



OPEN ACCESS



Association between tax on sugar sweetened beverages and soft drink consumption in adults in Mexico: open cohort longitudinal analysis of Health Workers Cohort Study

Luz María Sánchez-Romero,^{1,6} Francisco Canto-Osorio,¹ Romina González-Morales,¹ M Arantxa Colchero,² Shu-Wen Ng,³ Paula Ramírez-Palacios,⁴ Jorge Salmerón,⁵ Tonatihu Barrientos-Gutiérrez¹

¹Population Health Research Centre, National Institute of Public Health, Cuernavaca, Mexico

²Centre for Health Systems Research, National Institute of Public Health, Cuernavaca, Mexico

³Department of Nutrition and Carolina Population Center, University of North Carolina, Chapel Hill, NC, USA

⁴Epidemiological Research and Health Services Unit, Mexican Institute of Social Security, Cuernavaca, Mexico

⁵Research Centre in Policy, Population and Health, School of Medicine, National Autonomous University of Mexico, Mexico City, Mexico

⁶Cancer Prevention and Control, Lombardi Comprehensive Cancer Center, Georgetown University, Washington, DC, USA

Correspondence to: T Barrientos-Gutiérrez
tbarrientos@insp.mx
(ORCID 0000-0002-0826-9106)

Additional material is published online only. To view please visit the journal online.

Cite this as: *BMJ* 2020;**369**:m1311
<http://dx.doi.org/10.1136/bmj.m1311>

Accepted: 24 March 2020

ABSTRACT

OBJECTIVE

To examine changes in categories of soft drink consumption in a cohort of Mexican adults, three years after the implementation of the sugar sweetened beverage tax.

DESIGN

Open cohort longitudinal analysis.

SETTING

Three waves of the Health Workers Cohort Study, Mexico, spanning 2004 to 2018.

PARTICIPANTS

1770 people aged 19 years or older with information on drinks consumption available in at least one of the three cohort waves.

MAIN OUTCOME MEASURE

Change in probability of belonging to one of four categories of soft drinks consumption (non, low, medium, high) after the tax was implemented. Heterogeneity of associations by income and education was also assessed.

RESULTS

Before the implementation of the tax, more than 50% of the participants were medium and high consumers of soft drinks and less than 10% were in the non-consumer category. After the tax was implemented, 43% of the population was categorised as medium or high consumers and the prevalence of non-consumers increased to 14%. Three years after implementation

of the tax on 1 January 2014, the probability of being a non-consumer of soft drinks increased by 4.7 (95% confidence interval 0.3 to 9.1) percentage points and that of being a low consumer increased by 8.3 (0.6 to 16.0) percentage points compared with the pre-tax period. Conversely, the probability of being in the medium and high levels of soft drinks consumption decreased by 6.8 (0.5 to 13.2) percentage points and 6.1 (0.4 to 11.9) percentage points, respectively. No significant heterogeneity of the tax across income levels was observed, but stronger effects of the tax were seen in participants with secondary school education or higher, compared with those with elementary school or less.

CONCLUSIONS

The Mexican sugar sweetened beverage tax was associated with a reduction in the probability of consuming soft drinks in this cohort of employees from a healthcare provider. The results cannot be extrapolated to the Mexican population, but they suggest that three years after implementation, the tax had helped to increase the proportion of people who do not consume soft drinks while decreasing the proportion of high and medium consumers.

Introduction

Consumption of added sugars is a primary risk factor for non-communicable diseases.^{1,2} Sugar sweetened beverages are a main source of added sugars in the diet.³ High consumption of such drinks has been linked to obesity, diabetes, cardiovascular disease, hypertension, metabolic syndrome, and dental caries, as well as to some types of cancer.⁴⁻⁷ In 2017 the World Health Organization recommended limiting intake of free sugar to 10% of total energy.¹ To reduce sugar consumption, WHO now recommends the implementation of fiscal policies to increase the price of sugar sweetened beverages.^{8,9} Taxes on sugar sweetened beverages have been implemented in many countries, including Mexico, France, Hungary, Norway, South Africa, and the UK, as well as in some US cities such as Berkeley and Philadelphia.¹⁰⁻¹² Robust evaluations after the implementation of taxes on sugar sweetened beverages have shown important decreases in purchases or sales of such drinks.¹³⁻¹⁶

In Mexico, the consumption of added sugars represented 12.5% of the total energy intake in 2012, of which 70% came from sugar sweetened beverages.^{3,17} Owing to the high levels of consumption of these drinks, Mexico has been ranked first in mortality

WHAT IS ALREADY KNOWN ON THIS TOPIC

Taxes on sugar sweetened drinks have been recommended as an intervention to reduce sugar consumption

Evidence of the effectiveness of tax in reducing consumption of sugar sweetened drinks in Mexico has been established through purchases and sales studies at the household level

No study has analysed individual changes in consumption related to the tax in Mexico

WHAT THIS STUDY ADDS

Three years after implementation of the tax, the probability of being a medium or high consumer of soft drinks had decreased, and the probability of being a low consumer or non-consumer had increased

Stronger associations were observed in participants with secondary school and higher education than in those with elementary school or less

Taxes on sugar sweetened drinks are an effective means of deterring consumption; further increases to the tax could encourage further reductions in the very high consumption levels in Mexico

and morbidity attributable to sugar sweetened beverages.^{18 19} To begin countering this, the Mexican government implemented a tax of 1 peso (£0.03; €0.04; \$0.04) per litre (approximately 10% increase in price) on all non-alcoholic drinks with added sugar starting on 1 January 2014. Two years after implementation of the tax, household purchases of taxed beverages decreased by an average of 7.6%.²⁰ Larger reductions in purchases of these beverages were documented in urban areas, in households with children and adolescents, in low socioeconomic households, and among high sugar sweetened beverage purchasing households.²⁰⁻²² However, these studies have relied on purchase data, aggregated at the household level. More evidence about the effect of the tax on individual level consumption and health outcomes is needed.²³ Emerging studies with longer term results on the effect of the tax on consumption of sugar sweetened beverages and health related outcomes will allow us to understand the utility of these interventions at an individual level.

Using two pre-tax waves and one post-tax wave of data on consumption of soft drinks from a Mexican adult cohort, we aimed to estimate the change in categories of soft drink consumption three years after the implementation of the tax on sugar sweetened beverages and to assess the potential effect modification of the tax by income levels.

Methods

Setting and study design

We conducted longitudinal analysis using data from the Health Workers Cohort Study (HWCS). The HWCS is a prospective open cohort study composed of employees from the Mexican Institute of Social Security (IMSS for its Spanish acronym) and their families in Cuernavaca. IMSS is one of the three main public healthcare institutions in Mexico, providing healthcare to nearly 43 million people (30.1% of the national population).²⁴ The cohort is occupationally diverse, including medical doctors, nurses and nurse assistants, social workers, management, and administration and cleaning personnel, among others. Compared with the Mexican population, participants in the HWCS were, on average, in the seventh tenth of monthly average household income (\$14 100 MXN); by thirds, the average of the low income group in the cohort corresponded to the second tenth of national income, medium income to the sixth, and high income to the top tenth.

The HWCS has had three data collection waves: 2004-06, 2010-13, and 2017-18. The total number of employees at IMSS in the State of Morelos in 2004 was around 6000; of those, 75% (n=4500) were IMSS Cuernavaca employees. Of the total 4500 IMSS employees, the HWCS recruited 2500 people at baseline; the response rate was 77% for wave 2 and 50% for wave 3. Participants completed a self-administered questionnaire, which collected data on demographic characteristics, medical family history, past medical history, lifestyle (diet and physical

activity), psychosocial evaluation, quality of life, social support, and cognitive assessment. Detailed information can be found elsewhere.²⁵

Sample

For our analysis, we used data from all three waves of the cohort. We included participants aged 19 years and older with at least one food frequency questionnaire measurement and complete beverage consumption information.²⁵ From the original 4928 observations, we excluded pregnant women, participants with extreme values of energy intake (<600 Kcal (1 kcal=4.18 kJ) and >6550 Kcal), and those who reported soft drink consumption of 1500 mL or more per day.²⁶ Our total analytical sample included 1770 people with 3786 observations. Details about the development of the analytical sample can be found in appendix 1 table A1-1.

Soft drink consumption and tax implementation

Our outcome of interest was the change in the probability of belonging to one of four categories of consumption after the tax was implemented. The HWCS self-reported questionnaire assessed diet with a validated semi-quantitative food frequency questionnaire of 116 food items, asking about the frequency of food consumption over the previous 12 months.²⁷ The questionnaire was previously validated in a sample of Mexican women, showing moderately good validity for energy and most nutrients. We used information from the food frequency questions related to consumption of sugar sweetened beverages: “a bottle of cola” and “a bottle of flavored soft drink.” Frequency of consumption was recorded with 10 different options ranging from “never” to “six or more times per day.” The questionnaire assumed that one serving of soft drink equalled 355 mL. We compiled this information and classified the frequency of consumption into four categories, to make our results comparable to previous literature.^{28 29} A non-consumer had no soft drink consumption, a low consumer consumed less than one serving a week, a medium consumer consumed at least one serving a week but less than one serving a day, and a high consumer consumed at least one serving a day. The sugar sweetened beverages tax was implemented on 1 January 2014; thus, we created a dichotomous variable for the tax, being 0 for the pre-tax period (2004-13) and 1 for the post-tax period (2017-18).

Time invariant and time varying covariates

We included age at baseline centred to the mean as a time invariant variable to control for the age at the beginning of follow-up. Time varying covariates were updated at each wave of data collection. We included a continuous variable for time, which represents the number of years that a person spent in the cohort. We used annual gross domestic product in current USD and yearly inflation (base index on July 2018) reported by the National Institute of Statistics and Geography to adjust for macroeconomic variables.³⁰ We included dummy variables for education, classified into three

groups: elementary school or less, secondary school or high school, and college or higher. Income represents monthly family income as reported in the HWCS questionnaire, divided into three groups by tertiles (low, middle, high). We used thirds of income to identify differential effects by group, to allow for non-linearities, and to be comparable to previous analyses done at the household level.³¹ We allowed income to vary by wave as we wanted to see how changes in income categories were associated with changes in the probability of moving to a different consumption category, independently of the tax. We also adjusted for seasonality and changes in demand for beverages due to the weather, by using the monthly temperature in the Celsius scale as reported in Cuernavaca, Morelos, and linking it to the date at which participants completed each questionnaire. Finally, we included an interaction term between age at baseline and time spent in the cohort, to allow for different time trends according to the age at baseline of each participant.

Statistical analysis

We estimated the mean and standard deviation or the frequency and percentage of each covariate for each wave of data collection. We estimated the prevalence and 95% confidence interval of the sample in the four categories of soft drink consumption, for the three waves of data collection.

For our main analysis, we fitted an ordered logistic correlated random effect regression (OLCRE) model for unbalanced panel data, to evaluate the association of the tax with the probability of remaining in the same category of soft drink consumption. We selected this model because it can simultaneously estimate within individual and between individual effects. Briefly, the OLCRE model estimates coefficients for level 1 variables that vary between and within individuals, as well as level 2 variables that vary only between individuals.³² See appendix 1 for a detailed description of the model.

To fit the OLCRE model, we used the `-ologit-` command in Stata, following methods described by Schunck.³³ For this analysis, we focused on the within individual effect) of the sugar sweetened beverages tax. Complete OLCRE models translated to proportional odds ratios are available in appendix 1. To explore the potential effect modification of the tax on consumption by income and education, we introduced an interaction term between the tax period indicator variable and income category (low, middle, or high) and between tax and education (elementary school or less, secondary school or high school, and college or higher). To facilitate the presentation and interpretation of the models, we used the post-estimation Stata command `-margins-` to calculate the marginal effects of the tax on the probability of being in one of the categories of soft drinks consumption. We used Stata/SE 14.2 for all analyses.

Sensitivity analysis

We relied on an unbalanced panel to estimate the difference in soft drinks consumption before and

after implementation of the tax. This could introduce bias in the estimates due to missing data at different waves. To explore the robustness of our findings, we did a complete case analysis as a sensitivity analysis, restricting our analysis to participants with information in all three waves (n=650 for each wave, 50% of full analytical sample). A detailed description of the sample and regression analysis is available in appendix 2.

Patient and public involvement

The research design, questions, and outcomes were developed without participant involvement. Participants were not asked to contribute to interpretation or writing of the results. However, participants with abnormal findings were informed and referred for treatment.

Results

Table 1 shows the characteristics of the sample of HWCS participants at each wave of data collection. The average age during the study period was 47 years, with a slightly older sample at wave 3. In 2010 the male population was 7% higher than in 2004 and 2017 (male prevalence ~23%). Nearly 50% of our analytical sample was composed of people with a college degree or higher. In 2017 42% of the population was in the high income category; this represents an increase of 9% compared with 2004 and 13% compared with 2010.

Figure 1 shows the unadjusted distribution of soft drinks consumption before and after implementation of the tax. Before the implementation of the tax, more than 50% of the participants were medium and high consumers (56.9% in 2004 and 55.8% in 2010), and less than 10% were in the non-consumer category (5.1% in 2004 and 6.9% in 2010) of soft drink consumption. After the tax was implemented, 42.9% of the population was categorised as medium or high consumers and the prevalence of non-consumers increased to 13.6%. Before the tax, the prevalence of high consumers was increasing (11.3% in 2004 to 13.1% in 2010); after 2014 the prevalence of high consumers decreased to 8.1%.

Table A1-2 in the appendix shows the proportional odds ratios of the OLCRE model for the association between the tax and categories of soft drinks intake. After the tax was implemented, the proportional odds of being in a high consumption category, compared with being in any lower category became 61% lower (odds ratio 0.39; 95% confidence interval 0.16 to 0.94), after adjustment for time varying and time invariant covariates. Translated into changes in probabilities, this reduction implies that after the implementation of the tax, the probability of becoming a non-consumer increased by 4.7 (95% confidence interval 0.3 to 9.1) percentage points, and the probability of being a low consumer increased by 8.3 (0.6 to 16.0) percentage points. Conversely, the probability of being in the medium and high levels of soft drink consumption decreased by 6.8 (0.5 to 13.2) percentage points for

Table 1 | Sample characteristics of the Health Workers Cohort Study participants at each wave of data collection. Data are mean (SD) unless stated otherwise

Characteristics	Wave 1, 2004	Wave 2, 2010	Wave 3, 2017
No*	1203	1623	960
Age at baseline, years	47.3 (13.0)	46.9 (13.1)	47.8 (12.5)
No (%) male sex	288 (23.9)	504 (31.1)	207 (24.2)
Time in cohort, years	0	4.7 (3.4)	11.1 (3.0)
Education—No (%):			
Elementary school or less	179 (14.8)	230 (14.2)	118 (12.3)
Secondary school or high school	457 (38.0)	612 (37.7)	333 (34.7)
College and higher	567 (47.1)	781 (48.1)	509 (53.0)
Income—No (%):			
Low	356 (29.6)	540 (33.3)	249 (25.9)
Middle	452 (37.6)	609 (37.5)	305 (31.8)
High	395 (32.8)	474 (29.2)	406 (42.3)
Temperature, °C	24.9 (1.9)	25.5 (2.1)	23.7 (2.5)
Annual gross domestic product, US\$	7697.7 (363.3)	9435.1 (366.0)	9267.0 (100.0)
Inflation, %	4.1 (0.6)	3.3 (0.2)	4.6 (0.7)

\$ 1=£0.80; €0.91.

*This is an unmatched panel; thus, fluctuations could arise from actual change over time or from changes in participants. Descriptive information about a matched panel can be found in appendix 2.

medium consumers and 6.1 (0.4 to 12.0) percentage points for high consumers (fig 2).

Effect modification of sugar sweetened drink tax by income and education category

As a secondary analysis, we assessed the potential effect modification of the tax at different levels of individual income (low, middle, or high); the interaction between income and tax was marginally significant only for the middle income group (appendix table A1-3). However, consistent with results in figure 2, table 2 shows an increase in the probability of being in a non-consumer or low soft drink consumer category and a reduction in the probability of being in a medium or high category for all income categories.

We also assessed the effect modification of the tax by level of education; in this case, the interaction was statistically significant, indicating stronger effects of the tax for both participants with secondary school and high school education and those with college and higher levels of education, compared with those with elementary school or less (appendix 1 table A1-

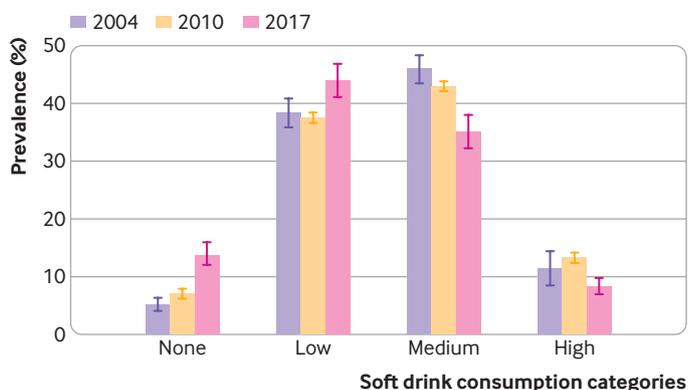


Fig 1 | Unadjusted distribution of categories of soft drinks consumption among participants in Health Workers Cohort Study between 2004 and 2017. Non-consumer=no soft drink consumption; low consumer=consumed <1 serving/week; medium consumer=consumed 1 serving/week to <1 serving/day; high consumer=consumed ≥1 serving/day

4). Table 3 shows the change in the probability of soft drinks consumption after the tax; the probability of being a non-consumer increased for participants with secondary and high school education (6.8 (0.7 to 12.9) percentage points) and college and higher education (6.7 (0.0 to 13.4) percentage points) but not for those with elementary school education (0.9 (−1.7 to 3.5) percentage points). We observed a similar pattern for the probability of being a low consumer. The probability of being in a high level of consumption decreased after implementation of the tax, particularly in participants with secondary and high school education (−6.8 (−11.7 to −2.0) percentage points) and with college and higher education (−5.0 (−9.1 to −0.9) percentage points), compared with participants with elementary school or less (−3.7 (−13.7 to 6.3) percentage points). We observed a similar pattern for medium levels of consumption.

Sensitivity analysis

We replicated our main model analysis in the subsample of participants with information in all three waves to do a complete case analysis (fig 3). Overall, the same patterns were observed and the strength of the associations increased. The probability of remaining in the medium level of consumption decreased by 10.8 (1.7 to 19.8) percentage points after implementation of the tax, compared with 6.8 percentage points in the unbalanced sample. Similarly, the probability of remaining in the high category of consumption decreased by 8.0 (1.3 to 14.8), compared with 6.1 percentage points in the unbalanced sample. Detailed information of the coefficients from this statistical model can be found in appendix 2.

Discussion

We aimed to estimate the change in the probability of consuming soft drinks after the sugar sweetened beverages tax was implemented, using 14 years of cohort data from the Health Workers Cohort Study in Cuernavaca, Mexico. We found that the tax was associated with a 6.8 percentage points and 6.1 percentage points decrease in the probability of being in the medium and high categories of soft drink consumption, respectively, with a corresponding increase in the low consumption (8.3 percentage points) and non-consumption (4.7 percentage points) categories. These findings suggest that the 1 peso per litre tax in Mexico helped to reduce soft drinks consumption in this population even three years after implementation.

Comparison with other studies

Although several studies have estimated the effect of sugar sweetened beverages taxes on household purchases, very few examples using individual level self-reported consumption data are available. To our knowledge, only Philadelphia and Berkeley have used a similar approach. In Philadelphia, a telephone survey was used to estimate changes in consumption of sugar sweetened drinks; the results showed that the odds

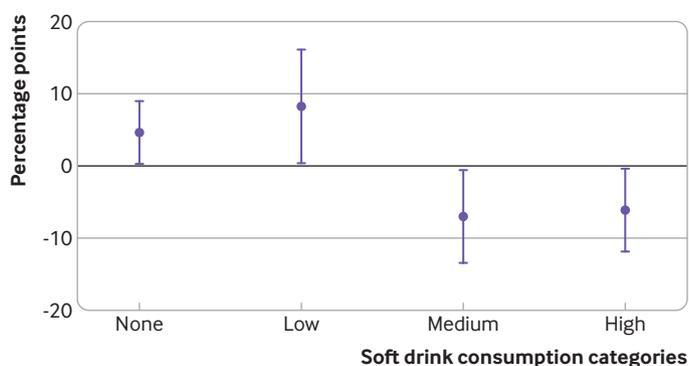


Fig 2 | Percentage difference in predicted probability of changing soft drink consumption categories between periods before (2004-13) and after (2017-18) implementation of sugar sweetened beverages tax in Mexico. Non-consumer=no soft drink consumption; low consumer=consumed <1 serving/week; medium consumer=consumed 1 serving/week to <1 serving/day; high consumer=consumed \geq 1 serving/day. Predicted values from ordered logistic correlated random effects regression models shown in appendix table A1-2

of daily soda consumption decreased by 40% after implementation of the tax.³⁴ In Berkeley, three studies included measures of self-reported sugar sweetened drinks consumption. One used 24 hour beverage recall surveys before and after the tax (collected in the same months one year apart) and found that consumption had fallen 21% eight months after the tax was implemented, but the study was insufficiently powered to detect an effect.¹¹ Another study interviewed shoppers in low income neighbourhoods in Berkeley using a short beverage frequency measure. This study found that consumption of soda and other sugary drinks fell significantly by 21% four months after implementation.¹⁵ The most recent study, by Lee et al, observed that consumption of sugar sweetened drinks in Berkeley three years after the tax decreased by 0.55 times per day.³⁵ Self-reported individual level consumption information provides a closer

approximation to individual level behaviours; however, it is subject to self-report measurement biases that other approaches, such as sales figures, are less prone to, making the analyses of all potential data sources valuable for policy analysis and evaluation. Although studies quantifying changes in consumption after sugar sweetened beverages taxes are lacking, countries such as Finland, Hungary, and France have produced evaluations using purchase data. Finland and Hungary decreased their demand for soft drinks by 4.7% and 10.2%, respectively, between 2011 and 2013. France also achieved a reduction of 6.7% in the demand for sugar sweetened drinks between 2012 and 2013.³⁶ Although the percentage of taxation is different across countries, all evaluations showed significant decreases in purchases.³⁷ Comparing these reductions with our results is difficult, as we used consumption data and focused on estimating the probability of change across consumption categories, with no quantification of the change in soft drink intake. However, our results suggest a change in soft drink consumption behaviours in the expected direction: an increase in the probability of becoming a low consumer or non-consumer after the tax.

The effect of the sugar sweetened beverages tax in Mexico has been extensively evaluated using household purchases.^{14 20 22} Our findings, although not comparable given the different measures used, are consistent with those of studies that showed reductions in household purchases of taxed beverages in urban areas or reductions in country level sales of sugary drinks associated with the sugar sweetened beverages tax.^{14 21} Household purchases per capita are a proxy for individual consumption and have been shown to adequately approximate dietary quality.^{38 39} However, household purchase data tend to omit drinks acquired in other venues (for example, food service) or consumed outside of home, a behaviour that is better captured by the food frequency questionnaire.

Previous Mexican studies reported a price elasticity for soft drinks of -1.06 and -1.16 for sugar sweetened beverages; these elasticities were higher for households in rural areas, in high marginalised zones, or with lower income.⁴⁰ Studies conducted using nationally representative samples in Mexico found that households with low socioeconomic status experienced the largest reduction in purchases of sugar sweetened drinks after the tax, compared with higher socioeconomic status strata.^{20 21} Our study found no statistically significant difference in the effect of the tax by income level, although there was an indication that participants in the middle level of income could have experienced a larger reduction in consumption than other income groups. This discrepancy could be explained by the differences in the income distribution of our cohort, compared with the Mexican population; for instance, our low income third captures people between the second and third deciles of the national income, whereas our high income third includes participants above the ninth decile of national income. Thus, the range of income captured by our cohort is

Table 2 | Percentage difference in predicted probability of being in soft drink consumption categories for periods before (2004-13) and after (2017-18) implementation of sugar sweetened beverage tax, by income level

Soft drink consumption categories*	Change in percentage points (95% CI) before to after tax
Non-consumer	
Low income	4.4 (-2.4 to 11.2)
Middle income	5.7 (0.3 to 11.1)
High income	5.1 (-0.1 to 10.2)
Low consumer	
Low income	4.3 (-1.5 to 10.0)
Middle income	9.4 (2.3 to 16.6)
High income	8.8 (1.4 to 16.2)
Medium consumer	
Low income	-5.7 (-14.0 to 2.6)
Middle income	-8.1 (-15.3 to -0.8)
High income	-7.2 (-14.3 to -0.1)
High consumer	
Low income	-3.0 (-7.1 to 1.1)
Middle income	-7.1 (-12.3 to -1.8)
High income	-6.6 (-12.2 to -1.1)

Predicted values from ordered logistic correlated random effects regression models shown in appendix table A1-3.

*Non-consumer=no soft drink consumption; low consumer=consumed <1 serving/week; medium consumer=consumed 1 serving/week to <1 serving/day; high consumer=consumed \geq 1 serving/day.

Table 3 | Percentage difference in predicted probability of being in soft drink consumption categories for periods before (2004-13) and after (2017-18) implementation of sugar sweetened beverages tax, by education level

Soft drink consumption categories*	Change in percentage points (95% CI) from before to after tax
Non-consumer	
Elementary school or less	0.9 (-1.7 to 3.5)
Middle and high school	6.8 (0.7 to 12.9)
College and higher	6.7 (0.0 to 13.4)
Low consumer	
Elementary school or less	3.3 (-5.9 to 12.6)
Middle and high school	9.0 (2.7 to 15.4)
College and higher	6.8 (1.4 to 12.2)
Medium consumer	
Elementary school or less	-0.5 (-3.4 to 2.4)
Middle and high school	-9.0 (-16.6 to -1.5)
College and higher	-8.5 (-16.3 to -0.6)
High consumer	
Elementary school or less	-3.7 (-13.7 to 6.3)
Middle and high school	-6.8 (-11.7 to -2.0)
College and higher	-5.0 (-9.1 to -0.9)

Predicted values from ordered logistic correlated random effects regression models shown in appendix table A1-4.
 *Non-consumer=no soft drink consumption; low consumer=consumed <1 serving/week; medium consumer=consumed 1 serving/week to <1 serving/day; high consumer=consumed ≥1 serving/day.

smaller and biased towards higher income, compared with national estimates (no representation of the poorest tenth and overrepresentation of the top 20% of income).

We observed heterogeneity of the effect of the tax by education level, with larger decreases in the probability of being a medium and high consumer of soft drinks and greater increases in the probability of being a low consumer or non-consumer in participants with secondary and higher education, compared with those with elementary education or less. A previous analysis using purchase data in a nationally representative sample found that households in which the family head had an education level of less than high school experienced the largest reduction in taxed beverage purchases after the tax.²² In our case, we relied on self-reported educational attainment level, which provides a closer link to individual level sugar sweetened

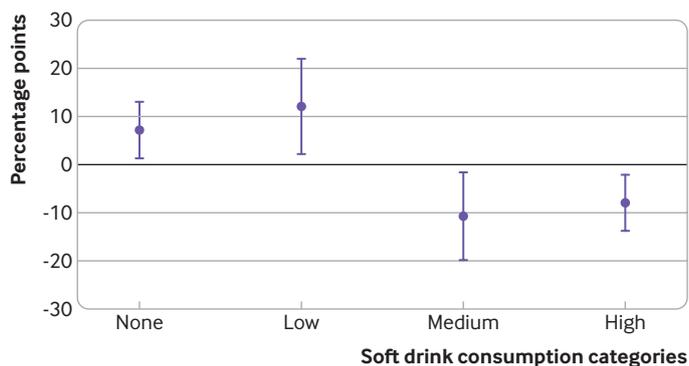


Fig 3 | Percentage difference in predicted probability of being in soft drink consumption categories between periods before (2004-13) and after (2017-18) implementation of sugar sweetened beverages tax in Mexico, complete case analysis. Non-consumer=no soft drink consumption; low consumer=consumed <1 serving/week; medium consumer=consumed 1 serving/week to <1 serving/day; high consumer=consumed ≥1 serving/day. Predicted values from ordered logistic correlated random effects regression models shown in appendix table A2-2

drinks consumption. However, more than 40% of our participants had college education or higher, compared with the 18% reported nationally; only 15% of our sample had primary school or less compared with 25% nationally.⁴¹ Along with the composition of our sample, our results need to be interpreted taking into consideration that our sample is composed of health professionals and their families, who are likely to be more informed about the health effects of sugar sweetened drinks than the overall population and might respond more positively than the rest of the population to the sugar sweetened beverages tax. Considering these limitations, our study still adds individual level, self-reported evidence suggesting that the tax has an important ability to positively influence consumption behaviours, in line with previous findings from household purchase and sales data.^{20 21} We believe these findings should encourage deeper investigation of the intersection between education, information, and the tax to generate reductions in the consumption of sugar sweetened beverages.

Strengths and limitations of study

Our analysis of Mexico's sugar sweetened beverages tax did not have a comparison group, as the tax is a national policy. Instead, we had information available from two time points before the implementation of the tax, which allowed us to estimate the trend between 2004 and 2010 and compare it with the observed consumption in 2017. Our results could be influenced by social and economic confounders that we were unable to account for. However, we included a large set of confounders at the individual and family level, as well as economic and weather data to adjust for seasonal differences, given that temperature and economic changes have a strong influence on beverage consumption. The food frequency questionnaire used was previously validated, but it was not assessed specifically for sugar content. Furthermore, it was validated in a sample of women of low socioeconomic status from Mexico City. This difference in validated population from the one used for our analysis could potentially influence our results.²⁷ Also, our sample consists of health workers and their families, who, besides being more affluent and better educated, are likely to be more informed about the health implications of sugar sweetened drinks than is the average Mexican; their socioeconomic status and professional involvement could make them more prone to health oriented lifestyle changes than the general population.⁴² This population might also underreport soft drink consumption if they understand and perceive the negative health implications of consumption of sugar sweetened drinks, particularly if the social desirability bias increased over time. We note, however, that the post-tax wave used here was at least three years after the media attention around the tax, so whether such a bias would have necessarily become stronger for the post-tax wave is unclear. Previous studies also found an increase in purchases of water at least within the first year of the tax.¹⁴ Unfortunately, we were unable to

investigate changes in water consumption in our study as the questions for water intake in the HWCS survey changed across the three waves.

Implication of results

The nature of the public health policy and the possible study designs available make isolating the effects of this intervention difficult. It is unclear whether changes in reported intakes of sugar sweetened beverages are due to actual behavioural changes in response to higher prices or to the growing perception and understanding that such drinks are unhealthy and that consumption should be lowered (norm changes). Nevertheless, our findings, together with published evidence, indicate that a fiscal measure such as taxation can be effective in helping to reduce intake of sugar sweetened drinks in the population.³⁷ These results have an important public health implication, as they add to the much needed evidence for the short term and longer term effects of sugar sweetened beverages taxation on sales and consumption that has been requested by policy makers and industry stakeholders. Continued close monitoring of changes in intake by the population is still needed to better understand the effects of this policy and assess potential future modifications.

Conclusion

Mexico's sugar sweetened beverages tax (1 peso per litre) was implemented with the aim of reducing consumption of unhealthy drinks. Our findings show the continuous role that taxation might play in reducing intake of soft drinks three years after implementation. Further research to understand the longer term implications that these changes could have for body weight or metabolic diseases is needed. A growing evidence base suggests that sizable reductions in consumption of sugar sweetened drinks might be obtained with the current tax.³⁷ Recent calls to increase the tax to 20% have been made, to further reduce consumption of unhealthy drinks.

Contributors: LMSR processed and analysed the data and wrote and finalised the manuscript. FCO and RGM participated in the literature search, processed data, and modified the manuscript. AMC and SN provided advice on the analysis and helped with the development of the manuscript. PRP collected data. JS contributed to the design of the study and participated in data collection. TBG designed the study, provided advice on the analysis, and helped to write the manuscript. All authors read and approved the final manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. LMSR is the guarantor.

Funding: This research received unrestricted funding from Bloomberg Philanthropies. The funders had no role in the design, analysis, interpretation, or writing of this paper.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: support from Bloomberg Philanthropies for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: The study protocol, questionnaires, procedures, and informed consent forms were approved by the corresponding institutional review boards of all participating institutions: the Mexican Social Security Institute (12CEI 09 006 14), the National Institute of Public Health (13CEI 17 007 36), and the Autonomous University

of the Mexico State (1233008X0236). All participants gave written informed consent to enrol in the study.

Data sharing: Code for all the analyses as well as the anonymised database will be made available on reasonable request.

Transparency: The lead author (the manuscript's guarantor) affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Dissemination to participants and related patient and public communities: Results were disseminated as a research poster at the Obesity Society Meeting 2019. Future plans for dissemination include but are not limited to: press release by the National Institute of Public Health in Mexico, in coordination with the University of North Carolina; release of infographics through social media; and presentations in national and international scientific seminars.

This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

- World Health Organization. Guideline: sugars intake for adults and children. 2015. https://apps.who.int/iris/bitstream/handle/10665/149782/9789241549028_eng.pdf?sequence=1.
- World Health Organization. *Global status report on noncommunicable diseases 2010*. WHO Press, 2011.
- Sánchez-Pimienta TG, Batis C, Lutter CK, Rivera JA. Sugar-sweetened beverages are the main sources of added sugar intake in the Mexican population. *J Nutr* 2016;146:1888S-96S. doi:10.3945/jn.115.220301
- Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *Am J Clin Nutr* 2013;98:1084-102. doi:10.3945/ajcn.113.058362
- Malik VS, Popkin BM, Bray GA, Després JP, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. *Diabetes Care* 2010;33:2477-83. doi:10.2337/dc10-1079
- Niebylski ML, Redburn KA, Duhaney T, Campbell NR. Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence. *Nutrition* 2015;31:787-95. doi:10.1016/j.nut.2014.12.010
- Vartanian LR, Schwartz MB, Brownell KD. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *Am J Public Health* 2007;97:667-75. doi:10.2105/AJPH.2005.083782
- World Health Organization. *Fiscal policies for diet and prevention of noncommunicable diseases: technical meeting report, 5-6 May 2015*. WHO; 2016.
- Mytton OT, Clarke D, Rayner M. Taxing unhealthy food and drinks to improve health. *BMJ* 2012;344:e2931. doi:10.1136/bmj.e2931
- Zhong Y, Auchincloss AH, Lee BK, Kanter GP. The short-term impacts of the Philadelphia beverage tax on beverage consumption. *Am J Prev Med* 2018;55:26-34. doi:10.1016/j.amepre.2018.02.017
- Silver LD, Ng SW, Ryan-Ibarra S, et al. Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: A before-and-after study. *PLoS Med* 2017;14:e1002283. doi:10.1371/journal.pmed.1002283
- Cornelsen L, Carriedo A. *Health-related taxes on foods and beverages*. Food Research Collaboration Policy Brief, 2015.
- Afshin A, Peñalvo JL, Del Gobbo L, et al. The prospective impact of food pricing on improving dietary consumption: A systematic review and meta-analysis. *PLoS One* 2017;12:e0172277. doi:10.1371/journal.pone.0172277
- Colchero MA, Popkin BM, Rivera JA, Ng SW. Beverage purchases from stores in Mexico under the excise tax on sugar sweetened beverages: observational study. *BMJ* 2016;352:h6704. doi:10.1136/bmj.h6704
- Falbe J, Thompson HR, Becker CM, Rojas N, McCulloch CE, Madsen KA. Impact of the Berkeley excise tax on sugar-sweetened beverage consumption. *Am J Public Health* 2016;106:1865-71. doi:10.2105/AJPH.2016.303362
- Guerrero-López CM, Unar-Munguía M, Colchero MA. Price elasticity of the demand for soft drinks, other sugar-sweetened beverages and energy dense food in Chile. *BMC Public Health* 2017;17:180. doi:10.1186/s12889-017-4098-x
- World Health Organization. Reducing consumption of sugar-sweetened beverages to reduce the risk of unhealthy weight gain in adults. 2016. https://www.who.int/elena/titles/ssbs_adult_weight/en/.

- 18 Pan American Health Organization. *Taxes on sugar-sweetened beverages as a public health strategy: the experience of Mexico*. PAHO, 2015. <https://iris.paho.org/xmlui/handle/123456789/18391>.
- 19 Singh GM, Micha R, Khatibzadeh S, Lim S, Ezzati M, Mozaffarian D, Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE). Estimated global, regional, and national disease burdens related to sugar-sweetened beverage consumption in 2010. *Circulation* 2015;132:639-66. doi:10.1161/CIRCULATIONAHA.114.010636
- 20 Colchero MA, Rivera-Dommarco J, Popkin BM, Ng SW. In Mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax. *Health Aff (Millwood)* 2017;36:564-71. doi:10.1377/hlthaff.2016.1231
- 21 Colchero MA, Molina M, Guerrero-López CM. After Mexico implemented a tax, purchases of sugar-sweetened beverages decreased and water increased: difference by place of residence, household composition, and income level. *J Nutr* 2017;147:1552-7. doi:10.3945/jn.117.251892
- 22 Ng SW, Rivera JA, Popkin BM, Colchero MA. Did high sugar-sweetened beverage purchasers respond differently to the excise tax on sugar-sweetened beverages in Mexico? *Public Health Nutr* 2018;22:1-7.
- 23 Wright A, Smith KE, Hellowell M. Policy lessons from health taxes: a systematic review of empirical studies. *BMC Public Health* 2017;17:583. doi:10.1186/s12889-017-4497-z
- 24 Gutiérrez J, Rivera-Dommarco J, Shamah-Levy T, et al. *Resultados Nacionales Encuesta Nacional de Salud y Nutrición (ENSANUT)*. Instituto Nacional de Salud Pública, 2012.
- 25 Denova-Gutiérrez E, Flores YN, Gallegos-Carrillo K, et al. Health workers cohort study: methods and study design. *Salud Publica Mex* 2016;58:708-16. doi:10.21149/spm.v58i6.8299
- 26 Valente H, Teixeira V, Padrão P, et al. Sugar-sweetened beverage intake and overweight in children from a Mediterranean country. *Public Health Nutr* 2011;14:127-32. doi:10.1017/S1368980010002533
- 27 Hernández-Avila M, Romieu I, Parra S, Hernández-Avila J, Madrigal H, Willett W. Validity and reproducibility of a food frequency questionnaire to assess dietary intake of women living in Mexico City. *Salud Publica Mex* 1998;40:133-40. doi:10.1590/S0036-36341998000200005
- 28 Schulze MB, Manson JE, Ludwig DS, et al. Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. *JAMA* 2004;292:927-34. doi:10.1001/jama.292.8.927
- 29 Narain A, Kwok CS, Mamas MA. Soft drinks and sweetened beverages and the risk of cardiovascular disease and mortality: a systematic review and meta-analysis. *Int J Clin Pract* 2016;70:791-805. doi:10.1111/ijcp.12841
- 30 INEGI. PIB y Cuentas Nacionales México: Instituto Nacional de Estadística y Geografía; 2018. https://www.inegi.org.mx/temas/pib/default.html#informacion_general.
- 31 Batis C, Rivera JA, Popkin BM, Taillie LS. First-year evaluation of Mexico's tax on nonessential energy-dense foods: an observational study. *PLoS Med* 2016;13:e1002057. doi:10.1371/journal.pmed.1002057
- 32 Wooldridge JM. *Econometric analysis of cross section and panel data*. 2nd ed. MIT Press, 2010.
- 33 Schunck R. Within and between estimates in random-effects models: Advantages and drawbacks of correlated random effects and hybrid models. *Stata J* 2013;13:65-76. doi:10.1177/1536867X1301300105
- 34 Zhong Y, Auchincloss AH, Lee BK, Kanter GP. The short-term impacts of the Philadelphia beverage tax on beverage consumption. *Am J Prev Med* 2018;55:26-34. doi:10.1016/j.amepre.2018.02.017
- 35 Lee MM, Falbe J, Schillinger D, Basu S, McCulloch CE, Madsen KA. Sugar-sweetened beverage consumption 3 years after the Berkeley, California, sugar-sweetened beverage tax. *Am J Public Health* 2019;109:637-9. doi:10.2105/AJPH.2019.304971
- 36 European Competitiveness and Sustainable Industrial Policy Consortium. Food taxes and their impact on competitiveness in the agri-food sector. 2014. https://ec.europa.eu/growth/content/food-taxes-and-their-impact-competitiveness-agri-food-sector-study-0_en.
- 37 Teng AM, Jones AC, Mizdrak A, Signal L, Genç M, Wilson N. Impact of sugar-sweetened beverage taxes on purchases and dietary intake: Systematic review and meta-analysis. *Obes Rev* 2019;20:1187-204. doi:10.1111/obr.12868
- 38 Appelhans BM, French SA, Tangney CC, Powell LM, Wang Y. To what extent do food purchases reflect shoppers' diet quality and nutrient intake? *Int J Behav Nutr Phys Act* 2017;14:46. doi:10.1186/s12966-017-0502-2
- 39 Kong A, Schiffer L, Antonic M, Braunschweig C, Odoms-Young A, Fitzgibbon M. The relationship between home- and individual-level diet quality among African American and Hispanic/Latino households with young children. *Int J Behav Nutr Phys Act* 2018;15:5. doi:10.1186/s12966-018-0645-9
- 40 Zheng Y, Zhen C, Dench D, Nonnemaker JM. US demand for tobacco products in a system framework. *Health Econ* 2017;26:1067-86. doi:10.1002/hec.3384
- 41 INEGI. Censo y Conteo de Población y Vivienda. Encuesta Intercensal 2015. <https://www.inegi.org.mx/temas/educacion/>.
- 42 Park S, Onufrak S, Sherry B, Blanck HM. The relationship between health-related knowledge and sugar-sweetened beverage intake among US adults. *J Acad Nutr Diet* 2014;114:1059-66. doi:10.1016/j.jand.2013.11.003
- 43 Bell A, Fairbrother M, Jones K. Fixed and random effects models: making an informed choice. *Qual Quant* 2019;53:1051-74. doi:10.1007/s11135-018-0802-x.

Web appendix: Appendices