1 (-0.3, 0.2)
High school	-4 (-8, -1)	-0.2 (-0.3, -0.0)	-6 (-11, -1)	-0.2 (-0.5, 0.0)
Certificate below bachelor's degree	-4 (-7, -1)	-0.1 (-0.2, -0.0)	-5 (-10, -1)	-0.2 (-0.3, -0.0)
Bachelor's degree or higher	Ref	Ref	Ref	Ref
Food Security				
Food insecure	-10 (-18, -3)	-0.4 (-0.7, -0.2)	-13 (-23, -3)	-0.6 (-0.9, -0.2)
Food secure	Ref	Ref	Ref	Ref
Income				
Quintile 1 (low)	-4 (-9, 1)	-0.4 (-0.6, -0.1)	-5 (-12, 1)	-0.5 (-0.8, -0.2)
Quintile 2	0 (-4, 4)	-0.2 (-0.3, -0.0)	1 (-5, 7)	-0.2 (-0.4, 0.0)
Quintile 3	-1 (-5, 3)	-0.2 (-0.4, 0.0)	-1 (-6, 4)	-0.2 (-0.5, 0.0)
Quintile 4	-1 (-4, 3)	-0.1 (-0.3, 0.0)	0 (-5, 5)	-0.2 (-0.4, 0.1)
Quintile 5 (high)	Ref	Ref	Ref	Ref

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

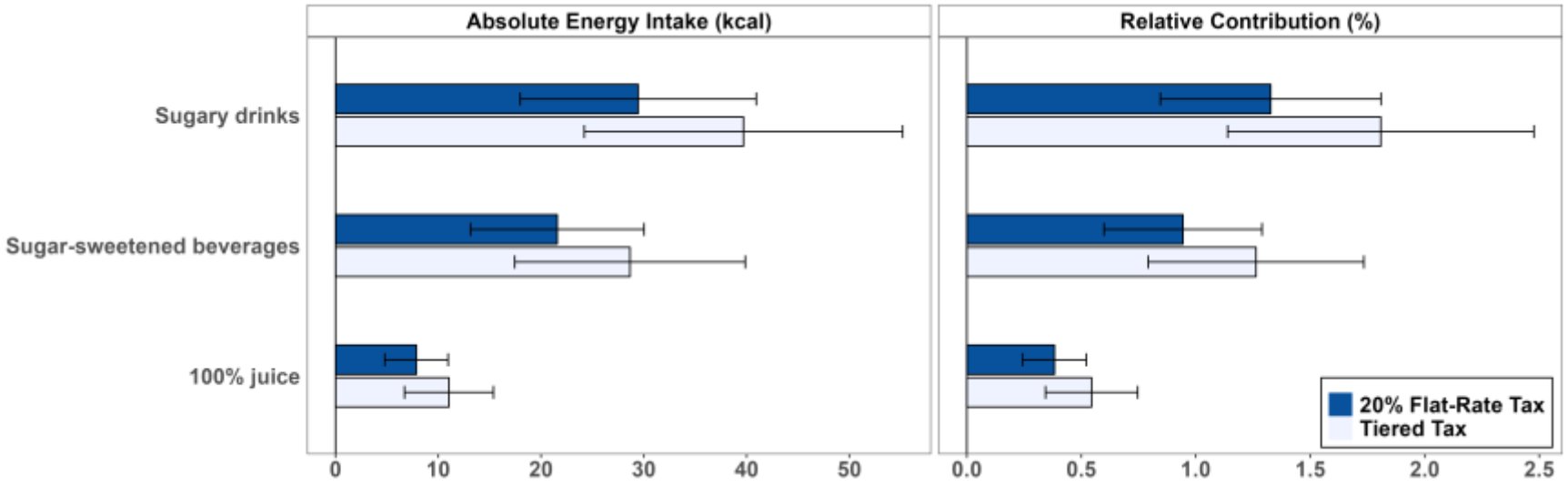

Figure 1.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

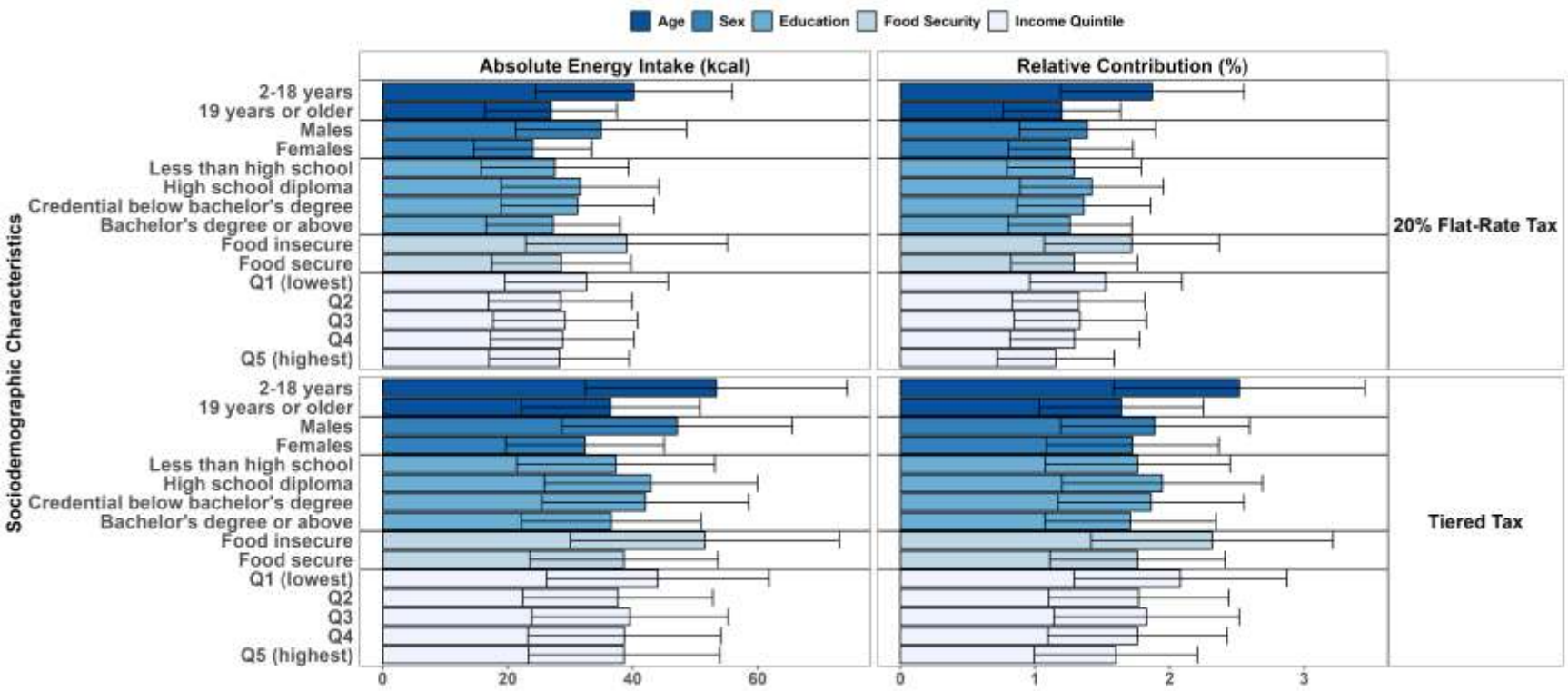

Figure 2.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press

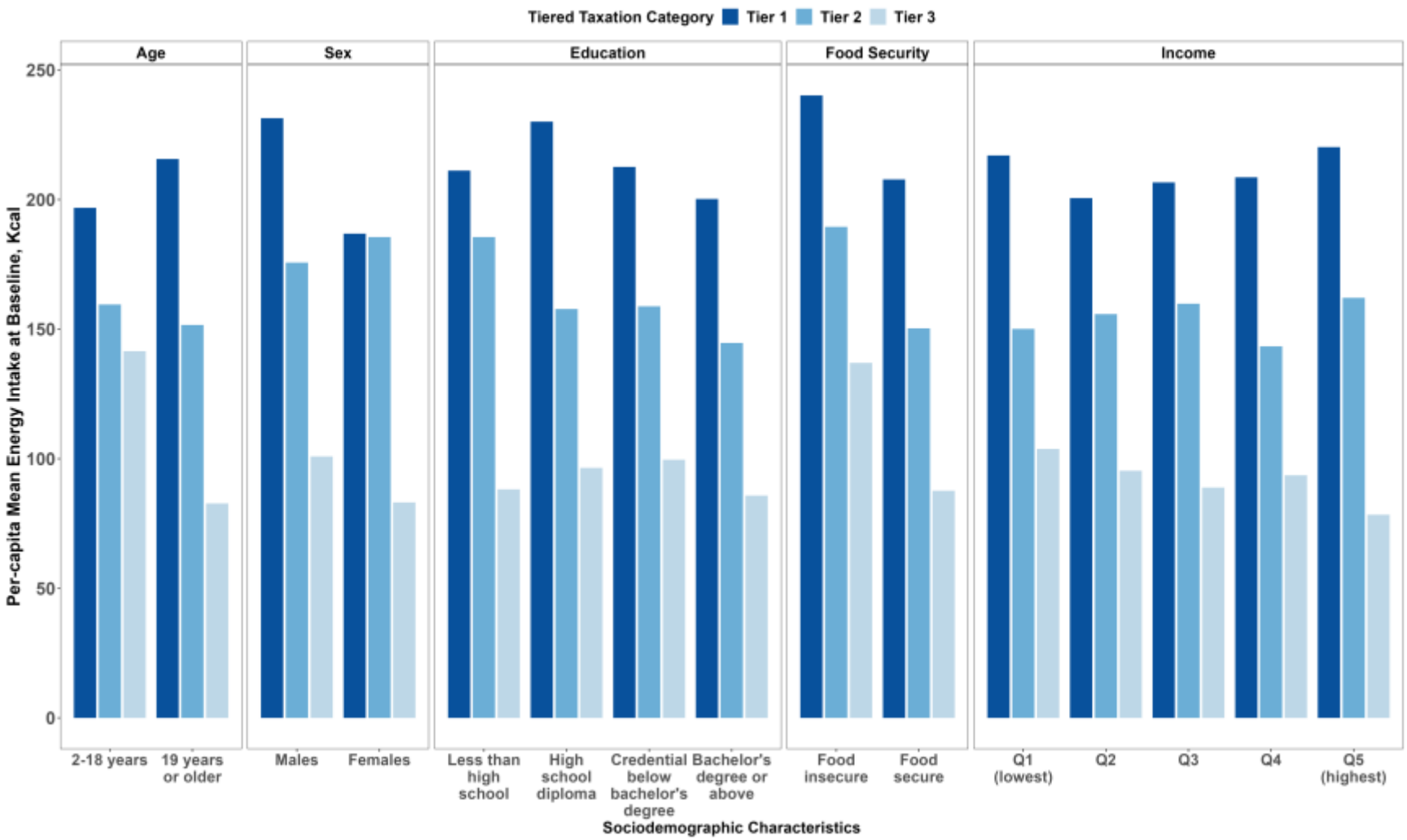

Figure 3.

https://doi.org/10.1017/S1368980024000545 Published online by Cambridge University Press