A MULTIMETHOD APPROACH TO EVALUATING A THRESHOLD-BASED SUGAR-SWEETENED BEVERAGE TAX IN SOUTH AFRICA: CHANGES IN DIETARY INTAKE, BEHAVIORAL DRIVERS, AND THE NEWS MEDIA

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ABSTRACT

Michael A. Essman: A Multimethod Approach to Evaluating a Threshold-Based Sugar-Sweetened Beverage Tax in South Africa: Changes in Dietary Intake, Behavioral Drivers, and the News Media
(Under the direction of Lindsey Smith Taillie)

In April 2018, the South African government implemented the first sugar-sweetened beverage (SSB) tax to be based on sugar per gram for drinks with more than 4g sugar/100mL, to reduce rising SSB consumption and associated chronic diseases. SSB taxes have been shown to reduce purchases, but few studies have included dietary intake data. Thus, it is unclear the extent to which SSB taxes are associated with changes in SSB intake, and whether these changes are driven more by behavioral shifts or reformulation. In addition, it is unclear whether other factors, like SSB knowledge or risk perception, modify these effects. Finally, national SSB taxes occur in a broader social environment, whereby media sources select which topics garner the most attention and how they should be understood, thereby influencing public knowledge about the policy which could change dietary intake.

Using repeated cross-sectional survey data collected from approximately 2,500 young adults living in Langa, South Africa and annually updated food composition tables, we examined pre-post tax changes in taxed and untaxed beverage intake, changes in drivers of behavioral change, and whether they moderated the effects of the tax on taxed beverage intake. We also conducted a quantitative media content analysis to examine how news media represented the tax. After the tax, taxed beverage energy intake declined by 24% due to behavioral change and an additional 8% due to reformulation. Most behavioral drivers were not strongly linked to taxed beverage intake, had small post-tax changes, and did not appear to modify the tax effect. Our

media analysis found industry expressed no support for the HPL, whereas academics, government, and other sources mainly expressed support. Health reasons were the most common justifications for support, and economic harms were the most common justifications for opposition.

This work demonstrates the threshold-based SSB tax successfully affected both behavior and industry reformulation, thereby refuting industry claims identified in our media content analysis that the tax would not change SSB intake. However, our results on behavioral drivers suggest further work is needed to understand the effects of mass media, including news and targeted campaigns, on behavioral drivers of SSB consumption.

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LIST OF ABBREVIATIONS AND SYMBOLS

BFQ Beverage Frequency Questionnaire

FCT Food Composition Table

HPL Health Promotion Levy

SSB Sugar-Sweetened Beverage

UK United Kingdom

CHAPTER 1. INTRODUCTION

Background

In 2010, the World Health Organization issued a call for national governments to help their citizens reduce added sugar consumption to less than 10% of daily energy intake.[1] Consumption of sugar-sweetened beverages (SSBs) is a key contributor to added sugar intake, is increasing globally, and is significantly associated with increased risk of obesity, diabetes, and cardiovascular diseases.[2–5] SSB taxes are one way to reduce sugar intake in the food supply because economic disincentives can reduce purchases.[6] Previous evaluations have demonstrated that taxes reduce SSB purchases, but the ability to track changes in diets after the tax is limited to crude store-intercepts,[7] household purchase data,[8–10] large aggregate sales data,[10,11] or mostly studies utilizing beverage frequency questionnaires,[12–15] which are poor estimators of absolute mean intake in a population.[16] This gap in knowledge is critical because it is unclear how purchases relate to intake, and the amount and quality of calories consumed is a key step on the path to obesity prevention.

Moreover, few studies have examined individual-level factors that may change in response to taxes to improve diets or modify the effects of the tax such as knowledge of the health harms of SSBs. Although low knowledge about the health harms of SSBs is associated with increased SSB intake,[17] and previous work has demonstrated that media campaigns can increase knowledge about the health risks of SSBs,[18] it is unknown whether changes in knowledge may modify the effects of SSB taxes on dietary intake. An interaction effect between SSB knowledge and time since tax implementation on taxed beverage intake could occur if the tax policy imparts new information about SSBs that was not previously considered. A tax policy

can have a signaling effect, whereby it not only affects prices but also provides additional information about the government's stated goal.[19–21] For the HPL, the tax may signal to consumers that the government considers SSBs to be harmful, and they should reconsider how they purchase beverages. This new information could modify how consumers make beverage consumption decisions going forward.

Beyond their effects on dietary intake, SSBs taxes, particularly those implemented at the national level, are often accompanied by mass media campaigns and news media coverage to discuss the purpose and potential effects of the tax on health and the economy.[22,23] Mass media framings can affect public health through second-level agenda setting, whereby media sources select which topics garner the most attention and how they should be understood.[24,25] This selective coverage can affect whether policymakers are likely to implement, maintain, strengthen or weaken the design of a policy, or add new policies. For the public, the media can influence their knowledge about SSBs and perceptions of risk, as well as their awareness and acceptance of the tax, which could influence intake. An understanding of how media frames SSB taxes is important for contextualizing and understanding changes in SSB knowledge, perceptions, and intake before and after the tax, and these results can help inform the implementation of future policies, such as mass media campaigns to increase knowledge and awareness, that can help maximize the effectiveness of the tax.

We have an opportunity to address these gaps in the scientific literature by focusing on a new tax policy in South Africa that builds upon the methods used in previous studies. South Africa, with one of the highest SSB consumption rates in Africa and a growing burden of type II diabetes,[26] is the first sub-Saharan African country to institute a sugary beverage tax, called the Health Promotion Levy (HPL), implemented in April 2018. South Africa provides a unique context for this study, as they have introduced a novel tax structure that applies a 2.1 cent tax rate each additional gram of sugar above a 4g/100 ml threshold.[27] This is the first national tax evaluation to examine changes in dietary intake of taxed beverages as a key outcome using

detailed 24-hour recall dietary data. We have a large study sample, with approximately 2,500 participants at each data collection period, with enough power to detect a statistically significant effect of an SSB tax on dietary intake.

A key goal of this study is to examine the more nuanced pathways to changes in dietary intake. We are able to account for reformulation effects across time, one of the central goals of threshold-based SSB taxes, due to the availability of nutrition facts panels collected annually. These nutrition facts panel data were linked with beverages reported in the 24-hour recalls to create food composition tables (FCTs) that were appropriate for the South African food supply and updated at each data collection period. First, we used the same FCTs linked to reported beverages across the entire study period to examine changes in beverage intake assuming behavioral change only and no reformulation. Next, we used the updated FCT in the post-tax period to examine total changes in beverage intake after the tax, with the difference amounting to reformulation's marginal effect.

To study whether psychological factors were associated with taxed beverage intake or modified the effects of the tax on intake over time, we collected data on potential modifiers including awareness of the tax, knowledge about SSBs and associated chronic disease risks, and intentions to reduce SSB consumption. This is the first study to investigate whether psychological factors may modify consumer response to a tax and is a crucial addition to a SSB tax evaluation to identify potential modifiers that can be targeted by future policies to improve the effectiveness of a national SSB tax.

Finally, given news media can increase public awareness and sway opinions, this study analyzed how the media represented the HPL, including expressions of support or challenge, topics associated with the levy, and stakeholder views of the HPL. We performed a quantitative content analysis of online South African news articles related to the HPL published between January 1, 2017 and June 30, 2019, analyzing health and economic topics as well as support or opposition discussed by source. This work can identify which topic frames are most commonly

used to support SSB taxes and which are most commonly used to undermine them. With a clear understanding of frames associated with policy support, policymakers may be better prepared to generate and maintain public support.

Research Aims

Aim 1: Estimate the pre-post changes in taxed and untaxed beverage intake in Langa, South Africa. To evaluate the South African 4g/100 ml threshold SSB tax policy, we analyzed 24-hour diet recalls from the Langa survey of young township adults from Cape Town, South Africa. We developed time-specific FCTs to reflect the changing food supply and assign beverage taxation status.

1a. We examined changes in sugar, energy and volume for taxed, untaxed and total beverages using the pre-tax FCT across the entire study period to isolate the effects of behavioral changes

1b. Repeated the analysis from 1a, this time using an updated FCT in the post-tax period to capture the marginal effect of reformulation.

Aim 2: Examine changes in tax awareness, SSB knowledge, and SSB risk perception, and determine whether these variables modify the relationship between SSB consumption and time since tax implementation. At pre-tax and post-tax, we collected data on drivers of behavior change including participants' awareness of the tax, SSB knowledge and risk perceptions, and intentions to reduce SSB consumption. We tested three primary research questions:

2a. Are SSB knowledge and SSB risk perception, tax awareness, or intentions to reduce SSB consumption associated with taxed beverage intake at baseline?

2b. Did mean SSB knowledge, SSB risk perceptions, tax awareness, or intention to reduce SSB consumption change from pre-tax to post-tax?

2c. Do SSB knowledge and SSB risk perception, tax awareness, or intentions to reduce SSB consumption modify the effect of time on taxed beverage intake?

Aim 3: Examine the news media reaction to the South African HPL. We performed a quantitative content analysis of online South African news articles related to the HPL published between January 1, 2017 and June 30, 2019.

3a. Code articles for presence or absence of mentions related to health and economic effects of the HPL, HPL support or opposition, and proposed solutions for excessive sugar consumption.

3b. Test whether the distribution of supporting, opposing, or balanced articles changed from before to after the HPL law was passed.

3c. Test whether topic mentions related to the HPL and supporting versus opposing views differed by source.

3d. Test whether proposed solutions to excessive sugar consumption differed by source.

CHAPTER 2. LITERATURE REVIEW

Why Study the Impact of SSB Taxes?

Consumption of SSBs is increasing globally[2], and is significantly associated with increased risk of obesity[3], diabetes[4], and cardiovascular disease[5]. In 2010, the World Health Organization issued a call for national governments to help their citizens reduce added sugar consumption to less than 10% of daily energy intake[28]. SSB taxes are one way to reduce sugar intake in the food supply because economic disincentives can reduce purchases[6]. Recent systematic reviews have found that SSB taxes are effective in reducing SSB purchases, but their role in reducing population obesity remains unclear[29,30]. In theory, reducing SSB consumption could reduce population obesity and associated chronic diseases in the long term[31] due to evidence that SSB demand is elastic, meaning that changes in consumption are closely proportional to changes in price[32–34]. In practice, most evidence for the health benefits of SSB taxes comes from simulations, which suggest that a price increase on SSBs could avert thousands of cases of diabetes in Mexico[35,36], the United Kingdom[37], Australia[38], India[39], Germany[40], and South Africa[41]. SSB taxes may also reduce health care costs as they can reduce the population burden of expensive, long-term chronic diseases[42,43]. Thus, there are large potential economic and health benefits of SSB taxes, but the mechanisms through which large scale policies may affect behavior are understudied[42,44]. Showing that SSB taxes are linked to decreased sugar intake would provide strong evidence that large potential economic and health benefits are possible.

Why is this Study Urgent?

There is an urgent need for governments to make progress on population obesity prevention and reduction due to the high economic and health burden of obesity and associated non-communicable diseases (NCDs)[45]. In 2016, over 1.9 billion adults were overweight or obese, and obesity is associated with a greater chronic disease burden than underweight[46]. Since 2018, the United Kingdom implemented a threshold based tax[47], Colombia introduced an SSB tax, and Peru modified their SSB tax rate[48,49]. Evaluations of sugar-tiered tax rates are urgently needed to inform policymakers. This study will improve upon SSB tax evaluations by incorporating a wider array of data that not only measures changes in actual SSB consumption before and after the tax, but also investigating pre-post measures of other modifiers of dietary choices, including knowledge and attitudes about the health effects of SSBs. Obesity is a complex, multifactorial disease, which will require comprehensive policy measures to make progress[50]. Thus, it is imperative that national-level policy analyses not only examine changes in intake before and after the policy, but also understand some of the key modifiers of behavior change. This comprehensive approach is needed to better understand the multiple pathways through which health taxes affect diets and weight outcomes. It is crucial to identify the key modifiers of behavior change to inform and improve future policies.

What's Missing in the SSB Tax Literature?

We have an opportunity to address gaps in the scientific literature by focusing on a new tax policy in South Africa that builds upon the methods used in previous studies. Previous evaluations have been used to demonstrate that these taxes reduce SSB purchases, but the ability to track changes in diets after the tax is limited to household purchase data, large aggregate purchase data, or only US based studies utilizing biased measures of dietary intake, the limitations of which are outlined below. Much less is known about SSB intake, which is critical, since it is changes in actual intake which will lead to potential changes in weight.

There have been two previous evaluations of SSBs taxes in the United States using dietary intake data, one in Philadelphia[15] and one in Berkeley, CA[13,14]. The evaluation of the Philadelphia tax estimated both SSB consumption volume and consumption frequency, but food (and beverage) frequency questionnaires are less accurate (subject to greater bias) than 24h recalls[51]. However, when used, these problems can be improved by an internal calibration study in a subsample of the study population[16], which was not done. One of the strengths of frequency questionnaires is they are better at estimating usual intake than 24-h recalls, but 24-h recall are the preferred method for assessing post-intervention changes in mean dietary intake in a population due to their greater accuracy[16].

The evaluation of the Berkeley SSB tax used a BFQ that only queried SSB consumption frequency but not intake volume. Estimating caloric intakes using only frequency measures (e.g. reduction of 0.5 servings per day) would require potentially invalid assumptions about mean serving size, particularly if there are high consumers in the population who consume large amounts per consumption event. Our study includes a BFQ that also asks for amounts, which is crucial for a high consuming population and requires fewer assumptions from the researchers regarding the usual portion size, and the addition of a 24h recall allows for more accurate measure of population mean intake than a BFQ alone.

Another severe limitation of the Berkeley and Philadelphia SSB tax evaluations using dietary data was the fact that dietary intakes are not linked to food composition tables, which are necessary to calculate nutrient intakes and total calories from 24-h recalls and FFQs. As a result, the study by Zhong and colleagues[15] is able to estimate changes in beverage volume consumption, but is unable to estimate changes in calories from SSBs, which is crucially important as changes in energy intake are central to weight loss. One of our study's key innovations will be to develop our own food composition tables that are appropriate for the South African context, which will be then linked with the dietary assessment instruments to better estimate changes in nutrient intakes from SSBs before and after the tax.

To summarize, diet has been rarely measured in SSB tax evaluations, and so far, has only been measured in studies based in the United States. The studies that do exist mostly consist of beverage frequency questionnaires, which are a poor estimator of absolute mean intake in a population[16]. Furthermore, few studies have examined the impact of SSB taxes in largely low-income communities. This is an important addition because two thirds of cardiovascular deaths occur in low and middle income countries, and within those countries it is the lowest income communities that have the highest risk[52]. It is therefore essential to understand how low income communities, particularly those at highest risk for diet-related NCDs, are affected by SSB taxes. Our study seeks to fill these gaps and improve upon the SSB tax evaluations to date by examining the changes in SSB consumption before and after an SSB tax using a repeated cross-sectional study of households in the Langa township of South Africa, using dietary intake data obtained from both 24h recalls and beverage frequency questionnaires.

Tax Structure Impact

As more SSB taxes are implemented every year[53], there is a growing need for evaluations to identify which tax structure is most effective for reducing added sugar consumption. Volume-based taxes are the most common[30] approach and may be more efficient for raising revenues to apply toward health promotion subsidies[54], but taxes based on sugar concentration may lead to greater impact on health outcomes by promoting both product reformulation as well as reduced purchases, thereby reducing the harm from excessive added sugar[55]. A tax on sugar content can incentivize industry reformulation because manufacturers can reduce the tax burden on their products by reducing their sugar content, not just by reducing sugar content below 4g/100mL but by reducing any additional sugar above this threshold (i.e. reducing sugar from 10g/100mL to 9g/mL)[56]. More data are needed to determine the tradeoffs between tax structures. The South African tax is the first of its kind, which applies a fixed 2.1 cent tax rate for every gram of sugar (both intrinsic and added) above a 4g/100 ml

threshold[27]. Early calculations suggest that the average tax rate is approximately 10%. It is important to understand this novel tax structure in the context of other SSB tax evaluations because rather than having a uniform tax on volume, the 4g/100 ml threshold creates a target for industry reformulation of SSB products. A similar threshold-based multi-tiered SSB levy has been passed in the United Kingdom, but the South African tax structure is potentially even stronger as each additional gram per 100mL imposes a greater tax.

Behavior Change is Complex and Likely Related to More than SSB Price Changes

In addition to price sensitivity, there may be individual-level factors that influence consumer responses to SSB taxes. For example, a tax policy may have a signaling effect, meaning that awareness of the policy may increase the odds of reducing SSB consumption compared to those who are not aware of the SSB tax policy[57]. Thus, the effect of SSB policies can be modified by factors beyond consumer's reactions to price changes. In Mexico, SSB consumption decreased in response to the tax to an even greater extent than economic models first predicted[8,58]. Some of this increase may be attributed to vocal and organized health advocacy campaigns that increased awareness and public acceptance[59]. Additionally, health knowledge about SSBs is associated with willingness to decrease SSB consumption[17].

This will be the first study to investigate whether factors such as SSB knowledge may modify consumer response to the tax by changing over time (Aim 2). SSB taxes are broad tools that have been demonstrated to affect SSB purchases, but the individual characteristics which may modify responses to national policies are poorly understood. We have collected data on potential modifiers including awareness of the tax, knowledge of what beverages can be identified as SSBs, and knowledge about the risk of developing obesity and non-communicable diseases (NCDs) as a result of excessive SSB consumption. The effect of these changing potential modifiers will be estimated to understand key variables that may modify the effects of SSB taxes on consumption. This is a crucial addition to a SSB tax evaluation because we may

identify potential modifiers that can be targeted by future policies to improve the effectiveness of a national SSB tax.

Media Response Impact

In the context of obesity prevention policy, SSB taxes are specifically designed to affect pricing and individual consumption decisions, but there may be broader societal factors that are also influenced by national level SSB taxes, which then in turn affect SSB consumption. Media representations of SSBs taxes shape public perceptions about their purpose[60], and resulting changes in awareness of the tax and understanding of the harms of SSBs can ultimately determine whether SSB taxes will be accepted by the public[44,61]. One mode through which media affects health is second-level agenda setting, whereby media sources not only select which topics garner the most attention, but also suggest the ways in which those topics should be understood[24]. By defining a social problem and the dimensions along which it should be understood, the media can influence how both policymakers and the general public approach solutions[25,62,63]. For example, studies of agenda setting have found a strong influence of South Africa's mainstream news media in shaping the discourse about HIV/AIDS due to an influential role in politics after apartheid[64]. However, no other studies exist that examine the effect of media on discourse about obesity in South Africa.

The frequency of media coverage can influence the topic salience[65], and urgency for policy action may vary with changing media coverage[62,66]. A recent systematic review of SSB tax implementation found that the framing of the SSB tax policy was crucial to whether the policy succeeded or failed in being passed and implemented[44]. Framing obesity as a disease/phenomena due to environmental factors rather than due to individual choice may improve public acceptance of government intervention and accelerate the implementation of SSB taxes[60,67,68]. Analysis of the media coverage of a SSB tax in the United Kingdom found increasing coverage of the SSB tax leading up to its implementation, a surge in opposing articles against the SSB tax, and an association between characterizing overconsumption of

SSBs as an industry-driven problem and needing governmental policy solutions[23]. In summary, media framings can affect both policymakers' decisions related to SSB tax legislation and consumers' decisions to purchase and consume SSBs. Following the example of previous studies[25,67], we will examine how the South African news media has framed the problem of SSB consumption, which has implications for whether taxation is an appropriate policy response that will be publicly supported.

This media content analysis will add to a growing body of literature examining the media environment related to reducing SSB consumption through taxes or other regulations[23,60,62,69]. Analyzing the framings used to debate public health policies is important because framings reflect the strategies that key stakeholders use to affect public health debates and decisions[62]. These studies can be useful to identify the conditions under which public health policies may be more or less likely to succeed. Studies that investigate media debates on NCD risk and policy are important for developing a more nuanced understanding of the complex ways in which media representations of unhealthy commodity industries are shaped by, and contribute to shaping, public, corporate and political discourse. These analyses can provide insights into how to frame effective public health messages and counter frames that undermine public health goals.

For our study, analysis of media representations of the tax will allow us to detect the framings that may make SSB tax acceptance more likely and to better understand the framings that are employed to either support or challenge the legitimacy of SSB tax policies. Including a media content analysis in our study will allow us to better understand the changing media landscape in which these changes in SSB consumption are occurring.

Why this Study Population in South Africa?

Understanding the effects of the SSB tax in South Africa is important for several reasons. First, SSB consumption in South Africa is one of the highest in Africa and continues to increase, carrying with it an increasing burden of obesity and NCDs[26]. Second, diabetes is the

greatest killer of women in South Africa, and 68% of women are overweight or obese, and approximately 20% have severe obesity (BMI ≥35)[26]. This is the highest obesity rate in sub-Saharan Africa. Therefore, unless it is halted, the growing SSB consumption is likely to increase the burden of obesity and chronic disease in the future[70]. Lastly, South Africa is also the first sub-Saharan African country to implement an SSB tax, which could serve as a guide to other African communities where overweight and diet-related NCDs are rapidly increasing.

This study population in the Langa township of South Africa, selected by our collaborators at the University of the Western Cape (UWC), is an ideal study population for evaluating the changes in SSB consumption before and after the SSB tax for several reasons. First, it is the oldest settlement area and a stable community that can be followed over time. Second, it contains a large number of individuals who are heavy consumers of SSBs and are at high risk of associated chronic disease. The predominant age group within the community is 17-35 years, the highest consumers of SSBs, and the population is largely black African[71], the group at greatest risk of chronic disease associated with poor diet[26]. Finally, this is a low income settlement with high unemployment, meaning this population is far less likely to be diagnosed and treated for sugar-related NCDs, making primary prevention an even higher priority.

We expect to see a change in SSB consumption as a result of the recent SSB tax in South Africa based on the availability of the price elasticity of demand for SSBs in South Africa. Price elasticity is a measure of how consumers respond to price changes for specific products. If consumers are price sensitive, then they will change their purchases in response to price changes. If consumers are price insensitive, then they may not change their purchases after price changes. In South Africa, the price elasticity of demand for SSBs in South Africa is -1.18 for carbonated soft drinks and -1.17 for concentrates[72]. For comparison, the price elasticity of demand for soft drinks in Mexico was recently determined to be -1.16[33]. Additionally, there was

a greater reduction in taxed SSBs among low-income populations in Mexico[8]. This suggests that the one-year expected change in SSB consumption in response to the tax in South Africa should be of similar magnitude to the one-year change in Mexico (6%).

CHAPTER 3. TAXED AND UNTAXED BEVERAGE CONSUMPTION BY YOUNG ADULTS IN LANGA, SOUTH AFRICA BEFORE AND ONE YEAR AFTER A NATIONAL SUGAR-SWEETENED BEVERAGE TAX

Introduction

Consumption of sugar-sweetened beverages (SSBs) is increasing particularly rapidly in low- and middle-income countries[2]. Given the major impact of SSBs on obesity and many key noncommunicable diseases,[4,5,73,74] and building upon evidence that national SSB taxes reduced SSB purchases in Mexico [8] and Chile[9] in 2014, over forty countries have now implemented a national SSB tax or increased an existing tax in the last decade.[53,75] South Africa, with one of the highest SSB consumption rates in Africa and a growing burden of type II diabetes,[26] is the first sub-Saharan African country to institute a sugary beverage tax, implemented in April 2018. The South African tax, called the Health Promotion Levy (HPL) is one of the first SSB taxes to be based on sugar content, applying a fixed 2.1 cent tax rate for every gram of sugar (both intrinsic and added) above a 4g/100mL threshold.[27] Early calculations suggest that the average tax rate is approximately 10%. A similar threshold-based multi-tiered SSB levy has been passed in the United Kingdom,[76] but the HPL structure is potentially stronger as each additional gram per 100mL imposes a greater tax. Taxes based on sugar concentration may lead to greater impact on health outcomes than volume-based taxes both by reducing the purchases of SSBs and by encouraging product reformulation to lessen the tax burden, thereby reducing excessive added sugars.[55,56]

Heretofore, no major national tax evaluation has examined changes in dietary intake of taxed beverages as a key outcome. This study is unique in using detailed dietary intake data on a sample of low income young adults in South Africa. This is important because two-thirds of

cardiovascular deaths occur in middle- and high-income countries, and within those countries it is the lowest income communities with the highest risk.[52] It is also the first SSB tax evaluation of a national tax to use detailed 24-hour recall dietary data. Previous work estimated crude store-intercepts[7] and SSB frequency questionnaires for small city evaluations[12–15] but these methods miss other sources of consumption and do not represent key segments of a country. Others have used high quality household purchase data[8–10] or cruder aggregate sales data.[10,11] While these data are important, they exclude many sources of SSBs which dietary measures overcome.

The objectives of our study are to estimate differences in total sugar, energy, and volume from taxed (≥4g sugar/100ml ready-to-drink), untaxed (<4g sugar/100ml ready-to-drink), and total beverages using 24h dietary recall data from the Langa township of South Africa before and one year after the HPL. A novel contribution of our study to the SSB tax literature involves linking updated food composition tables (FCTs) with dietary recall data. We developed time specific FCTs for South African beverages before and after the HPL, which are linked with the dietary assessment instruments. This allows us to examine separately for the first time the role of reformulation as distinct from behavioral changes in SSB intake.

Methods

Data Sources and Measures

To evaluate the HPL tax policy, we analyzed single day 24-hour dietary recalls from repeat cross-sectional surveys of young township adults aged 18-39 years living in the lower income Langa township near Cape Town, South Africa. Our study population in the Langa township was selected due to the stability of the community for repeated data collections across time and because it contains a large number of young adults who are heavy consumers of SSBs. At last count, Langa had 17,402 households and 52,401 inhabitants (50.4% female), of which 99.1% were of Black African race.[77] Participants were recruited using a door-to-door sampling method of all identifiable households in Langa until the target sample size of

approximately 2,500 households was achieved at each wave/collection. Participants received a supermarket voucher worth R30 (USD$2.19) after participating. At the post-tax data collection, participants were asked whether they had been previously surveyed. However, the data are not longitudinal because individuals' diet surveys cannot be linked across time.

Data were collected in February-March 2018 (pre-tax, two months before the SSB tax implementation; N=2,481) and a post-tax survey 12 months later in February-March 2019 (N=2,507) to measure differences in beverage consumption following the HPL. 22 diet records in the pre-tax group (0.9%) and 18 diet records in the post-tax group (0.7%) were dropped for reporting less than 400 daily kcal. Thus, 2,459 and 2,489 diet recalls were included in the final analysis for pre-tax and post-tax, respectively (**Table 3.1**). Because the survey was designed to capture young adults' SSB intake, the only eligibility criterion was being between 18-39 years of age. Only one diet assessment was completed for one individual within a given household. Where two qualifying participants were present in the household, the first qualifying participant was selected if the household number in the survey was an uneven number and the second participant was selected if the household number was an even number. If three or more qualifying participants were present in the household, a random numbers list was used to select the respondent.

To record anthropometry, fieldworkers used standardized scales and stadiometers to record the weight and height of each participant after the diet recall was completed, measuring each twice. Body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in meters, using the average of the two measurements.

Measuring dietary intake

For the diet assessment, 24-hour diet recalls were conducted by interviewers with nutrition training. Participants reported what foods and drinks were eaten, how foods and beverages were prepared, whether anything was added, and the quantity consumed. Multiple pass approach, including detailed prompting, was used to enhance completeness.

Linking food composition tables to beverage categories

We created composite nutritional records for beverages based on the current food supply and consumer purchases. First, nutrition facts panel (NFP) data were collected from South African grocery stores in February and March 2018. This was repeated exactly a year later in February and March 2019. Products from each round of NFP data collection were linked to a database of beverage codes for creating a South Africa FCT. Fieldworkers who coded the 24hr recalls created codes by brand name for each SSB, allowing linkages between NFP data and dietary intake data. Each beverage code was given an average nutrient profile, weighted by household purchase data from Kantar World Panel, a panel dataset of household packaged food and beverage purchases. The pre-tax beverage FCT was linked to 2018 NFP-Kantar data, and the updated post-tax beverage FCT was linked to 2019 NFP-Kantar data. Each FCT beverage code was also categorized by taxation status. Beverage taxation status was determined by a two-step process: (1) whether the product category is taxable, as 100% fruit juice and unsweetened milks are exempt from the HPL, and (2) among all other beverages that are taxable, those with a total sugar concentration greater than 4g/100ml are classified as taxed and those with 4g/100ml or less are untaxed. We considered all tax-exempt and <4g/100ml beverages as untaxed. Beverage categories were ultimately analyzed as either taxed or untaxed according to the beverage grouping system shown in **Supplementary Table 3.1**.

Analytical Approach

All analyses were conducted in Stata, version 16.[78] Our key outcome variables include mean adjusted intake of total sugar (grams), energy (kilocalories), and volume (mL) for total beverages, taxed beverages, untaxed beverages, and subcategories of taxed and untaxed beverages. Intake estimates for these beverage categories were made for the pre-tax and post-tax collection periods.

Estimation of beverage intake

We estimated beverage intake from 24-h recalls using a two-part model implemented with the Stata twopm command to account for beverage groups that have a high percentage of non-consumers.[79] We used a probit model for the first part (likelihood of consumption), and conditional on consumption, we used a generalized linear model with log-link, which gives unbiased estimates of amount consumed,[80] for the second part. Primary outcomes are reported with 95% confidence intervals,[81] and statistically significant differences between groups were calculated using a Wald test. The main comparisons were whether the predicted mean intake of sugar, energy, or volume were different in the post-tax period compared to pre-tax period. Models were adjusted for age (continuous, range 18-39), sex, weekday versus weekend of intake (binary), average daily temperature (obtained from National Centers for Environmental Information[82]), and socioeconomic status using the South African Audience Research Foundation's Living Standards Measure (LSM).[83] LSM 3 and LSM 4 were combined to increase power for comparisons with the lowest group. Models are adjusted for the same covariates in both steps.

In our main analyses, pre-post beverage intake comparisons were made using the pre-tax beverage FCT linked to both the pre-tax beverage intake data and the post-tax beverage intake data. Thus, any changes in beverage intake would be due to behavioral change alone, since we effectively assume no reformulation. Next, we analyzed post-tax beverage intake linked to the updated beverage FCT to reflect the nutritional composition of beverages at each time point. This analysis reflects the combined effects of reformulation and behavioral change.

Sensitivity analyses

We conducted a series of sensitivity analyses to test modeling decisions. We investigated whether adding BMI as a covariate in our models in case there were differences in reporting beverage intake by body mass or excluding participants who were present both at pre-tax and post-tax data collection (12.4% of post-tax sample) affected our results.

Results

Study population characteristics are presented in **Table 3.1**. From pre-tax to post-tax, the percent of respondents in LSM categories 4 and 5 increased ($p<0.001$), and the percent of respondents in the highest LSM category 6 decreased ($p<0.001$). There were no significant differences between the two time points for any other sociodemographic characteristics.

Adjusted Results

Total effects for sugar, energy and volume for taxed beverages

Sugar intake from taxed beverages decreased ($p<0.0001$) from 28.8 g/capita/day (95% CI 27.3 to 30.4) pre-tax to 19.8 (95% CI 18.5 to 21.1) post-tax, a 31.4% reduction (**Table 3.2**). Energy intake from taxed beverages decreased ($p<0.0001$) from 121 kcal/capita/day (95% CI 114 to 127) pre-tax to 82 (95% CI 76 to 87) post-tax, a 32.5% reduction (**Table 3.2**). Volume intake from taxed beverages decreased ($p<0.0001$) from 315 mL/capita/day (95% CI 297 to 332) pre-tax to 198 (95% CI 185 to 211) post-tax, a 37.1% reduction (**Table 3.2**). Confidence intervals for absolute differences are reported in **Table 3.2**. Sugar, energy, and volume intakes of taxed beverage subcategories are reported in **Supplementary Tables 3.2-4**.

Total effects for sugar, energy, and volume for untaxed beverages

Sugar intake from untaxed beverages increased ($p<0.0001$) from 15.0 g/capita/day (95% CI 13.9 to 16.0) pre-tax to 20.3 (95% CI 18.2 to 21.4) post-tax, a 35.5% increase. Energy intake from untaxed beverages increased ($p<0.0001$) from 105 kcal/capita/day (95% CI 99 to 112) pre-tax to 135 (95% CI 128 to 141) post-tax, a 28.6% increase. Volume from untaxed beverages increased ($p<0.0001$) from 587 mL/capita/day (95% CI 563 to 610) pre-tax to 926 (95% CI 899 to 953) post-tax (**Table 3.2**). The majority of this increase (52%) was due to increased water consumption (**Supplementary Table 3.4**). Sugar, energy, and volume intakes of untaxed beverage subcategories are reported in **Supplementary Tables 3.2-4**.

Total effects for sugar, energy, and volume for total beverages

Sugar intake from total beverages significantly decreased (p<0.01) from 43.8 g/capita/day (95% CI 41.9 to 45.7) pre-tax to 40.1 (95% CI 38.5 to 41.6) post-tax, a 31.4% reduction (**Table 3.2**). However, there was no significant change in energy intake comparing pre-tax (226 kcal/capita/day; 95% CI 217 to 235) with post-tax (216; 95% CI 208 to 224; p=0.1) (**Table 3.2**). Volume intake was 223 mL/capita/day (95% CI 184 to 261) greater post-tax, partially driven by the large increase in water (**Supplementary Table 3.4**).

Reformulation effects for sugar, energy, and volume for taxed beverages

We found a stepwise reduction in sugar, energy, and volume from taxed beverages from pre-tax to post-tax with the pre-tax FCT, which isolates behavioral changes with no reformulation, and greater reductions using the updated post-tax FCT, which captures reformulation's marginal effect (**Figs. 3.1-3**). For sugar, we estimated a change from 28.8 g/capita/day (95% CI 27.3 to 30.4) to 22.4 (95% CI 21.1 to 23.8), a 22.2% reduction, due to behavioral change and an additional 9.2% reduction to 19.8 g/capita/day (95% CI 18.5 to 21.1) due to reformulation (**Fig. 3.1**). For energy, we estimated a change from 121 kcal/capita/day (95% CI 114 to 127) to 92 (95% CI 86 to 97), a 24.1% reduction, due to behavioral change and an additional 8.4% reduction to 82 kcal/capita/day (95% CI 76 to 87) due to reformulation (**Fig. 3.2**). For volume, we estimated a change from 315 mL/capita/day (95% CI 297 to 352) to 241 (95% CI 227 to 256), a 23.3% reduction, due to behavioral change and an additional 13.7% reduction to 198 mL/capita/day (95% CI 185 to 211) due to reformulation (**Fig. 3.3**).

For untaxed beverages, we estimated a 3.1% reduction in sugar from 43.8 g/capita/day (41.9 to 45.7) to 42.4 (40.9 to 44.0) due to behavioral change and an additional 5.4% reduction to 40.1 (95% CI 38.5 to 41.6) g/capita/day due to reformulation, making the total difference from pre-tax statistically significant (p<0.01) (**Fig. 3.1**). Energy increased 33.9% from 105 kcal/capita/day (95% CI 99 to 112) to 141 (95% CI 134 to 148), but reformulation attenuated this increase to 135 (+27.5%) kcal/capita/day (95% CI 76 to 87) (**Fig. 3.2**). For total beverages,

energy increased from 226 kcal/capita/day (95% CI 217 to 235) to 233 (95% CI 224 to 241) accounting for behavioral change only, but decreased to 216 (-4.6%) kcal/capita/day (95% CI 208 to 87) accounting for reformulation, although this reduction was not statistically significant (**Fig. 3.2**).

Differences by SES

All SES groups consumed significantly less sugar, energy, and volume from taxed beverages at post-tax compared to pre-tax (**Supplementary Table 3.5**). For untaxed beverages, all LSM groups significantly increased their intake of sugar, energy, and volume at post-tax compared to pre-tax (**Supplementary Table 3.5**). For total beverages, only LSM 6 had statistically significant reductions in sugar intake post-tax (**Supplementary Table 3.5**). There were no differences in the magnitude of change between LSM groups for taxed, untaxed, or total beverages.

Sensitivity Analyses

The sensitivity analysis including BMI in the beverage intake model estimated an additional reduction of 0.5 g sugar (2 kcal/capita/day) post-tax compared to pre-tax for taxed beverages. Therefore, to be more conservative in our conclusions, we did not include BMI in the model for our main results. We also tested whether our results were affected by excluding participants who were present at both pre-tax and post-tax (12.4%) and estimated an additional 2 kcal/capita/day reduction when excluding any repeats. Therefore, to be more conservative in our conclusions, we kept the entire sample.

Discussion

This study of young adults in a Cape Town township found that the HPL was followed by a 9.1 g/capita per day (31.4%) reduction in sugar intake, a 39 kcal/capita per day (32.5%) reduction in energy, and a 117 mL/capita per day (37.1%) reduction in volume from taxed beverages at one year post implementation. Across all beverages, we found statistically significant total reductions of 3.7 g/capita/day (8.4%) in sugar consumption and a 10

kcal/capita/day (4.4%) reduction in energy. We were able to show overall that behavior change of these adults was responsible for reductions of 22% of taxed beverage sugar intake and 3.2% of total beverage sugar intake compared to pre-tax levels, and our estimate of reformulation was the remainder of the post-tax impact.

This is the first detailed dietary intake survey to find significant results of a national tax effort on dietary intake.[84] The present study collected 24-hour recalls which are more suitable for estimating mean intakes in a population than frequency questionnaires[16] and has a larger sample size than earlier studies. For example, Silver et al.[10] found a 19.8% reduction in volume and a 13.3% reduction in caloric intake of SSBs following the Berkeley, USA SSB tax, but these findings lacked precision and did not reach statistical significance, potentially due to low baseline intakes in Berkeley (45 kcal/capita/day),[10] compared to our larger high consuming population pre-tax (121 kcal/capita/day). Our study population was also a low income community, and greater reductions in taxed beverage intake could be due to greater price sensitivity. Results from Mexico have also shown the greatest reductions in SSB purchases among the lowest income groups following a tax.[85]

Our key methodological contribution is the ability to separate behavioral change from reformulation effects using time specific FCTs linked to each dietary intake collection period. Accurate FCTs are necessary to calculate nutrient intakes and total energy from 24-h recalls and FFQs.[86,87] A study on the threshold-based SSB tax in the United Kingdom noted the combined effects of behavioral change and reformulation in reducing sugar consumption from beverages,[88] but this is the first study to separately quantify the contribution of each. Behavioral change accounted for reductions of 24% energy, 22% sugar, and 23% volume compared to pre-tax, while reformulation accounted for additional reductions of 8% energy, 9% sugar, and 14% volume from taxed beverages.

This study also found an increase in sugar, energy, and volume of untaxed beverages after the tax, directionally consistent but greater in magnitude than a study in Berkeley that

measured changes in both taxed and untaxed beverages.[10] Water was a major driver, accounting for 177 mL/capita/day (52%) of the increase in untaxed beverage volume (**Supplemental Table 3.3**). Part of this effect could be seen as a shift away from taxed to untaxed beverages found in other studies.[10,14,15,85] However, Cape Town, South Africa experienced a drought and severe water use restrictions from March to September 2018.[89] Therefore, we cannot disentangle the taxed-related effects from the effects of the drought on water consumption.

Analyzing results by socioeconomic status, sugar, energy, and volume decreased from taxed beverages and increased from untaxed beverages for all groups (**Supplementary Table 3.5**). However, there were no differences in absolute changes between groups, likely because the sample as a whole is relatively low-income. For comparison, a recent pre-post study using purchase data from a nationally representative South Africa sample found greater reductions in sugar (-32.7%) in LSM 4-6—nearly the identical range to our sample—compared to the higher socioeconomic group of LSM 7-10 (-20.4%).[90]

This study has several limitations. Given our data are cross-sectional, we are not able to follow all individuals over time, only measure differences in population means. Social desirability bias could affect reporting and cause us to underestimate SSB intake. It is also possible that after the tax, social norms may have shifted so that the effect of social desirability bias is even greater after SSBs are subject to tax, causing an overestimation of reductions in SSB intake in this population. Finally, although we are able to separate the effects of behavioral change on beverage consumption from reformulation effects, we cannot isolate the specific types of reformulation effects that may have occurred. For example, changes may be due to reduced sugar content within taxation categories or products may have switched categorization from taxed to untaxed if they were reformulated below the 4g/100mL threshold. These could be changes linked with consumers by brand preferences.

Our study has several strengths, including a large sample of high-consuming young adults to increase study power and the ability to detect changes, the use of dietary intake data which is a more suitable measure for mean population intakes than frequency questionnaires,[16] the use of a two-part model for beverage intake,[91] and the development of time-varying food composition tables linked with these dietary data to estimate changes in sugar, energy, and volume after the HPL.

Conclusion

Using a large sample of a high-consuming, low-income population, we found large reductions in taxed beverage intake, separating the effects of behavioral change from reformulation. Because policies such as taxes can incentivize reformulation, our use of time specific beverage FCTs that reflect a rapidly changing food supply is novel and important for evaluating future taxation policies' impact on dietary intake.

Tables and Figures

Table 3.1 Sociodemographic information for Langa 18-39y survey

Variable	**Pre-tax** (n=2,459)	**Post-tax** (n=2,489)
	%	%
Male	34.8	34.8
Female	65.2	65.2
LSM category[1]		
LSM 3	1.2	1.6
LSM 4	13.1	19.1*
LSM 5	34.4	49.7*
LSM 6	34.9	27.2*
Missing/ incomplete data	16.4	2.5
	Mean (SD)	Mean (SD)
Age	27.9 (6.0)	27.7 (6.2)
Male BMI	23.1 (4.3)	22.7 (4.0)
Female BMI	29.5 (6.8)	30.1 (7.1)

[1]South African Living Standards Measure (LSM)[83]

*Indicates statistically significant difference ($p<0.001$) from pre-tax using Fisher's exact test.

Table 3.2 Model adjusted predicted values for sugar, energy, and volume for taxed, untaxed, and total beverages

	Sugar	**Energy**	**Volume**
	grams/capita/day	**kcal/capita/day**	**mL/capita/day**
Taxed Beverages	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**
Pre-tax	28.8 (27.3 to 30.4)	121 (114 to 127)	315 (297 to 352)
Post-tax	19.8 (18.5 to 21.1)	82 (76 to 87)	198 (185 to 211)
Absolute Difference	-9.1 (-11.2 to -6.9)**	-39 (-48 to -30)**	-117 (-139 to -94)**
Untaxed beverages			
Pre-tax	15.0 (13.9 to 16.0)	105 (99 to 112)	587 (563 to 610)
Post-tax	20.3 (19.2 to 21.4)	135 (128 to 141)	926 (899 to 953)
Absolute Difference	5.3 (3.7 to 6.9)**	29 (19 to 39)**	340 (303 to 376)**
Total Beverages			
Pre-tax	43.8 (41.9 to 45.7)	226 (217 to 235)	901 (876 to 927)
Post-tax	40.1 (38.5 to 41.6)	216 (208 to 224)	1124 (1097 to 1151)
Absolute Difference	-3.7 (-6.2 to -1.2)*	-10 (-23 to 2)	223 (184 to 261)**

From models adjusting for age, sex, weekday versus weekend, average daily temperature, and socioeconomic status (LSM)

*Indicates statistically significant difference at the $p<0.01$ level

**Indicates statistically significant difference at the $p<0.0001$ level

Figure 3.1 Estimated daily intake in grams of sugar per capita from taxed, untaxed, and total beverages. Errors bars represent 95% confidence intervals

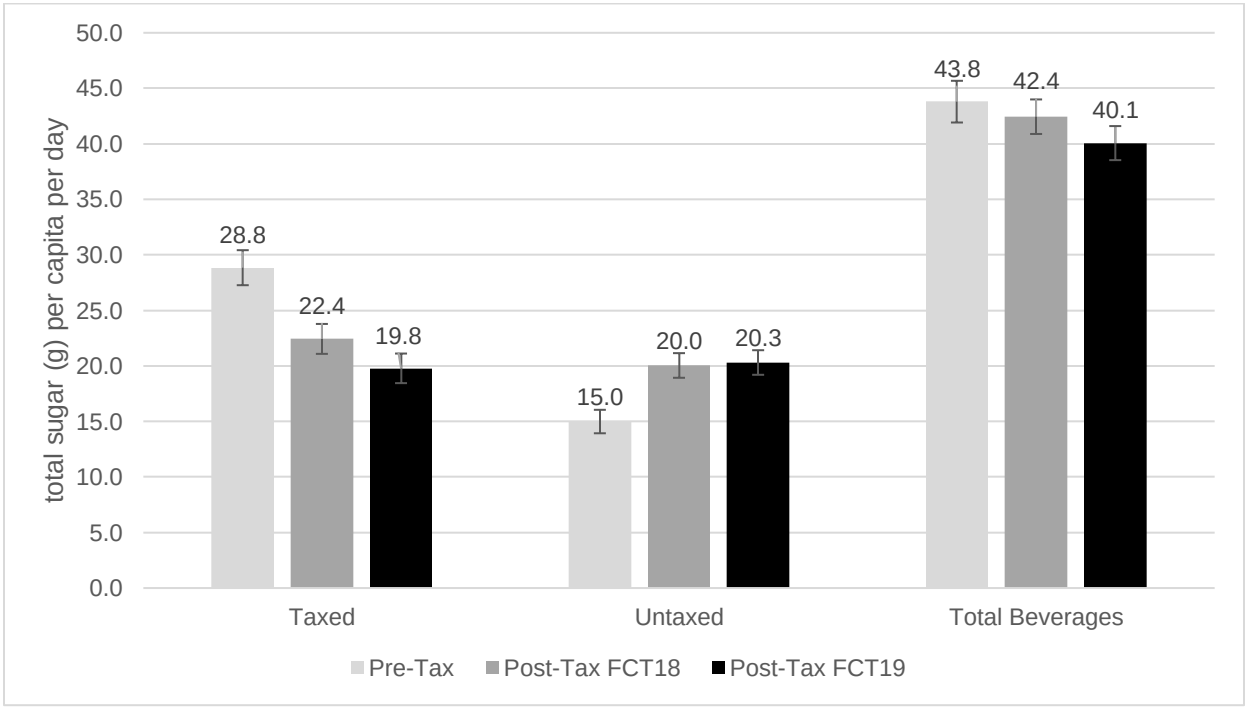


Figure 3.2 Estimated daily intake in energy (kcal) per capita from taxed, untaxed, and total beverages. Errors bars represent 95% confidence intervals

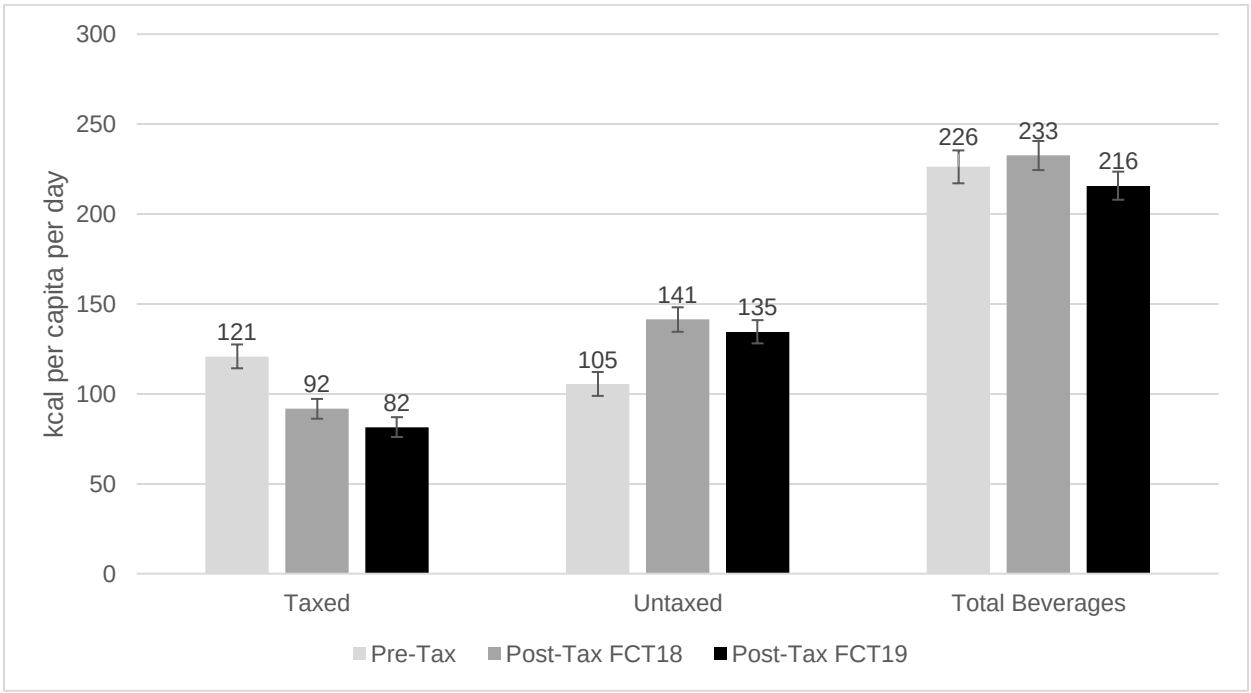
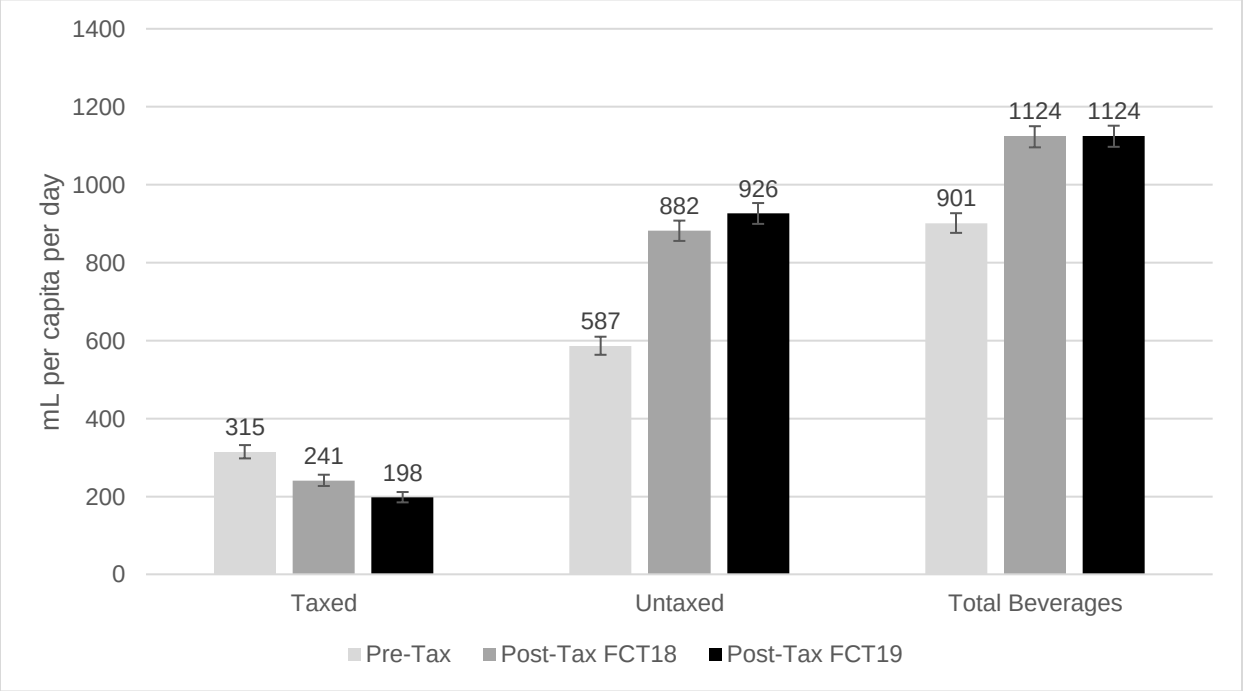


Figure 3.3 Estimated daily intake in mL per capita from taxed, untaxed, and total beverages. Errors bars represent 95% confidence intervals



Supplementary Table 3.1 Beverage classification system

Level 1	Level 2	Level 3
All beverages	Carbonates	< 4 g/100ml Untaxed
		≥ 4 g/100ml Taxed
	Fruit Drinks & Nectars	< 4 g/100ml Untaxed
		≥ 4 g/100ml Taxed
	Concentrates	< 4 g/100ml Untaxed
		≥ 4 g/100ml Taxed
	Sports & Energy Drinks	< 4 g/100ml Untaxed
		≥ 4 g/100ml Taxed
	Flavored Waters	< 4 g/100ml Untaxed
		≥ 4 g/100ml Taxed
	Bottled and Flavored Waters	< 4 g/100ml Untaxed
		≥ 4 g/100ml Taxed
	Milks (sweetened)	< 4 g/100ml Untaxed
		≥ 4 g/100ml Taxed
	Coffee/Tea	All untaxed, sugar added at home
	Milks (unsweetened)	Exempt, all untaxed
	100% Fruit Juice	Exempt, all untaxed
	Plain waters	All untaxed

Supplementary Table 3.2 Model adjusted predicted intake of total sugar for taxed and untaxed beverage subcategories, Langa adults 18-39y

Beverage category	Pre-tax			Post-tax		
	Total Sugar grams per capita			Total Sugar grams per capita		
	Mean	Lower 95 CI	Upper 95 CI	Mean	Lower 95 CI	Upper 95 CI
Taxed	28.9	27.3	30.4	19.8	18.5	21.1
Flavored waters	<0.5	--	--	<0.5	--	--
Carbonates	19.6	18.2	21.0	17.2	15.9	18.4
Fruit Drinks & Nectars	7.3	6.5	8.1	1.5	1.1	1.8
Concentrates	0.8	0	1.6	0.0	0	0.1
Sports & Energy	1.1	0.8	1.5	0.9	0.6	1.2
Dairy and dairy substitutes (flavored, sweetened)	0.4	0.0	2.8	0.5	0	5.4
Untaxed	15.0	13.9	16.0	20.3	19.2	21.4
Plain water	0	--	--	0	--	--
Flavored low sugar waters	<1	--	--	<1	--	--
Dairy and dairy substitutes (unflavored, unsweetened)	2.9	2.7	3.2	4.2	3.9	4.6
100% fruit juice	0.5	0.2	0.9	0.5	0.1	0.9
Carbonates	0	0	0	1.1	0.8	1.5
Fruit Drinks & Nectars	0.0	0.0	0.0	0.1	0.0	0.2
Concentrates	0.7	0.5	0.8	1.5	1.3	1.8
Coffee/Tea (all sugar content)	10.8	9.8	11.8	12.5	11.4	13.6
Sports & Energy	<1	--	--	<1	--	--
Total beverages	43.8	41.9	45.7	40.1	38.5	41.6

From models adjusting for age, sex, weekday versus weekend, and average daily temperature

Supplementary Table 3.3 Model adjusted predicted intake of energy (kcal) for taxed and untaxed beverage subcategories, Langa adults 18-39y

Beverage category	Pre-tax			Post-tax		
	kcal per capita			kcal per capita		
	Mean	Lower 95 CI	Upper 95 CI	Mean	Lower 95 CI	Upper 95 CI
Taxed	121	114	128	82	76	87
Flavored waters	<1	--	--	<1	--	--
Carbonates	79	74	85	69	64	74
Fruit Drinks & Nectars	32	29	36	7	5	8
Concentrates	3	0	7	0	0	1
Sports & Energy	5	4	7	4	3	5
Dairy and dairy substitutes (flavored, sweetened)	2	0	9	1	0	6
Untaxed	108	100	116	136	126	145
Plain water	0	--	--	0	--	--
Flavored low sugar waters	<1	--	--	<1	--	--
Dairy and dairy substitutes (unflavored, unsweetened)	49	45	54	62	57	67
100% fruit juice	2	1	4	2	1	4
Carbonates	0	0	0	5	3	6
Fruit Drinks & Nectars	0	0	0	<1	<1	<1
Concentrates	3	2	4	6	5	7
Coffee/Tea (all sugar content)	51	46	55	57	52	62
Sports & Energy	<1	--	--	<1	--	--
Total beverages	226	217	235	216	208	224

From models adjusting for age, sex, weekday versus weekend, and average daily temperature

Supplementary Table 3.4 Model adjusted predicted intake of volume for taxed and untaxed beverage subcategories, Langa adults 18-39y

Beverage category	Pre-tax			Post-tax		
	mL per capita			mL per capita		
	Mean	Lower 95 CI	Upper 95 CI	Mean	Lower 95 CI	Upper 95 CI
Taxed	315	297	332	198	185	211
Flavored waters	1	0	2	2	0	3
Carbonates	212	197	227	171	159	183
Fruit Drinks & Nectars	80	71	90	14	11	18
Concentrates	8	0	16	0	0	1
Sports & Energy	12	8	16	9	6	12
Dairy and dairy substitutes (flavored, sweetened)	1	0	1	<1	0	1
Untaxed	587	563	610	926	899	953
Plain water	342	321	363	519	498	540
Flavored low sugar waters (<4g/100ml)	<1	--	--	<1	--	--
Dairy and dairy substitutes (unflavored, unsweetened)	74	67	81	101	93	109
100% fruit juice	5	2	7	5	2	7
Carbonates	1	0	2	36	25	47
Fruit Drinks & Nectars	0	0	0	7	0	15
Concentrates	28	22	33	116	106	125
Coffee/Tea (all sugar contents)	138	127	148	137	127	147
Sports & Energy	<1	--	--	<1	--	--
Total beverages	901	876	927	1124	1097	1151

From models adjusting for age, sex, weekday versus weekend, and average daily temperature

Supplementary Table 3.5 Model adjusted predicted intakes of total sugar, energy, and volume from taxed beverages for each LSM category

LSM Category	Total Sugar (g/capita/day) 95% CI		Energy (kcal/capita/day) 95% CI		Volume (mL/capita/day) 95% CI	
Taxed Beverages	Pre-tax	Post-tax	Pre-tax	Post-tax	Pre-tax	Post-tax
3 and 4	28.6 (24.9 to 32.2)	18.6*** (15.7 to 21.5)	121 (106 to 137)	76*** (64 to 88)	311 (271 to 350)	184*** (156 to 213)
5	29.5 (27.1 to 31.9)	20.4*** (18.5 to 22.3)	123 (113 to 133)	84*** (77 to 92)	322 (296 to 348)	204*** (185 to 222)
6	28.3 (26.0 to 30.6)	19.7*** (17.3 to 22.1)	119 (109 to 128)	81*** (71 to 91)	309 (283 to 334)	199*** (175 to 223)
Untaxed Beverages						
3 and 4	13.8 (11.5 to 16.1)	19.3* (16.9 to 21.7)	102 (87 to 118)	127* (113 to 141)	588 (532 to 644)	968*** (908 to 1028)
5	14.1 (12.6 to 15.7)	20.6*** (19.1 to 22.1)	100 (90 to 110)	134*** (126 to 143)	586 (550 to 622)	890*** (854 to 925)
6	16.6 (14.9 to 18.3)	20.3*** (18.2 to 22.3)	114 (103 to 124)	138*** (126 to 150)	590 (556 to 623)	954*** (903 to 1005)
Total Beverages						
3 and 4	42.2 (37.8 to 46.6)	37.9 (34.7 to 41.2)	223 (201 to 245)	203 (186 to 220)	901 (840 to 962)	1152*** (1093 to 1212)
5	43.4 (40.6 to 46.3)	41.1 (38.9 to 43.2)	223 (209 to 237)	219 (208 to 230)	909 (870 to 948)	1093*** (1056 to 1129)
6	45.0 (42.1 to 47.8)	39.9* (37.1 to 42.7)	232 (218 to 246)	219 (204 to 233)	898 (861 to 935)	1154*** (1103 to 1206)

From models adjusting for age, sex, weekday versus weekend, and average daily temperature
*Indicates statistical significance within row (post-tax compared to pre-tax) at p<0.05 level
**Indicates statistical significance within row (post-tax compared to pre-tax) at p<0.01 level
***Indicates statistical significance within row (post-tax compared to pre-tax) at p<0.0001 level

CHAPTER 4. DOES HEALTH KNOWLEDGE, RISK PERCEPTION, OR TAX AWARENESS AFFECT CHANGES IN DIETARY INTAKE: THE IMPACT OF THE SUGAR-SWEETENED BEVERAGE TAX IN SOUTH AFRICA

Introduction

Sugar-sweetened beverage (SSB) consumption is linked to obesity[73,74] and other non-communicable diseases[4,5] and is increasing rapidly in low- and middle-income countries.[2] In response to rising SSB purchases, obesity, and type II diabetes incidence, South Africa became the first sub-Saharan African country to implement a sugary beverage tax, called the Health Promotion Levy (HPL), in April 2018.[26,92,93] The HPL has a unique structure that applies a fixed 2.1 cent tax for each additional gram of sugar (both intrinsic and added) above a 4g/100 ml threshold.[27] Such an approach has not been tried nor tested anywhere. The goal of this tax design is not only to increase prices, thereby reducing consumer purchases of SSBs, but also to spur beverage reformulation by industry.

The two clearest examples of sugar-based national SSB tax structures are from the United Kingdom's threshold-based multi-tiered SSB levy,[76] and South Africa's HPL. In both countries, studies have found large reductions in taxed beverage consumption, leading to fewer calories and grams of sugar consumed per capita. In the United Kingdom, the greatest changes in sugar content of beverage purchases were due to reformulation, with a reduction of 30% but only 4% without accounting for reformulation.[88] In South Africa, taxed beverage purchases decreased 33% in lower and middle income and 20% in higher income populations.[90] Another study using dietary intake data collected from a low income, high consuming South African township separated the effects of behavioral change from reformulation, finding a 24% reduction

in taxed beverage caloric intake due to behavioral change and an additional 8% reduction due to reformulation.[94]

In light of these results, the remaining question is what drives these behavioral changes. Price increases lead to reduced SSB purchases with varying effects by age, income and country.[95,96] However, behavior change is complex and likely related to more than SSB price changes, including psychological factors that influence consumer responses to SSB taxes. Additionally, national SSB taxes are often accompanied by mass media campaigns to promote the tax (prior to implementation) and inform the public about the purpose of the tax to reduce the disease burdens of obesity and diabetes.[18,59] Media campaigns about the health harms of SSBs have been shown to increase tax awareness, increase perceived risk about the health harms of SSBs, and increase behavioral intentions to reduce SSB consumption.[18,57,59,97,98] However, no studies have linked these psychological constructs with changes in dietary intake, the ultimate goal of SSB tax policy. Finally, although knowledge about the health harms of SSBs is inversely associated with SSB intake,[17] it is unknown whether changes in knowledge or behavioral intentions may modify the effects of SSB taxes. If changes in knowledge modify the effects of SSB taxes, then information campaigns to increase SSB knowledge may complement future SSB tax policies, leading to even greater reductions in SSB intake.

The purpose of this study is to examine changes in tax awareness, intentions to reduce SSB intake, SSB knowledge, and SSB risk perception in a population of low-income adults before and after implementation of South Africa's SSB tax, and to determine whether these variables modify the effects of an SSB tax on dietary intake a year after tax implementation.

Methods

Conceptual Model for Analysis

This analysis is based on the following conceptual model, whereby the SSB tax has two main pathways affecting dietary intake: reductions in sugar and energy due to (1) behavioral change and (2) reformulation (**Figure 4.1**). The pathway through behavioral change is not

limited to effects on SSB prices, as media coverage and other communications may affect SSB knowledge, risk perception, consumers' awareness of the tax, and create intentions to reduce SSB intake, all of which can affect behavior changes. The present study examined these potential modifiers of the behavioral change pathway after tax implementation.

Data Sources and Measures

Participants

Data were collected using cross-sectional surveys of young township adults aged 18-39 years living in the lower income Langa township near Cape Town, South Africa. Our study population in the Langa township was selected because it contains a large number of young adults who are high consumers of SSBs and is primarily a low income population, and both of these characteristics have been associated with greater reductions in unhealthy food or beverage purchases following a tax.[85,99,100] Langa is also a stable community, suitable for repeated data collections across time. At last count, Langa had 17,402 households and 52,401 inhabitants (50.4% female), of which 99.1% were of Black African race.[77] Participants were recruited using a door-to-door sampling method of all identifiable households in Langa until the target sample size of approximately 2,500 households was achieved at each wave/collection. Household surveys were recorded with geolocation to ensure all areas of Langa were sampled. Participants received a supermarket voucher worth R30 (USD$2.19) after participating.

Because the survey was designed to capture young adults' SSB intake, the only eligibility criterion was being between 18-39 years of age. Every household was approached to ascertain if they met the age requirement and if they were willing to participate. Only one diet assessment and one knowledge questionnaire were completed for a single individual within a given household. Where two qualifying participants were present in the household, the first qualifying participant was selected if the household number in the survey was an uneven number and the second participant was selected if the household number was an even number.

If three or more qualifying participants were present in the household, a random numbers list was used to select the respondent.

Data were collected in a pre-tax survey in February-March 2018, two months before the tax implementation in April 2018 (N=2,481) and a post-tax survey 12 months later in February-March 2019 (N=2,507). Unreliable diet records were dropped for reporting less than 400 daily kcal, totaling 22 diet records in the pre-tax group (0.9%) and 18 diet records in the post-tax group (0.7%), leaving 2,459 participants in pre-tax and 2,489 in post-tax groups. Our final analytic sample contained only variables with complete, reliable data totaling 2,094 in the pre-tax group and 2,316 in the post-tax group (**Table 4.2**). Missing data patterns on sociodemographic and psychological survey variables are available in **Supplementary Table 4.1**.

Measuring dietary intake

For the diet assessment, 24-hour diet recalls were conducted by interviewers with nutrition training using the multiple pass approach, including detailed prompting to enhance completeness. Interviewers were fluent in both Xhosa and English and conducted the interview in the language with which participants were most comfortable. Diet recalls and questionnaires were conducted aloud with all participants and recorded by interviewers. Participants reported what foods and drinks were eaten, how foods and beverages were prepared, whether anything was added, and the quantity consumed.

Linking dietary data to beverage categories

Data from 24h dietary recalls were linked to composite nutritional records for beverages based on the current food supply and consumer purchases. First, nutrition facts panel (NFP) data were collected from South African grocery stores during the same time period (February-March 2018) as diet intake data. The NFP data were linked to a database of beverage codes, allowing linkages between NFP data and dietary intake data. Each beverage code was given an average nutrient profile, weighted by household purchase data from Kantar World Panel

2018, a panel dataset of household packaged food and beverage purchases. Beverage codes were then categorized into taxed and untaxed categories based on the linked average nutrient profile. Beverage taxation status was determined by a two-step process: (1) whether the product category is taxable, as 100% fruit juice and unsweetened milks are exempt from the tax, and (2) among all other beverages that are taxable, those with a total sugar concentration greater than 4g/100ml are classified as taxed and those with 4g/100ml or less are untaxed. We considered all tax-exempt and <4g/100ml beverages as untaxed. The same food composition tables were used for our entire study period, which restricts all effects to behavioral change only and not reformulation. In a separate study we utilize the nutrition facts panel data from the 12-month period to allow us to examine reformulation separately from the behavioral change.[94]

Measuring knowledge, risk perception, tax awareness, and intentions to reduce SSB intake

After completion of the dietary intake assessment, participants completed a knowledge and attitudes questionnaire modeled after previous work that surveyed SSB-related knowledge, attitudes and behaviours, including a study conducted in South Africa.[101,102] The survey asked whether participants could classify the beverage categories listed in **Table 4.1** as (1) not sugary, (2) somewhat sugary, (3) sugary, or (4) do not know (coded missing) to determine the ability to identify SSBs among beverage categories. Next, after participants were given a definition of SSBs, they were asked to what degree SSB consumption increases the risk of selected chronic diseases and risk factors including diabetes, high blood pressure, obesity, dental problems, and cancer (hereafter referred to as “risk perceptions”). The degree to which SSBs increased the risk of these conditions could be answered as (1) Not at all, (2) A little, (3) Somewhat, (4) A lot, or (5) Not sure (coded missing). To assess perception of the tax, participants were asked whether they were aware of the SSB tax (yes/no) and whether they planned to reduce SSB consumption as a result of the tax (yes/no). Responses of “maybe” or “do not know” were coded as missing. Our four psychological constructs measured are shown in **Table 4.1** below. The more complex psychological constructs of SSB knowledge and risk perception were measured

with multiple questions, whereas the simpler constructs of tax awareness and intention to reduce SSB consumption were measured with a binary yes/no response.

Confirmatory factor analysis for SSB risk perception and SSB knowledge

All forms of measurement, particularly psychological measurement, are subject to measurement error. The observed values for questionnaire items are therefore a combination of both the true value of the construct being measured and measurement error. Given the difficulty of directly measuring knowledge and risk perception, Confirmatory Factor Analysis (CFA), a theory-driven measurement technique based on the understood relationships among observed and unobserved variables, can establish the validity of using a set of observations for measuring a latent variable.[103,104] The advantages of using CFA over individual question items include the ability to measure a single latent variable that cannot be measured directly but is related to observed indicator variables and the ability to account for measurement error in individual question items. By accounting for measurement error, CFA allows researchers to measure the approximate value of the latent variable (in this case knowledge or risk) and subsequently use it as a predictor uncontaminated by measurement error.[105]

CFA was used to measure two distinct constructs SSB knowledge and SSB risk perception including survey data from the pre-tax post-tax periods using MPlus8[106] statistical software. **Supplementary Figures 4.1 and 4.2** depict the measurement constructs for these two variables, and each question (Q) refers to the survey question described in **Table 4.1**. The full series of invariance tests for knowledge and risk perception are described in the Invariance Testing Procedure supplement, with fit statistics presented in **Supplementary Tables 4.2 and 4.3**.

Invariance testing

We performed a series of invariance tests for both time periods to test whether the same underlying construct has the same factor structure and is being measured in the same way across time.[107–109] Models for risk and knowledge were evaluated according to recommended fit

statistics cutoffs: <0.1 change in Comparative Fit Index (ΔCFI), <0.015 change in root mean square error of approximation (ΔRMSEA) and <0.030 change in the standardized root mean squared residual (ΔSRMR) for metric invariance, and ΔRMSEA<0.015 and ΔSRMR<0.010 for scalar invariance.[108,110] Given our large sample size of over 2,000 observations, we focused on changes in CFI, RMSEA and SRMR instead of the chi-square difference test, as it is highly influenced by sample size, and using the chi-square test alone can reject good-fitting models if the sample is large.[111]

The first step of invariance testing is configural invariance, which tests both factor models simultaneously to determine whether the same items measure the construct across time. The same factor loadings were highly significant (p<0.001), and models at both time points and overall model fit was high (CFI<0.95), satisfying conditions for configural invariance (**Supplementary Table 4.2**).[107] Next, to assess metric invariance, not only must the same items measure the construct, but the factor loadings must be equivalent. We followed the aforementioned guidance for determining metric invariance compared to the configural model: ΔCFI<0.1, ΔRMSEA<0.015, and ΔSRMR<0.030. All of these conditions were met (**Supplementary Table 4.3**). Although the chi-square difference test was highly statistically significant, this criterion is most affected by our large sample size, and we therefore determined metric invariance based on the other criteria.[108,110,111] We also found the magnitude of difference in factor loadings to be small in the configural model (**Supplementary Table 4.2**), suggesting the conditions for metric invariance were met. Finally, scalar invariance requires that item intercepts be equivalent at both time points. We used the following criteria for assessing scalar invariance comparing to the metric model: ΔCFI<0.1, ΔRMSEA<0.015, and ΔSRMR<0.010. We determined that our CFA models for both knowledge and risk perception were invariant across time according to recommended fit criteria.[108,110,111]

Main outcome and covariates

The main outcome for analysis questions 1 and 3 below was calories from taxed beverage intake. Using our two-part model, we estimated the odds of consuming taxed beverages (yes/no), and conditional on a positive outcome, the consumption-day amount. To examine changes over time in question 2, SSB knowledge, risk perception, tax awareness, and intention to reduce SSB intake were each used as outcomes. Main covariates for all analyses included age (continuous, range 18-39), sex, and weekday versus weekend of intake (binary). Socioeconomic status was assigned using the South African Audience Research Foundation's Living Standards Measure (LSM) as a categorical variable.[83] The LSM categories range from 1 to 10, but our sample only contains includes participants in the lower and middle part of the range. Adjusting for LSM changed our calculation of daily energy intake from taxed beverages by less than a 1kcal per capita per day. We therefore concluded that our results were not confounded by LSM and did not control for it in our final models due to the amount of missing data (16%) at baseline.

Analytical Approach

After using CFA to establish measurement invariance of our surveys for knowledge and risk perception, this analysis sought to answer three research questions outlined below.

1) *Are SSB knowledge and SSB risk perception, tax awareness, or intentions to reduce SSB consumption associated with taxed beverage intake at baseline?*

For research question 1, we estimated beverage consumption using a two-part model[79,91] in MPlus8[106] to account for zero values of taxed beverage intake due to non-consumers, using a logit model for the first step and a linear regression model for the second step with taxed beverage energy intake (kcal) as the dependent variable, the latent variables risk perception and knowledge as the independent variables. The equation for the two-part model was: taxed beverage intake (g/capita/month) = [Probability of consuming taxed beverages (probability/day)] * [Daily energy intake from taxed beverages (kcal/capita/day)].

Models were adjusted for age, sex, and weekday versus weekend of intake. Models are adjusted for the same covariates in both steps.

2) *Did mean SSB knowledge, SSB risk perceptions, tax awareness, or intention to reduce SSB consumption change from pre-tax to post-tax?*

For research question 2, we used linear regression models to test whether mean risk perception or knowledge changed over time, with each latent variable set as a dependent variable and time of data collection, age, sex, and weekday as covariates. A Wald Test was used to determine whether time was a statistically significant explanatory variable.

3) *Do SSB knowledge and SSB risk perception, tax awareness, or intentions to reduce SSB consumption modify the effect of time on taxed beverage intake?*

The analysis for research question 3 was conducted using the same two-part model as question 1, while also testing interaction terms for each psychological construct with time. The Stata margins command was used to generate predicted values and p values for differences in taxed beverage energy intake at each time point and level of each variable. A statistically significant model coefficient for an interaction term ($p<0.05$) suggests the latent variable modifies the effect of the tax over time.

Results

Sociodemographic Characteristics

Study population characteristics are presented in **Table 4.1**. From pre-tax to post-tax, the percent of respondents in LSM categories 4 and 5 increased ($p<0.001$), and the percent of respondents in the highest LSM category 6 decreased ($p<0.001$). There were no significant differences between the two time points for other sociodemographic characteristics.

Regression Results

1) *Are SSB knowledge and SSB risk perception, tax awareness, or intentions to reduce SSB consumption associated with taxed beverage intake at baseline?*

In models examining taxed beverage intake at baseline, there was no significant association between tax awareness, SSB knowledge, or SSB risk perception and odds of consuming taxed beverages or the consumption-day amount (**Supplementary Table 4.4**). Intention to reduce SSB intake as a result of the tax was significantly associated both with the odds of taxed beverages consumption and the consumption-day amount. Participants expressing intention to reduce SSB intake had 0.81 (95% CI 0.72 to 0.92) times the odds (p=0.001) of consuming taxed beverages compared to those who did not intend to reduce SSB intake. Participants who intended to reduce SSB intake who were also consumers of taxed beverages consumed 55 (95% CI 28 to 82) kcal/capita/day less than consumers who did not express intention to change.

2) *Did mean SSB knowledge, SSB risk perceptions, tax awareness, or intention to reduce SSB consumption change from pre-tax to post-tax?*

In models examining changes in the psychological constructs before and after the tax, there was a statistically significant increase in risk perception by 0.17 units (95% CI 0.124 to 0.218; p<0.001) on a 1-4 scale and a statistically significant increase in knowledge by 0.03 units (95% CI 0.01 to 0.055; p<0.05) on a 1-3 scale from pre- to post-tax (**Supplementary Table 4.5**). The adjusted percentage reporting that they were aware of the tax increased from 13.0% to 16.1% of the sample (p<0.01). The adjusted percentage reporting the intention to reduce SSB consumption decreased significantly (p<0.001) from 41.1% pre-tax to 14.9% post-tax.

3) *Do SSB knowledge and SSB risk perception, tax awareness, or intentions to reduce SSB consumption modify the effect of time on taxed beverage intake?*

Finally, we tested interaction models to determine whether the relationships between the psychological constructs and the tax effect changed over time. We found no significant interactions between time and risk perception or time and knowledge on dietary intake (**Supplementary Table 4.4**). For tax awareness, the interaction term was also not statistically significant (p=0.111), though the results were suggestive that time period did appear to modify

the association between tax awareness and SSB intake. Specifically, changes in energy intake from pre- to post-tax were predicted to be -19 (95% CI -42 to 4) kcal/capita/day lower among those aware of the tax compared to not aware. For within-group differences, among those aware of the tax at both time periods, taxed beverage intake decreased from 131 (95% CI 113 to 148) to 83 (95% CI 70 to 97) kcal/capita/day. Among those unaware of the tax at both time periods, taxed beverage intake decreased from 121 (95% CI 114 to 127) to 93 (95% CI 87 to 99) kcal/capita/day.

There was a statistically significant interaction ($p<0.01$) between intention to reduce SSB consumption and time period on predicted taxed beverage intake. While there was a reduction in adjusted mean SSB calories for both groups, reductions in energy intake from pre- to post-tax were predicted to be 27 (95% CI 9 to 46) kcal/capita/day greater among those expressing an intention to reduce SSB intake compared to no intention to reduce SSB intake. For within-group differences, among those who intended to reduce SSB consumption at both time periods, taxed beverage intake decreased from 116 (95% CI 107 to 126) to 61 (95% CI 48 to 73) kcal/capita/day. Among those who did not intend to reduce SSB consumption at both time periods, taxed beverage intake decreased from 125 (95% CI 117 to 134) to 97 (95% CI 90 to 102) kcal/capita/day.

Discussion

This study examined whether SSB knowledge, risk perception, tax awareness, and intentions to reduce SSB intake were associated with taxed beverage intake in the context of South Africa's SSB tax. We also tested whether these psychological constructs changed over time or modified the effects of the tax on taxed beverage intake. Overall, most psychological variables studied were not strongly linked to taxed beverage intake at baseline, had small changes after tax implementation, and did not appear to modify the association between policy implementation and dietary intake.

Building on previous work from the same study sample in Langa, South Africa, which showed reductions in taxed beverage intake due to behavioral change (i.e., an average decrease of 29 calories/capita/day of taxed beverage intake),[94] this study sought to examine the potential components of this behavioral change. This study's objective was to understand the relationship between four psychological constructs and taxed beverage intake at baseline. Of the four constructs analyzed, only the behavioral intention to reduce SSB consumption was significantly associated with taxed beverage intake. Participants expressing an intention to reduce SSB intake were significantly less likely to consume taxed beverages and consumed significantly fewer calories per consumption event than consumers who did not express an intention to change. One reason for this could be that behavioral intentions are a more proximate cause of dietary intake than beliefs and policy awareness. According to the theory of planned behavior, risk perceptions influence attitudes about the behavior of consuming SSBs, and an SSB tax policy can affect subjective norms, both of which may influence behavioral intentions and ultimately dietary intake.[112]

Given that we saw no association between SSB knowledge, risk perception, or tax awareness and taxed beverage intake during the baseline period, it appears that these psychological factors had minimal impact on decisions to consume taxed beverages in our low income study population. The present study builds upon previous work that examined public perceptions of SSB taxes in the United States and South Africa. Our SSB knowledge and risk perception survey was based on previous work by Rivard and colleagues in the United States, who found SSB knowledge and risk perceptions were associated with an intention to reduce SSB consumption in the event of an SSB tax.[101] However, this study did not measure dietary intake. A later study conducted with a sample of undergraduate dental and oral hygiene students in South Africa, a higher education group than the present study sample, built upon these findings by examining the association between these same survey questions and dietary intake using a beverage frequency questionnaire. Higher scores on knowledge and risk

perception were associated with lower SSB consumption, measured by a beverage frequency questionnaire.[102] By including dietary intake from 24h recalls, the present study further builds upon these results to determine whether the relationship between psychological measures are associated with dietary intake, and later whether this relationship changed as a result of the national SSB tax.

We found that SSB knowledge, risk perception, and tax awareness increased after the tax was implemented, but these changes were small. For example, the overall prevalence of tax awareness remained low, increasing to only 16% post-tax. Research from focus groups in Soweto, Johannesburg also found a low level of tax awareness and a high degree of skepticism that the tax was implemented to improve health.[113] Another study among South African dieticians found that although most patients were aware of the SSB tax, dieticians had not made the tax a focus of their clinical advice to patients, and did not expect it to reduce their consumption due to the small magnitude of the tax and patients' taste preferences.[114] These two studies suggest a need for more coordinated messaging emphasizing the purpose and importance of the SSB tax for vulnerable populations in South Africa. Higher income groups may also be receiving more information about the tax from news and communication campaigns. A recent study of in-person surveys conducted in South African provinces of Gauteng, Kwa-Zulu Natal, and Western Cape on the effects of a campaign to support the South African SSB tax found higher awareness of the media campaign among higher socioeconomic status adults.[18] Further work needs to be done to understand the differences in tax awareness and media exposure by socioeconomic status in South Africa and reasons for these disparities.

We also examined changes in latent means for SSB knowledge and risk perception after establishing measurement invariance across the two time periods. Although we found statistically significant increases in both knowledge and risk perceptions, these increases were very small. In the post-tax period, SSB knowledge was 0.03 units greater on a 3 point scale, equating to a 1% increase from pre-tax, and risk perception was 0.20 units greater on a 4 point

scale, equating to a 5% increase from pre-tax. Such small increases suggest a need for more widespread media campaigns to further increase knowledge and risk perceptions, particularly in low income settings. Previous research has found that media campaigns to prevent obesity have led to increased knowledge and concern about obesity as a health issue.[115–118] Other media campaigns specifically targeted at SSB consumption as a means to improve health. a study by Murukutla and colleagues examined the effects of a targeted mass media campaign on SSB knowledge and attitudes as well as intentions to reduce SSB consumption. However, many of these studies use psychological measures as their final outcomes, and greater emphasis may be needed to link these psychological measures with dietary intake outcomes to have the ultimate intended effects on intake.

Among our four psychological constructs, only intentions to reduce SSB consumption modified the effect of the tax, whereby the effect of time since implementation on intake was greater for participants who reported they would reduce their SSB intake. These results may be due to a signaling effect, whereby the SSB tax not only increases prices but also communicates important information to the consumer about the taxed product, with the justification for the tax made explicit and widely publicized.[19,20] However, these results may instead be affected by social desirability bias, whereby participants underreport taxed beverage intake post-tax after it became apparent that the SSB tax was identifying SSBs as harmful to health.

Our findings for tax awareness were directionally similar, with greater post-tax differences in taxed beverage intake among those who were aware of the tax compared to unaware, but this effect was not statistically significant. These findings suggest tax awareness was not sufficient in the South African context to affect behavior and are in contrast to findings from Mexico, where participants aware of the SSB tax were more likely to report they reduced their SSB consumption compared to those who were not aware.[57] The difference in the relationships between tax awareness and SSB consumption may be due to the magnitude and duration of the mass media campaign in Mexico leading up to the government vote on the tax,

which included over 1,000 media articles in a five-month period.[59] In the South African context, our results agree with those from Murukutla and colleagues, who found awareness of an SSB tax supporting media campaign was not associated with behavioral change, suggesting tax awareness is not sufficient to spur behavioral change.[18]

Overall, this study suggests a minor role of SSB knowledge, risk perceptions and awareness on the large reductions in taxed beverage consumption after the South African SSB tax. One possible explanation for the large changes in taxed beverage intake could be that price was the primary driver of behavior change. Indeed, studies using purchase data from Mexico[85] and South Africa[90] found greater reductions in taxed beverage consumption among lower income groups following national SSB taxes as well as a nonessential food tax,[119] and a recent global modeling study[95] found the lowest income populations were among the most responsive groups to price changes on SSBs, suggesting that prices—not knowledge or behavioral intentions—may better explain behavioral changes in low income populations following SSB taxes.

This study has several limitations. First, given the pooled cross-sectional nature of our data and pre-post approach, we are unable to make causal claims about the relationships between individual level psychological constructs and participant behavior, and how the SSB tax affected these. Although the majority of policy evaluation studies are observational, future studies on this topic would still benefit from linking survey participants across time with their psychological variables and dietary intake. Following the same participants across time with linked dietary data as well as psychological data would allow future studies to more closely examine the mechanisms through which policies operate, including the relative contributions of multiple pathways to the total effect. Second, our use of a constant food composition table across time means we are able to track changes in behavior, but we are not capturing any reformulation effects that may have occurred at one-year post tax implementation. This means that some beverages at one-year post tax implementation may be misclassified if the products

were reformulated below the 4g/100mL and should have been classified as untaxed, limiting our ability to completely detect changes in taxed beverage consumption after the tax.

This is the first study to test potential behavioral modifiers of an SSB tax using dietary intake data, which a more suitable measure for changes in mean population intakes than frequency questionnaires[16] or even cruder the intention to change as an outcome.[57] Another strength of this study is the use of a confirmatory factor analysis to better measure knowledge and attitudes instead of binary categorizations or single survey items. This comprehensive approach utilizing psychological measures alongside dietary intake data is needed to better understand the multiple pathways through which health taxes affect diets and ultimately weight outcomes.

Conclusion

In conclusion, this study found SSB knowledge and risk perception increased slightly after the South African SSB tax was implemented, tax awareness remains low in a low-income South African township, and only behavioral intention to change was strongly associated with tax beverage intake. Changes in SSB knowledge, risk perceptions, and tax awareness appeared to have little effect on the large changes in taxed beverage intake after the South African SSB tax. Future studies may benefit from longitudinal data to better understand individual-level changes across time after health policies such as SSB taxes.

Tables and Figures

Table 4.1 Psychological constructs measured in the present study

Construct	Definition	Question Items	Analytical measure
Risk perception	Expressed beliefs about potential health harms of consuming SSBs	**Question: To the best of your knowledge, does consumption of sugary drinks increase the suffering from…?**	CFA
		Q1: Diabetes	
		Q2: Blood Pressure	
		Q3: Obesity	
		Q4: Cavities	
Knowledge	Ability to correctly identify sugary beverages from a list	**Question: Is the following beverage sugary?**	CFA
		Q1: Flavored bottled water	
		Q2: 100% fruit juice	
		Q3: Nectars or canned juice that contain fruit (e.g. Tropicana)	
		Q4: Milk (sweetened and flavored) (e.g. Nesquick, Steristumpie)	
		Q5: Soda or soft drinks (e.g. Coca-Cola, Sprite, ginger beer)	
		Q6: Sweetened Iced tea (BOS, Lipton ice tea, Fuze)	
		Q7: Coffee/tea with sugar (including cappuccino, frapuccino)	
		Q8: Energy drinks (Red Bull, Monster, Dragon)	
		Q9: Sports drinks (e.g. Energade, Powerade, Lucozade)	
		Q10: Powdered drinks (e.g. Game)	
		Q11: Cordials and concentrates (e.g. Oros)	
Tax Awareness	Aware of the South African SSB tax	Question: “Are you aware of the new Health Promotion Levy (also called Sugary Beverage Tax)?”	Binary response (yes/no)
Intention to reduce SSBs	Expressed an intention to reduce SSB consumption as a result of the tax	Question: “The Government has approved a new tax on sugary sweetened beverages which will come into effect on 1 April 2018. If this tax will result in an increase in price of about R2 for 2liters of sugary beverages, how likely will it have the following effect on your purchasing intentions?” Response: “I will cut back on my sweetened beverage consumption (yes/no)”	Binary response (yes/no)

Table 4.2 Sociodemographic information for participants with complete survey data

Variable	**Pre-tax** (n=2,094)	**Post-tax** (n=2,316)	**p value***
	%	%	
Male	35.1	34.9	0.897
Female	65.0	65.1	
Diet surveyed on weekday	82.9	83.9	0.264
LSM category[1]			<0.001
LSM 3	1.3	1.7	
LSM 4	14.8	19.8	
LSM 5	39.0	51.5	
LSM 6	39.2	26.3	
Missing/incomplete data	5.7	0.7	
	Mean (SD)	Mean (SD)	0.207
Age	27.9 (6.0)	27.8 (6.2)	

[1]South African Living Standards Measure (LSM)[83]
*p value for difference in percentages calculated using Fisher's exact test and means with two-tailed t-test

Figure 4.1 Conceptual model of SSB tax policy effects, including SSB knowledge, risk perception, tax awareness and intentions to reduce SSB consumption, which may modify the relationship between time since taxation and taxed beverage consumption.

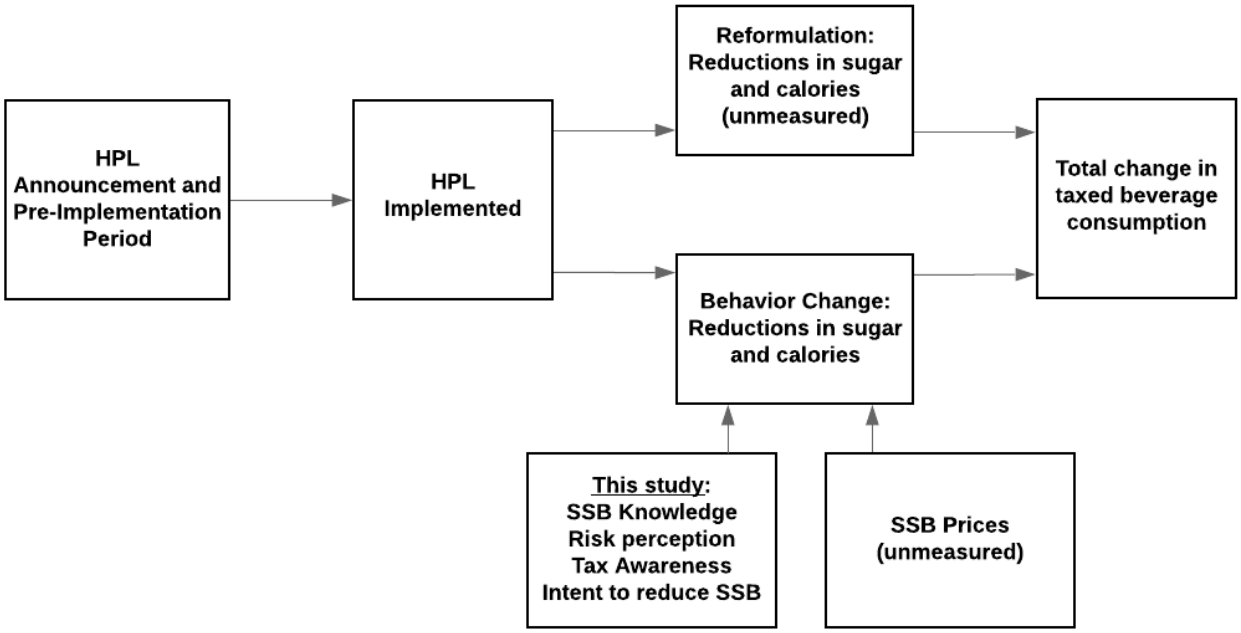


Figure 4.2 Interaction of time since implementation and tax awareness predicting taxed beverage intake (kcal per capita per day)

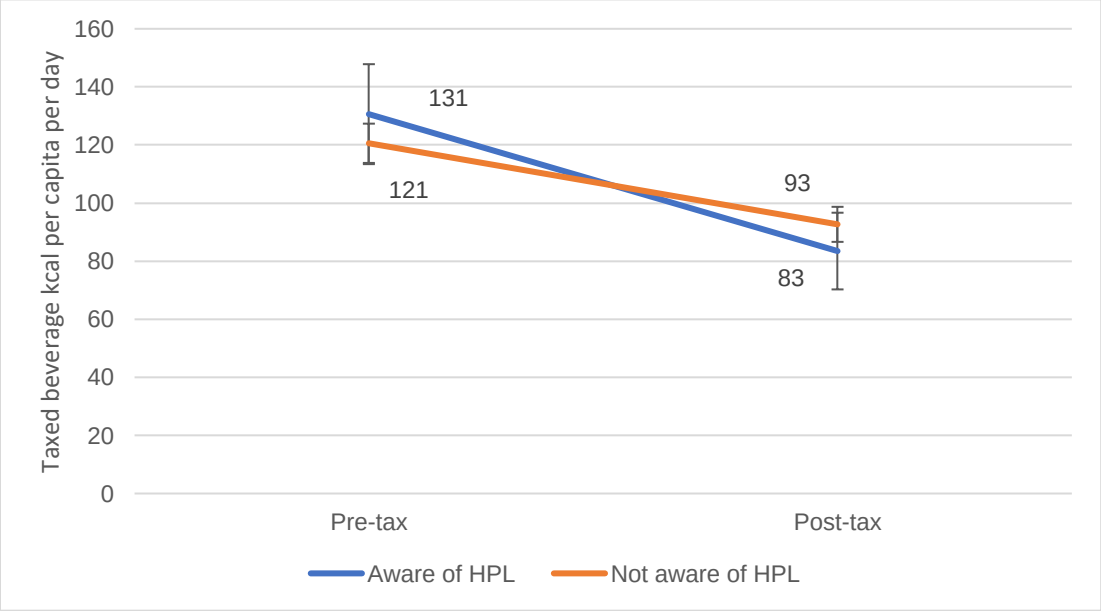
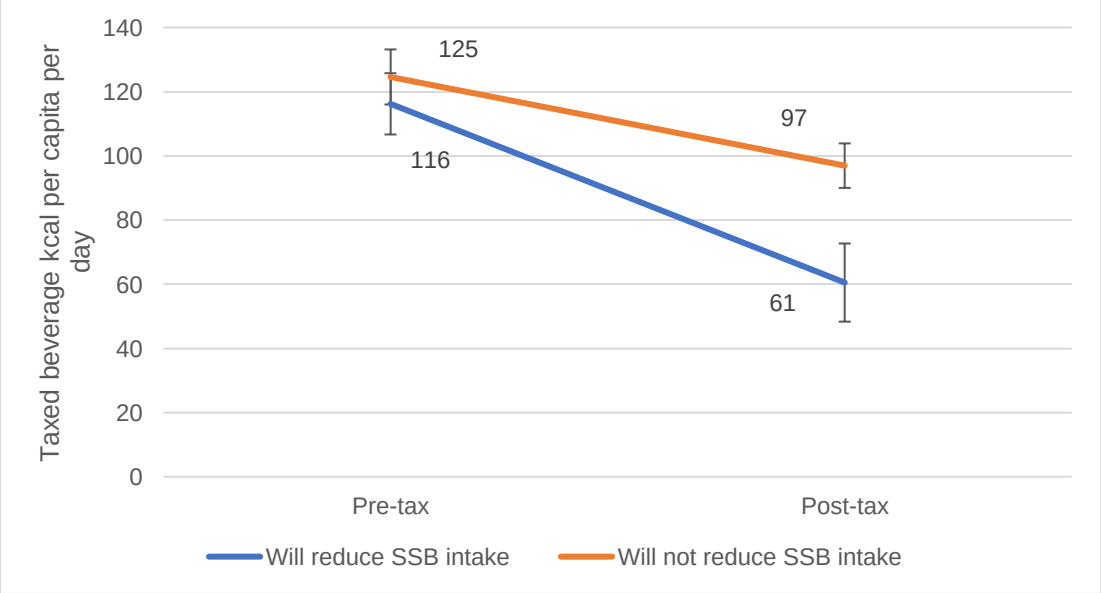


Figure 4.3 Interaction of time since implementation and intention to reduce SSB intake predicting taxed beverage intake (kcal per capita per day)



Supplementary Table 4.1 Total dataset including missing data on each analysis variable

	Pre-tax				Post-tax			
Variable	**Complete data (n=2,459)**	**Missing Tax Awareness (n=312)**	**Missing Intention to reduce SSB intake (n=342)**	**Missing Knowledge or Risk Perception (n=295)**	**Complete data (n=2,489)**	**Missing Tax Awareness (n=89)**	**Missing Intention to reduce SSB intake (n=153)**	**Missing Knowledge or Risk Perception (n=73)**
	%	%	%	%	%	%	%	%
Male	34.8	35.6	33.3	35.6	34.9	32.6	36	38.4
Female	65.2	64.4	66.7	64.4	65.1	67.4	64.1	61.6
Survey on weekday								
Yes	83.1	83.7	84.8	83.7	84.1	79.8	88.2	84.9
No	16.9	16.7	15.2	16.3	15.9	20.2	11.8	15.1
Tax Awareness								
Yes	11.4	--	1.5	0.7	15.3	--	4.6	2.7
No	75.9	--	12.28	1.4	81.1	--	46.4	6.9
Missing	12.7	--	86.26	98	3.6	--	49.02	90.4
Intention to reduce SSB intake								
Yes	35.3	1.6	--	1.0	14.1	2.3	--	5.5
No	50.8	3.9	--	1.0	79.8	13.5	--	4.1
Missing	13.9	94.6	--	98.0	6.1	84.3	--	90.4
Knowledge and risk survey								
Complete	88.0	7.4	15.5	--	97.1	25.8	56.9	--
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age	27.9 (6.0)	27.8 (6.2)	27.5 (6.0)	27.7 (5.9)	27.8 (6.2)	26.9 (6.6)	27.9 (6.7)	26.8 (6.5)

Supplementary Table 4.2 Invariance testing factor loadings from configural model

	Pre-tax (pre-tax, n=2,094)	Post-tax (post-tax, n=2,316)
Risk	**Factor Loading**	**Factor Loading**
Increased risk of diabetes	1.000	1.000
Increased risk of high blood pressure	0.964	0.966
Increased risk of obesity	0.907	0.742
Increased risk of cavities	0.751	0.804
Knowledge		
Sports drinks	1.000	1.000
Energy drinks	0.906	0.961
Flavored bottled waters	0.984	0.95
100% fruit juice	0.899	0.876
Nectars	0.966	0.877
Flavored milks	0.971	1.112
Sodas	0.914	1.184
Sweet tea	0.826	0.813
Sweetened coffee and tea	0.954	0.889
Powdered drinks	0.939	0.975
Cordials	0.988	1.024
100% fruit juice correlated with Nectars	0.276	0.363
Energy drinks correlated with Sports drinks	0.371	0.353

All factor loadings have a p value<0.001.

Supplementary Table 4.3 Invariance testing fit statistics for configural, metric, and scalar models

Risk	Configural Model	Metric Model	Scalar Model
CFI	0.981	0.982	0.977
Probability RMSEA ≤ .05	<0.001	0.012	0.198
SRMR	0.029	0.031	0.033
χ^2 test	<0.001	<0.001	<0.001
Knowledge			
CFI	0.971	0.975	0.970
Probability RMSEA <= .05	0.233	0.970	0.883
SRMR	0.047	0.049	0.051
χ^2 test (p value)	<0.001	0.009	<0.001

Supplementary Table 4.4 Results for two-part model estimating beverage intake, with first part estimating the odds ratio (OR) for consuming taxed beverages and the second part measuring the consumption-day amount

	Adjusted models		**Interaction model – Tax Awareness**		**Interaction model – Intention to reduce SSB**	
	Odds of consuming taxed beverages	**Taxed beverage consumption-day amount (kcal)**	**Odds of consuming taxed beverages**	**Taxed beverage consumption-day amount (kcal)**	**Odds of consuming taxed beverages**	**Taxed beverage consumption-day amount (kcal)**
Variable	**OR (95% CI)**	**Coeff. (95% CI)**	**OR (95% CI)**	**Coeff. (95% CI)**	**OR (95% CI)**	**Coeff. (95% CI)**
Risk Perception	1.01 (0.92 to 1.11)	5.18 (-16.09 to 26.44)	--	--	--	--
Knowledge	0.91 (0.76 to 1.08)	14.18 (-27.63 to 55.99)	--	--	--	--
Time (post-tax compared to pre-tax)	**0.53 (0.48 to 0.59)**	-16.81 (-41.59 to 7.97)	**0.59 (0.52 to 0.67)**	-0.67 (-12.56 to 11.23)	**0.61 (0.53 to 0.70)**	-4.12 (-16.97 to 8.73)
Tax Awareness	1.06 (0.92 to 1.23)	-27.20 (-56.02 to 1.62)	1.25 (0.97 to 1.63)	-1.98 (-23.55 to 19.60)	--	--
Awareness x Time	--	--	0.73 (0.52 to 1.03)	-9.32 (-40.60 to 21.97)	--	--
Intention to reduce SSB intake	**0.83 (0.74 to 0.93)**	**-53.70 (-80.16 to -27.23)**	--	--	**1.00 (0.84 to 1.19)**	**-14.11 (-29.14 to 0.92)**
Intention to reduce x Time	--	--	--	--	**0.60 (0.44 to 0.81)**	-16.01 (-45.80 to 13.78)
Sex	0.98 (0.88 to 1.09)	**-55.10 (-80.81 to -29.39)**	0.98 (0.86 to 1.11)	**-22.69 (-34.17 to -11.20)**	0.97 (0.86 to 1.10)	**-20.54 (-31.92 to -9.17)**
Age	**0.96 (0.96 to 0.97)**	-0.22 (-2.18 to 1.73)	**0.96 (0.95 to 0.97)**	-0.19 (-1.11 to 0.74)	**0.96 (0.96 to 0.97)**	0.03 (-0.89 to 0.94)
Weekday	**0.80 (0.70 to 0.92)**	-27.07 (-61.62 to 7.49)	**0.81 (0.69 to 0.95)**	-10.11 (-24.48 to 4.26)	**0.81 (0.69 to 0.96)**	-10.40 (-24.58 to 3.78)

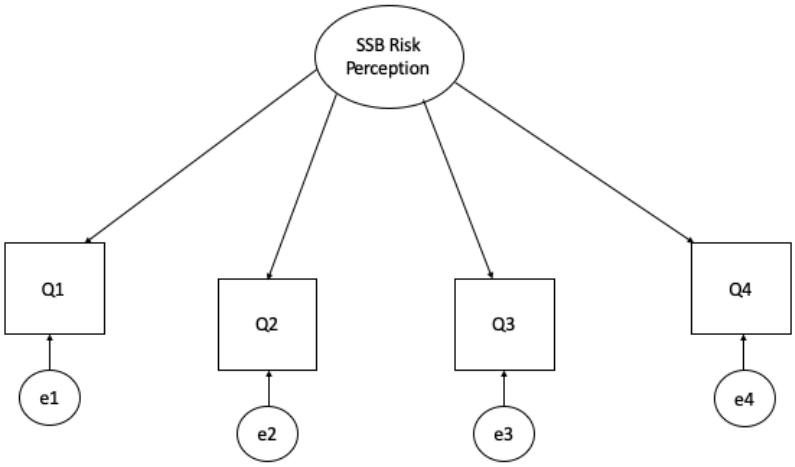
Bolded p values are statistically significant at the p<0.05 level or lower.

Supplementary Table 4.5 Results for changes in SSB knowledge, risk perception, tax awareness and intention to reduce SSB consumption from pre-tax to post-tax

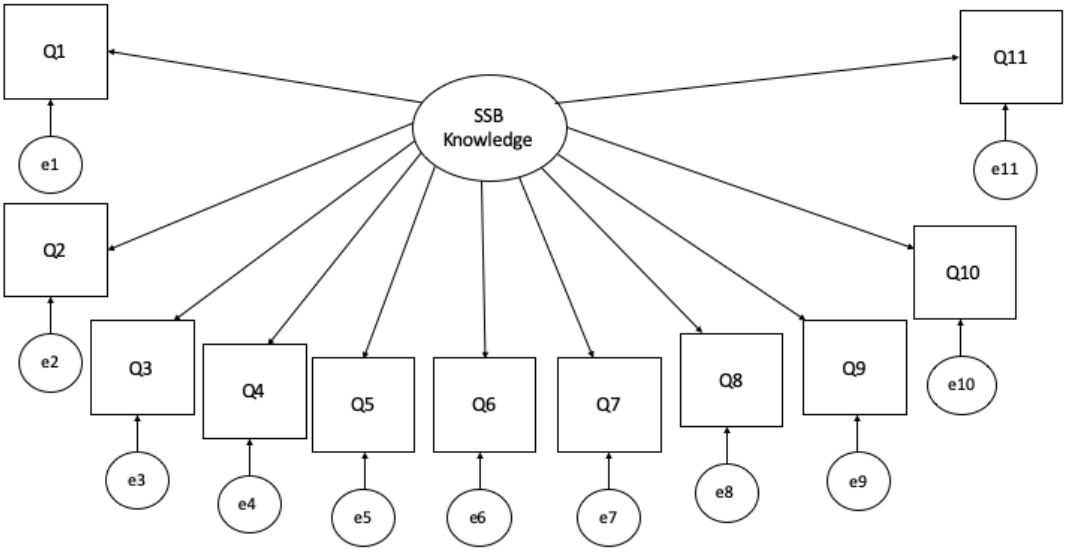
	Odds of tax awareness	**Odds of intention to reduce SSB consumption**	**Mean Knowledge**	**Mean Risk Perception**
Variable	**OR (95% CI)**	**OR (95% CI)**	**Coeff. (95% CI)**	**Coeff. (95% CI)**
Time	1.279* (1.080 to 1.514)	0.252* (0.219 to 0.292)	0.032* (0.009 to 0.055)	0.171* (0.124 to 0.218)
Sex	0.822 (0.692 to 0.978)	1.075 (.929 to 1.244)	0.013 (-0.011 to 0.037)	0.017 (-0.033 to 0.066)
Age	1.025 (1.011 to 1.039)	1.029 (1.017 to 1.041)	-0.002 (-0.003 to 0.000)	-0.002 (-0.005 to 0.002)
Weekday	1.085 (0.863 to 1.363)	0.945 (0.786 to 1.136)	0.020 (-0.010 to 0.051)	0.022 (-0.041 to 0.085)

*p values are statistically significant at the p<0.05 level or lower.

Supplementary Figure 4.1 Factor model for SSB Risk Perception



Supplementary Figure 4.2 Factor model for SSB Knowledge



CHAPTER 5. EXAMINING THE NEWS MEDIA REACTION TO A NATIONAL SUGARY BEVERAGE TAX IN SOUTH AFRICA: A QUANTITATIVE CONTENT ANALYSIS

Introduction

Sugar sweetened beverages (SSBs) are one of the largest global drivers of added sugar consumption[2] and are independently associated with increased risk of obesity,[3] diabetes,[4] and cardiovascular diseases.[5] In an effort to reduce SSB consumption at the population level, several countries and municipalities have introduced SSB taxes since 2014.[53,120] Although African countries do not purchase SSBs at rates as high as Western countries like the US, Mexico, and Chile, SSB sales are rapidly increasing across Africa.[121] In particular, South Africa has one of the highest SSB sales rates in Africa.[121] Such high rates of consumption are occurring in an environment where type II diabetes is the greatest cause of death in South African women and the second leading cause of death overall.[26] If left unchanged, the growing SSB consumption is likely to increase the burden of obesity and chronic disease in the future.[26,70,122] In response to this public health challenge, on April 1, 2018, South Africa became the first sub-Saharan African country to implement a tax on sugary beverages, called the Health Promotion Levy (HPL), to reduce South Africans' consumption of added sugar.

The HPL not only affects potential SSB consumers by causing price increases, but news media coverage of the tax can inform consumers as to the tax's existence and purpose. News media can assist a public health intervention, through its ability to reach a wide public audience and second, through agenda setting, whereby news organizations control topic salience for the public and urgency for policy action through the frequency of news coverage.[62,65,66,123] By controlling the public's frequency of exposure to the topic, news media affect how important the topic is perceived to be by the public. In addition to setting the public's agenda, the way news

media frame public policies related to health is important to the eventual effectiveness of such policies in reducing illnesses.[124] Framing defines how topics are understood by emphasizing certain aspects of the topic over others.[24] News media framing of obesity as a disease caused by environmental factors rather than poor individual choices may improve public acceptance of government intervention and accelerate the implementation of SSB taxes.[60,67,68] By defining a social problem and the dimensions along which it should be understood, framing of the SSB tax policy is crucial to whether the policy is ultimately passed and implemented.[44] News media can also influence public knowledge about SSBs and perceptions of risk, as well as their awareness and acceptance of the tax, which could affect dietary intake. For example, a recent study from Mexico found that increased SSB tax awareness was associated with increased odds of reducing SSB consumption after the tax.[57] Another study in Oregon, USA found that participants who were aware of the mass media campaigns were more likely to want to reduce their consumption and to agree that excessive sugar consumption leads to health problems.[97]

Studying media frames related to public health polices is essential for understanding the arguments and strategies that stakeholders use to influence public perceptions and government policies[62]. While an extensive literature has examined the role of news media in other public health policies, such as alcohol[125] and tobacco[126] control, evidence for news media responses to SSB policies remains scarce. Most of the current research comes from the United Kingdom (UK), where researchers found that the issue of sugar consumption as a problem for public health became increasingly discussed by the British media in the two years leading up to the passage of a UK SSB tax.[22,23,127] These articles have provided a systematic framework for understanding how news media in the UK changed leading up to the tax and after its passage, as well as identified the frames that the media has used to describe the problem of SSB consumption and the proposed solutions. In fact one article suggests major shifts in consumption in the UK as a result of this debate and law change in the two years before the SSB tax was initiated.[88] Without such an understanding of arguments that tend to support or

oppose public health policies for obesity prevention, it will be more difficult to identify those communication strategies that are most successful. For example, Buckton and colleagues[23] found that overall coverage of the UK SSB tax was favorable, and the problem of SSB consumption was largely attributed to industry actions. However, passage of the SSB tax legislation was also met with a corresponding increase in negative media coverage.[23] Despite the developing evidence from the UK, it is unclear whether national news media outlets in countries like South Africa will vary in their responses to new SSB taxes. This is important to understand, because how SSB news is reported in the media may affect an individual's response to the tax (perhaps via increased awareness of the health harms of SSBs), as well as governmental responses, such as whether politicians choose to discard, maintain, or strengthen the tax over time. Finally, according to the All Media Products Study 2015 by the South African Advertising Research Foundation (SAARF), newspapers remain an important source of information in South Africa, as nearly half of adults (43.8%) read newspapers.[128]

This is the first study of the news media response to an SSB tax in either a low- and middle- income country (LMIC) or African country. The purpose of this study is to examine the framing of online news articles related to the South African HPL before and after it was passed, how different stakeholder perspectives were portrayed in the news media discussion of the HPL including which topics they emphasized most, and finally examine the association between proposed solutions for high sugar intake and the stakeholders deemed most responsible for carrying out those solutions.

Methods

We performed a quantitative content analysis of South African newspapers, following previous methods developed for systematic search and coding of news media content related to SSB taxes.[22,23] Our article search strategy, codebook development, and analysis are outlined below.

Sample Selection

Search strategy

We selected online news articles covering the HPL using two databases: (1) Nexis Uni and (2) ProQuest Central, both global databases that provide access to full text news articles. We searched for articles using the following search string:

> ("Sugary beverages" OR "sugar-sweetened beverages" OR "sugar sweetened beverages" OR “health promotion levy”) AND (Levy OR Levies OR Tax OR Taxes OR Taxation OR Legislat*) AND (“South Africa” OR “Eastern Cape” OR Free State OR Gauteng OR “KwaZulu-Natal” OR Limpopo OR Mpumalanga OR “North West” OR “Northern Cape” OR “Western Cape” OR Bhisho OR Bloemfontein OR Johannesburg OR Pietermaritzburg OR Polokwane OR Nelspruit OR Mahikeng OR Kimberley OR Cape Town OR Port Elizabeth OR Durban OR Rustenburg OR Soweto OR Pretoria OR “Mitchells Plain” OR Umlazi OR Katiehong OR Tembisa OR Khayelitsha OR Soshabguve OR Mamelodi OR Ibhayi OR Tshivhase OR Sebonkeng OR Mabopane OR Chatswork))

South African city search terms were included to potentially pick up smaller, local papers published in South Africa. We did not restrict to particular newspapers and included any South African newspaper source captured by the Nexis Uni or ProQuest Central databases. **Supplementary Table 5.1** displays the study sample with circulation numbers, which includes most of the major English language newspaper publishers in South Africa.[129]

Eligibility criteria

Articles were included for analysis if they were published between January 1, 2017, one month prior to the initial announcement of a plan to tax SSBs by Finance Minister Pravin Gordhan, and June 30, 2019, when the article search was conducted. All articles were published in English, which is the primary language in South African education, journalism, broadcasting, and advertisements.[130]

To be included in the search, articles must have included discussion of the South African HPL. Discussion of the HPL was defined as including at least one of the following topics: the potential effects of the HPL (either on health, economics, or SSB consumption), statements of support or opposition toward the HPL, explanations of the purpose of the HPL (to reduce

consumption of unhealthy products or to improve health), or other statements that explain a purpose, goal, or likely outcome of the tax. Articles were excluded if they were duplicates of previous articles found in the search, if they were not relevant to the HPL (e.g. if they were about Value Added Taxes in South Africa or about general tax policy without any specific discussion of the HPL and its purpose or consequences), or if they were not published by a South African news source. Articles that discussed SSB consumption but did not discuss the HPL were excluded. Given our focus on news media, we also excluded reports from NGOs, law reviews and journals, and government documents. Articles could either be news articles written by journalists or opinion letters written to the newspaper and subsequently published, as publishing opinions was considered a view of the HPL presented by the newspaper. A flowchart for the article selection process is depicted in **Figure 5.1** below.

Data extraction

Articles from the initial search were downloaded to the online software product Covidence.[131] Two investigators (ME, FM) independently screened the article headline and first paragraph of the full text and excluded irrelevant articles using the inclusion and exclusion criteria. Disagreements were resolved after discussion of the inclusion/exclusion criteria between the two coders. Second, authors ME and FM independently screened the full text of relevant articles and eliminated those that did not fit the eligibility criteria. Articles were screened independently, with disagreements resolved after discussion between the two coders.

Final study sample

After the initial article search identified 571 articles, our final analytic sample included 193 articles published by the newspapers with the largest readerships in South Africa (**Supplementary Table 5.1**).[128]

Coding

Codebook

To achieve inter-rater reliability, investigators (ME and FM) used articles written about the UK SSB tax to refine codebook definitions. This training set of articles from the UK context was used to decide which topics would be included in our study, and the codebook was updated in an iterative process until the two coders reached high agreement in understanding and using the codes. After the codebook training, the final set of definitions was established (**Supplementary Table 5.2**), and ME and FM coded a random subsample of 42 articles (22% of full sample) to ensure inter-rater reliability. We used Gwet's AC1 as a measure for inter-rater agreement, as it has been showed to be a more stable measure of reliability than Cohen's Kappa in instances of skewed distributions (in this case, many values of zero).[132,133] Items that achieved an acceptable Gwet's coefficient were retained for the analysis, range = 0.77 – 0.97. After establishing acceptable inter-rater reliability and agreement, ME coded the remaining articles. Articles were coded by entering the data into a Microsoft Excel spreadsheet.[134]

Outcomes: topics mentioned

Topics analyzed included two major categories—health and economics, Health topics included statements that sugar consumption is (or is not) related to obesity, sugar consumption is (or is not) related to diabetes, sugar consumption is (or is not) related to NCDs, and the HPL will (or will not) improve health outcomes. Economics topics included statements that the HPL will (or will not) cause industry or economic harm, the HPL will (or will not) reduce health care costs, and the HPL will (or will not) economically harm the poor. We added two additional policy-relevant topics: changes in SSB consumption and SSB reformulation as a consequence of the HPL, as these are both important goals of the HPL. All topics used in our analysis are listed and defined in **Supplementary Table 5.2**.

Outcomes: sources

We expanded upon the codebook used by Buckton and colleagues[23] by including the source attributed to each topic mentioned to be able to identify how different stakeholder perspectives were portrayed in the news media discussion of the HPL. We categorized sources as any person other than the journalist whom the journalist paraphrased or quoted as giving a statement about the HPL. Statements for which no source was given were attributed to the journalist. We categorized six source types as follows: industry, government, academics and medical experts, economists, non-governmental organizations (NGOs), or private citizens. Industry representatives included leaders of SSB companies, leaders of trade organizations with workers in either the SSB industry or sugar growing industry, or any other representatives of companies in the SSB production or sales supply chain. Government representatives were defined as members of the South African parliament or any other government job relevant to the HPL, such as the Minister of Finance or Minster of Health. Academics and medical experts (henceforth referred to as academics) included persons with an academic or public health research job at a college or university. Medical experts in this category also included medical doctors, nurses, or other health professionals. Economists were sources referred to as such in the article, or any employee of a research organization or other company conducting economics research. NGO representatives were defined as sources from a non-governmental organization such as the World Health Organization or other relevant NGOs. Private citizens were defined as South African citizens or members of the public who expressed a view about the HPL that did not belong in any of the other aforementioned categories. Sources were categorized based on how they were described in the article or by searching for biographical information about the source or author if no description was given. All sources used in our analysis are listed and defined in **Supplementary Table 5.2**.

Outcomes: support or opposition

Statements expressing support or opposition to the HPL were categorized in the same manner as topics described above, with a support or opposition statement and the source. We also coded articles for whether (1) individual mentions of support or opposition were present in the article and (2) if the article as a whole supported or opposed the HPL (article-level support or opposition). We recorded individual mentions of support or opposition because news media reports can often include a variety of perspectives, and we wanted to capture all unique views expressed in each article and by each source. However, in our analysis, we were also interested in the number of *articles* published over time that were primarily in support of or opposition to the HPL. We classified articles as being in support of the HPL if they contained a greater number of supporting mentions than opposing mentions. Articles with more opposing mentions compared to supporting mentions were classified as opposing articles. Articles with an equal number of supporting and opposing mentions were classified as balanced articles. Supporting mentions were defined as statements noting that obesity is related to SSB consumption; the HPL will improve health outcomes; the HPL will reduce SSB consumption; the HPL will reduce health care costs; the HPL will not harm industry; the HPL will benefit the health of the poor. Opposing mentions were defined as statements that obesity is not related to SSB consumption; the HPL will not improve health outcomes; the HPL will not reduce SSB consumption; the HPL will not reduce health care costs; the HPL will cause industry or economic harm; the HPL will economically harm the poor.

Outcomes: proposed solutions

Proposed solutions were recorded if (1) there was a health problem described that was linked to sugar consumption (e.g. obesity, diabetes, other chronic diseases) and if (2) any of our key sources proposed a solution to this health problem (e.g. government should tax SSBs, industry should voluntarily reformulate their products, individuals should exercise more).

Proposed solutions were classified into four levels at which interventions could operate: changes in individual action, changes in individual beliefs, changes in the nutritional composition of food (e.g. reformulation of products or the introduction or removal of products), or other food environment-related changes. Individual actions included diet changes, exercise changes, seeking education or counseling or other health information. Individual beliefs included interventions, initiatives, or structural responses proposed whose first steps are intended to change how individuals think about food, including public health campaigns, educational initiatives, marketing restrictions, and nutrition labels. Changes in nutritional composition of food included environmental or structural measures that would change the composition of foods available in the food supply, such as proposals to specifically incentivize reformulation or voluntary industry agreements for product reformulation. These proposed solutions for voluntary product reformulation differed from the topic code “reformulation as consequence” in that the voluntary solutions were proposed as a response to the health problem mentioned in the text, whereas reformulation as a consequence was mentioned as a direct consequence of the HPL. The fourth category included environmental or structural measures proposed that change the affordability, accessibility, or availability of foods, such as school food restrictions, taxes on unhealthy foods, subsidies of healthy foods, or restrictions on using financial assistance programs to purchase foods. The full definitions of our proposed solutions are provided in **Supplementary Table 5.2**.

We examined solutions by level of intervention, by source proposing the solution, and by the actor most responsible for carrying out the solution. For example, an academic source proposing SSB taxes as a means of reducing sugar consumption would be classified as an intervention related to changes in the food environment, suggested by academic source, and carried out by government regulation. Actors responsible for carrying out the proposed solutions included industry, government regulation, NGOs, and private citizens. This classification allowed

us to separate an intervention into its component parts. Without this classification, government regulations would have all been categorized as the same.

Analysis

Supporting, opposing, and balanced articles published before and after HPL passed

First, to understand trends in article stance on the HPL over time, we conducted a descriptive analysis of the total number of supportive, opposing, or balanced articles published during our search timeframe, as well as before and after HPL implementation. A Pearson χ^2 test was used to evaluate whether the proportion of pro, con, and balanced articles differed by whether articles were published before versus after the tax was passed. To contextualize trends over time, we identified the timing of publication relative to additional key events, including the announcement of the South African Government's plan to tax SSBs (February 2016), the publication of a key research article showing the two year impact of an SSB tax in Mexico (February 2017), and the South African government passing the bill to tax SSBs (December 2017).

Topic mentions before and after HPL passed

Next, we analyzed the relative frequencies of topic mentions according to whether they were published before or after the HPL. Fisher's exact tests were used to determine if the number of topic mentions differed based on being published before or after the HPL was passed, with a threshold for statistical significance set at 5% (α=0.05).

Topic mentions by source

Next, we examined whether the proportion of topic mentions and support/opposition for HPL differed by source. We stratified by the proportion of those topic mentions that came from our six sources in addition to journalist opinion (statement attributed to the journalist). A Pearson χ_2 goodness-of-fit test was used to determine whether the distribution of sources within topic categories was different from the distribution of sources within all topics (i.e. the expected

distribution assuming no relationship between topic and source), setting our significance level at 5% (α=0.05). We pooled all articles across time for this analysis because only 23% of our study sample was published after the HPL was implemented, which would leave many cell sizes small (less than 5), and therefore make statistical testing of differences between topics by source unreliable.

Supporting or opposing views of HPL by source

Because articles could contain more than one opinion of support or opposition from more than one source, we analyzed the total supportive or opposing views as the unit of analysis to characterize the perspectives presented from each of our six sources. Articles were analyzed according to total supporting and opposing opinions presented by each source. Fisher's exact tests were used to determine if the number of supporting versus opposing views of the HPL within each source group were different, with a threshold for statistical significance set at 5% (α=0.05).

Proposed solutions: actor responsible and level of action

To analyze the solutions proposed to solve health problems related to excess sugar intake, we first calculated the proportion of solutions that would be carried out by each actor as well as the sources that suggested that these actors should be responsible for carrying out the solutions. Next, we calculated the proportions of each level of action by the source suggesting the solution. Again, we used a χ^2 goodness-of-fit test to determine whether these distributions differed significantly (α=0.05) from the expected distributions based on the total number of sources mentioned in the study sample. Post hoc Fisher's exact probability z tests were used for pairwise comparisons between the percent contribution to solutions by source and the expected percent contribution based on overall prevalence of the source in the study sample. All statistical analyses were performed in Stata 16.[78]

Results

Supporting, opposing, and balanced articles published before and after HPL passed

Coverage of the HPL increased alongside three key events: after the Finance Minister's announcement of a plan to tax SSBs, after the publication of a now widely cited research article on the two-year effects of a national SSB tax in Mexico,[8] and the South African parliament's passage of the bill to tax SSBs. Overall tax coverage decreased after passage of the bill in December 2017 (**Figure 5.2**). Of all articles published in our sample frame, 54% were in support, 26% were in opposition, and 20% presented a balanced number of opinions (**Figure 5.2**). There was no statistically significant difference in the proportion of articles expressing pro, con, or balanced stances towards HPL before vs. after the HPL was passed.

Topic mentions before and after HPL passed

Across the entire sample period, 82% contained any mention of health-related topics and 68% contained any mention of economics-related topics. The most common topics mentioned were: sugar consumption is related to obesity (79.8%), the HPL will improve health (69.9%), and the HPL will cause industry or economic harm (59.6%) (**Figure 5.3**). A third of the articles suggested there would be no effect of the HPL on health. There were no statistically significant differences in the proportion of articles mentioning most topics before and after the HPL was passed. However, the proportion of articles mentioning that the HPL causes reformulation increased from 7% before to 36% after the HPL was passed ($p<0.001$).

There were zero mentions that sugar was *not* related to diabetes or *not* related to NCDs, that the HPL would *not* reduce health care costs, and few statements were made directly denying economic harm to the poor—which made coding inter-rater agreement unreliable due to small sample size—so these topics are not presented in **Figure 5.3** even though they were searched for in our coding process.

Topic mentions by source

The three most common sources cited in the news articles across all topics and across the sample period were industry (25%), government (31%), and academics (25%) (**Figure 5.4**). Compared to all sources combined, the industry a had a higher percentage of statements that sugar consumption is *not* related to obesity; HPL will *not* reduce SSB consumption; and HPL will cause industry or economic harm. Compared to all sources combined, government sources had a higher percentage of statements that sugar consumption is related to obesity; HPL will improve health; sugar consumption is related to NCDs significantly more often than the expected values, while academic sources had a higher percentage of statements that sugar consumption is related to obesity and diabetes and that the HPL will reduce health care costs. When analyzed over the entire time period, there was no statistically significant relationship between source and mentions that HPL caused reformulation or that HPL will reduce SSB consumption, suggesting that each source mentioned these topics in proportion to their overall prevalence in the study sample. However, when analyzed by whether mentions were published before or after the HPL was passed, both industry and economists were significantly more likely to mention that reformulation would result from the HPL after the tax was passed compared to before.

Supporting or opposing views of HPL by source

Among all articles, there were 303 total unique supporting or opposing opinions expressed about the HPL (**Figure 5.5**). Industry sources did not express any support for the HPL and were by far the most likely to oppose it. Government representatives expressed significantly more supporting (94%) versus opposing (6%) views ($p<0.001$); Academics expressed significantly more supporting (97%) versus opposing (3%) views ($p<0.001$). NGOs expressed significantly more supporting (82%) versus opposing (18%) views ($p<0.01$). Private citizens expressed significantly more supporting (75%) versus opposing (25%) views, as did

economists (63% supporting, 37% opposing), but these results did not reach statistical significance.

Proposed solutions: actor responsible and level of action

Considering all sources, industry (15%) or government (73%) were the actors most commonly proposed to fix the problem of overconsumption of sugar. Industry was the most likely to propose industry voluntary actions as a solution (38.3% of mentions of this solution came from industry), followed by government sources (31.7% of mentions). Government was the most likely to propose governmental regulations as a solution (46.3%), followed by academic sources (23.8% of mentions). Only one statement was recorded, by a government official, that NGOs were a key actor responsible for solutions. Finally, governmental sources were the most likely to propose individual level decisions and behavior changes as a solution (27.7%), followed equally by industry and academic sources (23.4% of mentions) (**Table 5.1**).

There was a total of 222 different proposed solutions in all articles, with 27 solutions occurring at the level of individual action, 32 occurring at the level of individual beliefs, 25 occurring at the level of food nutrition (i.e. reformulation), and 138 occurring at the level of the food environment (**Table 5.2**). There were no statistically significant differences among the five different types of sources that proposed solutions at the level of individual action. Industry was the most likely to propose solutions that operated at the level of individual beliefs and voluntary changes in food supply. The government as well as academic and health experts were the most likely to suggest structural changes in the food environment including taxes that could increase the price of SSBs. Industry actors were least likely to suggest structural changes in food environment to improve health (**Table 5.2**).

Discussion

This analysis of South African newspaper articles about the April 2018 implementation of the Health Promotion Levy, a sugary drinks tax, found overall HPL coverage was highest from the month of the initial announcement to the passage of the bill in December 2017, after which

coverage declined. Although we found a surge in coverage, overall, following the announcement of the HPL, we did not find surges in the proportion of negative views of the tax in the month of the announcement or in the month of implementation, as was found in the United Kingdom.[23] In terms of overall supporting or opposing articles written about the HPL, there were no significant differences in the proportion of supporting, opposing, or balanced articles before compared to after the tax was passed.

In terms of stakeholder representation, industry, government, and academics (including medical experts) were nearly equally represented as sources in newspaper articles (25%, 31%, and 25% of sources, respectively). When analyzing total number of supporting and opposing opinions by source, we found no evidence of industry offering supporting opinions of the HPL in any articles in our sample. In fact, almost all opposing claims about the HPL were made by representatives of companies that sell SSBs or companies in the sugar industry. On the other hand, government officials, academics and medical experts, and NGO representatives offered significantly more supporting opinions of the HPL than opposing ones. These results corroborate previous findings that among stakeholders including industry, government, public health experts, and the public, opposition from industry is a common barrier to SSB tax implementation.[135]

Overall, health topics were discussed more often than economics topics (82% of articles vs. 68% of articles). Among health topics, government and academic experts were more likely than industry to draw links between SSBs or sugar and health problems (obesity, diabetes). Industry actors were more likely than government or academics to question or challenge claims that sugar consumption is not related to obesity. Industry was also more likely than other sources to challenge claims that the HPL would lead to improved health outcomes through questioning or counter-claims. This latter tactic casts doubt on public health policies aimed at improving diets and has been used in other business sectors to weaken the direct link between policy and the problem that policy is meant to address. Other studies have found unhealthy

commodity industries resist regulation by arguing that singling out particular commodities is unlikely to solve the stated problem and therefore is not worth the costs.[136] In the case of opposing the HPL, if sugar is not the *only* cause of obesity, then it is unjustified to single out SSBs for regulation.

For economics topics, claims that the HPL would cause economic harm were made almost entirely by industry representatives who have a financial interest in SSB sales. These harms included harming the poor through increased SSB prices, harming vulnerable workers directly through job loss, overall harm to the South African economy, or harming the sugar and SSB production industries. Disproportionate financial burden on the poor, known as "regressivity," is a common criticism of health-related taxes, including sugary drinks taxes but also taxes on cigarettes, alcohol, and other health-harming products[137–139]. Yet, poorer populations also tend to potentially gain the most from these taxes in terms of the potential health benefits of lower SSB consumption.[137–139] In terms of overall harm, Barnhill and King argue that, compared to the cost of soda, it is the disproportionate disease burden of low-income populations from unhealthy diets that is the more morally urgent concern.[137] Many of these claims of economic harm can be assessed in light of available evidence from other national SSB taxes. A study on the effects of SSB taxes in Mexico by income found that low income households had the greatest reductions in SSB purchases,[85] suggesting that low income households would potentially receive the greatest health benefits. In South Africa, a country with high wealth inequality and unemployment, low-income populations are far less likely to be diagnosed and treated for sugar-related NCDs, making primary prevention an even higher priority. With respect to job loss, evidence from Mexico published in December 2017 suggests there was no drop in employment in either the manufacturing or food and beverage sales sectors following an SSB and nonessential food tax.[140] With respect to the overall economy, there was also no evidence of an effect on national unemployment figures. However, this evidence was published in the middle of our study sample period, so it is unclear whether

the sources referenced in our study sample were aware of it to respond to this claim. Another study from the UK found a short-term negative impact on the beverage industry after the national SSB tax was announced, but these effects did not persist post-implementation. Future studies are needed to determine if the economic effects of the HPL were similar to those of the national SSB taxes in Mexico or the UK.[141]

Although most economics topics were used in opposition to the tax, non-industry actors pointed to the possible economic benefits of the HPL. Consistent with extensive modeling studies from multiple countries that SSB taxes could reduce burden on health systems[35,38–41,142,143], governments and academics were disproportionately more likely highlight this potential economic benefit of the HPL.

This tension between health frames and economic frames for discussing public health policies has been a consistent finding in media studies of health policy. Weishaar and colleagues[62] trace this enduring conflict back to Beauchamp,[144] who identified "market justice" as an opposing force to "social justice". In this conflict, public health seeks to protect people, particularly the vulnerable, and in doing so may infringe on corporations' rights to sell a product or to evade responsibility for disease prevention.[144] Previous work has found these SSB policy frames may be key to influencing public opinion.[60,63,135,145,146] In New York City, where a ban on large SSB portion sizes failed, 84% of newspaper articles studied contained opposing frames centered around economic concerns and freedom of the market compared to only 36% pro policy frames that covered potential health benefits of the policy.[69] In other contexts, food taxes framed positively as beneficial to health corresponded with increased public support.[61,68,147,148] We found similar opposing frames in our news media study of the HPL in South Africa, wherein health related frames were more likely to be utilized by government and academics in ways that were supportive of the HPL, whereas economic frames more likely to be utilized by industry in ways that were in opposition to the HPL.

Our results can inform policymakers by demonstrating that health frames are more commonly used to support SSB taxes, and economic frames are more commonly used to undermine them. However, it is notable there has been limited to no evidence of actual economic harm caused by these policies,[140] whereas there is published evidence of potential health benefits from modeling studies.[35,38–41,142,143] With a clear understanding of frames associated with policy support, public health officials may be better prepared to generate public support.

Among the solutions for health problems related to excessive sugary beverage consumption that were proposed in the newspaper articles we analyzed, the most common solution was government regulation of the food environment. These results corroborate findings from online newspapers in the UK, where government intervention was the most commonly proposed solution for addressing sugar overconsumption.[23] Government representatives were the mostly likely to propose this intervention, followed by academics and medical experts, whereas industry representatives were the most likely to suggest their own voluntary solutions. Although it is common for food and beverage companies to commit to self-regulation, voluntary self-regulation has proven largely ineffective.[149,150] For example, a systematic review of initiatives to limit the advertising of food and beverage products to children found that peer-reviewed academic literature was more likely to find high levels of advertising unhealthy foods despite industry commitments to self-regulation, contradicting industry-sponsored reports.[151]

One limitation of this analysis is the ability to make causal claims about the effects of the news media on how people respond to SSB taxes. Future studies would benefit from linking news media exposure to individual-level consumption of SSBs to better understand their relationship. Another limitation is our focus on only English language sources. South Africa has great language diversity, with eleven official languages, many of which are acquired as a first language. It is therefore possible that our results are biased if coverage of the SSB tax differs between non-English and English sources. The circulation of our sources is presented in

Supplementary Table 5.1. The time restrictions on our sampling frame could also limit the number and type of articles considered in this analysis. Although our analysis did not include other forms of media and political commentary including social media or television, a focus on newspapers has been used as a method to analyze the media response to SSB and tobacco regulations.[22,60,62,69,127,152–154]

Despite these limitations, this study has several strengths. Our analysis captured the major national English language newspapers: according to the South African Audience Research Foundation (SAARF), our analysis includes 23 of the top English language newspapers in South Africa.[128] In addition, by including sources in our analyses, we are able to capture not only what topics are invoked most often but also the perspectives of key stakeholders in the news media discussion about the purpose and consequences of the HPL. This is an important inclusion as it more thoroughly characterizes the news media environment in South Africa responding to the SSB tax.

Conclusion

This study found that industry representatives were more likely to oppose the HPL than academics, government representatives, NGOs, or economists, with the most common reason being negative economic impacts. Within all non-industry sources, a majority expressed a supportive view of the tax. The most common reasons for supporting the HPL were the link between sugar consumption and obesity and likely health benefits from the HPL. Understanding the news media response to the national sugary beverage tax may provide insight for future studies evaluating the effects of the tax on public perception of SSBs and their consumption. More studies are needed to not only characterize the media environments related to public health policies, but also to link media exposure to individual level changes in policy perception.

Tables and Figures

Table 5.1 Who is responsible for proposed solutions to excessive sugar intake stratified by source proposing the solution

	Actor responsible for solution:	Industry voluntary (n=29)	Government regulations (n=141)	NGO (n=1)	Individual (n=26)
Source proposing the solution:	Industry	38.3%[a]	11.2%[b]	0.0%	23.4%
	Government	31.7%	46.3%[a]	100.0%	27.7%
	Academic	16.7%[b]	23.8%	0.0%	23.4%
	Economist	1.7%	1.9%	0.0%	0.0%
	NGO	8.3%	12.6%	0.0%	10.6%
	Private Citizen	3.3%	4.2%	0.0%	14.9%
	Total	100.0%	100.0%	100.0%	100.0%

[a]Significantly greater percentage than expected based on overall prevalence of source
[b]Significantly lower percentage than expected based on overall prevalence of source

Table 5.2 Levels of action for proposed solutions stratified by source proposing the solution

	Level of change for solution:	Individual actions (n=27)	Individual beliefs (n=32)	Food supply (n=25)	Other food environment (n=138)
		% of Solution by Source	% of Solution by Source	% of Solution by Source	% of Solution by Source
Source proposing the solution:	Industry	27%	38%[a]	73%[a]	1%[b]
	Government	15%[b]	14%[b]	12%[b]	54%[a]
	Academic	24%	22%	12%[b]	26%
	Economist	0%	0%	4%	2%
	NGO	9%	14%	0%	14%
	Private Citizen	24%	14%	0%	3%
	Total	100%	100%	100%	100%

[a]Significantly greater percentage than expected based on overall prevalence of source
[b]Significantly lower percentage than expected based on overall prevalence of source

Figure 5.1 Flowchart for article selection process

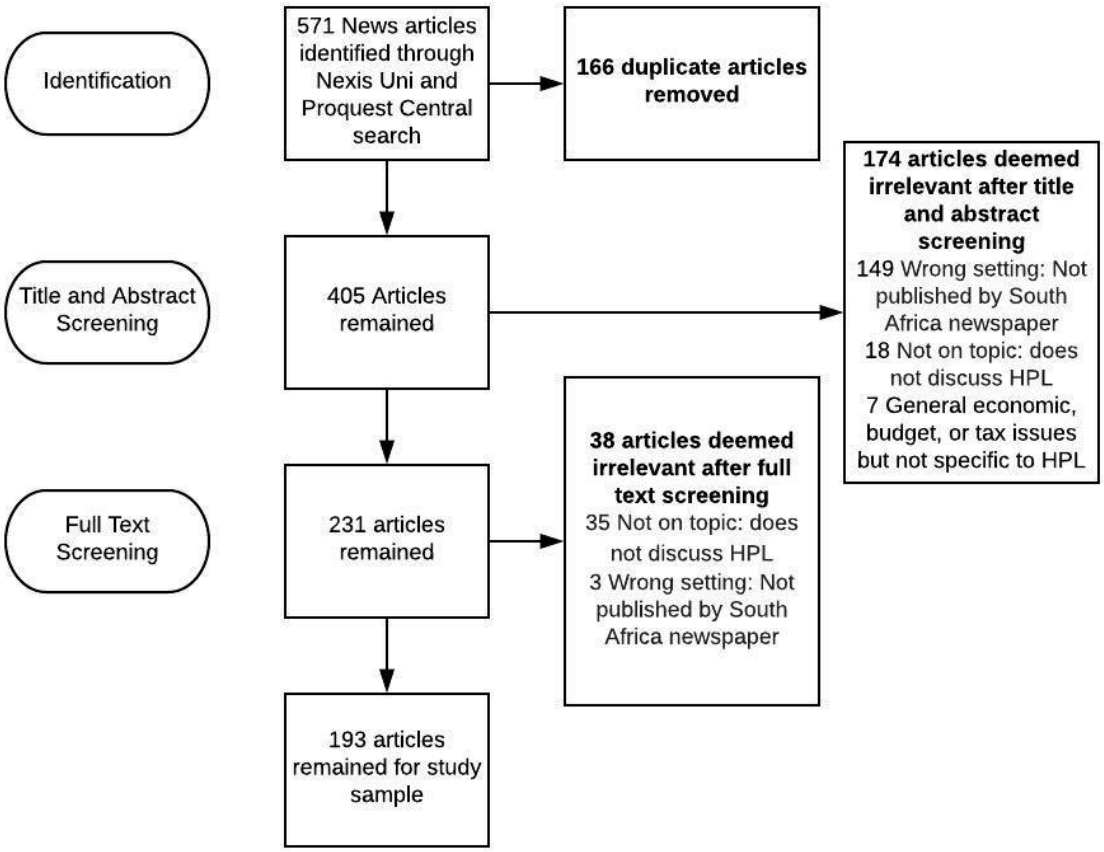


Figure 5.2 Prevalence of support, opposition, or balanced article coverage of HPL beginning with government announcement in 2016

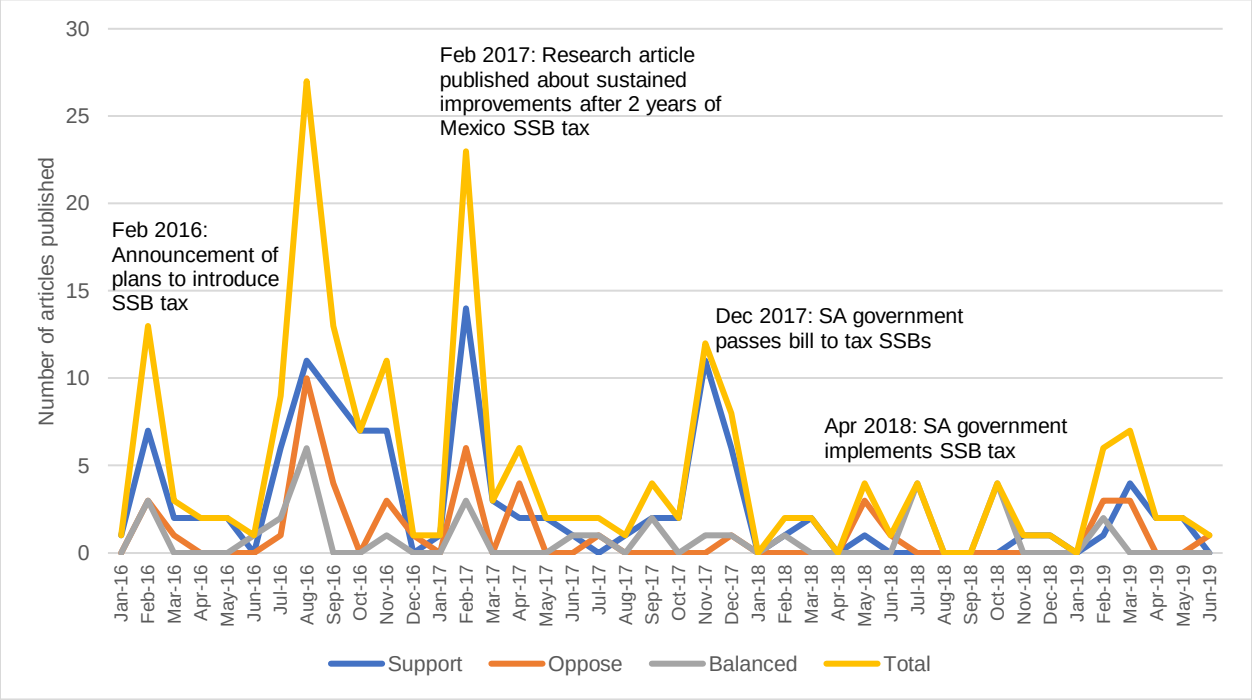


Figure 5.3 Frequency of total articles (n=193) that mention any of the topics. Orange bars indicate articles published before HPL was passed, and blue bars indicate articles published after HPL was passed

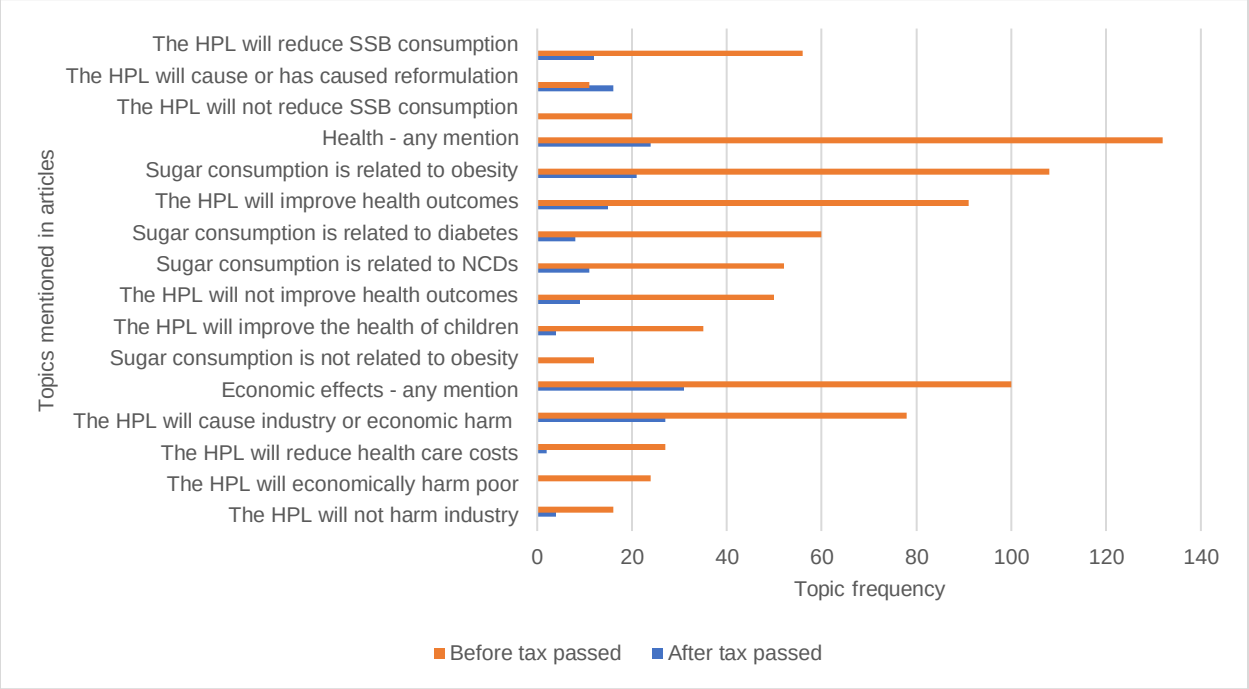


Figure 5.4 Percent contribution of each source to the total topic mentions, pooled across entire study timeline

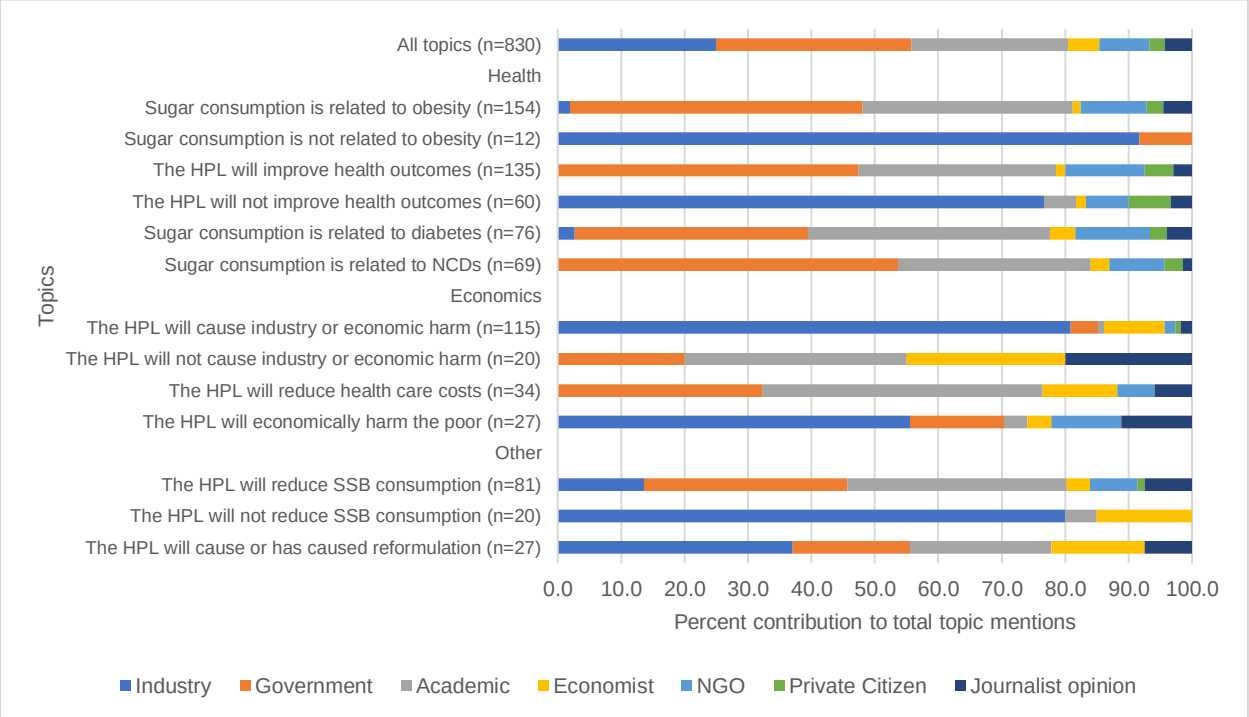
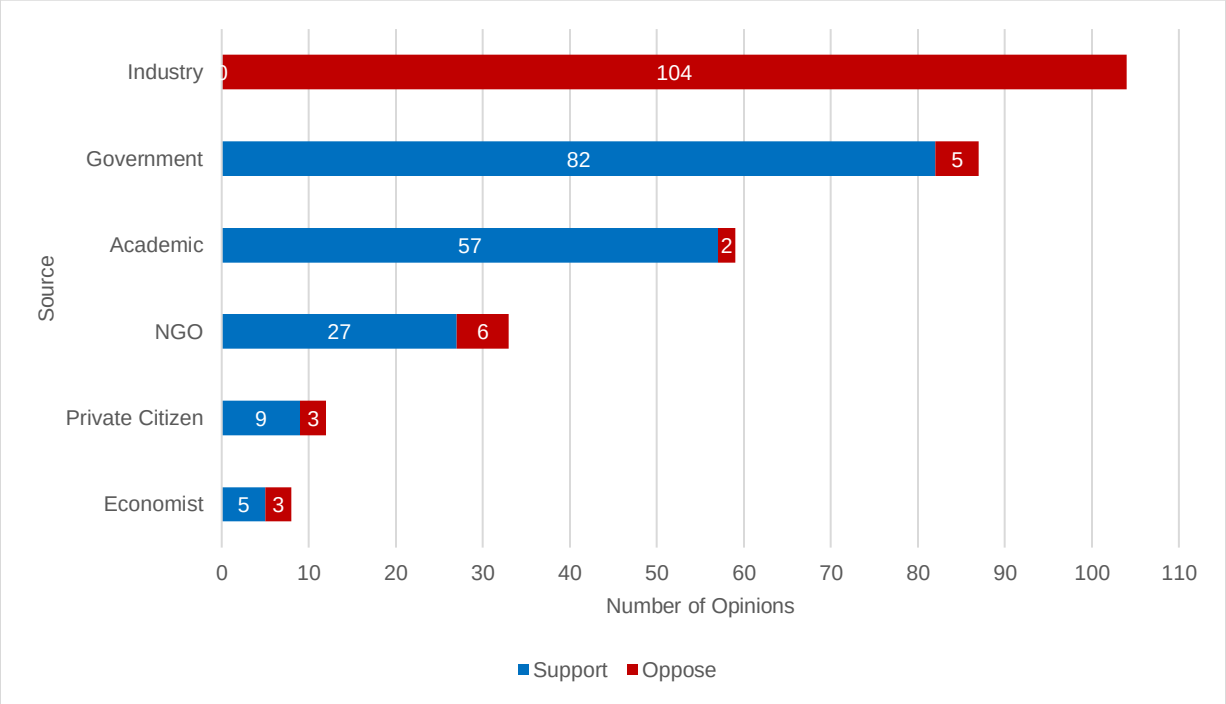


Figure 5.5 Mean frequency of supporting or opposing opinions of the HPL by source



Supplementary Table 5.1 Frequency of articles published about the Health Promotion Levy by major South African newspapers (n=193 total), from February 2016 to June 2019

Publication name	Frequency	% of sample	Monthly readers*
Daily Newspapers			
Sowetan	6	3.1	1482000
The Star	17	8.8	621000
Daily News	11	5.7	257000
The Daily News	2	1	257000
The Times	10	5.2	255000
Daily Dispatch	8	4.2	251000
Post	2	1	247000
Cape Argus	15	7.8	216000
The Herald	8	4.2	205000
The Mercury	20	10.4	200000
Cape Times	23	11.9	183000
Pretoria News	14	7.3	144000
The New Age	8	4.2	136000
DFA	2	1	108000
Business Day	12	6.2	79000
Weekly Newspapers			
Sunday Times	6	3.1	3704000
Sunday World	1	0.5	1311000
Mail & Guardian	10	5.2	564000
Sunday Tribune	9	4.7	290000
Argus Weekend	1	0.5	227000
The Independent on Saturday	4	2.1	95000
The Sunday Independent	4	2.1	63000

*****Readership numbers reported by South African Advertising Research Foundation's All Media Products Survey (Amps) Newspaper Readership and Trends for 2015.[128]

Supplementary Table 5.2 Codebook definitions including major categories of health, economics, and proposed solutions followed by definitions of sources

Topic	**Definition**
The HPL will reduce SSB consumption	Mark yes if there is any mention that the HPL will reduce the consumption of sugar-sweetened beverage by citizens. This is about consumers, NOT about producers
The HPL will not reduce SSB consumption	Mark yes if there is any mention that the HPL will do little or nothing to reduce the consumption of sugar-sweetened beverage by South Africans
The HPL will cause or has caused reformulation	Mark yes if there is any mention, specifically related to the HPL, that will cause or has caused changes in the sugar content or other ingredient content in beverages. Also includes any mention of using of non-caloric sweeteners (including alternate names, e.g., Stevia, Splenda, aspartame, Nutrisweet, artificial sweeteners, etc.). This is about consequences that have either occurred or are thought will occur in the future as a result of the HPL
Support HPL	Mark yes if there is an explicit mention of support or implied support by any previous codes that suggest the country of South Africa or its citizens will benefit from the tax. It is not enough to say that SSB consumption needs to be reduced, the support needs to be explicitly for the tax.
Oppose HPL	Mark yes if there is an explicit mention or implication that suggests the country of South Africa or its citizens will not benefit from the tax. This can either be a statement of the government *should* not tax or that the tax is not justified, or it can be a statement saying the tax will not have the desired consequences (e.g. will not reduce obesity)
Health - any mention	Mark yes if there is ANY mention of health issues such as population obesity, diabetes, tooth decay, or other non-communicable diseases. Other topics that are clearly health outcomes are also acceptable
Obesity is related to SSB consumption	Mark yes if there is any mention/endorsement/suggestion that SSB consumption or sugar consumption is related to obesity or weight gain
Obesity is not related to SSB consumption	Mark yes if there is any mention/endorsement/suggestion that SSB consumption or sugar consumption is NOT related to obesity. For example, the article may say that sugar is merely a source of calories, and therefore SSBs have no increased risk of obesity beyond any other food. This is not the same as an absence of the topic altogether. Do not code yes merely for absence of any mention.
Diabetes is related to SSB consumption	Mark yes if there is any mention/endorsement/suggestion that SSB consumption or sugar consumption is related to diabetes
NCDs related	Mark yes if there is any mention/endorsement/suggestion that SSB consumption or sugar consumption is related to NCDs (other than obesity, diabetes, dental problems)

The HPL will improve health outcomes	Mark yes if there is any mention that the HPL has had, or will have a beneficial effect on health outcomes (obesity, diabetes, dental, or other NCDs). This code is about health-related outcomes, or measurable health improvements. We are not including behaviors such as reduced SSB consumption.
The HPL will not improve health outcomes	Mark yes if there is any mention that the HPL has not had, will not have, or has unlikely or uncertain benefits to health outcomes (obesity, diabetes, dental, or other NCDs). Mark yes if the author or source says that the HPL will not improve health in the short or in the long term
Economic/Pricing - any mention	Mark yes if there is any mention of economy or economic issues, including sales of beverages, how the revenue that beverage companies make will be affected (for example if sales decrease). Mark yes also if there is any mention of other related industries (for example sugar cane farming) will be affected by the HPL. Also mark yes if INDIVIDUALS will be financially affected by the HPL
The HPL will economically harm the poor	Mark yes if there is any mention that the HPL will in any way harm the economic situation of the poor (for example they will suffer a greater economic burden from the HPL compared to other groups because they will still purchase SSBs but spend even more money).
The HPL will cause industry or economic harm	Mark yes if there is any mention that the sugar sweetened beverage industry or beverage selling companies have been or will be harmed by the HPL. Also mark yes if there is any mention of economic harm specific to related industries (but not SSB manufacturers/sellers), such as sugar cane growers, or wider negative economic effects of the HPL (e.g., inflation). If there is no specific industry indicated (for example, just says it will lead to job losses), mark yes here. The previous code, SSB industry harm, is for that specific industry.
The HPL will not harm industry	Mark yes if there is a refutation of the argument that the HPL will cause harm to either the SSB industry or to other industries (including farmers and other workers in the SSB supply chain). This includes any statement that says there will be limited to no economic harm as a result of the tax.
The HPL will reduce health care costs	Mark yes if there is a mention of economic consequences that will help reduce the burden of health care costs in the short or long term. for example, the HPL will reduce the number of overweight/obese or diabetic in the population, which will reduce health care costs.
Proposed Solutions	Does the article propose solutions for any of the health challenges mentioned earlier (too much sugar consumption, too much obesity, diabetes, NCDs, dental caries). Mark 1 if yes, if no solutions proposed, then skip entire section.
Individual actions	Is a personal action proposed? Include diet changes, exercise changes, seeking education or counseling or other health information.
Individual beliefs	Is an intervention, initiative, or structural response proposed that is intended to change how individuals think of food? Include public health campaigns, educational initiatives, marketing restrictions, etc. Labels would also qualify if they are providing information. If reformulation also happens, that is a different category.

Changes in food supply	Is an environmental or structural measure proposed that changes the food directly? Include nutrient thresholds/limits and reformulation. Industry agreements to reformulate would count in this category, with industry the most responsible.
Other food environment changes	Is an environmental or structural measure proposed that changes the availability of foods or the price of foods? Include school food restrictions, taxes, subsidies, restrictions on using financial assistance programs to purchase foods, etc.
Level of Intervention	
Individual actions	Changes in individual actions include diet changes, exercise changes, seeking education or other health information.
Individual beliefs	Changes in individual beliefs about food include public health campaigns, educational initiatives, marketing restrictions, and nutrition labels.
Food supply	Changes in the food supply include nutrient thresholds/limits and industry agreements to reformulate.
Other food environment	Other changes in the food environment include school food restrictions, taxes, and subsidies.
Sources	**Definition**
Industry	The source of the information, either directly stating or being quoted works for a sugary beverage company or another business firm whose profits may be affected by the HPL
Government	The source of the information, either directly stating or being quoted is from a member of the South African Government or the statement is from a government body.
Academics and Health Experts	The source of the information, either directly stating or being quoted is from a person with an academic job at a college or university. This should also include medical doctors, nurses, or other health professionals.
Economist	The source of the information, either directly stating or being quoted is from a source who is quoted as an economist or employee of a contract research organization conducting economics research.
NGO	The source of the information, either directly stating or being quoted is from a nongovernmental organization (e.g. World Health Organization)
Public Citizen	The source of the information, either directly stating or being quoted is a South African citizen who does not belong in any of the other above categories

CHAPTER 6. SYNTHESIS

Overview of Findings

The South African SSB tax, called the Health Promotion Levy (HPL), has a unique threshold-based tax structure specifically designed to reduce sugar intake by leading to price increases and beverage reformulation by industry to reduce their tax burden. The aims of this project were (1) to examine changes in sugar, energy, and volume intakes from taxed, untaxed, and total beverages from pre-tax to post-tax 12 months later, separating the effects of behavioral change from reformulation (2) to test whether behavioral drivers were associated with taxed beverage intake, whether they changed over time, and whether they modified the effects of the South African SSB tax on dietary intake a year after tax implementation, and (3) to examine the broader societal discussion of the HPL using a quantitative content analysis, identifying expressions of support or opposition to the policy, topics associated with the levy, and identified how media represented the views of key stakeholders.

Using cross-sectional survey data collected from approximately 2,500 adults aged 18-39 years living in Langa, South Africa, we created two sets of food composition tables (FCTs) based on the South African food supply using nutrition facts panel data collected during the same periods as the dietary intake data. For the new media content analysis, we obtained 193 online news articles using global news databases Nexis Uni and ProQuest. Below, we address each research aim's specific findings, the strengths and weaknesses of the project, its significance and public health impact, strengths and weaknesses of the HPL, and finally, directions for future research.

Changes in Sugar, Calories, and Volume for Taxed, Untaxed, and Total Beverages

This is the first study that (1) uses higher quality 24-hour recalls to evaluate a national SSB tax, (2) has enough power to detect a statistically significant effect of an SSB tax on dietary intake, and (3) can separate the two crucial effects of an SSB tax: behavioral change and reformulation. These separate effects are important to inform future policy modifications by considering the relative magnitude of each.

We linked nutrition facts panel data from South African grocery stores to composite nutritional records for beverages. This is a strength compared to other studies because the global food supply is changing rapidly, and accurate FCTs that are regularly updated and country-specific are needed to evaluate these changes. This data collection procedure allowed us to estimate pre- and post- tax changes in sugar, energy, and volume from taxed, untaxed, and total beverages by first using a pre-tax FCT with the same nutritional information across the entire study period, followed by the same analysis using an FCT with updated nutritional information in the post-tax period to account for any additional changes due to reformulation. Among taxed beverages, sugar and energy intake decreased by 22% and 24%, respectively, due to behavioral change, with additional reductions in sugar and energy intake by 9% and 8%, respectively, due to reformulation. Sugar, energy, and volume intake from untaxed beverages increased from pre-tax to post-tax. However, the majority of the increase in untaxed beverage volume was driven by increased water consumption. Viewed in terms of total beverages, there was a small reduction in total sugar but a slight increase in energy post-tax due to behavior change. However, after accounting for reformulation, sugar and energy intake from total beverages were lower in the post-tax period.

Reductions in taxed beverage intake were significantly greater in magnitude than previous studies using dietary intake, likely because our study population is primarily low-income and, therefore, more price-sensitive than populations from previous research.[84,85] Other reasons besides income for why we found changes in dietary intake could relate to greater

statistical power to detect a change and higher SSB consumption at baseline in our study population, allowing greater reductions in intake. Indeed, greater consumption changes after food and beverage taxes have occurred among higher consuming populations.[99,100] The baseline taxed beverage intake in our study was 121 kcal/capita/day compared to previous work that reported 45 kcal/capita/day in higher-income areas like Berkeley in the United States.[10]

Our results on beverage intake changes after the HPL are corroborated by another pre-post study using nationally representative purchase data that found greater reductions in sugar (-32.7%) among the same low-income range as our sample compared to a 20.4% reduction in the higher socioeconomic group.[90] Considering these findings, socioeconomic status of our population has implications for generalizability. We would expect to find lower average reductions in taxed beverage intake if our study population included higher income individuals, who may be less sensitive to SSB price changes.

The best cross-country comparison to the South African HPL is the United Kingdom's (UK) Soft Drinks Industry Levy.[76] Recent studies found the announcement of the UK SSB tax led to substantial reformulation of products by 50 days before implementation, followed by further reformulations to bring products just below the taxable threshold.[88,141] However, these studies are limited in that they can only reflect changes in the food supply and the content of purchased beverages. There have been no comparable studies to measure impact on per capita dietary intake in a UK population after the SSB tax. Our use of updated FCTs linked to dietary intake data is therefore a significant innovation in this field, as it can more directly measure policy impact on diet.

These results suggest that future evaluations should begin collecting data as soon as possible after announcement of plans to tax SSBs as product reformulation may begin immediately. These results also have implications for threshold-based taxes. Thresholds should be carefully considered so sugar levels will be acceptable if industry reformulates products to just below the threshold. In the three years leading up to the UK SSB tax implementation, the

authors found that sugar consumption from soft drinks dropped by 4.6 grams per capita per day. Over one year, our study found reductions of 9.1 grams of sugar per capita per day from taxed beverages, suggesting a greater impact of the HPL on reformulation than UK SSB tax.

As a policy aim, product reformulation can lead to improvements in the food supply depending on the strictness of policy standards.[155,156] However, there are limits to the benefits of reformulation. Some nutrient substitutions may not improve health or potentially could lead to even unhealthier substitutions, and changes to whole, unprocessed foods may be healthier.[157] For example, in the case of SSBs, early evidence from Chile suggests an increase in purchases of non-calorically sweetened beverages after labeling and marketing restrictions were implemented in 2016.[158] Further research is needed to understand the potential benefits and harms of these substitutions.

Analogous to harm reduction approaches that aim to limit the harms of tobacco and drug use, a food policy approach to harm reduction may be optimal by accepting the reality that individuals are going to eat processed unhealthy foods—and multinational corporations will continue to want to sell these products—but one way to reduce the public health harm from these unhealthy products is to reformulate them to improve their nutrient profile. Put simply, if people are going to consume SSBs, then the harm reduction approach claims it would be better for them to drink lower-sugar products. It is always important to keep in mind potential substitution effects that may result from a new food policy, but reformulation allows the possibility for improved substitution effects *within* products categories and does not require the greater step of choosing between product categories. Meanwhile, complementary long-term strategies should also be supported to reduce overall sweetener intake and increase consumption of minimally processed foods.

Changes in Behavioral Drivers and their Relationship with Taxed Beverage Intake

The results of our first aim showed the majority of shifts in beverage intake were due to behavior change, and the remaining question was what drives these behavioral changes.

Although the SSB tax led to reduced SSB intake, behavior change is complex and likely related to more than SSB price changes, including psychological factors that drive behavioral responses to SSB taxes. Previous work examined the effects of SSB taxes or media campaigns related to SSB taxes on psychological measures. However, conclusions related to SSB intake are limited as these psychological measures are analyzed as the outcome.[18,57,148] Although these studies are important, they miss the critical link in the causal chain most proximate to energy balance: dietary intake.

We examined whether behavioral drivers tax awareness, SSB knowledge and risk perception, or intentions to reduce SSB consumption were associated with taxed beverage intake at baseline, whether means changed from pre-tax to post-tax, and whether they modified the relationship between time since tax implementation and tax beverage intake. Overall, most psychological variables studied were not strongly linked to taxed beverage intake, had small changes after-tax implementation, and did not appear to modify the association between policy implementation and dietary intake.

We designed this study examining potential drivers of behavior change in light of evidence that successful SSB taxes have often been accompanied by news coverage and mass media campaigns to generate support for SSB taxes.[59] In the context of South Africa, a mass media campaign about the health harms of SSBs and the purpose of the HPL found increased public awareness of the HPL and increased SSB risk perceptions for some chronic diseases.[18] However, given the low awareness of the HPL and the focus of this campaign on the policy, we expect this mass media campaigns did not reach our study population to a high degree in Langa and therefore had little effect on their SSB knowledge and risk perceptions. Although other studies have not examined the relative importance of these behavioral drivers together with price, a nationally representative study of beverage purchases in South Africa found greater reductions among lower income groups, suggesting income is a major driver of taxed beverage intake.[90] Taken together, the low HPL awareness, lack of association between knowledge and

risk perceptions with SSB intake, and greater reductions in SSB purchases among lower income groups suggest price changes may instead be the primary driver of behavior change in our low-income population. Future studies and media campaigns may benefit from focusing their efforts on behavioral drivers that are more proximate causes of dietary intake such as intentions, in keeping with the theory of planned behavior.[112]

The most significant behavioral driver associated with taxed beverage intake was the expressed intention to change. Although we did see increases in tax awareness, it remained low, and was not significantly associated with intake. This suggests awareness of a policy is not sufficient to drive behavioral change, and awareness may need to be supplemented with messaging about the policy's goal. However, it is important to note these results may be susceptible to social desirability bias, if participants underreported their taxed beverage intake believing it was more socially desirable to consume less SSBs. One of the ways we tried to reduce this tendency was by conducting the 24-hour recall before all other survey questions related to the HPL, so participants would not respond defensively by underreporting their sugary beverage intake. Although social desirability bias is a concern, particularly for a policy that singles out SSBs for being unhealthy, it is encouraging that our results are similar to those found in the aforementioned study on beverage purchases, which is not susceptible to this type of reporting bias, within the same socioeconomic range as our study.[90]

Our media content analysis, outlined below, found broad support for the HPL and coverage of the policy in at least twenty-two major South African newspapers, but the Langa study population may not have been exposed to this news, as tax awareness remained low despite a small increase. One reason for lower exposure to online news media could be lower online access and usage skills in lower-income populations.[159] However, a study of adolescents in grade 11 in South Africa found newspapers were one of the top four media used to access current events news, and about a quarter surveyed did accessed online news on a mobile phone at least once a day.[160] Although the lowered taxed beverage intake results are positive,

significant concerns remain about broad public awareness of the tax and understanding its purpose. Our study found low tax awareness in both the pre- and post-tax periods (14 vs 16%, respectively). A study from Soweto, a low income area, found low tax awareness and a high degree of skepticism about the purpose of the tax.[113] The study was conducted three months before HPL implementation but two years after the initial announcement of plans for an SSB tax, suggesting media discussion around the tax had not reached these areas of Soweto. Another study found higher tax awareness among diet patients but dieticians did not emphasize its important or include it in their treatment plans.[114] These lines of evidence point to a need for more pervasive messaging about the existence and purpose of the South African Health Promotion Levy, particularly among lower income populations.

News Media Representations of Government, Academics, and Industry Related to the HPL

Finally, national SSB taxes occur in a broader social environment, influenced by news media agenda setting, whereby media sources select which topics garner the most attention and how they should be understood. This selective coverage of health policies can affect whether policymakers are likely to implement, modify, or add new policies. The media can influence public knowledge about SSBs and perceptions of risk, public awareness, and acceptance of the tax, which could influence intake.

We conducted a quantitative content analysis of online South African news articles related to the HPL published between January 1, 2017 and June 30, 2019. We coded the presence or absence of mentions related to the health and economic effects of the HPL, HPL support or opposition, and which sources (industry, government, academics, other) were connected to these statements. Industry expressed no support for the HPL, whereas academics, government, and other sources mainly expressed support. Health reasons were the most common justifications for support, and economic harms were the most common justifications for opposition. Statements that sugar intake is not related to obesity, the HPL will

not reduce SSB intake, and the HPL will cause industry or economic harm were all disproportionately high in industry sources. Statements that sugar intake is related to obesity and non-communicable diseases were disproportionately high in both government and academics.

The majority of previous work on the news media response to a national sugary beverage tax is from the United Kingdom. Buckton and colleagues found increasing coverage of the SSB tax leading up to its implementation, with more articles supporting the tax than in opposition, a surge in opposing articles against the SSB tax after implementation, and a consistent message of sugar being a health risk.[23] Elliott-Green and colleagues found a consistent message among the British news media that SSBs were unhealthy, potentially bolstering public opinion for an SSB tax.[22] Conversely, in New York, where a ban on large soft drinks failed, Donaldson and colleagues found the majority of news coverage about the policy contained opposing frames similar to the legal challenges against the policy that ultimately caused it to fail.[69] Similar to the UK context, our media analysis found consistent support for the tax by government representatives, academics, and non-governmental organizations. Overall, these study findings demonstrate a close connection between the media discussion around the tax and the ultimate success or failure of the policy.

We sought to build upon these findings by classifying the most common statements about the tax and expression of support and opposition, and then linking these statements to the key stakeholders referenced in the news articles to better understand not only what was being said about the tax but *who* was saying it. With a clear understanding of frames associated with policy support, policymakers may be better prepared to respond to policy criticism. Previous work has examined the parallels between arguments used by the tobacco industry and more recently the sugar-sweetened beverage industry against the regulation of their products.[161] Our study found overwhelming support for the HPL among all stakeholder groups besides industry, citing health concerns as the most frequent reason. Economic concerns about job loss

and overall economic harm caused by the tax and were most frequently discussed by industry. However, thus far, evidence on the economic impacts of SSB taxes in Mexico found no drop in employment.[140] Future studies should examine whether this is the case in South Africa, as any potential economic harm of the HPL would be especially concerning given the high rates of unemployment. Any regressivity of the tax could potentially exacerbate existing racial inequalities in South Africa. However, reinvesting the tax revenue gains into effective health or economic programs may lead to the best outcomes for vulnerable communities.[162]

Given our low-income population, it is likely that Langa was exposed to more radio than online news media. Radio is one of the largest mass media forms in South Africa, with estimates of radio listenership totaling approximately 33 million among a total population of 38 million adults.[163] Given the larger use of radio media over print media, it is possible that our sample was less exposed to the media coverage about the purpose and stakeholder perspectives related to the HPL. Both our media study and others that examine the response to health policies are limited in the types of media captured. There is a need for more studies on how media can impact policies, including all types of media and social media.[164] If we are interested in reducing SSB consumption in the highest consuming younger population in South Africa, future studies will benefit from incorporating data from social media to understand youth perceptions of the HPL.

Another challenge to the media study was collecting data retrospectively. Examining all forms of mass media is a complicated task. Given the HPL was passed in April 2018 and this project began in the summer of 2019, it was not possible to retrospectively acquire and code radio broadcasts relevant to the tax. Therefore, we had to focus on the online print media, which is still one of the most extensive forms of mass media, totaling approximately 11 million adults.[165] Future studies could solve this issue by preparing their analysis closer to the time of policy announcement to either capture live or obtain recordings of discussions of the tax both in the post-announcement and post-implementation periods.

In summary, the South African SSB tax led to large reductions in a low-income population of young adults in Langa, South Africa. The greatest reductions were due to behavioral change, but reformulation also contributed statistically significant calories and sugar reductions. This work demonstrates that the threshold-based SSB tax was successfully affected both behavior and industry reformulation, thereby refuting industry claims identified in our media content analysis that the tax would not have the desired effect on SSB intake. However, our results on behavioral drivers suggest further work is needed to understand the effects of mass media, including news and targeted campaigns, on behavioral drivers of SSB consumption.

Strengths of Study

Data Collection: Diet Assessment Instrument Linked to Food Composition Tables

This project has several strengths related to the data collection methods. First, our use of 24-hour recalls was advantageous for these study aims, allowing us to more accurately estimate mean sugar, energy, and volume intakes from beverages in our population. The National Cancer Institute recommends using 24-hour recalls over beverage frequency screeners or questionnaires to evaluate the effects of an intervention on diet because they are less biased in estimating mean intake.[16]

A second strength of our approach was the use of food composition tables (FCTs) based on the South African food supply. Accurate FCTs are necessary to calculate nutrient intakes and total calories from diet assessment instruments, and using FCTs from different countries is inappropriate as the food supply differs by country.[86,87] This is a strength compared to other studies because the global food supply is changing rapidly, particularly in the context of policies that may regulate sugar or critical nutrients, yet many other countries rely on data that is unchanging, out of date, or from other countries.

Third, a major strength was using a pre-tax and updated post-tax FCT linked to our dietary recall data. This novel method for an SSB tax evaluation allowed us first to calculate changes based on behavioral change, assuming nutrient fact panels were constant across the

year. In the second step, we calculated the tax's total effect including the updated FCT that accounted for reformulated beverages. Taking the difference between the total effect and the effect due to behavioral change allowed us to isolate the marginal effect due to reformulation. This is important because if we only had one of the FCTs, then we would have estimated a smaller total effect of the tax by not accounting for reformulation effects. We would also not be able to estimate the relative effects of each for a tax that is specifically designed to encourage both effects. Our results can inform future policy developments that aim to maximize the effects of each. The flat tax rate applied could be increased closer to the recommended 20% rate for even greater effects on behavior change.[162,166] In terms of reformulation, effects could potentially have been even greater if the sugar threshold were set even lower on future SSB tax policies.

Analysis: Two-Part Model to Estimate Beverage Intakes

Finally, our use of a two-part model to estimate beverage intake was a strength of our analysis. Two-part models are useful for modeling mixed discrete-continuous outcomes. In the case of beverage intake, the two-part model first uses a binary choice model for whether or not the person consumed the beverage type, and then it models the positive continuous outcome.[79] Our model consisted of a probit model for the first part and a generalized linear model with log-link for the second part, which reduces the potential for biased beverage intake estimates.[79,80] In the second part of the model, a generalized linear model with a log-link has advantages over common procedures such as using ordinary least squares regression on a log transformed y, as the latter procedure assumes homoscedasticity of residuals, but heteroscedasticity is common in two-part consumption decisions.[79]

Dataset: Linking Psychological Survey Data to Dietary Intake

Another strength related to our data collection was linking our dietary intake data with survey data on the potential drivers of behavior change. Previous studies have examined relationships between policy implementation or related media campaigns and potential behavioral drivers of behavior change or surveyed SSB attitudes related to SSB tax

policy.[18,148,167] Other work examined the associations between behavioral drivers and a binary response of whether individuals recalled reducing their SSB intake.[57] However, no prior study has examined how behavioral drivers changed in response to a tax and examined the association between those drivers and taxed beverage intake. From policy implementation to behavioral drivers to measuring behavioral change, these linkages allow for a more comprehensive study of the full effects of the SSB tax. These linkages are important because policy effects are heterogeneous and can depend on each country's particular circumstances and culture.[168] By connecting these variables in a national evaluation study, future studies may be able to identify which pathways to behavior change are the most significant and which others may need greater support from either governments or advocacy groups.

Improved Measurement Tool: Confirmatory Factor Analysis (CFA)

Another strength of the approach for our second aim was the use of CFA for complex psychological constructs that require multiple survey questions to measure. Psychological phenomena are particularly challenging to measure, and using CFA to examine changes in SSB knowledge or risk perception allows for a more global measure that can capture individuals' knowledge or risk perception overall. For example, another study using the same knowledge and risk perception questionnaire set a threshold for adequate knowledge at 50% or more correct responses to survey questions and poor knowledge for scoring 49% or below. The researchers are therefore only be able to detect shifts in "acceptable" knowledge levels across this arbitrary threshold. Our study is able to go a step beyond this approach as CFA allowed us to measure the psychological construct and use it as a predictor of taxed beverage intake, uncontaminated by measurement error.[105]

Data Collection: Linking Topic Mentions and to Source

Our media analysis captured the major national English language newspapers, according to the South African Audience Research Foundation.[128] Our analysis built upon previous methods by capturing not only what topics were discussed most often but also the

perspectives of key stakeholders in the news media discussion about the purpose and consequences of the HPL. Including sources in the analysis is crucial. It more thoroughly characterizes the news media environment in South Africa responding to the SSB tax, demonstrating not only what perspectives are presented but also the sources to which perspectives are attributed. This more detailed media content analysis is critical because industry interests are often at odds with public health interests, and corporations may seek to either improve their reputation or delegitimize efforts to regulate their products.[161,169] News media analyses can identify these arguments to help public health policymakers and advocates generate more effective counter arguments.[62] By identifying sources associated with opposition to the HPL, our results suggest that indeed it is industry that is virtually alone in their opposition to the HPL in South Africa, using potential economic harms as the justification.

Limitations of Study

Dataset

Although our dataset has several strengths outlined above, it also has some important weaknesses. First, given the data are repeated cross-sectional, we cannot follow all individuals over time to evaluate longitudinal changes. We only measured differences in population means. This means that our results could potentially be biased if the pre- and post-tax data collection periods are significantly different along measures that are associated with beverage intake. For example, if higher income groups typically consume fewer SSBs at baseline than lower income groups, we could overestimate the degree of reduction in taxed beverage intake if the study sample was higher income in the post-tax period. We did find significantly more participants from higher socioeconomic status in the post-tax period, but we found no significant differences between groups after calculating predicted intakes by socioeconomic status. Our estimates of energy intake from taxed beverages changed by less than one kilocalorie per capita per day when controlling for socioeconomic status. Therefore, we do not suspect our results to be greatly biased by differences in socioeconomic status in our study population.

We were also unable to make causal claims about the relationships between individual-level psychological constructs and participant behavior, and how the SSB tax affected these. With cross-sectional data, we do not have the benefit of temporality, an essential criterion for causal inference, and therefore only can measure associations within snapshots of time, not examine how variables change together across time.[170] Although most policy evaluation studies are observational, future studies on this topic would still benefit from linking survey participants across time, particularly if the study goal is to understand the multiple pathways leading to behavior change.

Second, although the approach to using time-specific FCTs is a novel and useful approach for assigning beverage taxation status and linking updated nutrition facts panel data across time, beverages are potentially susceptible to misclassification. We were able to capture whether the *average* nutrient profile for beverage subcategories changed from pre-tax to post-tax, but it is possible that certain brands were either reformulated to a greater or lesser extent than the average. For example, if participants consumed a certain high sugar beverage product that was not reformulated when the rest of the beverage subcategory was, then that beverage may have been misclassified as having lower sugar according to the group average. Future work could improve this limitation by ensuring that all beverages recording during diet recalls are linked with specific brand and product.

Reporting Bias

Social desirability bias could affect reporting and cause us to underestimate SSB intake. It is also possible that after the tax, social norms may have shifted so that the effect of social desirability bias is even higher after SSBs are subject to tax. This can lead to an overestimation of reductions in SSB intake in this population. However, we are encouraged that our beverage intake results closely reflect those using purchase data, which are not prone to this type of reporting error. To correct for this in the future, we could include a short, revised version of the

Marlowe-Crowne social desirability scale to control for study participants who are more prone to social desirability bias.[171,172]

Secular Trends

We are not able to control for secular trends in beverage intake that were happening at the same time as our study period that may be unrelated to the HPL. For example, increases in water intake post-tax account for just over half the volume increase in untaxed beverage intake. However, Cape Town, South Africa mandated severe water use restrictions from March to September 2018 during a drought.[89] Other studies found smaller increases in water after SSB taxes as one of the substitution effects,[10,14,15,85] but a substantial portion of this increase was likely due to lifted water restrictions. However, it is worth nothing that the restrictions began only in the latter half of our pre-tax data collection period. We do not have data on trends in intake in Langa outside of our one-year data collection period, but national level purchase data from Euromonitor International suggest that SSB consumption in South Africa has been rising every year since at least 2003. Although we are not able to quantify the degree of difference between our results and secular trends, this broader national trend over the last fifteen years at least suggests a meaningful reduction occurred.

Media Analysis: Lack of Media Exposure Data

In our media analysis, we do not have individual-level data about media exposure data, which means we can only describe the news media environment overall, not how discussions in the media affected South African perceptions of the tax. Therefore, we are also unable to make causal claims about the effects of the news media on how people respond to SSB taxes. Future studies would benefit from linking news media exposure to individual-level consumption of SSBs to better understand their relationship. Another limitation is our focus on only English language sources in the online news media. South Africa has great language diversity, and our results may be biased if coverage of the SSB tax differs between non-English and English sources.

However, a focus on newspapers has been used as a method to analyze the media response to SSB and tobacco regulations.[22,60,62,69,127,152–154]

Significance and Public Health Impact

The HPL Led to Meaningful Reductions in Taxed Beverage Intake

Our results demonstrate that the HPL, a threshold-based SSB tax, can spur reformulation, thereby reducing sugar and energy intake from taxed and total beverages. Our evaluation strategy is important for public health because it provides a clear demonstration of the complementary effects of a threshold-based SSB tax on behavior change and industry reformulation. Our research provides a sense of the magnitude of each effect in order to better design and subsequently evaluate the effects of sugar-based taxes on dietary intake, which may be relevant for policymakers and scientists.

This is the first study that used 24-hour recalls to find a statistically significant reduction in taxed beverage intake in a national SSB tax evaluation. The magnitude of the HPL impact on our study population amounted to a reduction of 9.1 grams of sugar and 39 kcal per capita per day from taxed beverages and a reduction of 3.7 grams of sugar and 10 kcal per capita per day from total beverages.[84] This is a small but meaningful reduction, mainly because previous evidence on SSB taxes have a near one-to-one change in consumption relative to price increases.[96,166,173] For example, a 10% increase in price would be expected to correspond to an approximately 10% reduction in consumption. Before HPL implementation, a modeling study predicted a 20% tax would reduce energy intake by 8-9 kcal/capita/day.[41] Recent evidence suggests price increases were approximately 10% among taxed beverages.[174] Our study found a similar magnitude reduction, -10 kcal/capita/day, but with approximately half the tax burden, suggesting the tax was even more effective than predicted in our study population. However, this greater effect may have been due to our study population being low-income. In any case, these results are a promising start, but future studies will be needed to understand the long term impacts, as some evidence suggests even greater long-term reductions due to changing

preferences. For example, after Mexico's SSB tax, consumption decreased by 5.5% in year one and 9.7% in year two.[8]

Implications for a Low-Income Population

This study also provides relevant evidence about the effects of an SSB tax on a high consuming, low-income population to inform a broader policy debate about the ethics of financial incentives and disincentives to improve diets. In the context of SSB taxes, some commentators have argued SSB taxes are harmfully regressive and may even infringe on individual freedoms.[137–139,175,176] One of the arguments in favor of SSB taxes, particularly for high-risk populations, is that those populations could benefit the most from improved diets.[137–139] The present study lends empirical evidence to this debate by showing large reductions in taxed beverage intake in a low-income population that is particularly at risk of developing chronic diseases associated with poor diet. In South Africa, a country with high wealth inequality and unemployment, low-income populations are far less likely to be diagnosed and treated for sugar-related NCDs, making primary prevention an even higher priority. Diabetes prevalence has been estimated to be approximately 11% in South Africa, of which over a third is undiagnosed, and as many as two-thirds of South African adults may be prediabetic.[177,178] In light of this public health challenge, these study results suggest that the South African HPL is an effective way to reduce energy and sugar intake from beverages as one component of a strategy to reduce chronic diseases.

Our findings that the policy successfully reduced taxed beverage consumption refute several industry claims identified in our media content analysis that it would have no effect and only serve to punish the poor economically. Several spokespersons from South African beverages associations claimed, "if the minister's intention was to 'curb excessive sugar intake' evidence from other markets that had taken this path would show it would fail," and there was "no guarantee that people would cut down on sugary beverages with the introduction of the tax."[179,180] Our media content analysis is useful for identifying and directly responding to

misleading claims regarding the effects of the HPL and can prepare policymakers to refute claims opposing the development and implementation of similar policies in other countries.

Strengths and Weakness of the HPL

There are several strengths specific to the South African HPL. One strength is that in terms of single policies, fiscal policy like SSB taxes can lead to significant changes in energy and sugar consumption. However, until recently, many governments have allowed the industry to dictate the terms and be "part of the solution" by making voluntary commitments to self-regulation.[181] These voluntary compacts allowed food and beverage corporations to voluntarily sign up to collective agreements for health promotion, without binding conditions or rigorous evaluation. Voluntary industry self-regulation has been criticized for a lack of incentives for industries to keep their promises and for being a cover to proceed with "business as usual."[182–184] By going beyond industry commitments for self-regulation and reformulation, SSB taxes, particularly threshold-based ones, can give industry concrete targets to reformulate products and thus avoid the tax burden, thereby reducing products' sugar content.

Sugar taxes have also been ranked among the most cost-effective policies for reducing healthcare costs and disease burden.[185] This type of tax may have greater health impact than volume-based tax structure by having the two-pronged effect of reducing SSB consumption and promoting reformulation.[55] However, communication about the tax is also important as signaling the tax's purpose may be helpful to its success. A recent randomized study found a greater reduction in SSB demand when participants were told SSB tax revenues would be used for other health purposes like nutritional education and physical sport activities of school-aged children.[21] This evidence suggests intentions about the tax's purpose should also be made clear, as communication about policy purpose and productive use of revenue leads to greater public acceptance.[23,61]

Another strength of the HPL is that it does tax sweetened dairy products. Historically, many SSB policies do not include restrictions on milk and dairy products due to both nutritional

and political concerns. For nutrition, there are concerns about kids needing milk and dairy products for optimal growth and development.[186] Related to politics, dairy lobbies have pushed for milk to be included in school lunches.[187,188] The balance of evidence suggests regular milk should not be taxed as they do not contribute to weight gain in children, but flavored and sugary milks should be taxed as the added sugars are associated with weight gain, lower diet quality, and they also can influence taste preferences for sweetness.[189,190] Although we found a low intake of sweetened dairy in our adult population, studies from Chile have shown large baseline intakes and large post-implementation changes in dairy in children and adolescents.[191,192] Future studies on sugary beverage intake in South African children and adolescents are needed to understand how sugary beverage consumption patterns may differ and how they are changing after the HPL.

Despite these encouraging reductions, the HPL still has limitations. Most experts suggest a 20% tax is necessary to meaningfully improve diets, whereas the tax burden of the HPL has been estimated at approximately 10%.[30,174,193] We suggest this study justifies strengthening the policy to cause even more significant reductions in energy and calories from taxed beverages. Another encouraging result of our study is that we already found evidence of substantial reformulation of products by industry within a year. This suggests a level of compliance with the law, at least at the average beverage type level. However, more work is needed to understand reformulation at the product level. It is possible that some beverage products within our subcategories may have been reformulated more than others, but we were not able to capture product-level differences.

The rest of the African region could benefit from adopting a threshold-based SSB tax policy similar to the HPL. Although there is great diversity in dietary intake, economic circumstances, and healthcare access, overall SSB purchases are increasing rapidly throughout Africa according to data from Euromonitor International.[121] In the Africa and Middle East regions, SSB purchase volumes have more than doubled since 2003, from 98 mL per capita per day to

over 200 mL per capita per day.[121] According to a recent WHO report, Algeria and Mozambique have some of the highest rates of adolescent SSB consumption in the world, and other African countries including Morocco, Mauritania, Egypt, Ghana, Namibia, and Tanzania are all known to have 40-60% of adolescents consuming SSBs daily.[162] These rates of SSB consumption by adolescents are already even greater than in the United States and most of Europe.[162] There are also concerns about rising type II diabetes rates across Africa, which are expected to double in the next 35 years, in the context of widespread needs for diabetes diagnosis and care in the region that remain unmet.[194,195] African governments have an opportunity to blunt these rising trends by implementing fiscal policies to improve diets early. Despite the promising benefits of SSB taxes in South Africa and the rest of Africa, there are potential concerns about regressivity of the tax placing an economic burden on lower income groups. Care must be taken to offset these burdens including reinvesting tax revenue in health promoting programs such as improved health care systems, healthier food environments, or environments that allow increased physical activity.[162]

Future Directions

That the South African HPL successfully reduced energy and calorie intakes from taxed and total beverages in our study population justifies strengthening the policy to levels recommended by the World Health Organization. Although there is overwhelming evidence for the effectiveness of taxes from modeling studies, purchase studies, and now dietary intake studies, regulations on the sale of SSBs have faced considerable political opposition.[196] Public support for SSB taxes is strongest when the benefits of the tax and health harms of SSB intake are clearly articulated and when funds raised are earmarked for other health promoting or public benefitting aims. It is therefore essential that communication efforts from governments and advocacy groups clarify the intentions, use of revenue and expected health benefits from SSB taxes.

However, no matter the changes in SSB intake, it is important to consider the limitations of single policy approaches to reduce obesity. Obesity is a complex, multifactorial disease,[50] described by Rutter and others as a "wicked problem," like climate change, with myriad inputs and feedback loops, requiring a broad ecological approach to prevention.[50,197] SSB taxes can be an important component of a comprehensive approach to obesity prevention, but many more avenues exist to improve diets and, ultimately, health. For example, combining healthy food subsidies with taxes may lead to even greater diet improvements.[54,166,198–201] A broader, more comprehensive approach to policymaking means policies must be mutually reinforcing, acting synergistically to shift population obesity in a better direction. A real-world example is Chile, which implemented a small tax increase on high sugar beverages in 2014 that led to small reductions in taxed beverage intake.[9] In 2016, Chile implemented a comprehensive set of policies, including front-of-package warning labels on packaged foods and beverages that are high-in nutrients of concern, restrictions on marketing to children, and restrictions on selling unhealthy foods and beverages near schools.[202] A recent evaluation found that warning labels and marketing restrictions had a much greater impact on consumption than the small price increase on taxed beverages.[192] Other countries in Latin America are implementing similar policies, and more evidence is needed to understand how these policies work and how to implement them in other settings.

In conclusion, this study attempted to unify several key overlapping areas into an SSB tax evaluation. We found large reductions in taxed beverage intake but limited effects of potential behavioral drivers on taxed beverage intake. Future studies are needed to determine whether these null effects exist in higher income populations as well as other countries where the media environment related to SSB taxes may differ. One of the critical challenges to smart food policies for obesity prevention is variation in pre-learned food and beverage preferences and other mediators, causing policy effects to be heterogeneous between populations.[168] Therefore, future policy evaluations must make the linkages between policy, psychology, and

behavior to understand these mediated effects better. Future studies would benefit from longitudinal data, which can better establish causal effects of policies by assessing individual-level changes across time. A longitudinal approach would also be particularly useful for assessing the relative effects of new policies introduced across time. We envision future studies that incorporate individual-level psychological measures and different media exposure types over time to understand how these factors relate to dietary intake. Such an approach could be used to conduct mediation analyses that estimate each pathway's relative contributions of to changes in dietary intake.

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