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Early Introduction and Cumulative Consumption of Sugar-sweetened Beverages during the Pre-school Period and Risk of Obesity at 8–14 years of Age

Alejandra Cantoral¹, Martha Maria Tellez-Rojo¹, Adrienne Ettinger^{2,3}, Howard Hu⁴, Mauricio Hernandez-Avila¹, and Karen Peterson^{3,5}

¹National Institute of Public Health, Cuernava, Morelos, Mexico

²Department of Chronic Disease Epidemiology, Yale School of Public Health, New Haven, CT, USA

³Department of Nutritional Sciences, University of Michigan School of Public Health, Ann Arbor, MI, USA

⁴Dalla Lana School of Public Health, University of Toronto, Toronto, ON, Canada

⁵Department of Nutrition and Department of Social and Behavioral Sciences, Harvard School of Public Health, Boston, MA, USA

Abstract

Background—Consumption of sugar-sweetened beverages (SSB) has been associated with risk of obesity, but little evidence exists to evaluate if age of introduction and cumulative SSB consumption increases risk in children.

Objectives—To estimate the relationship between age of introduction and cumulative SSB consumption with the risk of obesity in a cohort of 227 Mexican children.

Methods—SSB intake was measured every six months; age of introduction and cumulative consumption during the pre-school period were calculated. Height, weight, waist circumference, SSB intake and other relevant variables were measured at age 8–14 years and obesity defined using standard criteria.

Results—All participants were introduced to SSB before age 24 months and most (73%) before 12 months. Early SSB introduction (< 12 months) was not significantly associated with increased odds of obesity (OR=2.00, 95% CI: 0.87, 4.59). However, children in the highest tertile of cumulative SSB consumption, compared to the lowest, had almost three times the odds of general

Corresponding Author: Alejandra Cantoral, ScD, National Institute of Public Health, Av. Universidad 655, Sana María Ahuacatlán, Cuernavaca 62100 Morelos, México, alejandra.cantoral@insp.mx.

Conflict of Interest Statement

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(OR=2.99, 95% CI: 1.27, 7.00) and abdominal (OR=2.70, 95% CI: 1.03, 7.03) obesity at age 8–14 years.

Conclusions—High SSB consumption increased the likelihood of obesity in 8–14 year-old children. Our results suggest that SSB intake should be delayed and excessive SSB consumption in pre-school period should be avoided.

Introduction

During the past two decades, overweight and obesity have been increasing among children and adolescents worldwide. According to the World Health Organization, over 42 million children under the age of five were overweight or obese in 2013. At the same time, consumption of sugar-sweetened beverages (SSB), defined as liquids that are sweetened with various forms of sugars (e.g., soda, fruit drinks, sport and energy drinks) (1), has been increasing (2;3). SSB represent the largest source of added sugars and significantly contributes to calories in children's diets (4). In younger children, the Feeding Infants and Toddlers Study reported that 10.7% of infants aged 9 to 11.9 months and 14.3% of children aged 12 to 14.9 months consumed SSB on a given day (5).

SSB provide little nutritional benefit, and previous studies have reported that high intakes during childhood are associated with negative health outcomes such as: dental caries (6), weight gain (7) and enlarged waist circumference. Increased risk of weight gain has been attributed to the body's low satiety response to liquid calories and the failure to compensate for excess caloric intakes (8;9).

Mexico is among the countries with the highest consumption of caloric beverages contributing 20–23% of the total energy intake in the population (2;10). From 1999–2006, a 226% increase in consumption of caloric beverages was documented among Mexican children and adolescents (2;10). The 2012 Mexican National Health and Nutrition Survey reported the prevalence of overweight and obesity, respectively, of 19.8% and 14.6% in children (5 to 11 years of age) and of 21.6% and 13.3% in adolescents (12 to 19 years old) (11).

Increased attention has focused on reducing SSB intake in an effort to reduce overweight/obesity, particularly in children. The American Academy of Pediatrics recommends that sweetened beverages, such as naturally sweet beverages and fruit juice, should be limited to 4–6 oz. per day for children 1 to 6 years old and to 8–12 oz. per day for children 7 to 18 years old (12). In Mexico, government agencies suggest several actions: the Mexican National Beverage Guidelines recommended an intake of only 4 oz. per day of natural juices in children with no intake of other SSB (13); the National Agreement for Healthy Nutrition included the reduction of fat and sugar beverages as primary objectives (14); and the School Guideline for Healthy Foods recommended the consumption of natural juices or water with fresh fruit (commonly consumed in Mexico) only 1–2 times per week in a maximum amount of 4 oz. (120 ml) per serving during school lunches (15).

Previous studies report that children who consumed SSB during infancy increased the likelihood of consuming SSB later in childhood (16) and had higher odds of childhood

obesity than non-SSB consumers (17). The aim of this study is to estimate the relationships between: 1) age of introduction to SSB and 2) cumulative consumption of SSB during the pre-school period with risk of obesity at 8–14 years of age in a prospective birth cohort study of Mexican children with repeated measures of diet in early life.

Methods

Study population

This study included children born from two birth cohort studies from the *Early Life Exposure in Mexico to Environmental Toxicants* (ELEMENT) project which has been described previously (18;19). Pregnant women were enrolled between 1997 and 2002 during the first trimester of pregnancy and 1,079 children born to these women were assessed for growth and development at six-month intervals from birth to 5 years of age. Beginning at the 12-month visit, diet was assessed to identify when the child was introduced to SSB and the amounts consumed. Other relevant measurements were recorded including: maternal and infant anthropometry and information about breastfeeding practices.

Between 2008–2009, 622 of the original cohort children (58%) were enrolled in a follow-up study and, in 2010, a convenience sample of 250 children were selected when they were between 8–14 years old as part of an NIEHS/EPA P20 Formative Children's Environmental Health (CEH) Center. The purpose of the Formative CEH Centers was to foster and stimulate new research ideas that were in the early phase of scientific inquiry, so the number of participants represents only a subset of the children born to the original birth cohorts. Mothers and their children were apprised of the follow-up study objectives and procedures and signed an informed consent or child assent prior to participation. From those, 227 (91%) had complete information for all of the relevant socio-demographic, dietetic, anthropometric and physical activity variables for this study (n=23 participants were missing information on mother's BMI or breastfeeding practices). This study was evaluated and approved by the Research, Ethics and Biosafety Committees of the National Institute of Public Health of Mexico, the Institutional Review Board of the University of Michigan and the Institutional Review Board from the Harvard School of Public Health.

Dietary Assessment

Diet was assessed using a semi-quantitative Food Frequency Questionnaire (FFQ) which was validated by Hernández-Ávila et al. (20) using the Willett methodology. Trained personnel administered the FFQ to the mother at each visit beginning when the child was 12 months old. The FFQ was used to estimate dietary intakes over the previous three months.

The FFQ included 116 foods grouped into ten categories (dairy products, fruits, vegetables, legumes, cereals, sweets, fats, snacks, eggs and meats) and beverages (natural juices, milk, sodas, commercial fruit drinks and flavored water with sugar). Ten reported frequency values (ranging from never to six or more times a day) were used to calculate average daily frequencies: 0 = never, 0.016 = less than once a month, 0.08 = two-three times a month, 0.14 = once a week, 0.43 = two-four times a week, 0.8 = five-six times a week, 1 = once a day, 2.5 = two-three times a day, 4.5 = four-five times a day and 6 = six or more times a day.

These frequencies were then multiplied by the standard serving size of each reported item to obtain average daily intakes (beverages, ml/day).

We considered SSB as the sum of daily intake of sodas, commercial fruit drinks and flavored water with sugar (not including natural fruit or vegetable juices). Average daily intake of SSB (ml/day) was multiplied by the number of days since the last interview and then summed over all visits to calculate the cumulative consumption of SSB (ml) during the pre-school period (age 1 to 5 years). Cumulative consumption of SSB was then categorized into tertiles. Using information provided on the FFQ, we calculated the age in months when infants started consumption of SSB and dichotomized this information as initiating SSB consumption ≤ 12 months or >12 months of age.

At the re-visit stage (8–14 years of age), we administered the FFQ used in the 2006 Mexican National Health and Nutrition Survey (ENSANUT 2006) directly to the children who were assisted by their mothers, when necessary, particularly at the younger ages. This instrument used a one-week recall period and queried about the consumption of natural juices, commercial fruit drinks, flavored water with sugar, tap water, sodas, diet sodas, whole fat milk, coffee and tea. Average energy intake (kcal) derived from reported food and beverage consumption was also calculated and, from this information, we obtained the SSB and non-SSB energy intakes.

Anthropometric measurements

Weight, height, and waist circumference were obtained using standardized procedures by trained personnel at the re-visit stage (8–14 years of age). Weight was measured with a Bame scale (model 420, Puebla, Mexico) rounded to the nearest 0.1 kg; height was recorded with a stadiometer (Perspective Enterprises, Portage, WI USA) to the nearest 0.1 cm; and waist circumference was obtained using a measuring tape (Quick Medical, Issaquah, WA USA) to the nearest 0.1 cm.

Weight and height were used to calculate BMI (kg/m^2) and participants were classified as “obese” according to the World Health Organization criteria (21) ($>2\text{SD}$ of the Z score for BMI), using WHO Anthro (version 3.2.2, January 2011, World Health Organization, Geneva, 150 Switzerland) software. Waist circumference $\geq 90^{\text{th}}$ percentile for age and sex was used to define abdominal obesity (22). We obtained concurrent information of the following variables: hours watching TV per week (as a proxy for inactivity) and hours of physical activity per week using a validated questionnaire (23).

Other covariates

We identified the presence of maternal obesity ($\text{BMI} \geq 30 \text{ kg}/\text{m}^2$) using the anthropometric measurements at 12 months post-partum. We also created a dummy variable indicating any breastfeeding up to 12 months of age. We estimated socioeconomic status (SES) using the standard criteria of the Asociación Mexicana de Agencias de Investigación (AMAI) which classifies households into six levels according to family income in Mexican pesos per month.

Statistical Analysis

Descriptive data are presented as means (\pm standard deviations) or proportions (depending on the measurement scale of the corresponding variable) and stratified by the age of introduction SSB (χ^2 test and t-test, according to the scale of measure). We tested the normality of the distribution of concurrent SSB consumption with a Shapiro-Wilk test and rejected the hypothesis that it was normally distributed ($p < 0.01$). We performed a test for trend to compare concurrent SSB intake between participants by tertiles of cumulative SSB consumption during the pre-school period. We examined the Spearman correlations between concurrent intake and cumulative SSB consumption.

To assess the relationship between: 1) age of introduction to SSB (≤ 12 months and >12 months) and 2) cumulative consumption of SSB (milliliters, tertiles) during the pre-school period (age 1–5 years) with the odds of obesity at 8–14 years of age, we performed logistic regression both unadjusted and adjusted by: child sex, any breastfeeding up to age 12 months (yes/no), maternal obesity (BMI ≥ 30 kg/m² at 12 months post-partum), concurrent age (years), non-SSB-energy intake (kcal), physical activity (hours/week) and TV watching (hours/week).

All statistical analyses were performed using STATA 11.0 (StataCorp LP, College Station, Texas USA, Copyright 1985–2009).

Results

Characteristics of the study participants are presented in Table 1. Among the 227 participants, 46% were male and the majority (47%) was between 8 and 9 years old. Most participants (73%) were introduced to SSB before 12 months of age and all participants had initiated SSB consumption by age 24 months.

Thirty-one percent of the children were at least partially breastfed through 12 months of age and there were no overweight or obese children. However, at 8 to 14 years, obesity prevalence increased to 22.4% with no statistical difference between sexes (boys 47%, girls 53%, $p = 0.8$). There was a significant correlation between the BMI Z-score at 12 months and the BMI Z-score at 8–14 years ($r = 0.20$, $p = 0.005$).

On average (mean \pm SD), children spent four hours per day (4.0 ± 0.91) watching TV while less than one hour per day (0.82 ± 0.47) was spent on physical activity at age 8–14 years. Average total energy intake was 2,637 (± 844) kcal with SSB contributing 6.7% of total calories. There were no statistically significant differences in the age of introduction SSB by socioeconomic status and 94% of participants had SES corresponding to a monthly family income level less than \$35,000 Mexican pesos (equivalent to approximately \$2,333 U.S. dollars).

Concurrent SSB consumption (ml/day), at 8 to 14 years of age, was positively correlated with the cumulative SSB intake during pre-school period ($r = 0.22$, $p < 0.01$) (Supplemental Figure 1). There were no significant differences in concurrent consumption (median ml/day) of water, milk, sweetened tea or coffee, or natural juices by cumulative SSB intake (in

tertiles) during the pre-school period. However, there was a significant difference in concurrent SSB consumption by tertiles of cumulative SSB intake during preschool period (Table 2). The mean (\pm SD) daily concurrent SSB intake was 333.5 (\pm 293.3) ml, 397 (\pm 340.4) ml and 534 (\pm 387.5) ml, respectively, for the 1st, 2nd and 3rd tertiles (p -trend <0.01). Children in the highest tertile of preschool SSB consumption had the highest concurrent intake of soda at 8–14 years of age (253.8 ± 301.1 ml/d, compared to those in the lowest tertile 121.5 ± 151.6 ml/d, p -trend <0.01). No diet soda intake was reported in our sample.

Early SSB introduction (< 12 months) was associated with increased odds of obesity (OR=2.00, 95% CI: 0.87, 4.59) and abdominal obesity (OR=1.70, 95% CI: 0.70, 4.09) although these results were not statistically significant (Table 3). With increasing cumulative SSB intake during the pre-school period, there was a statistically significant trend for increasing general ($p=0.01$) and abdominal ($p=0.03$) obesity. Children in the highest tertile of cumulative SSB consumption, compared to the lowest tertile of cumulative SSB intake, had almost three times the odds of general (OR=2.99, 95% CI: 1.27, 7.00) and abdominal (OR=2.70, 95% CI: 1.03, 7.03) obesity at age 8–14 years.

Maternal obesity at 12 months post-partum also significantly increased the odds of the child being generally (OR=2.81, 95% CI: 1.32, 5.95) and abdominally (OR=3.97, 95% CI: 1.79, 8.77) obese at 8–14 years of age. Breastfeeding until 12 months of age appeared to decrease the odds of obesity by about 40–50%, but these results were not statistically significant.

Discussion

This study documented the early introduction of SSB in Mexican children's diets and indicated that the cumulative amount of SSB consumed in pre-school period (age 1 to 5 years) was associated with risk of both general and abdominal obesity in later childhood. This is consistent with previous findings that have linked SSB intake to obesity in children (17;24).

Early SSB introduction (< 12 months) was associated with increased odds of obesity although this result was not statistically significant. This could be because almost all (73%) of the children started consumption of SSB at or before 12 months, which implies a small sample size in the category of introduction after 12 months of age. However, we documented that these pre-school habits with respect to SSB intake persist later in childhood. Those participants with the highest concurrent SSB intakes, especially of soda, were children who were in the highest tertile of cumulative SSB consumption in the first years of life, which is also consistent with previous findings (16).

Our results indicate that maternal obesity at 12 months post-partum was also significantly associated with increased likelihood of childhood obesity. This could be due to shared environmental factors, such as similar household diets, or to other yet unknown early life factors that trigger abnormal metabolic responses. Breastfeeding until 12 months of age may protect children against obesity later in life which is plausible because it may delay the introduction of SSB and also diminishes the risks of abdominal adiposity (25). However, our

results indicating about a 40–50% reduction in risk were not statistically significant possibly because only about 30% of the sample received any breastfeeding through 12 months of age and we did not evaluate exclusive breastfeeding.

We found no association between non-SSB energy intake and obesity which could be due to underreporting of dietary intake by overweight or obese participants, which has been demonstrated previously (26). This could also be due to reverse causality, in so far as those children (particularly adolescents) who are overweight or obese may diminish their overall intakes in order to lose weight. Previous reports have shown that not adjusting for total energy in the association between SSB and body weight in children generated larger estimates (27). In our study, we adjusted for non-SSB-energy as a covariate; however, in models excluding this covariate, the results were very similar (data not shown).

One of the limitations is the measurement error associated with the dietary assessment, specifically for the FFQ, as respondents' recall plays a major role in their responses (28). However, the FFQ is the method most applied to measure SSB intake compared with other assessment methods. Also, evaluation of diet in early childhood is complex and potentially contributing to errors is the possibility that dietary habits change rapidly at young ages, parents share their feeding responsibility with other adult caregivers, and children do not necessarily consume all the food they are given (29). Finally, the way in which we constructed our exposure variable (total SSB consumption) assumed that the reported intake was constant during the included months.

Previous cohort studies have reported no association between sweet drink intake and changes in weight or adiposity (30), but in this prospective study, one of the main strengths was the ability to capture children's beverage intakes from the time of first introduction with the use of a series of repeated measures design over the four-year pre-school period. These results confirm previous findings and suggest that delaying the introduction of SSB intake and limiting cumulative SSB consumption in early childhood is an important strategy to help avoid overweight and obesity in later years. New policies of taxing sodas with corresponding nutrition education could be a positive intervention on the population level and should be evaluated in future studies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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What is already known about this subject

- SSB intake during infancy increases the likelihood of consuming SSBs later in childhood and is also associated with increased risk of later obesity
- Less is known about the age of introduction and cumulative consumption of SSB on later childhood obesity risk

What this study adds

- Early SSB introduction (\leq 12 months of age) is associated with increased odds of obesity compared to later SSB introduction ($>$ 12 months of age)
- Higher cumulative SSB consumption during the pre-school period is associated with almost three times the odds of both general and abdominal obesity at 8–14 year of age

Table 1

Characteristics of the participants (N=227)

	Age of Introduction to SSB				p-value
	All (N=227)	12 months (N=166)	>12 months (N=61)		
	Mean (SD) or N (%)	Mean (SD) or N (%)	Mean (SD) or N (%)		
Sex					
Male	104 (46)	75 (45)	29 (47)	0.75	
Female	123 (54)	91 (74)	32 (26)	0.75	
Age					
8–9 years	106 (47)	85 (51)	21 (34)	0.02	
10–11 years	71 (31)	40 (24)	31 (51)	<0.01	
12–14 years	50 (22)	41 (25)	9 (15)	0.10	
Socioeconomic status (SES) level*					
E (\$0 to \$2,699/month)	17 (8)	13 (8)	4 (7)	0.71	
D (\$2,700 to \$6,799/month)	43 (20)	30 (19)	13 (22)	0.63	
D+ (\$6,800 to \$11,599/month)	111 (51.3)	80 (51)	31 (52)	0.83	
C (\$11,600 to \$34,999/month)	42 (19.3)	31 (20)	11 (19)	0.85	
C+ (\$35,000 to \$84,999/month)	3 (1.4)	3 (2)	0	0.28	
A/B (>\$85,000/month)	0	-	-	-	
Obesity (>2 SD BMI Z score)	51 (22)	42 (25.3)	9 (14.7)	0.09	
Waist circumference >90 th percentile	44 (19.4)	35 (21.1)	9 (14.7)	0.28	
TV watching (hours per week)	24.0 (6.4)	23.8 (6.4)	24 (6.1)	0.87	
Physical activity (hours per week)	5.8 (3.3)	5.6 (3.1)	6.2 (3.7)	0.35	
Total energy intake (kcal/day)	2637 (844)	2661 (820)	2571 (910)	0.47	
Non-SSB-energy intake (kcal/day)	2465 (809)	2487 (784)	2406 (877)	0.50	
Percentage of total energy from SSB intake	6.7 (5.5)	6.6 (5.4)	6.2 (5.3)	0.64	
Tap water (ml/day)	522 (452)	553 (476)	437 (372)	0.08	
Whole milk (ml/day)	515 (251)	519 (256)	507 (240)	0.76	
Natural juice (ml/day)	39 (62)	38 (59)	42 (68)	0.71	
Tea or coffee with sugar added (ml/day)	77 (124)	81 (137)	64 (76)	0.35	

	Age of Introduction to SSB				p-value
	All (N=227)	12 months (N=166)	>12 months (N=61)		
	Mean (SD) or N (%)	Mean (SD) or N (%)	Mean (SD) or N (%)		
SSB (ml/day)	421 (352)	426 (348)	403 (364)		0.66
Soda (ml/day)	177 (233)	173 (222)	186 (264)		0.70
Sweetened fruit drinks (ml/day)	244 (275)	253 (283)	217 (255)		0.38
Maternal obesity at 12 months postpartum	47 (21)	34 (20.5)	13 (21.3)		0.89
Partial breastfeeding until 12 months of age	70 (31)	51 (30.7)	19 (31.1)		0.95
Cumulative SSB intake during pre-school period					
1 st tertile (1,642 – 15,242 mL)	78 (34.4)	53 (32)	25 (41)		0.20
2 nd tertile (15,410 – 22,484 mL)	74 (32.6)	55 (33)	19 (31)		0.77
3 rd tertile (22,731 – 55,913 mL)	75 (33)	58 (35)	17 (28)		0.31

* According to the Asociación Mexicana de Agencias de Investigación (AMAI) levels for family income in Mexican pesos per month (N=11 missing information on SES level)

Concurrent beverage consumption (mL/day) by tertiles of cumulative SSB intake during the pre-school period (N=227)

Table 2

Concurrent Beverage Consumption (ml/day)	Cumulative SSB Intake								
	1 st tertile (N=78)			2 nd tertile (N=74)			3 rd tertile (N=75)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p-trend
Tap water	513.5	448.0	536.1	416.5	517.3	494.4	0.98		
Whole milk	480.7	250.5	511.7	205.8	555.7	287.3	0.09		
Natural Juice	32.1	54.2	50.3	73.4	35.4	55.8	0.68		
Tea or coffee with sugar added	62.5	103.0	90.8	155.3	77.9	108.7	0.48		
SSB (soda + sweetened fruit drinks)	333.5	293.3	397.0	340.4	534.0	387.5	<0.01		
Soda	121.5	151.6	157.3	205.9	253.8	301.1	<0.01		
Sweetened fruit drinks	212.0	250.1	239.8	265.5	280.2	307.5	0.33		

Odds Ratio (95% CI) for obesity and abdominal obesity at 8–14 years of age by: age of introduction to SSB, cumulative intake of SSB (tertiles) during the pre-school period, and covariates (N=227)

Table 3

	Obesity (>2 SD BMI Z score)		Abdominal Obesity (WC >90th percentile)	
	Unadjusted OR	Adjusted 95% CI	Unadjusted OR	Adjusted 95% CI
Age of Introduction to SSB				
>12 months	ref	-	ref	-
12 months	1.86	0.83, 4.18	2.00	0.87, 4.59
			1.45	0.64, 3.28
Cumulative SSB intake				
1 st tertile (1,642 – 15,242 mL)	ref	-	ref	-
2 nd tertile (15,410 – 22,484 mL)	0.84	0.34, 2.02	0.84	0.32, 2.13
3 rd tertile (22,731 – 55,913 mL)	2.69	1.25, 5.79	2.99	1.27, 7.00
			2.29	1.01, 5.19
Covariates				
Sex (female)	0.84	0.42, 1.67		2.02
Age (years)	0.91	0.72, 1.14		0.83
Non-SSB-energy intake (per 100 kcal/d)	0.99	0.99, 1.00		0.99
TV watching (hours per week)	1.01	0.95, 1.06		1.04
Physical activity (hours per week)	0.96	0.85, 1.08		0.89
Breastfeeding up to 12 months of age	0.59	0.27, 1.26		0.44
Maternal obesity at 12 months postpartum	2.81	1.32, 5.95		3.97
				1.79, 8.77