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POPULATION HEALTH INTERVENTION RESEARCH

Exploring the main and moderating effects of individual-level characteristics on consumer responses to sugar taxes and front-of-pack nutrition labels in an experimental marketplace

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Abstract

Intervention This study examined whether the impacts of sugar taxes and front-of-pack (FOP) nutrition labels differ across socio-demographic subgroups.

Research question What are the main and moderating effects of individual-level characteristics on the nutrient content of participants' purchases in response to varying taxation levels and FOP labels?

Methods Data from an experimental marketplace were analyzed. A sample of 3584 Canadians aged 13 years and older received $5 to purchase an item from a selection of 20 beverages and 20 snack foods. Participants were shown products with one of five FOP labels and completed eight within-subject purchasing tasks with different tax conditions. Linear mixed models were used to estimate the main and moderating effects of 11 individual-level variables on the sugars, sodium, saturated fats, and calorie content of participants' purchases.

Results Participants who were younger, male, and more frequent consumers of sugary drinks purchased products containing more sugars, sodium, saturated fats, and calories. Sex and age moderated the relationship between tax condition and sugars or calories purchased: female participants were more responsive than males to a tax that included fruit juice, and younger participants were more responsive to all sugar tax conditions than older participants. Reported thirst and education level also moderated the relationship between tax condition and calories purchased. No individual-level characteristics moderated the effects of FOP labels.

Conclusion A small proportion (7 of 176) of the moderating effects tested in this study were significant. Sugar taxes and FOP labelling policies may therefore produce similar effects across key socio-demographic groups.

Résumé

Intervention Dans cette étude, nous avons cherché à déterminer si les effets des taxes sur le sucre et de l'étiquetage nutritionnel sur le devant des emballages sont les mêmes dans différents sous-groupes sociodémographiques.

Question de recherche Quels sont les principaux effets et les effets modérateurs des caractéristiques individuelles sur le contenu nutritionnel des achats des participants quand le niveau des taxes et l'étiquetage sur le devant des emballages varient?

Méthode Nous avons analysé les données d'un marché expérimental. Nous avons offert à un échantillon de 3 584 Canadiens de 13 ans et plus 5 $ pour acheter un article parmi 20 boissons et 20 grignotines. Les participants se sont fait présenter des produits portant l'une de cinq étiquettes sur le devant de l'emballage et ont effectué huit tâches d'achat intra-sujet avec différentes modalités de taxation. Des modèles linéaires mixtes ont servi à estimer les principaux effets et les effets modérateurs de 11 variables individuelles sur la teneur en sucres, en sodium, en graisses saturées et en calories des achats des participants.

Résultats Les jeunes, les participants de sexe masculin et les consommateurs fréquents de boissons sucrées ont acheté des produits contenant plus de sucres, de sodium, de graisses saturées et de calories. Le sexe et l'âge ont modéré la relation entre la modalité de taxation et les sucres ou les calories achetés : les filles et les femmes étaient plus sensibles que les garçons et les hommes à une taxe incluant les jus de fruits, et les jeunes étaient plus sensibles à toutes les modalités de taxation du sucre que les

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participants plus âgés. La soif et le niveau d'instruction autodéclarés ont aussi modéré la relation entre la modalité de taxation et les calories achetées. Aucune caractéristique individuelle n'a modéré les effets des étiquettes sur le devant des emballages.
Conclusion Seule une petite proportion (7 sur 176) des effets modérateurs testés dans l'étude était significative. Les politiques de taxation du sucre et d'étiquetage sur le devant des emballages pourraient donc produire des effets semblables dans plusieurs groupes sociodémographiques clés.

Keywords Nutrition policy · Health policy · Taxes · Nutrition labelling · Socio-economic factors · Epidemiologic effect modifiers

Mots-clés Politique nutritionnelle · politique de santé · taxes · étiquetage nutritionnel · facteurs socioéconomiques · modificateurs d'effets épidémiologiques

Introduction

The growing burden of non-communicable diseases has prompted a global movement towards policies to improve dietary patterns (Gorski and Roberto 2015). Two such strategies include taxes on high-sugar products and front-of-package (FOP) nutrition labelling systems (World Cancer Research Fund International 2020). There is growing evidence to suggest both sugar taxes and FOP nutrition labels can be effective at improving the healthiness of diets (WCRFI 2018, 2019); however, uncertainty remains regarding whether their impacts are consistent across different subpopulations (Fernandez and Raine 2019; Kanter et al. 2018).

Sugar taxes

Given the substantial contribution of sugary drinks and snacks to intake of sugars and energy both in Canada and globally (Langlois and Garriguet 2011; Popkin and Hawkes 2016), sugar taxes—particularly those on sugar-sweetened beverages (SSBs)—are an increasingly prominent health-focused fiscal strategy (WCRFI 2020). Evidence from SSB taxes in countries like Mexico and Chile—where SSB consumption rates are some of the highest globally—and several cities in the United States suggests that such measures are effective in reducing purchasing and consumption of taxed beverages (Teng et al. 2019). However, our understanding of whether these taxes produce differential effects across population subgroups is nascent.

The majority of studies assessing the impacts of sugar taxes do not disaggregate their analyses by demographic characteristics. Among those that do, the focus tends to be on income or socio-economic status (SES) (Backholer et al. 2016). Evidence thus far largely suggests lower SES households are likely to spend a slightly greater proportion of their income on the tax, but also demonstrate greater reductions in purchasing and consumption of the taxed products—and therefore greater projected health benefits—compared with higher SES consumers (Backholer et al. 2016). Aside from income, there is little evidence on the extent to which individual-level characteristics—such as age, sex, ethnicity, weight status, or dietary intake patterns—may moderate the effects of sugar taxes. One controlled experimental study found that a tax reduced purchases only among participants with weights corresponding to obesity (Temple et al. 2011); however, results from an experimental web-based supermarket suggested body mass index (BMI) had no impact on the effectiveness of a high-energy-dense food tax (Nederkoorn et al. 2011). Some observational studies evaluating city-level taxes in the US have reported differences across socio-demographic characteristics. A study evaluating Philadelphia's beverage tax found no detectable impacts on children's consumption of taxed beverages, unless they were frequent consumers prior to the tax (Cawley et al. 2019). In Oakland, one study detected no substantial changes in consumption among African American or Hispanic groups following implementation of an SSB tax; however, consumption of taxed beverages was reduced among groups receiving federal nutrition assistance benefits (Cawley et al. 2020). In Mexico, reductions in SSB purchases were higher among individuals living in urban versus rural areas following implementation of a national 1 peso/litre SSB tax (Colchero et al. 2017). Observational evidence from Mexico's national 8% tax on non-essential energy-dense foods, as well as from a £0.10/beverage SSB tax implemented within a national chain of restaurants in the United Kingdom, suggest impacts were greater among individuals with higher baseline consumption or preference for the taxed products (Cornelsen et al. 2017; Taillie et al. 2017). Last, an observational study of Chile's 8% tax increase on SSBs found that patterns in purchasing did not differ by household obesity status (Nakamura et al. 2018).

Front-of-package nutrition labels

FOP nutrition labelling is another policy strategy being implemented in an attempt to make healthy choices easier for consumers (Kanter et al. 2018). FOP labels aim to improve consumption patterns similarly to sugar taxes; however, they require greater agency on the part of the consumer to impact behaviours. Countries have implemented FOP labels in a

variety of formats, ranging from *nutrient-specific*, such as the UK's multiple traffic light (MTL) system or Chile's 'high in' warning labels, to *summary indicator* systems, such as Australia and New Zealand's Health Star Ratings or France's Nutri-Score system (Kanter et al. 2018; WCRFI 2020). Although many studies have examined consumers' perceptions, understanding, and behavioural responses to FOP nutrition labels, few report results across relevant individual-level characteristics (Shangguan et al. 2019).

The results of FOP labelling studies that have examined differences across demographic characteristics are mixed. Although some online or in-person experimental studies have reported that participants with higher BMI (Temple et al. 2011), lower income (Lima et al. 2018), and lower education status (Balcombe et al. 2010) are less responsive to FOP labels, other online experimental studies have reported the opposite (Ducrot et al. 2015; Machín et al. 2017). The heterogeneity in findings appears to be driven by differences in FOP label design. Labels that present predominantly quantitative information—such as Guideline Daily Amount labels—tend to show greater disparities in understanding across SES or literacy levels compared with other more interpretive systems such as Health Star Ratings, Nutri-Score, or nutrient-specific warning symbols (Hammond et al. 2018). Results also vary based on the country or setting in which the research was conducted, as well as the measures used to assess responses (Hammond et al. 2018). The most consistent evidence on demographic differences relates to overall nutrition label *use*: consumers who are female, White, those with higher education and income status, and those trying to lose, gain or maintain weight, as well as those with an existing chronic disease tend to be more likely to read or use nutrition labels (Anastasiou et al. 2019).

For both sugar taxes and FOP labels, additional studies assessing the direct and moderating effects of individual-level characteristics are warranted. By identifying potential main or moderating effects of consumer characteristics, such research can aid in the interpretation of these policies' impacts across populations, as well as guide more effective and targeted policy implementation in the future. In particular, testing for potential moderating effects allows us to identify individual-level factors that influence the *relationship* between sugar taxes or FOP nutrition labels and purchasing behaviours. In other words, moderation analyses tell us whether these nutrition policies work differently among consumers with different socio-demographic backgrounds or health behaviours; this provides a more comprehensive understanding of the policies' impacts, which we do not get from simply examining the main effects of individual-level factors, as most studies have done to date. It is particularly important to identify moderating effects of individual-level characteristics on nutrition policies to ensure that the policy does not exacerbate existing health inequities across a population. Significant moderating effects may signify inequities in the policy (e.g., if greater positive impacts were observed among higher-income groups than lower-income consumers), or may identify strengths (e.g., if greater positive impacts were observed among disadvantaged groups) that could be replicated by policymakers in other jurisdictions. Experimental research using objective measures to assess behavioural outcomes, rather than self-reported preferences or hypothetical purchases, can offer important insights into how the impacts of sugar tax and FOP labelling strategies are influenced by individual-level characteristics.

In a previous study by the research team, data from a randomized experimental marketplace were analyzed to investigate the impacts of various sugar taxes and FOP nutrition labels on the sugars, sodium, saturated fats, and calorie content of consumers' beverage and snack food purchases (Acton et al. 2019). Sugar taxes and FOP labels were incorporated into this study to allow evaluation of their potential cumulative and interactive effects. Participants who viewed a 'high in' symbol on products purchased beverages with 11% less sugars, 18% less saturated fats, and 12% fewer calories, and snack foods with 8% less sodium and 5% fewer calories compared to the no label control. All of the sugar taxes tested for both beverages and snack foods resulted in substantial reductions in the sugars and calorie content of participants' purchases (up to 19%), and in some cases, reductions in sodium and saturated fats content. Additional analyses found no differences in the protein or calcium density of participants' snack food purchases, but modest increases in fibre density under the sugar taxes and some FOP labels (Acton and Hammond 2020). The analyses presented here expand upon these findings to examine differential effects across socio-demographic groups. The main objective of the current study was to identify whether key socio-demographic and behavioural characteristics moderated the effects of the sugar taxes and FOP nutrition labels on participants' purchasing of beverages and snack foods containing the abovementioned nutrients of interest. Secondary objectives included identifying the main effects of these individual-level characteristics, and examining the price paid and tax paid by participants to estimate the degree of financial regressivity of the sugar taxes tested.

Methods

Study design

An experimental marketplace provides the opportunity to manipulate price and other variables of interest to assess their influence on consumers' purchases. In such studies, participants are given a pre-specified amount of money to spend and shown a range of products available for purchase. Following their selection, participants keep any remaining funds, along

with the product they selected. Thus, participants spend real money and incur a financial cost for their purchases, leading to more realistic product selections compared to hypothetical purchase scenarios. The study protocol is described below, with additional details available elsewhere (Acton et al. 2019).

Study protocol

Data collection was conducted from March to May 2018. Ethical approval was granted by the Office of Research Ethics at the University of Waterloo.

Participants and recruitment

Participants aged 13 years and older were recruited from large shopping centres in three Canadian cities (Toronto, Kitchener, and Waterloo) using convenience sampling. Research assistants recruited potential participants from stations in high-traffic areas in the shopping centres. All interested participants were required to provide their age prior to giving informed consent and participating in the study.[1]

Participants completed the study in the same location immediately following consent. A total of 3702 participants completed the study. Data for 118 participants were omitted due to data quality concerns, including significant cognitive difficulties or distraction, visual impairment, or substantial influence from peers, as reported by the research assistants.[2] The final analytic sample thus includes 3584 individuals.

Purchasing tasks

The purchasing tasks were administered via a 5 (FOP label condition) × 8 (tax condition) between-within group experiment. Participants were randomly assigned by the survey program to one of five FOP label conditions and completed eight consecutive purchasing tasks, each corresponding to a different tax condition. In each of the eight purchasing tasks, research assistants showed participants a selection of beverage or snack food products (Supplementary Table 1) on a large laminated print-out, designed to resemble a grocery or convenience store shelf (Supplementary Fig. 1). A unique shelf image was shown in each purchasing task to reflect the appropriate label and tax condition for that purchase. Nutrition Facts table information was not available to participants. For the first five purchasing tasks, participants selected from 20 beverage products. For the last three purchases, participants selected from 20 snack food products. The order of the tax conditions was randomized by the survey program within the five beverage tasks and within the three food tasks. For each task, participants made their selection on an iPad after viewing the shelf image. Participants did not have the option to decline a purchase. Following completion of all survey items, the survey program randomly selected one of the eight purchasing tasks to be 'real'. Research assistants provided participants with the product and their change from the $5.00 corresponding to that purchase.[3] Participants were unaware of which beverage or snack food selection they would receive until the end of the experiment, and were therefore instructed to treat all eight tasks as actual purchases.

Prior to each purchasing task, research assistants emphasized the following to participants: (1) they had a budget of $5.00 to purchase one item, (2) the labels may be different from what they have seen in the past, (3) the prices may have changed since the last task, and (4) they would receive their change from the $5.00 and the actual food or beverage product from one of the eight purchases.

Experimental conditions

Five FOP label conditions were tested: *no label* (control); a *high in* system labelling foods high in sugars, sodium, or saturated fats; a multiple traffic light system (*MTL*) for sugars, sodium, and saturated fats; a *health star rating* label; and a five-colour *nutrition grade* label (Fig. 1).

Five beverage-based sugar tax conditions were tested: *no tax* (control), a 20% tax on SSBs (*20% SSB*), a 20% tax on sugary drinks (*20% SD*), a tiered tax on SSBs (*tiered SSB*), and a tiered tax on sugary drinks (*tiered SD*) (Table 1). The 20% tax rate was selected due to consensus among public health authorities that SSB taxes should be implemented at a rate equivalent to at least 20% to achieve measurable improvements in consumption and health outcomes (WCRFI 2018). Beverages were categorized as SSBs if they contained added sugars (any sugars added during processing or preparation), such as regular soft drinks, sports drinks, flavoured waters, and fruit drinks. Beverages were categorized as sugary drinks if they contained free sugars, defined as all added sugars, plus those naturally present in honey, syrups, fruit juices, and fruit juice concentrates (World Health Organization 2017). Sugary drinks therefore encompass all beverages under the umbrella of SSBs, plus 100% fruit juice products. The tiered tax design was modelled on the SSB tax implemented in the UK (UK HM Treasury 2016). Three food-based sugar tax conditions were tested: *no tax* (control), a 20% tax on high-sugar foods (*20%*), and a tiered tax on high-sugar foods (*tiered*) (Table 1).

[1] Additional consent from a parent or guardian was required for participants under the age of 16 years; if a parent or guardian was not present, the shopper was not permitted to participate.

[2] Omitted participants were more likely to be 13–18 or > 45 years of age, less likely to report efforts to consume less sugars in the past year, and tended to have lower education compared to the analytic sample.

[3] The budget of $5.00 provided sufficient money to cover the prices of any beverage or snack food products, while also offering an appropriate amount of 'change' to give financial significance to the purchases.

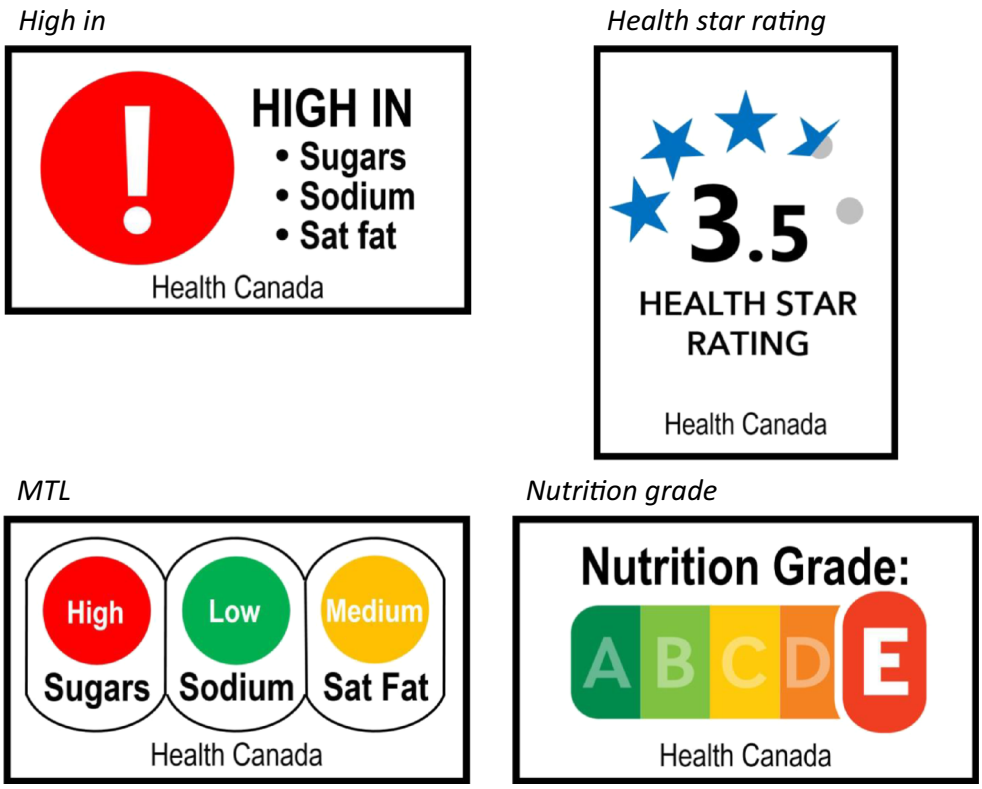

Fig. 1 Sample images of front-of-pack nutrition labelling conditions (excluding a *no label* control), applied to beverage and snack food products in an experimental marketplace. Clockwise from top left: *high in*, *health star rating*, *nutrition grade*, *multiple traffic light*

Socio-demographic and health behaviour measures

Information on 11 individual-level characteristics was collected (Table 2). Prior to beginning the purchasing tasks, participants were queried about (1) age, (2) sex, (3) current hunger, and (4) current thirst. Age was categorized into five groups (13–18, 19–25, 26–35, 36–45, >45 years) that best captured the distribution of ages in the sample. Following the purchasing tasks and using the iPad, participants then provided information on (5) previous 7-day sugary drink (SD) consumption; (6) efforts to modify intake of sugars, sodium, saturated fats, and calories in the previous year; (7) ethnicity; (8) education status; (9) perceived income adequacy; (10) health literacy; and (11) height and weight to calculate BMI. The above characteristics were explored due to their demonstrated associations with dietary intake (Duffey and Popkin 2006; Hiza et al. 2013; Spronk et al. 2014; Statistics Canada 2017).

Outcome variables

To assess the impacts of the sugar taxes and FOP labels on participants' purchases, four nutrient outcomes were examined: grams of sugars, milligrams of sodium, grams of saturated fats, and number of calories purchased. These nutrient outcomes were defined as the total amount of sugars, sodium, saturated fats, or calories in the entire package of the product selected in each purchasing task. Each outcome variable was assessed for beverages and snack foods separately. 'Price

Table 1 Sugar tax conditions applied in an experimental marketplace

	Tax condition	Price increase	Threshold for application
Beverage tax conditions	No tax	n/a	
	20% SSB tax	20%	>5 g added sugars/100 ml
	20% SD tax	20%	>5 g free sugars/100 ml
	Tiered SSB tax	10%, 20%	5–8 g added sugars/100 m, >8 g added sugars/100 ml
	Tiered SD tax	10%, 20%	5–8 g free sugars/100 ml, >8 g free sugars/100 ml
Snack food tax conditions	No tax		n/a
	20% tax	20%	>10 g total sugars/100 g
	Tiered tax	10%, 20%	10–20 g total sugars/100 g, >20 g total sugars/100 g

SD, sugary drink; *SSB*, sugar-sweetened beverage

Table 2 Survey questions for individual-level characteristics queried in an experimental marketplace

Domain/variable	Survey item*
Age	[Asked verbally] 'Can you please tell me your age?'
Sex	[Recorded by research assistant]
Hunger	Please think about how HUNGRY you are right now. Select the choice below that best represents how HUNGRY you are right now: Not at all hungry Slightly hungry Moderately hungry Extremely hungry
Thirst	Please think about how THIRSTY you are right now. Select the choice below that best represents how THIRSTY you are right now: Not at all thirsty Slightly thirsty Moderately thirsty Very thirsty Extremely thirsty
Previous 7-day sugary drink consumption	During the PAST 7 DAYS, how many sugary drinks did you have? (This includes pop, fruit drinks, fruit juice, sports drinks, vitamin waters, energy drinks, chocolate milk, tea/coffee with more than 5 teaspoons of sugar, and specialty coffees.) Do NOT count diet or sugar-free drinks. Do NOT include today. [open text response]
Efforts to modify intake	Have you made an effort to consume more or less of the following in the past year? [For each of the following: calories, saturated fat, sugar/added sugar, salt/sodium] Consume LESS Consume MORE No effort made
Health literacy	[Score of 0–6 calculated based on responses to a computerized version of the Newest Vital Sign tool [a]]
Ethnicity	Are you an Aboriginal person, that is, First Nations (North American Indian), Métis, or Inuit (Inuk)? Yes No [Not asked for respondents who identified as an Aboriginal person:] People living in Canada come from many different cultural and racial backgrounds. Are you… (Select all that apply) White Chinese South Asian (e.g., East Indian, Pakistani, Sri Lankan) Black Filipino Latin American Southeast Asian (e.g., Cambodian, Indonesian, Laotian, Vietnamese) Arab West Asian (e.g., Afghan, Iranian) Japanese Korean Other ➔ Please specify: [open text]
Education	[age 17+] What is the highest level of formal education that you have completed? Grade 10 or lower Grade 11 Grade 12 (completed high school) Technical / trade school or college Some university, no degree Completed university degree Post-graduate degree (e.g., Master's or PhD, professional programs) [age<17] What is the highest level of formal education that you have completed? Grade 5 or lower Grade 6 Grade 7 Grade 8 Grade 9

Table 2 (continued)

Domain/variable	Survey item*
	Grade 10 Grade 11 Grade 12/high school diploma or equivalent
Perceived income adequacy	Thinking about your total monthly income, how difficult or easy is it for you to make ends meet? Very difficult Difficult Neither easy nor difficult Easy Very easy
BMI classification	[Calculated based on self-reported height and weight]

*Response options 'Don't know' and 'Refuse to answer' were available for all survey items completed by participants

[a] Mansfield et al. (2018)

paid' (tax-inclusive cost (CAN$) of the product selected within each purchasing task) and 'tax paid' (portion of the product price (CAN$) coming from tax, if any) were included as secondary outcomes to explore the potential financial regressivity for the taxes tested.

Statistical analyses

All statistical analyses were pre-specified and conducted using SPSS software (version 25.0; IBM Corp., Armonk, NY; 2017). Likert-scale data were verified to be normally distributed. To account for the possibility of falsely detecting a significant result among multiple comparisons, we controlled for the false discovery rate (FDR) using the Benjamini-Hochberg procedure and a conservative FDR of 0.05. All linear mixed models (LMMs) described below used a compound symmetry covariance matrix and specified tax condition as the repeated measure.

Main effects

Eight LMMs were fitted, corresponding to eight continuous outcomes: sugars, sodium, saturated fats, and calories purchased from beverages; and sugars, sodium, saturated fats, and calories purchased from snack foods. LMMs were used to account for the repeated nature of the purchasing tasks. In each model, variables included *tax condition*, *label condition*, and the 11 individual-level characteristics to assess their main effects on the eight outcomes.

Moderating effects

Statistical tests for two-way interactions assessed whether any of the 11 individual-level variables moderated the effects of the sugar taxes or FOP labels on each of the eight nutrient outcomes. Moderating effects of these 11 characteristics were tested because previous research has indicated that each characteristic may influence how consumers perceive, understand, or respond to pricing strategies and nutrition labelling policies, suggesting that they may also impact how consumers respond to the sugar taxes and FOP labels in this study (Anastasiou et al. 2019; Backholer et al. 2016; Hammond et al. 2018; McGill et al. 2015). First, as a conservative test for inclusion, we tested two-way interactions for each of the 11 individual-level variables with tax condition and label condition, separately in LMMs for each of the 8 outcomes of interest (resulting in a total of 176 two-way interactions). All moderating effects that were significant at $p < 0.05$ were added to the final model for each of the 8 nutrient outcomes. Final models also included variables for *tax condition*, *label condition*, and the 11 individual-level characteristics.

Financial regressivity

To investigate the potential financial regressivity of the sugar taxes tested, *price paid* and *tax paid* were examined. First, mean values for *price paid* and *tax paid* were reported by tax condition and by level of reported income adequacy. Second, two separate LMMs (one for beverage purchases and one for snack food purchases) were fitted with *price paid* as the outcome, and another two with *tax paid* as the outcome. All LMMs included variables for *tax condition*, *label condition*, and the 11 individual-level characteristic variables, with *income adequacy* the key variable of interest.

Results

The mean age of study participants was 32.9 years (SD 16.3). Over half were female (56.0%), almost half (44.9%) identified as White, almost two thirds (61.7%) had completed some

Table 3 Socio-demographic and health behaviour characteristics of sample participating in an experimental marketplace ($N = 3584$)

Characteristic	%
Sex	
Female	56.0
Male	44.0
Age, mean=32.9 years (SD 16.3)	
13–18	15.3
19–25	31.0
26–35	20.6
36–45	11.9
>45	21.3
Hunger	
'Not at all hungry'	26.4
'Slightly hungry' or 'moderately hungry'	61.7
'Very hungry' or 'extremely hungry'	11.9
Thirst	
'Not at all thirsty'	10.0
'Slightly thirsty' or 'moderately thirsty'	68.4
'Very thirsty' or 'extremely thirsty'	21.7
Weekly sugary drink consumption, mean=4.0 sugary drinks (SD 5.3)	
0	20.6
1–3	36.4
4–7	23.0
8–14	8.9
>14	3.7
Don't know	7.3
Efforts to modify intake ('Have you made an effort to consume more or less of the following in the past year?')	
Calories	
'Consume less'	54.9
'Consume more'	10.4
'No effort made' or 'Don't know'	34.7
Saturated fat	
'Consume less'	54.7
'Consume more'	4.2
'No effort made' or 'Don't know'	41.2
Sugar/added sugar	
'Consume less'	70.5
'Consume more'	3.5
'No effort made' or 'Don't know'	26.0
Salt/sodium	
'Consume less'	50.1
'Consume more'	3.7
'No effort made' or 'Don't know'	46.2
Health literacy (NVS score)	
High likelihood of limited literacy (0–1)	19.2
Possibility of limited literacy (2–3)	27.0
Adequate literacy (4–6)	53.9
Ethnicity	
White	44.9
Other, mixed, not stated	51.8
Indigenous	3.3
Education	
High school or less	26.6
Technical/trade school or college (partial or complete)	11.7
University (partial or complete)	61.7
Perceived income adequacy ('Thinking about your total monthly income, how difficult or easy is it for you to make ends meet?')	
'Very difficult' or 'Difficult'	19.5
'Neither easy nor difficult'	41.4
'Easy' or 'Very easy'	39.1
BMI classification	
Underweight	3.3
Normal weight	46.0
Overweight	22.8
Obesity	12.1
Not reported	15.8

BMI, body mass index; *NVS*, Newest Vital Sign

university education, over half (53.9%) demonstrated adequate health literacy, and 41.4% indicated it was neither easy nor difficult to make ends meet. Almost half (46.0%) were considered 'normal weight' based on self-reported heights and weights, and a majority of participants (50.1–70.5%) reported making an effort to consume less sugars, sodium, saturated fats, and calories in the past year.

Main effects of individual-level variables

After adjustment for multiple comparisons, seven of the 11 individual-level variables showed a significant effect on at least one outcome of interest (Table 4). Overall, *sex*, *age*, *hunger*, *weekly SD consumption*, and reported *efforts to modify intake* demonstrated the most consistent associations with nutrients purchased across the beverages and snack foods. Compared with females, males purchased beverages with more sodium and saturated fats, and snack foods with more sugars, saturated fats, and calories. Younger participants purchased beverages with more sugars and sodium and snack foods with more sugars, sodium, and calories than those purchased by older participants. Participants who reported being 'not at all' hungry at the time of the study purchased snack foods with less sodium, saturated fats, and calories than those purchased by participants who reported being 'very' or 'extremely' hungry. Participants reporting higher sugary drink consumption purchased beverages with more sugars, sodium, and calories, and snack foods with more sodium, saturated fats, and calories. Last, compared with participants who reported no efforts to modify their intake, those who

Table 4 Main effects of 11 individual-level characteristics on the amounts of sugars, sodium, saturated fats and calories purchased in beverages and snack foods in an experimental marketplace ($N = 3584$)

	Beverage purchases								Snack food purchases							
	Sugars (g)		Sodium (mg)		Saturated fats (g)		Calories (kcal)		Sugars (g)		Sodium (mg)		Saturated fats (g)		Calories (kcal)	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Sex																
Male	1.17 (−0.13, 2.48)	0.08	20.46 (15.83, 25.08)	<0.0001†	0.08 (0.02, 0.14)	0.008†	6.20 (0.67, 11.72)	0.03	2.61 (2.00, 3.22)	<0.0001†	0.06 (−8.87, 8.75)	0.99	0.20 (0.11, 0.30)	<0.0001†	13.94 (8.32, 19.56)	<0.0001†
Female*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Age																
13–18	3.57 (0.94, 6.20)	0.008†	9.64 (0.29, 18.98)	0.04	−0.06 (−0.18, 0.06)	0.32	9.72 (−1.15, 20.60)	0.08	2.15 (0.93, 3.37)	<0.001†	21.85 (4.06, 39.65)	0.02	−0.01 (−0.20, 0.18)	0.89	16.53 (5.47, 27.60)	0.003†
19–25	2.80 (0.87, 4.73)	0.004†	12.74 (5.85, 19.63)	<0.001†	−0.03 (−0.12, 0.05)	0.45	8.68 (0.66, 16.71)	0.03	2.10 (1.20, 3.00)	<0.0001†	19.06 (5.95, 32.18)	0.004†	0.11 (−0.03, 0.25)	0.13	11.50 (3.33, 19.66)	0.006†
26–35	−0.11 (−2.09, 1.87)	0.92	5.79 (−1.29, 12.87)	0.11	−0.05 (−0.14, 0.04)	0.28	−3.37 (−11.58, 4.84)	0.42	2.10 (1.18, 3.03)	<0.0001†	3.12 (−10.35, 16.60)	0.65	0.18 (0.03, 0.32)	0.02	8.25 (−0.11, 16.60)	0.05
36–45	−0.88 (−3.14, 1.37)	0.44	2.17 (−5.83, 10.16)	0.60	−0.06 (−0.16, 0.04)	0.21	−6.25 (−15.59, 3.09)	0.19	0.45 (−0.60, 1.50)	0.398	11.26 (−3.97, 26.50)	0.15	0.08 (−0.09, 0.24)	0.36	4.00 (−5.50, 13.51)	0.41
>45*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hunger																
Not at all	−0.50 (−2.81, 1.81)	0.67	−7.78 (−15.96, 0.40)	0.06	−0.07 (−0.17, 0.03)	0.19	−3.15 (−12.71, 6.40)	0.52	0.43 (−0.64, 1.51)	0.43	−28.63 (−44.21, −13.57)	<0.001†	−0.30 (−0.46, −0.13)	<0.001†	−13.82 (−23.55, −4.10)	0.005†
Slightly or moderately	0.57 (−1.47, 2.61)	0.58	−0.70 (−7.91, 6.50)	0.85	0.01 (−0.09, 0.09)	0.97	3.67 (−4.76, 12.09)	0.39	−0.44 (−1.39, 0.51)	0.36	−14.93 (−28.66, −1.20)	0.03	−0.23 (−0.38, −0.09)	0.002†	−9.41 (−17.99, −0.84)	0.03
Very or extremely*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thirst																
Not at all	−0.67 (−3.20, 1.86)	0.60	1.32 (−7.61, 10.26)	0.77	0.19 (0.08, 0.30)	<0.001†	3.91 (−6.54, 14.35)	0.46	−0.16 (−1.34, 1.01)	0.79	−11.26 (−28.27, 5.75)	0.20	−0.10 (−0.28, 0.08)	0.27	−12.79 (−23.43, −2.16)	0.02
Slightly or moderately	−1.07 (−2.65, 0.51)	0.18	0.83 (−4.75, 6.40)	0.77	0.10 (0.03, 0.17)	0.005†	−1.19 (−7.71, 5.33)	0.72	−0.40 (−1.14, 0.33)	0.28	7.98 (−2.64, 18.60)	0.14	0.07 (−0.04, 0.19)	0.21	1.02 (−5.62, 7.66)	0.76
Very or extremely*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Weekly SD consumption	0.64 (0.51, 0.76)	<0.0001†	1.06 (0.62, 1.49)	<0.0001†	0.01 (−0.01, 0.01)	0.42	2.62 (2.11, 3.13)	<0.0001†	−0.01 (−0.06, 0.05)	0.86	2.07 (1.24, 2.90)	<0.0001†	0.01 (0.01, 0.02)	0.001†	0.93 (0.40, 1.45)	<0.001†
Efforts to modify intake‡																
Consume less	−4.10 (−5.59, −2.61)	<0.0001†	−1.79 (−6.43, 2.85)	0.45	−0.02 (−0.07, 0.04)	0.61	−18.11 (−23.90, −12.31)	<0.0001†	−0.87 (−1.56, −0.17)	0.01	−10.94 (−19.78, −2.10)	0.02	−0.09 (−0.18, 0.01)	0.08	−8.79 (−14.69, −2.89)	0.004†

Table 4 (continued)

	Beverage purchases								Snack food purchases							
	Sugars (g)		Sodium (mg)		Saturated fats (g)		Calories (kcal)		Sugars (g)		Sodium (mg)		Saturated fats (g)		Calories (kcal)	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Consume more	1.83 (−2.15, 5.82)	0.37	4.52 (−7.85, 16.89)	0.47	−0.04 (−0.19, 0.11)	0.63	−7.76 (−17.38, 1.87)	0.11	0.53 (−1.32, 2.38)	0.58	−9.60 (−33.16, 13.96)	0.42	−0.07 (−0.31, 0.18)	0.59	−8.58 (−18.37, 1.21)	0.09
No effort made*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Health literacy																
High likelihood of limited literacy	0.89 (−1.00, 2.77)	0.35	−6.13 (−12.79, 0.52)	0.07	−0.09 (−0.17, −0.01)	0.03	3.90 (−3.82, 11.63)	0.32	0.54 (−0.33, 1.41)	0.23	6.94 (−5.74, 19.61)	0.28	0.19 (0.06, 0.33)	0.005†	5.16 (−2.70, 13.02)	0.20
Possibility of limited literacy	1.12 (−0.37, 2.62)	0.14	−0.85 (−6.14, 4.45)	0.75	−0.01 (−0.07, 0.06)	0.92	5.46 (−0.70, 11.63)	.08	0.27 (−0.42, 0.96)	0.45	2.36 (−773, 12.44)	0.65	0.10 (−0.01, 0.20)	0.08	1.30 (−4.97, 7.58)	0.68
Adequate literacy*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ethnicity																
White	−3.74 (−7.62, 0.14)	0.06	−4.99 (−18.70, 8.70)	0.48	−0.06 (−0.23, 0.11)	0.48	−19.41 (−35.43, −3.40)	0.02	0.05 (−1.75, 1.86)	0.95	−7.10 (−33.19, 19.00)	0.59	−0.08 (−0.36, 0.19)	0.55	−5.99 (−22.29, 10.30)	0.47
Other, mixed, not stated	0.26 (−3.60, 4.13)	0.89	−6.24 (−19.92, 7.43)	0.37	−0.13 (−0.30, 0.04)	0.15	−4.31 (−20.29, 11.66)	0.60	−0.19 (−2.00, 1.60)	0.83	−8.55 (−34.60, 17.49)	0.52	−0.08 (−0.35, 0.20)	0.59	−7.38 (−23.63, 8.88)	0.37
Indigenous*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Education																
High school or less	−0.34 (−2.20, 1.52)	0.72	−0.83 (−7.40, 5.74)	0.80	−0.02 (−0.11, 0.06)	0.56	−3.12 (−10.80, 4.56)	0.43	0.44 (−0.43, 1.30)	0.32	10.40 (−2.11, 22.92)	0.10	0.09 (−0.05, 0.22)	0.20	3.30 (−4.51, 11.12)	0.41
Technical/trade school or college	−0.34 (−2.40, 1.71)	0.74	−2.21 (−9.47, 5.05)	0.55	0.01 (−0.08, 0.10)	0.79	−1.11 (−9.62, 7.40)	0.80	0.43 (−0.52, 1.39)	0.37	0.39 (−13.45, 14.23)	0.96	0.05 (−0.10, 0.20)	0.50	4.32 (−4.34, 12.98)	0.33
University*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perceived income adequacy																
Very difficult or difficult	−0.26 (−2.06, 1.54)	0.78	−4.48 (−10.86, 1.90)	0.17	0.01 (−0.07, 0.09)	0.86	−0.79 (−8.24, 6.67)	.84	−0.56 (−1.40, 0.28)	0.19	−4.50 (−16.65, 7.64)	0.47	−0.03 (−0.15, 0.10)	0.69	−9.88 (−17.47, −2.29)	0.01
Neither easy nor difficult	−0.46 (−1.88, 0.96)	0.52	−0.86 (−5.88, 4.16)	0.74	0.03 (−0.03, 0.09)	0.32	−0.69 (−6.56, 5.18)	0.82	−0.42 (−1.08, 0.24)	0.21	−2.39 (−11.96, 7.18)	0.62	−0.05 (−0.15, 0.05)	0.33	−4.03 (−10.01, 1.95)	0.19
Easy or very easy*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
BMI classification																
Underweight	2.36 (−1.57, 6.29)	0.24	3.92 (−10.00, 17.85)	0.58	0.12 (−0.05, 0.30)	0.16	10.02 (−6.30, 26.35)	0.23	−1.37 (−3.20, 0.46)	0.14	0.32 (−26.20, 26.85)	0.98	−0.19 (−0.47, 0.09)	0.18	−9.69 (−26.30, 6.92)	0.25
Normal weight	−0.65 (−2.68, 1.37)	0.53	4.76 (−2.41, 11.94)	0.19	0.09 (0.01, 0.18)	0.05	0.59 (−7.80, 8.98)	0.89	0.31 (−0.63, 1.25)	0.52	−6.77 (−20.43, 6.90)	0.33	−0.04 (−0.18, 0.11)	0.61	−2.20 (−10.74, 6.34)	0.61

Table 4 (continued)

	Beverage purchases								Snack food purchases							
	Sugars (g)		Sodium (mg)		Saturated fats (g)		Calories (kcal)		Sugars (g)		Sodium (mg)		Saturated fats (g)		Calories (kcal)	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Overweight	−1.32 (−3.57, 0.93)	0.25	5.98 (−1.97, 13.93)	0.14	0.05 (−0.05, 0.15)	0.32	−1.93 (−11.23, 7.37)	0.69	0.13 (−0.91, 1.18)	0.81	−7.52 (−22.66, 7.63)	0.33	−0.12 (−0.28, 0.04)	0.14	−4.01 (−13.47, 5.46)	0.41
Obesity	−2.45 (−5.02, 0.13)	0.06	3.47 (−5.63, 12.57)	0.46	0.02 (−0.09, 0.14)	0.71	−7.95 (−18.60, 2.69)	0.14	−0.71 (−1.91, 0.49)	0.25	3.96 (−13.38, 21.29)	0.66	0.06 (−0.12, 0.24)	0.53	−6.52 (−17.36, 4.31)	0.24
Not reported*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

* Reference category

† Significant following a Benjamini-Hochberg adjustment assuming a false discovery rate of 0.05

‡ Only the modification effort relating to the outcome of interest (e.g., "sugars/added sugars" for the 'sugars (g)' outcome) were included in the corresponding model

BMI, body mass index; *CI*, confidence interval; *SD*, sugary drink

reported making an effort to consume less sugars/added sugars or calories in the past year purchased beverages with less sugars and beverages and foods with fewer calories, respectively.

Moderating effects of individual-level variables on the impacts of nutrition policies

Seven significant moderating effects were identified between the individual-level variables and *tax condition* (Fig. 2). No significant moderating effects were identified for *label condition*, and no moderating effects were significant for the sodium or saturated fats outcomes. Full results for all moderators can be found in Supplementary Table 2, and results of sensitivity analyses testing the inclusion of *age* as a continuous rather than categorical variable can be found in Supplementary Table 3. There were no differences in the overall pattern of results between the two sets of models.

Sex moderated the impact of *tax condition* on the amount of sugars purchased from beverages (Fig. 2). In particular, in the *tiered SD* tax condition (vs. *20% SSB* and *tiered SSB*), female participants purchased beverages containing fewer sugars whereas male participants did not. *Age* also moderated the impacts of *tax condition* on sugars purchased from beverages: participants aged 13–18 years purchased beverages with fewer sugars in response to each of the four beverage tax conditions (vs. *no tax*), whereas taxes had less impact on purchasing among participants aged >45 years. Similarly, participants aged 19–25 years purchased beverages with fewer sugars in response to the *20% SD* (vs. *no tax* and *20% SSB*), *tiered SSB* (vs. *no tax*), and *tiered SD* (vs. *no tax* and *20% SSB*), whereas this was not the case among participants aged >45 years.

Both *sex* and *age* moderated the impacts of tax condition on calories purchased from beverages, with results similar to those for sugars. Female participants purchased beverages with fewer calories in response to the *tiered SD* tax condition (vs. *20% SSB* and *tiered SSB*) whereas this was not the case for male participants, and participants in the youngest age categories tended to purchase beverages with fewer calories in response to most tax conditions (vs. *no tax*) whereas this was not the case for older participants. Participants' reported level of *thirst* also moderated the impacts of *tax condition* on calories purchased from beverages. Those who reported being 'slightly or moderately' thirsty purchased beverages with fewer calories in the *20% SSB* and *tiered SSB* tax conditions (vs. *no tax*) whereas this was not the case for those who reported being 'not at all' thirsty.

Within the snack food purchases, *age* and *education* moderated the impacts of tax condition on sugars and calories purchased, respectively. Again, compared to *no tax*, participants in younger age categories purchased snack foods with fewer sugars in response to either of the two sugary food taxes whereas there was little

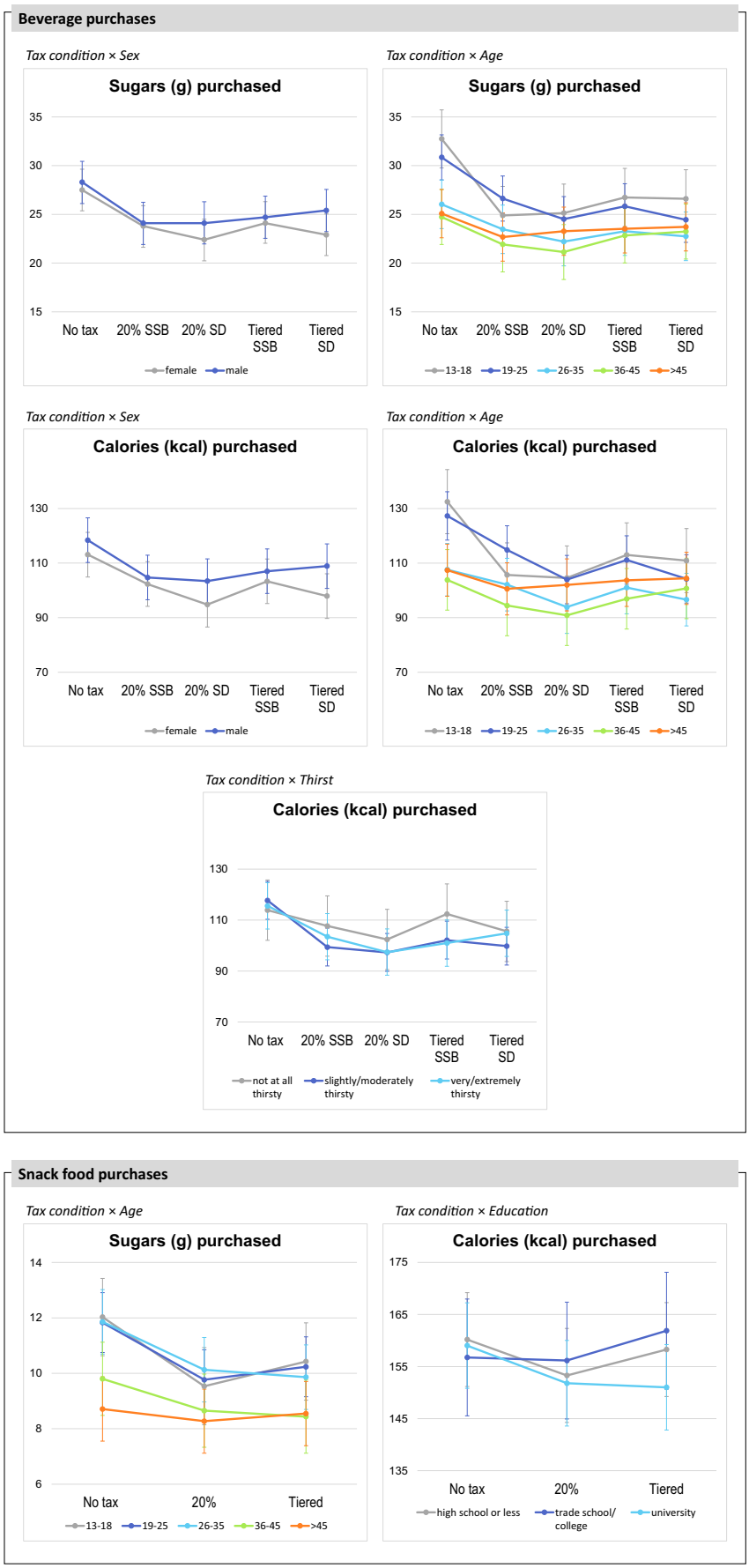

Fig. 2 Graphical representation of the moderating effects of individual-level characteristics on tax condition for sugars and calories purchased in beverages and snack foods in an experimental marketplace. Values presented for categorical variables (sex, thirst, education) are estimated marginal means. Values for continuous variables (age) represent lines of best fit for predicted values derived from the associated linear mixed model. Error bars represent 95% confidence intervals

change in purchasing among the oldest participants. In terms of *education*, participants reporting partial or complete university education purchased snack foods with fewer calories in the tiered tax condition (vs. *no tax*) whereas this was not the case for those reporting a trade school/college education.

Financial regressivity of sugar taxes

Table 5 presents the mean *price paid* and *tax paid* by participants across tax conditions and by perceived income adequacy level. *Income adequacy* was associated with *price paid* in the snack food purchases: participants reporting lower perceived income adequacy ('very difficult' or 'difficult' to make ends meet) purchased snack foods with slightly lower prices (−$0.04, 95% CI [−0.06, −0.01], $p = 0.007$) compared with those reporting a higher-income adequacy ('easy' or 'very easy' to make ends meet). Perceived income adequacy was not significantly associated with *price paid* in the beverage purchases or of *tax paid* in the beverage or food purchases.

Discussion

Our findings shed light on whether the sugars, sodium, saturated fats, and calorie content of beverages and snack food purchases differs across socio-demographic or health behaviour subgroups and whether these individual-level characteristics moderate the effects of sugar taxes and FOP labels on purchasing. The patterns of purchasing observed overall are consistent with research suggesting that younger, male individuals are more likely to consume higher amounts of sugars, sodium, and calories compared with their female and older counterparts (Health Canada 2018; Langlois and Garriguet 2011; Statistics Canada 2017) and that higher consumption of sugary drinks is often associated with other indicators of poor diet quality (Duffey and Popkin 2006). In this study, participants who were male, were younger, and reported more frequent consumption of sugary drinks were more likely to

Table 5 Mean price paid and tax paid in an experimental marketplace, by perceived income adequacy level, and by tax condition

Perceived income adequacy level	Tax condition	Mean price paid (SD)		Mean tax paid (SD)	
Beverage purchases					
'Very difficult' or 'Difficult'	No tax	$2.33	(0.42)	--	
	20% SSB tax	$2.50	(0.57)	$0.19	(0.24)
	20% SD tax	$2.49	(0.60)	$0.22	(0.25)
	Tiered SSB tax	$2.46	(0.55)	$0.16	(0.22)
	Tiered SD tax	$2.49	(0.57)	$0.21	(0.23)
'Neither easy nor difficult'	No tax	$2.33	(0.41)	--	
	20% SSB tax	$2.49	(0.56)	$0.19	(0.24)
	20% SD tax	$2.51	(0.60)	$0.23	(0.25)
	Tiered SSB tax	$2.49	(0.53)	$0.17	(0.22)
	Tiered SD tax	$2.51	(0.57)	$0.21	(0.23)
'Easy' or 'Very easy'	No tax	$2.30	(0.42)	--	
	20% SSB tax	$2.48	(0.56)	$0.18	(0.24)
	20% SD tax	$2.50	(0.58)	$0.22	(0.25)
	Tiered SSB tax	$2.47	(0.53)	$0.17	(0.22)
	Tiered SD tax	$2.49	(0.57)	$0.20	(0.23)
Snack food purchases					
'Very difficult' or 'Difficult'	No tax	$1.27	(0.27)	--	
	20% tax	$1.30	(0.31)	$0.06	(0.11)
	Tiered tax	$1.32	(0.31)	$0.06	(0.11)
'Neither easy nor difficult'	No tax	$1.29	(0.28)	--	
	20% tax	$1.34	(0.32)	$0.06	(0.12)
	Tiered tax	$1.34	(0.32)	$0.06	(0.12)
'Easy' or 'Very easy'	No tax	$1.28	(0.29)	--	
	20% tax	$1.34	(0.33)	$0.07	(0.12)
	Tiered tax	$1.34	(0.34)	$0.07	(0.12)

SD, standard deviation

purchase products containing higher amounts of the nutrients of interest. Additionally, participants who reported trying to consume less of a nutrient in the past year were more likely to purchase products containing lower amounts of that nutrient.

Furthermore, the findings suggest that a small number of socio-demographic and health behaviour characteristics played a moderating role in the relationship between the policies tested and participants' purchasing behaviours. In general, the taxes targeting sugary drinks (i.e., those including fruit juice) were more effective in reducing the sugars and calorie content of purchases among female participants than among male participants. *Age* also demonstrated moderating effects: younger participants reduced their purchasing of sugary products in response to the taxes to a greater extent than their older counterparts. As a result, the discrepancy in the sugars and calorie content of purchases between younger and older participants was reduced, although not eliminated, when the taxes were present. Young shoppers are a key target group for population-level nutrition interventions due to their high consumption of sugars, sodium, and SSBs (Health Canada 2018; Langlois and Garriguet 2011; Lopez and Fantuzzi 2012), and their strong response to the taxes may suggest an important advantage of these policies. Participants' *education* moderated the effect of tax on the calorie content of their snack purchases: in the presence of the tiered tax compared to no tax, the most highly educated participants reduced their purchasing of calories from snack foods to a greater extent than those who reported a trade school or college education. It is possible those with higher *educational* attainment were better able to navigate the greater variety of product types and ambiguous healthfulness across the snack foods compared with the beverages as compared with those with less formal education. Participants' reported level of *thirst* also emerged as a significant moderating effect on the number of calories purchased from beverages.

No moderating effects were identified for the FOP labelling conditions in this study. This may be due, in part, to the between-subject nature of the FOP labelling conditions and the resulting limited statistical power. The sample size was calculated based on the primary outcomes of the original analyses (i.e., sugars, sodium, saturated fats, and calories purchased) and therefore may have been insufficient to capture small but meaningful differences in the current analyses. Furthermore, the impacts of FOP labels on participants' purchases overall were smaller in magnitude compared with those of the taxes (Acton et al. 2019), and therefore, the moderating effects of FOP labels may have been more difficult to detect.

No moderating effects were observed between the policies tested and key variables of interest—such as perceived income adequacy and health literacy—that are often a focus when assessing the equity of population-wide nutrition policies. The absence of such moderating effects suggests that the effects of the taxes and FOP labels were consistent regardless of participants' perceived income adequacy or health literacy status. Income is a key variable of interest—particularly in discussions of sugar taxation policies—due to the potential for financially regressive effects, even when the health effects may be progressive (Backholer et al. 2016). Interestingly, models assessing *price paid* identified that participants with lower-income adequacy purchased snack food products with slightly lower prices as compared with those with higher income adequacy, with no differences in *tax paid*. The extent to which these data reflect actual financial consequences of sugar taxes in the real world is limited by the controlled nature of the study: participants were required to purchase a product, which disregards an important possible response to taxation (that is, to not purchase a product at all). The results, nevertheless, are provocative in the context of existing literature suggesting regressive effects (Backholer et al. 2016).

Ideally, given evidence of poorer dietary intake among low SES and low literacy groups (Hosseini et al. 2019), nutrition policies should aim to produce greater impacts among these populations to reverse existing inequities. Given that many existing nutrition and obesity interventions have proven to be less effective for low SES and low literacy individuals (McGill et al. 2015), the consistency of the sugar taxes and FOP labels across groups in this study supports these policies as a strong starting point for promoting equity. As interest increases for both sugary beverage and food taxes, the equity of these policies will be an important area for further investigation. It should also be noted that this study did not consider the policies' influence on other broader outcomes, such as individuals' relationships with foods. For example, labelling and taxation have the potential to stigmatize certain foods and beverages, including those most accessible to populations with lower SES. Such possible unintended consequences of these policies, beyond financial regressivity, warrant attention in the interest of promoting overall healthy eating and well-being among populations.

Several limitations of the current study should be noted. Non-probability recruitment methods were used, limiting the representativeness of the sample. The sample was younger, more highly educated, and represented a larger proportion of visible minorities compared with the general Canadian population. However, the study sample provided good variability across socio-demographic and health behaviour characteristics. An experimental marketplace design was used to replicate genuine purchasing behaviours; however, it may not represent how consumers interact with price and labels in real-world settings, in which other unmeasured influences may come into play. In addition, participants did not spend their own money, which may have generated more carefree purchases. Both policy measures tested were presented to participants without any description or explanation. Subsequently, the impact of the policies (and the potential to detect any moderating effects) may be diminished in comparison with real-world conditions in which

consumers may be more likely to be aware of a tax or FOP labelling system. Our analysis exploring price paid and tax paid was intended to provide insight into how income level may influence the way consumers respond to taxes, but these data may not be directly applicable to real-world financial outcomes of sugar taxes. Although our study featured purchases with real money and real financial consequences, results must be interpreted in the context of the controlled nature of the purchases and the limited range of products available for purchase. Despite these limitations, results from the current study provide important evidence on the consistency of the effects of sugar tax and labelling policies across key subpopulations and can be used in conjunction with other types of data—such as real-world evidence from other jurisdictions—to inform future policy.

Conclusion

The current study identified individual-level characteristics that may moderate the effects of sugar tax and FOP labelling policies; however, these moderators represented a small proportion of those tested, and the policies' effects were largely consistent across subgroups, including key socio-economic indicators such as perceived income adequacy and health literacy. In particular, the FOP nutrition labels tested showed uniform effects across all subgroups, suggesting that their impacts on consumer purchases are likely to be consistent regardless of literacy skills or education level. As more countries adopt sugar taxes and FOP labelling systems, it is ever more important to ensure these policies are producing effects that do not exacerbate existing health and economic disparities across populations, but rather contribute to eliminating them.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.17269/s41997-021-00475-x.

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Authors' contributions RBA, SIK, and DH designed research; RBA conducted research; RBA performed statistical analysis; RBA wrote the initial draft of the manuscript; SIK and DH contributed significantly to the manuscript; RBA had primary responsibility for final content. All authors have read and approved the final manuscript.

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Data availability Data can be made available upon request.

Declarations

Ethics approval and consent to participate All procedures performed in studies involving human participants were in accordance with the ethical standards of the University of Waterloo Office of Research Ethics (ORE #22494) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Consent for publication Not applicable.

Conflict of interest David Hammond has provided paid expert testimony on behalf of public health authorities in response to legal challenges from the food and beverage industry. All remaining authors declare no conflicts of interest.

Code availability Code can be made available upon request.

References

Acton, R. B., & Hammond, D. (2020). Impact of sugar taxes and front-of-package nutrition labels on purchases of protein, calcium and fibre. *Preventive Medicine 136*, 106091. https://doi.org/10.1016/j.ypmed.2020.106091.

Acton, R. B., Jones, A. C., Kirkpatrick, S. I., Roberto, C. A., & Hammond, D. (2019). Taxes and front-of-package labels improve the healthiness of beverage and snack purchases: a randomized experimental marketplace. *International Journal of Behavioral Nutrition and Physical Activity, 16*(1), 46. https://doi.org/10.1186/s12966-019-0799-0.

Anastasiou, K., Miller, M., & Dickinson, K. (2019). The relationship between food label use and dietary intake in adults: a systematic review. *Appetite, 138*, 280–291. https://doi.org/10.1016/J.APPET.2019.03.025.

Backholer, K., Sarink, D., Beauchamp, A., Keating, C., Loh, V., Ball, K., 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 Nutrition, 19*(17), 3070–3084. https://doi.org/10.1017/S136898001600104X.

Balcombe, K., Fraser, I., & Di Falco, S. (2010). Traffic lights and food choice: a choice experiment examining the relationship between nutritional food labels and price. *Food Policy, 35*(3), 211–220.

Cawley, J., Frisvold, D., Hill, A., & Jones, D. (2019). The impact of the Philadelphia beverage tax on purchases and consumption by adults and children. *Journal of Health Economics, 67*. https://doi.org/10.1016/j.jhealeco.2019.102225.

Cawley, J., Frisvold, D., Hill, A., & Jones, D. (2020). Oakland's sugar-sweetened beverage tax: impacts on prices, purchases and consumption by adults and children. *Economics and Human Biology, 37*. https://doi.org/10.1016/j.ehb.2020.100865.

Colchero, M. A., Molina, M., & Guerrero-López, C. M. (2017). After Mexico implemented a tax, purchases of sugar-sweetened beverages decreased and water increased: difference by place of residence, household composition, and income level. *The Journal of Nutrition, 147*(8), 1552–1557. https://doi.org/10.3945/jn.117.251892.

Cornelsen, L., Mytton, O. T., Adams, J., Gasparrini, A., Iskander, D., Knai, C., et al. (2017). Change in non-alcoholic beverage sales following a 10-pence levy on sugar-sweetened beverages within a national chain of restaurants in the UK: interrupted time series analysis of a natural experiment. *Journal of Epidemiology and Community Health, 71*(11), jech-2017-209947. https://doi.org/10.1136/jech-2017-209947.

Ducrot, P., Méjean, C., Julia, C., Kesse-Guyot, E., Touvier, M., Fezeu, L., et al. (2015). Objective understanding of front-of-package nutrition labels among nutritionally at-risk individuals. *Nutrients, 7*(8), 7106–7125. https://doi.org/10.3390/nu7085325.

Duffey, K. J., & Popkin, B. M. (2006). Adults with healthier dietary patterns have healthier beverage patterns. *The Journal of Nutrition, 136*(11), 2901–2907. https://doi.org/10.1093/jn/136.11.2901.

Fernandez, M. A., & Raine, K. D. (2019). Insights on the influence of sugar taxes on obesity prevention efforts. *Current Nutrition Reports*. https://doi.org/10.1007/s13668-019-00282-4.

Gorski, M. T., & Roberto, C. A. (2015). Public health policies to encourage healthy eating habits: recent perspectives. *Journal of Healthcare Leadership, 7*, 81–90. https://doi.org/10.2147/JHL.S69188.

Hammond, D., Goodman, S., & Acton, R. B. (2018). Front-of-package (FOP) nutrition labelling: evidence review.

Health Canada. (2018). Sodium intake of Canadians in 2017. https://www.canada.ca/content/dam/hc-sc/documents/services/publications/food-nutrition/sodium-intake-canadians-2017/2017-sodium-intakes-report-eng.pdf. Accessed 18 Sep 2020.

Hiza, H. A. B., Casavale, K. O., Guenther, P. M., & Davis, C. A. (2013). Diet quality of Americans differs by age, sex, race/ethnicity, income, and education level. *Journal of the Academy of Nutrition and Dietetics, 113*(2), 297–306. https://doi.org/10.1016/j.jand.2012.08.011.

Hosseini, Z., Whiting, S. J., & Vatanparast, H. (2019). Canadians' dietary intake from 2007 to 2011 and across different sociodemographic/lifestyle factors using the Canadian health measures survey cycles 1 and 2. *Journal of Nutrition and Metabolism, 2019*, 1–8. https://doi.org/10.1155/2019/2831969.

Kanter, R., Vanderlee, L., & Vandevijvere, S. (2018). Front-of-package nutrition labelling policy: global progress and future directions. *Public Health Nutrition, 21*(08), 1399–1408. https://doi.org/10.1017/S1368980018000010.

Langlois, K., & Garriguet, D. (2011). Sugar consumption among Canadians of all ages. *Health Reports, 22*(3), 23–27.

Lima, M., Ares, G., & Deliza, R. (2018). How do front of pack nutrition labels affect healthfulness perception of foods targeted at children? Insights from Brazilian children and parents. *Food Quality and Preference, 64*, 111–119.

Lopez, R. A., & Fantuzzi, K. L. (2012). Demand for carbonated soft drinks: implications for obesity policy. *Applied Economics, 44*(22), 2859–2865. https://doi.org/10.1080/00036846.2011.568397.

Machín, L., Cabrera, M., Curutchet, M. R., Martínez, J., Giménez, A., & Ares, G. (2017). Consumer perception of the healthfulness of ultra-processed products featuring different front-of-pack nutrition labeling schemes. *Journal of Nutrition Education and Behavior, 49*(4), 330–338.e1. https://doi.org/10.1016/j.jneb.2016.12.003.

Mansfield, E. R., Wahba, R., Gillis, D. E., Weiss, B. D., & L'Abbé, M. (2018). Canadian adaptation of the Newest Vital Sign©, a health literacy assessment tool. *Public Health Nutrition, 21*(11), 2038–2045.

McGill, R., Anwar, E., Orton, L., Bromley, H., Lloyd-Williams, F., O'Flaherty, M., et al. (2015). Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. *BMC Public Health, 15*(1), 457. https://doi.org/10.1186/s12889-015-1781-7.

Nakamura, R., Mirelman, A. J., Cuadrado, C., Silva-Illanes, N., Dunstan, J., & Suhrcke, M. (2018). Evaluating the 2014 sugar-sweetened beverage tax in Chile: an observational study in urban areas. *PLoS Medicine, 15*(7), e1002596. https://doi.org/10.1371/journal.pmed.1002596.

Nederkoorn, C., Havermans, R. C., Giesen, J. C. A. H., & Jansen, A. (2011). High tax on high energy dense foods and its effects on the purchase of calories in a supermarket. An experiment. *Appetite, 56*(3), 760–765. https://doi.org/10.1016/j.appet.2011.03.002.

Popkin, B. M., & Hawkes, C. (2016). Sweetening of the global diet, particularly beverages: patterns, trends, and policy responses. *The Lancet Diabetes and Endocrinology*. https://doi.org/10.1016/S2213-8587(15)00419-2.

Shangguan, S., Afshin, A., Shulkin, M., Ma, W., Marsden, D., Smith, J., et al. (2019). A meta-analysis of food labeling effects on consumer diet behaviors and industry practices. *American Journal of Preventive Medicine, 56*(2), 300–314. https://doi.org/10.1016/J.AMEPRE.2018.09.024.

Spronk, I., Kullen, C., Burdon, C., & O'Connor, H. (2014). Relationship between nutrition knowledge and dietary intake. *The British Journal of Nutrition, 111*(10), 1713–1726. https://doi.org/10.1017/S0007114514000087.

Statistics Canada. (2017). Health fact sheets: nutrient intakes from food, 2015.

Taillie, L. S., Rivera, J. A., Popkin, B. M., & Batis, C. (2017). Do high vs. low purchasers respond differently to a nonessential energy-dense food tax? Two-year evaluation of Mexico's 8% nonessential food tax. *Preventive Medicine*. https://doi.org/10.1016/j.ypmed.2017.07.009.

Temple, J. L., Johnson, K. M., Archer, K., LaCarte, A., Yi, C., & Epstein, L. H. (2011). Influence of simplified nutrition labeling and taxation on laboratory energy intake in adults. *Appetite, 57*(1), 184–192. https://doi.org/10.1016/j.appet.2011.04.018.

Teng, A. M., Jones, A. C., Mizdrak, A., Signal, L., Genç, M., & Wilson, N. (2019). Impact of sugar-sweetened beverage taxes on purchases and dietary intake: systematic review and meta-analysis. *Obesity Reviews, 20*(9), 1187–1204. https://doi.org/10.1111/obr.12868.

UK HM Treasury. (2016). Budget 2016: George Osborne's speech - oral statements to Parliament. https://www.gov.uk/government/speeches/budget-2016-george-osbornes-speech. Accessed 16 Apr 2020.

World Cancer Research Fund International. (2018). Building momentum: Lessons on implementing a robust sugar sweetened beverage tax. https://www.wcrf.org/int/policy/our-publications/lessons-implementing-sugar-sweetened-beverage-tax. Accessed 18 Sep 2020.

World Cancer Research Fund International. (2019). Building momentum: lessons on implementing a robust front-of-pack food label. https://www.wcrf.org/int/policy/our-publications/lessons-implementing-front-of-pack-label. Accessed 18 Sep 2020.

World Cancer Research Fund International. (2020). Nourishing framework. https://www.wcrf.org/int/policy/policy-databases/nourishing-framework. Accessed 18 Sep 2020.

World Health Organization. (2017). Taxes on sugary drinks: why do it? https://apps.who.int/iris/handle/10665/260253. Accessed 18 Sep 2020.

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