Taxes to Unhealthy Food and Beverages and Oral Health in Mexico: An Observational Study

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Keywords

Dental caries · Taxes · Sugar-sweetened beverages · Energy-dense nutrient-poor food · Public dental health

Abstract

In January 2014, taxes on sugar-sweetened beverages and nonessential energy-dense food were implemented in Mexico to discourage the consumption of these products. Published evaluations have shown reductions in purchases of taxed food and beverages associated with the implementation of this fiscal policy. Although there are some studies on the impact on health based on simulation studies, no evaluations with empirical data on changes in oral health have been published. We used administrative records and data from an epidemiological surveillance system to estimate changes in (1) outpatient visits related to dental caries; (2) having experienced dental caries: Decayed, Missing and Filled Teeth (DMFT) >0 for permanent dentition or dmft >0 for primary dentition (dmft); (3) number of teeth with caries experience (DMFT and dmft), (4) cases with DMFT >0 or dmft >0, and (5) the series of mean DMFT or dmft, associated with the taxes. We estimated probit and negative binomial models for outcomes at individual level, and interrupted time se-

ries analysis for population-level outcomes. The implementation of the taxes was associated with negative changes in the trends of outpatient visits, as well as for cases with DMFT >0, dmft >0 and mean DMFT. Taxes were also associated with a lower probability of having experienced dental caries and with a lower number of teeth with caries experience in the samples studied. Our results suggest positive impacts of the implementation of taxes on unhealthy food and beverages in the oral health of Mexicans, which are the first health benefits observed, and add to the health benefits predicted by modeling studies.

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Introduction

Mexico is one of the countries with the highest per capita consumption of sugar-sweetened beverages (SSB) in the world [Basu et al., 2013] and the second largest consumer of ultra-processed food and beverages in Latin America [Pan American Health Organization, 2019]. As a consequence, added sugars in Mexico contributed on average with 12.6% to total energy intake in 2012; SSB accounted for 69% of these added sugars and food with an

additional 24% [Sánchez-Pimienta et al., 2016]. The excessive consumption of SSB and ultra-processed food fails the WHO recommendations to keep the contribution of added sugars to total energy intake below 10% [World Health Organization, 2015].

Dental caries is a multifactorial disease with socioeconomic [Costa et al., 2012], behavioral and biological determinants [Lee and Brearley Messer, 2011; Martínez-Mier and Zandona, 2013; Bernabé and Sheiham, 2014]; diet being one of the major risk factors [Bernabé et al., 2015]. Specifically, the intake of free sugars (added sugars plus sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates) at frequent time intervals has been pointed out as the major dietary risk factor in the pathogenesis of dental caries [Burt et al., 1988; Holt, 1991; World Health Organization, 2017]. Therefore, the WHO recommendation to keep the consumption of added sugars below 10% arose not only because of its association with poor dietary quality, obesity and risk of noncommunicable diseases, but also for its contribution to dental caries [World Health Organization/Food and Agriculture Organization, 2003; World Health Organization, 2015]. Since it is rarely fatal, dental caries is often overlooked in middle-income countries [Executive Board, 2006], although it is the most prevalent condition in the 2015 Global Burden of Disease Study [Vos et al., 2016].

The prevalence of untreated caries is 77.7% in the population below 19 years old and 92.6% among adults [Secretaría de Salud, 2018]. Preventing dental caries is important because severe cases can lead to infection, pain, and ultimately tooth extraction, affecting overall health and wellbeing [World Health Organization, 2017]. Dental care prevention has also proven to be a cost-effective intervention [Fraihat et al., 2019]. Despite the implementation of public health programs in Mexico since 1981, such as the promotion of oral hygiene or salt fluoridation, dental caries is still a public health problem that requires other public health policies for prevention [Presidencia de la República, 1981; Irigoyen and Sánchez-Hinojosa, 2000; Irigoyen et al., 2012; Bernabé et al., 2015; World Health Organization, 2017].

Since January 2014, Mexico implemented an 8% tax to nonessential energy-dense food and a one peso per liter tax to SSB. Taxed beverages include all non-alcoholic beverages with added sugar. Taxed food includes chips and deep-fried salted snacks, sugar confectionery, chocolates, crème caramel and puddings, candied fruits, peanut and hazelnut spreads, caramel sauces, cereal-based sweet foods, ice cream and popsicles, provided they have an energy density ≥ 275 kcal/100 g. All these products are com-

mon sources of added sugars [Sánchez-Pimienta et al., 2016].

Impact evaluations have proven the effectiveness of the fiscal policies implemented in Mexico: 2 years after its implementation, taxes reduced SSB household purchases by 7.6% on average [Colchero et al., 2017]; while for taxed food the reduction was around 5% on the first and 3 years after [Batis et al., 2016; Hernández-F et al., 2019]. Published papers on the potential impact of these taxes on health are based on simulation models [Sánchez-Romero et al., 2016; Barrientos-Gutierrez et al., 2017]. There is a lack of studies about the short-term effects on health outcomes, such as oral health conditions.

The objective of this study was to estimate changes in oral health outcomes associated with the implementation of the taxes in Mexico. We analyzed the following outcomes: outpatient visits, dental caries and number of teeth with dental caries experience.

Materials and Methods

We used two sources of information. The first data set comes from administrative records on oral outpatient visits for the population without social security provided by public health facilities from the Ministry of Health, which represent approximately half of the Mexican population. The data are managed through an information system called “Dynamic Cubes”. Although the data set does not provide information on oral health status, we identified outpatient visits that could be related to dental caries. The second source of information provides data on oral health reported to the Epidemiological Surveillance System of Oral Pathologies (SIVEPAB by its acronym in Spanish), which tracks 452 sentinel units that belong to any of the institutions that make up the health system and that are fully or partially financed by public resources.

Sources of Information and Outcomes

Oral Health Outpatient Visits (Dynamic Cubes)

The Ministry of Health collects monthly information on outpatient visits through Dynamic Cubes [Secretaría de Salud, 2019], which is uploaded to the system by the state health ministries and validated by the national Ministry of Health. Validated data covered the period between 2007 and 2018.

We analyzed outpatient visits that include first and subsequent visits. From the 36 reasons listed for outpatient visits in the data set, with assistance of an oral health practitioner, we selected those more likely related to dental caries: amalgam or resin fillings, extractions of primary or permanent teeth, pulp therapy, and pharmacotherapy.

Dental Caries (SIVEPAB)

The SIVEPAB is the system that monitors the state of oral health in Mexico, which tracks sentinel medical units distributed in each of the 32 states since 2009. Dentists responsible in each sentinel unit report information related to patients receiving dental treatment for the first time in the year; they conduct diagnostic

procedures and criteria recommended by the WHO and described in the Manual of Standardized Procedures for Epidemiological Surveillance of the Sentinel Unit Dentist [Secretaría de Salud, 2018]. They fill a unique format and upload the information to the SIVEPAB. The Ministry of Health is responsible for reviewing and integrating the information into annual aggregated databases. The information available in the SIVEPAB covers the period between 2009 and 2018.

The SIVEPAB reports various indices, such as the Decayed, Missing due to caries and Filled Teeth index for permanent dentition (DMFT), which is the number of teeth with caries, and the equivalent index for primary dentition (dmft). DMFT ranges from 0 to 32 and dmft from 0 to 20. The WHO recommends these indices for the assessment of oral health status in relation to dental caries experience in oral health surveys [World Health Organization, 2013].

We excluded cases of individuals older than 12 years for whom the dmft index was specified, cases of children under 6 years for whom the DMFT index was specified, as well as cases in which the age of the individual exceeded 99 years for considering them implausible. We also excluded children under 1 year of age because the widespread consumption of infant formulas to feed infants in Mexico [Colchero et al., 2015], more than the consumption of taxed food and beverages, could be the leading cause of dental caries. Additionally, we excluded cases of individuals without sex registration. Cases excluded for these reasons account for 0.5% of the original sample. In addition, we lost 77,828 cases because they had no information on the Simplified Oral Hygiene Index [Greene and Vermillion, 1964], a relevant variable to adjust the models at individual level. Our analytical sample was of 2,648,893 individuals. Details on the analytical sample can be found in the online supplementary Table S1 (see www.karger.com/doi/10.1159/000515223).

Statistical Analyses

Oral Health Outpatient Visits

To estimate the association between taxes and oral health outpatient visits, we used Interrupted Time Series Analysis (ITSA) [Linden, 2015]. This approach has been followed to evaluate the effectiveness of population-level health interventions that have been implemented at a clearly defined point in time, in the absence of an experimental design [Lopez et al., 2016], as is the case of the taxes implemented in Mexico in January 2014. Changes in oral health outpatient visits could be associated, in addition to the taxes, with other demographic, seasonal and budgetary factors. We adjusted the models for population growth, binary variables for each month of the year and per capita public health spending for the population without social security.

Despite the adjustment for other variables in time series analysis, random errors may be correlated over time, what is known as autocorrelation [The Pennsylvania State University, 2018]. The autocorrelation order of a series is the number of immediately preceding values in the series, relevant to predict their value in the present [The Pennsylvania State University, 2018]. We applied the Cumby-Huizinga general test to the estimated models to assess autocorrelation [Cumby and Huizinga, 1992], using a user-written program that allows simultaneous testing for several orders of autocorrelation [Baum and Schaffer, 2013]. We explored autocorrelation structure for up to 24 months. When we detected an autocorrelation of order ≥ 1 , we re-estimated the ITSA model controlling for the maximum lag with statistically

significant autocorrelation at 5% significance level [Linden, 2015].

To test the robustness of the results, we estimated the model for an outcome that should not be affected by the taxes. We estimated an ITSA model for preventive oral outpatient visits, not related to caries, as a falsification test. Preventive visits not related to caries include: review of prosthetic hygiene, review of oral tissues and topical application of fluoride. We also performed falsification tests for outpatients and preventive visits by deliberately modifying the implementation year to 2012.

Dental Caries

With individual-level information from the SIVEPAB, we estimated a probit model for having experienced dental caries for various age strata based on temporary or permanent dentition as a function of a binary variable indicating the year the taxes were implemented. For groups of 1–5 years and 1–12 years, we defined the outcome of having experienced dental caries as $dmft > 0$, while for groups 6–19, 20 or more and 30 or more years, as $DMFT > 0$. In addition, we estimated a probit model for the probability of relatively more severe dental caries ($DMFT > 3$) in the group of 12-year-old children, because this was an indicator for oral health by the year 2000 [International Conference on Primary Health Care. Alma-Ata., 1978], and this stratum is a typical reference for children [World Health Organization, 2013]. We adjusted the model for sociodemographic, socioeconomic and behavioral variables, including the month of diagnosis, region (northern; central; southern), age group (1–5 y; 6–12 y; 13–19 y; 20–65 y, 66–99 y), education level (elementary or lower; junior/high school or equivalent; undergraduates/graduates; not specified), sex (male; female), affiliation institution, per capita public health spending for the publicly funded health system, and the Simplified Oral Hygiene Index. The latter is a continuous variable which assigns zero to proper hygiene and 6 to the cases with abundant presence of debris in the oral cavity. Additionally, models for adults were adjusted for occupation (professionals and technicians; low-skilled employees; workers without paid employment; students). Given the possibility of cluster effects per medical unit because medical units may not have the same equipment, or the responsible dentist may not be strictly following diagnostic practices, we adjusted for potential intragroup correlation at the medical unit.

We estimated negative binomial models for the number of teeth with caries experience that are used to handle overdispersion in count data. Several studies have shown that the number of teeth with caries experience has overdispersion [Preisser et al., 2012]. We compared mean and variance for dmft and DMFT by year in our data and found a moderate overdispersion between 18 and 26%.

In addition, we built quarterly series, using the date when the instrument to collect information was applied to patients receiving dental treatment for the first time in the year. We constructed two series: one for the number of individuals having experienced caries ($DMFT > 0$ for permanent dentition and $dmft > 0$ for primary dentition) and a second series using average DMFT and dmft indices, calculated for the age groups of 6 or more years or up to 12 years, respectively. We analyzed the series using ITSA models adjusting for binary variables for each quarter, population growth, and per capita spending on institutions that are fully or partially funded from the public budget.

Table 1. Changes in oral health outpatient visits before and after the taxes were implemented

	Coefficient (SE)	
	outpatient visits related to dental caries	preventive outpatient visits for oral health (falsification test)
Pre-tax trend	−88.1 (367.1)	297 (665.8)
Intercept change	41,197.0 (10,210.3)**	136,402.6 (22,124.6)**
Post-tax trend change	−2,920.5 (592.1)**	−1,706.2 (1,245.6)

** Significant at 1%; * significant at 5%; + significant at 10%. Author analyses using monthly oral outpatient and preventive visits at facilities from the Ministry of Health, 2007–2018. Interrupted time series analyses adjusted for population growth, binary variables for each month of the year and per capita public health spending. Maximum lag for autocorrelation: 16 for outpatient visits and 4 for preventive visits.

Fig. 1. Oral health outpatient visits related to complications of untreated caries during the period 2007–2018: unadjusted and predicted values.

We considered the results statistically significant at conventional levels (1, 5, 10%). We performed all analyses in STATA 13 [STATA Corp., 2013].

Results

Oral Health Outpatient Visits

Figure 1 shows the number of outpatient visits related to dental caries. The vertical line identifies the time when the taxes were implemented. The dots represent the unadjusted/observed data and the lines are the predicted values from the estimated ITSA model. The graph shows a clear annual seasonality, with an almost constant trend before the implementation of taxes, and decreasing thereafter.

Table 1 shows the results of the ITSA models. For outpatient visits, there was a negative pre-tax trend showing a non-statistically significant average reduction of 88.1 visits per month (significant at 10%), an immediate positive change (intercept change) after the taxes were implemented of 41,197 visits, followed by a negative post-tax trend showing an average reduction on the number of outpatient visits of 2,920.5 per month. In contrast, for preventive outpatient visits (falsification test), there was an immediate increase of 136,402.6 visits but the post-tax trend was not statistically significant suggesting that the taxes had no impact on preventive visits unrelated to dental caries.

Table 2 shows the results of the falsification test using January 2012 as the time that taxes were implemented. For outpatient visits, there is a statistically significant in-

Table 2. Falsification tests for changes in oral health outpatient visits before and after the taxes were implemented (hypothetical intervention in January 2012)

	Coefficient (SE)	
	outpatient visits related to dental caries	preventive outpatient visits for oral health
Pre-tax trend	−909.1 (700)	−726.6 (1,435.9)
Intercept change	4,696.6 (17,533.8)**	2,136.4 (36,059)
Post-tax trend change	−946.0 (807.4)	1,901.5 (1,639.8)

** Significant at 1%; * significant at 5%; + significant at 10%. Author analyses using monthly oral outpatient and preventive visits at facilities from the Ministry of Health, 2007–2018. Interrupted time series analyses adjusted for population growth, binary variables for each month of the year and per capita public health spending. Maximum lag for autocorrelation: 8 for outpatient visits and 8 for preventive visits.

Table 3. Probability of having experienced dental caries and number of teeth with caries experience for temporary and permanent dentition before and after the taxes were implemented

Age group	Probability of having experienced dental caries ¹		Number of teeth with caries experience ²	
	outcome	AME (SE)	outcome	AME (SE)
1–5 years	dmft >0	−0.005 (0.012)	dmft	−0.105 (0.115)
1–12 years	dmft >0	−0.022 (0.009)*	dmft	−0.209 (0.057)**
12 years	DMFT >3	−0.037 (0.009)**	DMFT	−0.298 (0.079)**
6–19 years	DMFT >0	−0.028 (0.006)**	DMFT	−0.305 (0.062)**
20 years or more	DMFT >0	−0.021 (0.003)**	DMFT	−0.573 (0.119)**
30 years or more	DMFT >0	−0.017 (0.003)**	DMFT	−0.643 (0.118)**

** Significant at 1%; * significant at 5%; + significant at 10%. Author analyses using oral health data from sentinel medical units reported in the SIVEPAB, 2009–2018. ¹ Probit models, ² negative binomial models, both adjusted for population growth, month of diagnosis, region, education, sex, affiliation, the simplified oral hygiene index and per capita public health spending. dmft, temporary dentition, DMFT, permanent dentition.

crease of 4,696.6 just after the taxes were implemented but the post-tax trend was not significant. For preventive visits, none of the coefficients of interest were statistically significant.

Dental Caries

Table 3 shows the results of the analyses based on the SIVEPAB data at the individual level, for relevant age groups. There are no differences before and after the implementation of taxes in the probability of having experienced dental caries or the number of teeth with caries experience in the age group of 1–5 years. However, there is a reduction in both outcomes in all age groups when it comes to permanent dentition: 3.7% for 12 years old, 2.8% for children between 6 and 19 years old, 2.1% for adults over 20 years old and 1.7% for adults over 30 years old. Mean number of teeth decreased by 0.209 for children be-

tween 1 and 12 years old, 0.298 for 12 years old, 0.305 for children between 6 and 19 years old, 0.537 for adults over 20 years old and 0.643 for adults over 30 years old.

Table 4 shows changes in the number of individuals having experienced dental caries from the ITSA models. For dmft, we see an immediate reduction of 2,162.9 individuals and an average post-tax reduction of 107.5 individuals having experienced dental caries per quarter. For DMFT, the results show an immediate reduction in the number of individuals experiencing dental caries of 6,147.5 and a post-tax trend reduction of 393.6 individuals per quarter. Figure 2 graphically displays unadjusted and predicted values from the model.

Table 5 shows changes in the mean number of teeth with caries experiences from the ITSA models. For dmft, the results show an immediate reduction of 0.146 in the mean number of teeth with caries after the tax was implemented

Table 4. Changes in the number of individuals having experienced dental caries for temporary and permanent dentition, before and after the taxes were implemented

	Coefficient (SE)	
	individuals with dmft >0, ages ≤12	individuals with DMFT >0, ages ≥6
Pre-tax trend	−8.8 (137)	−1,135.6 (747.3)
Intercept change	−2,162.9 (286.6)**	−6,147.5 (1,563.1)**
Post-tax trend change	−107.5 (36.5)**	−393.6 (128.9)**

** Significant at 1%; * significant at 5%; + significant at 10%. Author analyses using oral health data from sentinel medical units reported in the SIVEPAP, 2009–2018. Interrupted time series analyses adjusted for population growth, binary variables for each quarter of the year, per capita public health spending. Maximum lag for autocorrelation 0. dmft, temporary dentition; DMFT, permanent dentition.

Fig. 2. Population with dental caries experience during the period 2009–2018: unadjusted and predicted values.

and a negative post-tax trend with an average reduction of 0.004 per quarter in the mean number of teeth with caries (significant at 10%). For DMFT, the results show a negative post-tax trend with an average quarterly reduction of 0.026 in the mean number of teeth with caries. Figure 3 graphically displays the unadjusted and predicted values from the model (Fig. 3a for average dmft score in primary dentition and Fig. 3b for DMFT score in permanent dentition).

Discussion

We estimated changes in several oral health outcomes associated with the implementation of the taxes in Mexico. Our results show monthly reductions in the post-tax period for outpatient visits related to caries. We also found a reduction in the probability of having experi-

enced dental caries for all age groups, except for children under 5 years old and in the number of teeth with caries. We also found immediate reductions after the taxes were implemented for the number of individuals having experienced dental caries and mean number of teeth with caries experiences and decreasing trends thereafter.

No evaluations of fiscal policies to food and beverages on oral health using empirical data have been published. The literature shows some modeling studies for SSB taxes, which commonly assume increases in consumer prices of around 20% [Schwendicke et al., 2016; Briggs et al., 2017; Sowa et al., 2018; Jevdjovic et al., 2019; Urwannachotima et al., 2020]. Although the magnitude of the changes in oral health between studies is not comparable with our study given the different assumptions made in each model, all studies predicted positive effects on dental caries, except for one conducted in Thailand [Urwannachotima et al., 2020]. Differ-

Table 5. Changes in the mean number of teeth with caries experience for temporary and permanent dentition, before and after the taxes were implemented

	Coefficient (SE)	
	mean dmft, ages ≤12	mean DMFT, ages ≥6
Pre-tax trend	0.003 (0.002)	0.002 (0.007)
Intercept change	−0.146 (0.011)**	0.04 (0.065)
Post-tax trend change	−0.004 (0.002) ⁺	−0.026 (0.007)**

** Significant at 1%; * significant at 5%; ⁺ significant at 10%. Author analyses using oral health data from sentinel medical units reported in the SIVEPAP, 2009–2018. Interrupted time series analyses adjusted for population growth, binary variables for each quarter of the year, per capita public health spending. Maximum lag for autocorrelation 0 for mean dmft, 3 for DMFT. dmft, temporary dentition; DMFT, permanent dentition.

ent assumptions including the magnitude and type of the tax, products covered, pass through prices, as well as the baseline consumption could lead to different results on changes in dental caries. For instance, Mexico has a higher SSB consumption than the countries included in the modeling studies [Singh et al., 2015], we may expect higher positive effects in a setting with higher consumption.

Our results on oral health associated with the taxes are plausible. Consumption of fluoride in Mexico is high in some population groups associated to the high consumption of fluoridated salt, the widespread use of fluoride toothpastes, the consumption of water from sources that naturally have a high concentration of fluoride, and/or the consumption of beverages made from this water [Martínez-Mier et al., 2003]. Fluoride consumption could be protective against dental caries; however, no studies have been conducted on the trends of fluoride intake at the national level and its effect on caries. Even if fluoride intake had a nationwide protective effect against dental caries [Irigoyen and Sánchez-Hinojosa, 2000; Irigoyen et al., 2012], dietary patterns could offset the effect [Burt and Pai, 2001], particularly for a country with high intake of sugar-sweetened beverages [Basu et al., 2013; Popkin and Hawkes, 2016]. Hence our results on changes in oral health are plausible given the evidence of reductions in purchases of taxed food and beverages [Batis et al., 2016; Colchero et al., 2017; Hernández-F et al., 2019], which have a high contribution to added sugar in the diet of Mexicans [Sánchez-Pimienta et al., 2016]. Substitutions for untaxed beverages with added sugar may have been small since the tax covered all beverages with added sug-

ars except 100% juices. In addition, the evaluation of the tax showed increases in purchases of untaxed beverages, mostly bottle water [Colchero et al., 2016]. Moreover, in the period under study, there were no major changes in public policies with the potential to enhance oral health, since the effective national salt fluoridation program started in 1981 [Presidencia de la República, 1981; Secretaría de Salud, 1995], and in the period 2013–2018, no extraordinary actions were implemented to prevent dental caries [Secretaría de Salud, 2014]. Finally, the follow-up of 4 years after the taxes were implemented seems adequate to observe a change in dental caries. A study published in 2011 shows significant positive effects on dental caries associated with the United Nations Sanction in Iraq after 5 years of implementation [Jamel et al., 2004].

The lower impact found in outcomes related to dental caries at the individual level on children aged up to 12 years, and especially those under 5 years old, may be explained by several factors associated to dental caries in this age group, including the higher consumption of sugary food and beverages that were not affected by the taxes such as 100% juices [Stern et al., 2014], the inadequate oral hygiene [Chu et al., 2012], the frequency and the intake of SSB, snacks or sweets with a high cariogenic index [Tinanoff and Palmer, 2000].

Our study has some limitations. We acknowledge that there is not an experimental design as the taxes were implemented at the national level. However, it is possible to make causal inference from observational data using quasi-experimental methods [Listl et al., 2016]. In this paper, we used interrupted time series analyses that allowed us to get estimates adjusting for previous trends in caries rates. A descriptive report on oral health in Mexico between 2005 and 2014 suggests a slight improvement in oral health, mainly among 12-year-old children [Secretaría de Salud, 2015]. These improvements may have happened before the tax period, especially when it comes to primary dentition of children. Our methodological approach adjusts for previous trends and for variables that may be associated with changes in the outcomes of interest over time. Therefore, our findings show that, beyond improvements in specific age groups, taxes have improved the oral health of the general population.

Other limitations of our study relate to the sources of information. The two data sets used in our study are not representative at the national level but they represent a large proportion of the population. The Ministry of Health conducts 54.8% of the dental outpatient visits of the health system that are fully or partially funded by the public budget [Secretaría de Salud, 2015], and the Dynamic Cubes

Fig. 3. Mean number of teeth with caries experience during the period 2009–2018: unadjusted and predicted values.

capture all these outpatient visits. The SIVEPAB is representative of the public health system with the exception of the IMSS in its ordinary regime. Another limitation is that data on outpatient visits do not provide information on oral health status. However, because there is evidence of a dose-response relationship between sugar consumption and dental caries, we can expect to see a reduction in oral health outpatient visits [World Health Organization, 2017]. We selected visits of complications more likely related to untreated caries, although we cannot guarantee that all of them are related to dental caries complications.

The last limitation of the data is that we can only observe the population that accesses health services. Access to services may have changed over time, however, there were no reforms in the oral health public health system that could have biased our results.

A limitation of models used in our study to estimate the number of individuals with dental caries is that there is no information on eating habits that could be related to caries. However, we adjusted for an indicator of oral hygiene practices, which is another important predictor of oral health [Petersen, 2003].

Other studies have used indices with greater sensitivity to detect changes in the health status of teeth than DMFT or dmft indices reported in the SIVEPAB such as the Caries Detection and Assessment System [Andrade and De la Cruz, 2014]. It is possible that the tax is only delaying the progression from caries to cavitation but this cannot be studied with the data available in the SIVEPAB.

Despite the limitations, this is the first study that estimated changes in oral health associated with ongoing taxes. We used two sources of information that represent large segments of the Mexican population. We applied different methodological approaches to analyze information at the individual and population level. Our results show statistically significant improvements on caries rates associated with the implementation of the taxes on unhealthy food and beverages, which are the first health benefits observed, and add to the health effects predicted by modeling studies. Higher benefits in caries rates could be expected if in addition to taxation, other cost-effective measures were implemented such as workplace bans to SSB [Basu et al., 2020] and front-of pack labeling [Jevdjevic et al., 2020] which was implemented in Mexico since October 2020 [Secretaría de Economía, 2020].

Statement of Ethics

This research is based in non-identifiable human data, collected by the Mexican Ministry of Health in accordance with the regulations of the General Health Law on research and the principles of Helsinki.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

M.H.-F. literature review, data analyses, interpretation of results, writing of the first draft, critical review of the manuscript, approval of the final version. A.C. literature review, interpretation of results, critical review of the manuscript, approval of the final version. M.A.C. conception of the study, literature review, review data analyses, interpretation of results, critical review of the manuscript, approval of the final version.

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