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Association between type, amount and pattern of carbohydrate consumption with dental caries in 12-year-olds in Puerto Rico

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Abstract

Objective—To identify the types, food sources, and pattern of carbohydrates that significantly contribute to dental caries in Puerto Rican children.

Methods—As part of an island-wide oral health cross-sectional study in 1,587 12 years-olds, diet intake was assessed in a representative subset (n=801) with a 24-hr dietary recall. Carbohydrates' intake was quantified using a computer-based diet analysis program. Caries was assessed using the NIDCR diagnostic criteria. Odds ratios were used to associate carbohydrate intake quartiles with caries, after controlling for important confounders.

Results—A total of 723 subjects had complete data. Most were females (54%) and attended public schools (77%). Caries prevalence was 33%. The highest quartile intake for the following sugars significantly increased the odds of caries compared to the lowest quartile: total carbohydrates (OR=1.93, 95% CI: 1.08–3.46), total sugars (OR=1.88, 95% CI: 1.01–3.51), sucrose (OR=2.05, 95% CI: 1.13–3.70), fructose (OR=1.95, 95% CI: 1.05–3.62) and inositol (OR=2.52, 95% CI: 1.38–4.63). The main food sources of these sugars were juices, including natural juices with no added sugars, and sweetened beverages. The odds of caries also increased significantly in children whose 10% of total energy intake was from total sugars (OR=3.76, 95% CI: 1.03–13.7).

Conclusion—After adjusting for important caries risk factors, total carbohydrates, total sugars, 10% kcal from total sugars, sucrose, fructose and inositol intake significantly increased caries risk. Our findings can help raise awareness about the potential caries risk of the main sources of these sugars, natural fruit juices and sweetened beverages, which are highly consumed in many societies.

Keywords

Dental caries; carbohydrate; sugars; sucrose; fructose; inositol; Hispanic; children

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Declaration of Interests

All authors read and approved the final manuscript. None of the authors have a conflict of interest.

Introduction

Dental caries is one of the most common health problems worldwide [Islam et al., 2007]. In the United States (US), 58% of adolescents 12–15 years have caries in their permanent teeth [Dye et al., 2015]. In Puerto Rico (PR), this prevalence is higher, 61% among 12-year olds [Elias-Boneta et al., 2016], which may be attributed to several factors, such as the lack of a fluoridation program [Elias-Boneta et al., 2016], dietary patterns, among others. Dental caries can have important clinical complications depending on its severity and whether or not they are treated early [Konig and Navia, 1995]. Untreated tooth decay leads to pain and infections of the maxillofacial region, but it can also impact the person's diet, esthetics and quality of life [Newbrun, 1983].

Dental caries is a disease with a multifactorial etiology; consumption of dietary carbohydrates is one of the most important etiological factors as they are processed by bacteria in the dental plaque via the glycolytic pathway producing acids, mainly lactate [Konig and Navia, 1995]. Frequent and prolonged exposure of the teeth to dietary carbohydrates generates an acidic plaque environment, which promotes the demineralization of the dental enamel, causing caries. In addition, frequent consumption of simple carbohydrates promotes the overgrowth of cariogenic bacteria in the dental plaque, such as the mutans streptococci and the lactobacilli, as these are more resistant to acidic environments than the less cariogenic species [Marsh, 1991]. This explains how diets rich in sugars increase the risk of caries [Campain et al., 2003]. In fact, the World Health Organization in 2015 published a guideline on sugar intake, recommending an intake of free sugars (includes added sugars as well as sugars naturally present in fruit juices as well as fruit juice concentrates) below 10% of total energy intake [WHO, 2015]. This recommendation was based on an analysis of cohort studies in children showing higher rates of dental caries with greater than 10% of total energy intake from free sugars compared to less than 10%.

The cariogenic potential of a carbohydrate depends mainly on how efficiently it can be metabolised by oral bacteria through the glycolytic pathway, which is reflected by the intensity of acidification that it induces in dental plaque [Maehara et al., 2005]. For example, monosaccharides such as glucose and fructose can enter the glycolytic pathway directly after being converted to fructose-1,6-biphosphate, while more complex carbohydrates such as starch, first need to be broken down into more simple sugars before entering glycolysis. Consequently, glucose and fructose induce a faster and more pronounced pH drop in the dental plaque than starch, and are more cariogenic [Bibby and Krobicka, 1984]. The milk sugar lactose produces a smaller pH drop in plaque compared to glucose, fructose, and sucrose; consequently, milk is less cariogenic [Johansson and Lif Holgersson, 2011]. Table sugar (sucrose) is considered the most cariogenic sugar, not only because it usually produces the most pronounced pH drop in plaque, but also because it can serve as a substrate for the synthesis of extracellular (EPS) and intracellular (IPS) polysaccharides by oral bacteria [Lingstrom et al., 2000; Newbrun, 1967; Bowen, 2002]. The insoluble glucans can facilitate bacterial adherence [Schilling and Bowen, 1992] and can increase the porosity of the plaque, which allows sugar and bacteria to diffuse deep along the tooth structure [Shellis and Dibdin, 1988], forming a “sticky” plaque compared to the plaque formed in the absence of

sucrose. These polysaccharides can increase the formation and the adhesion of plaque on the teeth, and they can prolong the acidification in the plaque at times when there are no carbohydrates available from the diet. These differences in the cariogenic potential of sugars have been tested mainly in *in vitro* and *ex vivo* studies.

Although a vast body of literature demonstrates the almost linear dose-response relationship between sugar consumption and dental caries [Moynihan and Kelly, 2014; Sheiham and James, 2014a; Sheiham and James, 2014b], to our knowledge, no epidemiologic studies have evaluated the types of sugars, their food sources, and pattern of consumption in relation to dental caries at a population level in children [Moynihan and Kelly, 2014]. Therefore, this study evaluated the relationship between type, amount and pattern of carbohydrate consumption with dental caries in 12-year-old children.

Materials and Methods

Study Design and Participants

Data for the present study were drawn from an island-wide cross-sectional study designed to examine oral health, dietary practices, and weight status in a sample of 1,587 12 year-old children in Puerto Rico in 2010–2011. A probabilistic stratified sample of children from 133 schools, stratified by gender, was used from the different regions of Puerto Rico as published previously [Elias-Boneta et al., 2016]. From this sample, a representative and subset sample completed a 24-h dietary recall. This was done by randomly selecting 50% of the participants within each school (n=796). The study was approved by the Institutional Review Board of the Medical Sciences Campus of the University of Puerto Rico. Parents signed a consent form and children assented to participate in the study.

Socio-demographics and health

Participants completed a questionnaire with information on socio-demographics and on frequency of brushing, flossing and use of mouthwash. Trained staff measured children's weight and height following the NHANES III procedures [Centers for Disease Control and Prevention, 2011], while children wore their uniforms (without socks, shoes, and accessories). Body Mass Index (BMI) was calculated as kg/m². Weight status was classified according to the Center for Disease Control and Prevention's age and gender specific growth charts [Center for Disease Control and Prevention, 2010]. Underweight children (<5th percentile for BMI) were excluded.

Dietary Assessment

Participants completed a 24-hour dietary recall interview by trained personnel. Participants were asked about their intake of all the foods and beverages consumed during the previous day, the time and place of consumption of each meal, quantity of each ingredient, preparation or brands, and use of seasonings, dressings, sauces, butter and sugar. For estimation of portion sizes, we used a booklet with black and white drawings of actual serving portions [Friedman et al., 2012]. Data was analyzed using the Windows-based dietary analysis program "Nutrition Data System for Research software" (version 2011, Nutrition Coordinating Center, University of Minnesota, MN). We here report the following:

- Total carbohydrates, which is approximately equal to the sum of available carbohydrates (starch and sugars) and dietary fiber.
- Total sugars, which included sugars naturally present in foods as well as “Added sugars”.
- Added sugars, which includes those sugars and syrups added to foods during food preparation or commercial food processing, such as sucrose, brown sugar, powdered sugar, honey, molasses, pancake syrup, corn syrup, high fructose corn syrup (HFCS, a sweetener made by industry from corn starch added to sweetened beverages and other sweetened foods), invert sugar, invert syrup, malt extract, malt syrup, fructose, glucose, galactose and lactose
- Starch, which includes dextrin and glycogen.
- Total dietary fiber, which includes unavailable carbohydrates (cellulose, hemicellulose, pectins, gums, and mucilages) and lignin.
- Artificial sweeteners.
- Monosaccharides: glucose, fructose, and galactose
- Disaccharides: sucrose, lactose, and maltose
- Sugar alcohols, which are less sweet than sugar; some occur naturally in foods and others are added as sweeteners to food products. These are: erythritol, inositol, isomalt, lactitol, maltitol, mannitol, pinitol, sorbitol and xylitol.

Dental clinical exams

Clinical oral health examinations were performed using the National Institute of Dental and Craniofacial Research (NIDCR) diagnostic criteria [National Institute of Dental Research. Epidemiology and oral disease prevention program, 1991] by two trained and calibrated dentists and conducted in two mobile examination units, as previously described [Elias-Boneta et al., 2016]. For the present analysis, we used the decayed component (DT) of the Decayed, Missing, Filled Tooth index, which detects the teeth with present and past caries experience at the time of the examination. The DT scores for each subject were organized into two categories: 0 (caries-free children) and 1 (untreated caries) [National Institute of Dental Research, 1991].

Statistical Analysis

All analyses accounted for sampling methods (sample was stratified by GHI regions and clustered within schools), using weights inversely proportional to the probability of selection, adjusted for non-response, and later normalized, as previously described [Elias-Boneta et al., 2016]. Descriptive statistics were used to describe the distribution of the study variables. Since the consumption of different sugars within two caries groups was not normally distributed, the non-parametric Wilcoxon test was used to compare the intake levels by DT categories. For multivariate analysis, quartiles of sugar intake levels were derived based on the distribution of the intake levels among non-underweight children (children above the 5th percentile for BMI). Logistic regression was used to evaluate the

association between quartiles of sugar intake and DT, adjusting for important confounders including age, gender, type of school (public vs. private), region (which was regrouped into 3 regions: San Juan Metropolitan Area, Central/Mountain, and Coastal) in model 1, and additionally for health insurance (government-provided insurance, private, none), BMI (3 categories) and oral hygiene practices (tooth brushing in 4 categories, flossing in 3 categories, and mouthwash use in 3 categories) in model 2. Odds ratios (OR) and 95% confidence intervals (CI) were reported. For sugars that had a suggestion of a dose-response relation between the quartiles of sugar and odds of untreated caries (based on OR estimates for second, third and fourth quartiles, respectively), we additionally explored the possibility of a linear relationship, treating the quartiles as a continuous variable.

Logistic regression was also used to evaluate the association between percent of total energy (kcal) intake from sugars and DT, using quartiles, as well as using the cut-off point recommended by the WHO (<10%)[WHO 2015]. Although the NDSR Program provides estimates for “Total sugars” as well as “Added sugars”, we used the former to match the WHO definition of “Free sugars”. “Total Sugars” includes all sugars in foods, including added sugars and sugars from fruit juices and fruit juice concentrate as well as sugars present in other foods such as fruits (which was very low in our sample) while “Added sugars” does not include sugars from fruit juices and fruit juice concentrate (which was very high in our sample). In addition, there are inherent problems on how NDSR calculates “Added sugars”, as in some cases the program provided unreliable estimates of percent of total energy (kcal) intake from these (i.e. higher than 100%).

In addition, we explored the patterns of sugar intake throughout the day, comparing intake levels at different times of the day (breakfast, lunch, afternoon snack(s), dinner, bedtime snack) from children with and without caries using the Wilcoxon test. All analysis was limited to schoolchildren with no missing information on confounders (final N=723). All statistical analyses were performed using SAS software (Version 9.3, SAS Institute, Cary, NC); a p-value of 0.05 was considered statistically significant.

Results

A total of 801 participants completed the dietary recalls. From these, we excluded 46 underweight children, 31 children with incomplete data; therefore, a total of 723 subjects were included in the analysis. Most participants were females (54%), attended public schools (77%), had insurance (95%), brushed their teeth at least once a day (80%), flossed (80%) and used mouthwash (74%) (Table 1). Caries prevalence was 33%, which was higher among children from public schools and among those who did not brush and use mouthwash frequently ($p<0.05$).

Table 2 shows the association of carbohydrate intake with caries status. After adjusting for gender, type of school, insurance type, BMI, and oral hygiene practices, children in the highest quartile of total carbohydrates intake (>260 g/d) had higher odds of caries (OR=1.93, 95% CI: 1.08–3.46), compared to those in the lowest quartile (<155 g/d). In addition, children in the highest quartile of total sugars intake (>141 g/d) had higher odds of caries (OR=1.88, 95% CI: 1.0–3.46), compared to those in the lowest quartile (<69 g/d). Also,

those in the highest quartile of percent of energy (kcal) intake from total sugars (>32.1%) had higher odds of caries (OR=2.02, 95% CI 1.06–3.86), compared to the lowest quartile (<19.67%). When using the WHO cut-off point of 10% kcal from total sugars, those with 10% energy had significantly higher odds of caries (OR 3.76, 95% CI 1.03–13.7) compared to those below the cut-off. Being in the highest quartile of sucrose intake (>52 g/d) was also associated with had higher odds of caries (OR=1.98, 95% CI: 1.10–3.57), compared to the lowest quartile (<21 mg/d). We also found a significant association with fructose intake; those consuming fructose in the highest quartile (>39 g/d) had higher odds of caries (OR=1.92, 95% CI: 1.04–3.56), compared to those in the lowest quartile (<15 g/d). Quartiles of fructose distribution were also linearly associated with higher odds of caries (OR=1.24, 95% CI: 1.02–1.51). Inositol consumption was also significantly associated with caries; those in the highest quartile of inositol intake (>7.6 mg/d) had higher odds of caries (OR=2.54, 95% CI: 1.38–4.67), compared to those in the lowest quartile (<2.4 mg/d). With each increase in the quartile of inositol distribution, the odds of caries were 1.38 higher (95% CI: 1.13–1.68).

Figure 1 shows the top main food sources of the sugars that were significant in the multivariate model. For sucrose, the main sources were juices (mainly fruit punch and other fruity drinks), but also sweetened beverages (mainly sweetened tea and orange or lemon flavored sodas) and desserts (i.e. cookies, cakes, donuts, pancakes). For fructose, the main sources were sweetened beverages, such as sodas (cola and lemon flavored), fruit drinks (apple, grape, and cranberry juices), sweetened tea and 100% fruit juices. For inositol, the main source was orange juice (89%). In addition, we compared the consumption of these beverages by DT. Juice intake was higher in those with caries (1.1 servings/d) compared to those caries free (0.93 servings/d; $p=0.06$). Sweetened beverages intake was also higher in those with caries (1.94 servings/d) compared to those caries free (1.67 servings/d; $p<0.05$).

Figure 2 shows the sugar intake pattern throughout the day. The intake of total sugars, sucrose and fructose was higher among those with caries at 3pm and 5pm ($p<0.05$). Inositol consumption was high early in the morning and then again late at night, particularly in those with caries, but these differences were not significant between groups.

Discussion

This analysis in a representative large sample of 12-year-old Hispanic children living in Puerto Rico showed that children with high intake of total carbohydrates (>257 g/d), total sugars (>135 g/d), percent of energy from total sugars higher than recommended (<10%), intake of sucrose (>52 g/d), fructose (>37.6 g/d), and inositol (>0.09 mg/d) had significantly higher odds of caries compared to those with the lowest intake.

This study was able to confirm the recommendation of the WHO on limiting the intake of sugars to below 10% of total energy intake for preventing caries. Children consuming 10% of total energy intake from total sugars had almost 4 times greater odds of caries. These results have to be interpreted with caution, because we used “total sugars” instead of “free sugars”. The difference between “free sugars”, as defined by WHO, and our “total sugars” estimates is that “total sugars” includes sugars naturally present in solid fruits and

vegetables. However, since the consumption of fresh fruits and vegetables in our population was extremely small (approximately less than 2% of total energy intake) the values of “total sugars” in our study are very close to the “free-sugar” definition of WHO. When we used “added sugars” in our analyses, no significant association was observed with caries experience. As previously explained, this may be due to inherent problems of the NDSR software in the calculation of this variable.

Sucrose is considered to be more cariogenic than glucose and fructose because it can serve as a substrate for the synthesis of EPS and IPS, which lead to increased biofilm accumulation and prolonged acidification [Tinanoff and Palmer, 2000]. However, we also found that the intakes of fructose and inositol were significantly associated with caries, in a dose-response manner. The cariogenicity of fructose has been established in *in vitro* and *in vivo* models [Scheinin et al., 1976; Bowen et al., 1990; Lingstrom et al., 2000], but, to our knowledge, its relationship with caries has never been shown on a population level. Fructose is naturally found in honey, fruits and vegetables. However, in our sample, the main food sources of fructose were not these natural foods, but soda and other sweetened beverages, which were consumed very frequently in the sample. The form of fructose commonly used by industry for these beverages is HFCS. This type of sugar has been shown to have detrimental effects on health [Sobel and Dalby, 2014; Chan et al., 2014]. Recent *in vitro* studies have shown that HFCS has a higher acidogenic potential than sucrose [Ma et al., 2013]. Furthermore, even though *S. mutans* does not utilize HFCS as a substrate for EPS synthesis, it appears that HFCS has a significant influence on the expression of biofilm-associated genes, especially *gtfB*, and it can, therefore, enhance *S. mutans* biofilm formation indirectly in the presence of sucrose [Sun et al., 2014]. Based on these observations, we believe that the association we observed between fructose and caries in our sample was mostly due to the detrimental effects of HFCS.

An interesting and novel finding in our study was the association of inositol with caries, which also followed a dose-response pattern. Inositol is polyhydric alcohol with a chemical structure similar to glucose. Some enteric bacteria have been shown to ferment inositol to acids, including lactic acid [Anderson and Magasanik, 1971; Field et al., 1953], but to the best of our knowledge, its metabolism by oral bacteria and its role in caries development have never been evaluated. In our sample, inositol intake was very minimal in comparison to the other sugars, and its main food source was orange juice. Orange juice contains a large amount of sugars, such as fructose (22–31g/L), glucose (18–31g/L), and sucrose (22–50g/L) [Navarro-Pascual et al., 2015], and, consequently, it is highly cariogenic [Mahajan et al.; Saeed and Al-Tinawi, 2010]. In addition, other fruit juices, such as apple, pineapple, and grape have high sugar content and are highly acidogenic [Navarro-Pascual et al., 2015; Mahajan et al.], as high as sucrose. These observations suggest that in contrast to the common belief, fruit juices without added sugar should not be considered safe, or harmless for the teeth.

Intake of total sugars, sucrose and fructose were significantly higher in children with caries during the afternoon snacks. Other studies have found significant associations between the frequency of consumption of snacks, of foods high in sugars and the number of eating occasions with caries risk [Chankanka et al., 2011; Jaghasi et al., 2012; Marshall et al.,

2005]. Also, inositol intake was higher during the morning and just before bedtime, particularly among children with caries, but no significant differences were seen between groups. It is likely that children with caries were consuming orange juice and not cleaning their teeth, creating an acidic environment to act on the dental enamel. However, to our knowledge, this is the first study to assess the amount of these nutrients consumed at different times during the day.

Consumption of juices and sweetened beverages has increased significantly in many modern societies and it has been linked to health problems, including obesity and diabetes [Malik et al., 2010]. Our results indicate that fruit juices (with and without added sugars) and sweetened beverages were the main sources of the sugars. These findings add to an increasing body of evidence suggesting that the high intake of these drinks may be responsible for the prevalence of dental caries in modern societies [Lee and Messer, 2010; Lee and Brearley Messer, 2011]. This highlights the potential risks of these seemingly “innocent” and presumably “healthy” popular drinks (juices) for the oral health of children.

To our knowledge, this is the first published study that evaluates the types of sugars, their food sources, and pattern of consumption in relation to dental caries at a population level in children. However, some limitations should be considered in the interpretation of the results. Dietary patterns were assessed with a single 24-h recall; however, at the population level, a single 24-h recall can be used to assess dietary intake to examine its association with an independent variable (e.g., caries) [National Cancer Institute, 2014]. Among the strengths of the study, we included a large representative sample of children, stratified by gender, school type and region and the research staff was trained to perform the assessments with calibrated standardized methods.

In conclusion, this study showed that after adjusting for important caries risk factors, the consumption of total carbohydrates, total sugars (and intake from total sugars 10% of total kcal intake), sucrose, fructose, and inositol significantly increased the odds of caries in this sample. The main food sources of these sugars were 100% fruit juices and sweetened beverages. In addition, these cariogenic sugars appear to be consumed more often during the afternoon snacks. Our findings are novel, important, and with clinically relevant information that can help raise awareness about potential dietary sources of cariogenic sugars in children that may be partially responsible for the higher prevalence of dental caries in this population. It can also raise awareness to other populations as these drinks are highly consumed in many modern societies. In light of these results, it is imperative to test the cariogenic effects of HFCS, the main source of fructose used in many of these sweetened beverages.

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The authors' contributions were as follows—AREB, SRT, and CP: designed research; AREB: supervised data collection; AMC and RYT entered data; SRT and CP: analyzed data; CP, AREB and EMB: wrote the paper. CP: had primary responsibility for final content.

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Figure 1.

Main sources of total carbohydrates, total sugars, sucrose, fructose and inositol in the sample (g/d) by caries status.

Figure 2.

Pattern of total carbohydrates, total sugars, sucrose, fructose and inositol intakes during the day by caries status. *Significantly different from DT=0 (caries free) by T-test ($p<0.05$).

Table 1

Demographic characteristics of participants by caries status

Characteristic	All (n=723)		DT=0 (n=481)		DT 1 (n=242)	
	n	%	n	%	n	%
Gender						
Male	331	46	217	45	114	47
Female	392	54	264	55	128	53
School Type¹						
Public	560	77	354	74	206	85
Private	163	23	127	26	36	15
School's Region						
San Juan-Metro	318	44	207	43	111	46
Coast	325	45	218	45	107	44
Mountain	80	11	56	12	24	10
Relative weight						
Healthy weight (5 th – <85 th percentile)	416	58	268	56	148	61
Overweight (85 th – <95 th percentile)	136	19	91	19	45	19
Obese (95 th percentile)	171	24	122	25	49	20
Insurance type						
Government-issued	371	51	234	49	137	57
Private	320	44	224	47	96	40
None	32	4.4	23	4.8	9	3.7
Tooth brushing frequency²						
Three or more times a day	108	15	70	15	38	16
Twice a day	209	29	148	31	61	25
Once a day	260	36	172	36	88	36
Less than once a day or never	146	20	70	19	55	23
Mouth wash frequency³						
More than once a day	202	28	138	29	64	26
Once a day	330	46	224	47	106	44

Characteristic	All (n=723)		DT=0 (n=481)		DT=1 (n=242)	
	n	%	n	%	n	%
Less than once a day or never	191	26	119	25	72	30
Flossing frequency						
More than once a day	260	36	163	34	97	40
Once a day	318	44	207	43	111	46
Less than once a day or never	145	20	111	23	34	14

DT: decayed teeth.

- ¹Significantly higher caries prevalence among children from public schools compared to private schools (chi-square p<0.05);
- ²Significantly higher caries prevalence among children who did not brush frequently (chi-square p<0.05);
- ³Significantly higher caries prevalence among children who did use mouthwash frequently (chi-square p<0.05).

Table 2

Odds ratios (ORs) and 95% confidence intervals (CIs) for the association between quartiles of carbohydrate intake and caries status (DT>0 vs. DT=0)

Type of carbohydrate	Model 1		Model 2	
	OR	95% CI	OR	95% CI
Total carbohydrates				
Quartile 1 (<156 g/d)	1	–	1	–
Quartile 4 (>260 g/d)	1.83	(1.02–3.25)	1.93	(1.08–3.46)
Total sugars				
Quartile 1 (<69 g/d)	1	–	1	–
Quartile 4 (>141 g/d)	1.80	(0.98–3.30)	1.88	(1.0–3.46)
% Energy (kcal) from total sugars				
Quartile 1 (19.67 %)	1	–	1	–
Quartile 4 (> 32.1%)	2.08	(1.13–3.82)	2.02	(1.06–3.86)
<10%	1	–	1	–
10%	4.8	(1.16–14.38)	3.76	(1.03–13.7)
Added sugars				
Quartile 1 (<44 g/d)	1	–	1	–
Quartile 4 (>111 g/d)	0.87	(0.47–1.61)	0.95	(0.51–1.76)
Starch				
Quartile 1 (<60 g/d)	1	–	1	–
Quartile 4 (>103 g/d)	0.93	(0.52–1.67)	0.96	(0.53–1.72)
Total dietary fiber				
Quartile 1 (<5.4 g/d)	1	–	1	–
Quartile 4 (>10.6 g/d)	1.01	(0.56–1.85)	0.99	(0.54–1.82)
Pectins				
Quartile 1 (0.42 g/d)	1	–	1	–
Quartile 4 (>1.51 g/d)	0.85	(0.46–1.57)	0.83	(0.44–1.57)
Fructose				
Quartile 1 (<15 g/d)	1	–	1	–
Quartile 4 (>39 g/d)	1.71	(0.92–3.17)	1.92	(1.04–3.56)
Galactose				
Quartile 1 (4.9 mg/d)	1	–	1	–
Quartile 4 (>49.9 mg/d)	1.14	(0.63–2.06)	1.33	(0.73–2.34)
Glucose				
Quartile 1 (14 g/d)	1	–	1	–
Quartile 4 (>39 g/d)	1.21	(0.66–2.21)	1.32	(0.73–2.43)
Lactose				
Quartile 1 (<3.08 g/d)	1	–	1	–
Quartile 4 (>20 g/d)	0.98	(0.52–1.89)	0.95	(0.50–1.81)
Maltose				
Quartile 1 (0.59 g/d)	1	–	1	–

Type of carbohydrate	Model 1		Model 2	
	OR	95% CI	OR	95% CI
Quartile 4 (>2.46 g/d)	0.91	(0.50–1.65)	0.95	(0.51–1.75)
Sucrose				
Quartile 1 (<21 g/d)	1	–	1	–
Quartile 4 (>52 g/d)	1.91	(1.05–3.45)	1.98	(1.10–3.57)
Sucralose				
No (0 mg/d)	1	–	1	–
Yes (>0 mg/d)	6.88	(1.23–38.5)	2.79	(0.60–13.0)
Inositol				
Quartile 1 (2.4 mg/d)	1	–	1	–
Quartile 4 (>7.6 mg/d)	2.43	(1.32–4.49)	2.54	(1.38–4.67)
Erythritol				
No (0 mg/d)	1	–	1	–
Yes (>0 mg/d)	1.10	(0.48–2.51)	1.08	(0.47–2.47)
Maltitol				
No (0 mg/d)	1	–	1	–
Yes (>0 mg/d)	10.6	(0.83–137)	5.15	(0.47–56.0)
Mannitol				
Quartile 1 (5.5 mg/d)	1	–	1	–
Quartile 4 (7.6 mg/d)	0.78	(0.42–1.44)	0.81	(0.43–1.49)
Pinitol				
No (0 mg/d)	1	–	1	–
Yes (>0 mg/d)	1.17	(0.66–2.06)	1.11	(0.64–1.92)
Sorbitol				
Quartile 1 (0 mg/d)	1	–	1	–
Quartile 4 (1.3 mg/d)	0.86	(0.45–1.63)	0.80	(0.42–1.52)
Xylitol				
Quartile 1 (0 mg/d)	1	–	1	–
Quartile 4 (2.6 mg/d)	1.09	(0.65–1.81)	1.08	(0.65–1.82)
Aspartame				
No (0 g/d)	1	–	1	–
Yes (>0 g/d)	0.47	(0.17–1.31)	0.41	(0.15–1.15)

Model 1: Adjusted for gender (male, female), type of school (public, private) and region (San Juan Metropolitan, Coastal, Central); Model 2: adjusted for gender, type of school, region, insurance (government-provided insurance, private, none), relative weight (obese, overweight, healthy weight) and frequency of brushing (less than once a day/never, once a day, twice a day, 3 or more times a day), flossing (less than once a day/never, once a day, more than once a day) and mouthwash use (never, once a day, more than once a day).