RESEARCH

Cariogenicity of soft drinks, milk and fruit juice in low-income African-American children

A longitudinal study

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ABSTRACT

Background. The authors conducted a study to test the hypothesis that high consumption of soft drinks, relative to milk and 100 percent fruit juice, is a risk factor for dental caries in low-income African-American children in Detroit.

Methods. Trained dentists and interviewers examined a representative sample of 369 children, aged 3 to 5 years, in 2002-2003 and again two years later. The authors used the 2000 Block Kids Food Frequency Questionnaire (NutritionQuest, Berkeley, Calif.) to collect dietary information. They assessed caries by using the International Caries Detection and Assessment System.

Results. Soft drinks, 100 percent fruit juice and milk represented the sugared beverages consumed by the cohort. A cluster analysis of the relative proportion of each drink at baseline and follow-up revealed four consumption patterns. Using zero-inflated negative binomial models, the authors found that children who changed from being low consumers of soft drinks at baseline to high consumers after two years had a 1.75 times higher mean number of new decayed, missing and filled tooth surfaces compared with low consumers of soft drinks at both time points.

Conclusion. Children who consumed more soft drinks, relative to milk and 100 percent fruit juice, as they grew older were at a greater risk of developing dental caries.

Clinical Implications. Health promotion programs and health care providers should emphasize to patients and caregivers the caries risk associated with consumption of soft drinks.

Key Words. Cariogenicity; soft drinks; low-income children; caries.
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Beverage intake in children in the United States has become more diverse and extensive during the last several decades,[1,2] and the increasing consumption of sugared drinks among children has raised concerns in the public health community.[1,3,4] Some of these concerns center on the risk of dental caries. Cariogenic bacteria need simple carbohydrates to produce the organic acids that initiate the carious process in enamel,[5] so the concern is that an increased intake of drinks containing sugar may increase the risk of developing dental caries.

Kolker and colleagues[6] found that the three sugared drinks most consumed by low-income African-American children in Detroit were soft drinks (defined here as soda plus fruit drinks), milk and 100 percent fruit juice. Using a cross-sectional analysis, they demonstrated that high consumption of soft drinks in the presence of gingival plaque deposits was significantly related to caries in low-income children[6] and adults.[7] These findings confirmed those of previous

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cross-sectional studies of the cariogenic potential of soft drinks.[1,3] Milk is considered to have low cariogenic potential,[8] while 100 percent fruit juice, which contains about the same amount of sugar as soft drinks,[3] can be cariogenic if consumed frequently.[9,10] The cariogenicity of sugared drinks is determined not only by their potential to induce demineralization of enamel, but also by the frequency of consumption.[11]

The aims of this longitudinal study were to identify the intake patterns of soft drinks, milk and 100 percent fruit juice among low-income black children over a two-year period and to investigate the association between these patterns and the development of new carious lesions. The study tested the hypothesis that children with a high consumption of soft drinks, relative to milk and 100 percent fruit juice, over two years were at a higher risk of developing new carious lesions.

SUBJECTS AND METHODS

Study population. Data used in this analysis were collected as part of the Detroit Dental Health Project, a longitudinal study designed to investigate why some low-income black children and their caregivers have better oral health than others, even when socioeconomic and environmental conditions appear similar. [6,7,12-14] The rationale for this study is based on the hypothesis that understanding the determinants of intracommunity disparities provides better insights for designing interventions to promote oral health in the communities in which oral or dental disease levels are high.[6,7,12-14]

The sampling design consisted of a stratified two-stage area probability sample of households from the 39 census tracts with the highest proportion of low-income residents in the city of Detroit. To be eligible for the study, households needed to have a black child aged up to 5 years, and the family's income needed to be lower than the 250th percentile of the federal poverty guidelines. Power calculations showed that we needed 994 families to complete data collection for the project. Among contacted households, 1,386 families were eligible. Of these families, 1,021 dyads of child and caregiver completed the baseline dental examination and interviews in 2002-2003 (response rate = 74.0 percent). Details of the sampling and data collection procedures are described elsewhere.[7,14] At the two-year follow-up visit in 2004-2005, 790 dyads of child and caregiver (77.0 percent) returned to complete an interview and a clinical examination.

This study focused on children 3 years and older at baseline (n = 522) for whom follow-up data were collected (n = 403). We omitted from these analyses children who were 2 years and younger at baseline because no data regarding their beverage consumption were collected. We excluded 34 additional children because of implausible dietary intakes, leaving a final sample of 369 children.

The Institutional Review Board for Health Sciences at the University of Michigan, Ann Arbor, reviewed and approved the study each year. All caregivers or legal guardians signed consent forms for all children in this study.

Data collection. One of four dentists (W.S. and three others) examined the children in this study at the Dental Assessment Center in Detroit. They used a portable dental chair and halogen light.[7] They cleaned the teeth of loose debris and dried them using an air syringe. The dentists assessed the caries status of all primary tooth surfaces using the International Caries Detection and Assessment System.[15] The reliability of the examiners ranged from good to excellent (κ coefficients = 0.59-0.82).[16] In particular, the interexaminer reliability for the decision regarding the stage of dental caries was 0.63 to 0.78, indicating good reliability of the examiners in terms of identifying noncavitated surfaces.[16]

Caries severity. We counted the numbers of noncavitated surfaces (d_1), cavitated/dentinal surfaces (d_2), filled surfaces (f) and missing surfaces owing to caries (m) for each child. We computed the following four indexes to evaluate caries severity in the primary dentition: d_1, d_2, $d_2$mfs ($d_2 + f + m$) and $d_t$mfs ($d_1 + d_2 + f + m$).[14]

We classified the few sealed surfaces detected as sound. We compared the caries status of each tooth surface at follow-up with the status at baseline and assessed caries increments for each child. We adjusted the increments of d_2, f and m surfaces for reversals due to examiner misclassifi-

ABBREVIATION KEY. d_1: Noncavitated surfaces. **d_2:** Cavitated/dentinal surfaces. **$d_t$mfs:** Noncavitated surfaces, cavitated/dentinal surfaces, missing owing to caries, filled surfaces. **f:** Filled surfaces**. FFQ:** Food Frequency Questionnaire. **IRR:** Incidence rate ratio. **m:** Missing surfaces owing to caries. **PAM:** Partitioning around medoids. **s**: Surfaces. **ZINB:** Zero-inflated negative binomial regression.

cation by using the prevalence-based adjustment formula.[17] We did not carry out any adjustment for new d_1 scores, because noncavitated surfaces at baseline could regress naturally. The resulting outcomes included the increments of d_1, d_2, f and m surfaces, as well as $d_2$mfs and $d_t$mfs.

We collected dietary information for children 3 years and older by using the 2000 Block Kids Food Frequency Questionnaire (Kids FFQ) (NutritionQuest, Berkeley, Calif. [formerly Block Dietary Data Systems]). Trained interviewers administered the questionnaire in person. The reliability of the FFQ instrument is accepted widely as a result of its use in field studies.[18,19]

The Kids FFQ asked caregivers about the frequencies of consumption of a wide variety of food and drink items during the previous week and the usual amount of each item consumed in one day. We used the FFQ data to generate estimates of usual dietary intake, which is more representative of an individual's general diet when compared with 24-hour recalls that provide information for only one day.[20] Using an algorithm, the company that supplied the questionnaire quantified the collected data in grams (or milliliters for liquids). From these dietary outcomes, which were correlated highly with the frequencies of consumption (r = 0.77-0.94), we selected the beverage items and combined them to create three beverage variables (soft drinks, milk and 100 percent fruit juice) based on the American Diabetes Association and American Dietetic Association's Exchange Lists for Meal Planning (Table 1).[21]

Solid foods such as candies also are known to be cariogenic,[22] and we computed the total sugar intake for each child to control for the cariogenic potential of solid foods. Public water supplies in the city of Detroit are fluoridated at optimal levels (0.97 parts per million).[23] Plain nonbottled water and soft drinks sweetened with low-calorie sweetener were not measured in the Kids FFQ.

Definition of clusters according to beverage intake. We used cluster analysis to define and evaluate the best grouping of children on the basis of their similarities in beverage intake. We determined the total beverage intake for each child by aggregating soft drinks, milk and 100 percent juice. The primary variable used in the cluster analysis was the proportion of intake of each beverage relative to the total beverage intake. This method was data-driven, so given the correlation among the intakes of the three beverages, cluster analysis should be more valid than a subjective classification.

TABLE 1

Beverage items in Block Kids Food Frequency Questionnaire (FFQ).*

BEVERAGE	BEVERAGE ITEMS IN KIDS FFQ
Soft Drinks†	Coca-Cola, Sprite, other carbonated drinks (excluding diet soft drinks); Sunny Delight, Hi-C, Hawaiian Punch or Ocean Spray, Kool-Aid or Gatorade
Milk	Milk in cereal, whole milk, rice milk, soy milk, milk with lunch, milk with dinner or snack, low-fat 1% milk
100 Percent Fruit Juice	Real orange juice, other real fruit juices

* NutritionQuest (Berkeley, Calif.).
† Coca-Cola, Sprite and Hi-C are manufactured by The Coca-Cola Company, Atlanta; Sunny Delight, Sunny Delight Beverages, Cincinnati; Hawaiian Punch, Dr Pepper Snapple Group, Plano, Texas; Ocean Spray, Ocean Spray Cranberries, Lakeville-Middleboro, Mass.; Kool-Aid, Kraft Foods, Northfield, Ill.; Gatorade, Gatorade, Chicago.

In this study, we used a statistical technique known as "partitioning around medoids" (PAM) in R software.[24] This method is more robust than the conventional k-means method because it does not require an assumption that the data are normally distributed.[25] In addition, PAM, unlike the k-means method, does not require initial guesses of the cluster center, and it is not affected by outliers.[25] The statistical program identified a median point (medoid) where a sum of the unsquared distance between each data point of the three beverages and that point is minimized. The software assigned each child, on the basis of his or her beverage intake, to the cluster corresponding to its nearest medoid. This analysis identified three clusters of children at baseline and two clusters of children at follow-up.

We found that the clusters defined by PAM had some overlap on the basis of the silhouette coefficient, an estimate of the quality of the clustering structure.[25] This finding was not unexpected given the sociodemographic homogeneity of the sampled children.

Four intake patterns. Using the clusters at both time points, we defined four intake patterns across two years. Children were classified with regard to whether they had high intake of milk or 100 percent fruit juice at both waves (that is, baseline and follow-up) (high-high milk-juice), had high intake of soft drinks at both waves (high-high soft drinks) or switched between high intake of

TABLE 2

Daily beverage intake for different clusters at baseline.

VARIABLE	WEIGHTED MEAN CONSUMPTION, IN MILLILITERS (MEAN PERCENTAGE OF TOTAL BEVERAGE INTAKE)*		
	Cluster 1 (Milk) (n = 127)	Cluster 2 (100% Fruit Juice) (n = 135)	Cluster 3 (Soft Drinks) (n = 107)
Soft Drinks	299.2 (30)	601.8 (42)	864.9 (72)
Milk	**478.1 (48)**	240.1 (18)	178.9 (18)
100% Fruit Juice	214.1 (22)	**588.6 (40)**	142.4 (10)

* Means in bold are significantly different from those of the other clusters at $P < .05$.

TABLE 3

Daily beverage intake for different clusters at two-year follow-up.

VARIABLE	WEIGHTED MEAN CONSUMPTION, IN MILLILITERS (MEAN PERCENTAGE OF TOTAL BEVERAGE INTAKE)*	
	Cluster 1 (Milk–100% Fruit Juice) (n = 189)	Cluster 2 (Soft Drinks) (n = 180)
Soft Drinks	338.9 (27)	**991.3 (68)**
Milk	**444.6 (41)**	274.5 (21)
100% Fruit Juice	**414.9 (32)**	198.2 (11)

* Means in bold are significantly different from those of the other cluster at $P < .05$.

milk or 100 percent juice and that of soft drinks (low-high soft drinks, high-low soft drinks).

Utilization of dental services. We received Medicaid dental records for children whose caregivers consented to the release of these data (Medicaid records were not available for 31 children). Using the Medicaid data, we identified three types of children's dental visits during the two-year period:

- no dental visit (n = 118; 32.0 percent) or no record in the Medicaid database (n = 31; 8.4 percent);
- preventive care–only visit (n = 129; 35.0 percent);
- restorative/surgical visit (n = 91; 24.7 percent).

Statistical analysis. We used the χ^2 test to evaluate unadjusted bivariate associations between the longitudinal intake patterns and demographic characteristics, as well as oral health behaviors. We used zero-inflated negative binomial regression (ZINB) to model the association between the longitudinal intake pattern and the increments of decayed (that is, d_1 and d_2), f or m tooth surfaces; this is the appropriate model for analysis of an outcome measure with a high proportion of zeros (that is, no new carious surfaces in this study).[26] We evaluated the association after controlling for children's age, total sugar intake, baseline caries and caregiver's education and income, as well as for children's oral health behaviors. We considered differences to be statistically significant at $P < .05$.

We conducted statistical analyses using software (STATA version 10) to account for the clustering effect from the complex sample design.[27] We adjusted all analyses by using sample weights to account for unequal selection probabilities and nonresponse. We substituted imputed values for the small number of missing values (< 4 percent) on predictor variables by using the IVEware software.[28]

RESULTS

At baseline, the cluster analysis identified three groupings of children on the basis of their consumption of milk, 100 percent fruit juice and soft drinks (Table 2). We labeled clusters as "milk," "100 percent fruit juice" and "soft drinks" on the basis of the largest percentage of total beverage intake. At baseline, 107 (29.0 percent) of the 369 children had 72.0 percent or more of their beverage consumption from soft drinks. At follow-up, the analysis identified two clusters labeled as "milk-100 percent fruit juice" and "soft drinks" (Table 3). Unlike the baseline pattern, children with high milk intake at follow-up also were high consumers of 100 percent fruit juice. The proportion of children with high consumption of soft drinks increased to 48.8 percent (180 of 369).

Table 4 presents the distribution of children according to the four longitudinal intake patterns defined earlier. Of 369 children, 158 (42.8 percent) had a high-high milk-juice pattern, and 104 (28.2 percent) had a low-high soft drink pattern. In addition, 31 children (8.4 percent) had a high-low soft drink pattern and 76 (20.6 percent) had a high-high soft drink pattern.

Table 5 (page 964) presents the associations between the longitudinal intake pattern, demographic characteristics, total sugar intake, oral health behaviors and dental caries. We found significant differences between the four intake patterns with regard to the number of new f surfaces, $d_t$mfs and $d_2$mfs, as well as toothbrushing frequency. According to the questionnaire findings, children with high-high milk-juice and low-high soft drink patterns had a higher frequency of toothbrushing than did children with a high-high soft drink pattern. The results showed a higher prevalence of baseline caries in the high-high soft drink group compared with the other consumption groups.

Of the 369 children, 160 (43.4 percent) had no new $d_2$mfs. Consequently, the most appropriate statistical model for these data (that is, number of new carious lesions or $d_t$mfs) is the ZINB, as described previously. Table 6 (page 965) presents the outcome of the ZINB models for the four longitudinal patterns associated with caries increments after we adjusted for a large number of zero counts (such as no new carious lesions between baseline and follow-up), age, baseline caries, total sugar intake, caregiver's income and education, and children's oral health behaviors.

We chose children with a high-high milk-juice pattern to be the reference group in the models. After adjusting for all other confounding factors, we found that children with a low-high soft drink pattern (low consumption at baseline but high consumption at follow-up) had a 1.75 times greater risk of developing new $d_2$mfs and a 2.67 times greater risk of developing new f surfaces compared with children in the reference group. In contrast, children with a high-high soft drink pattern had a similar significant risk of developing new f surfaces, but not new $d_2$mfs, as did children in the reference group. The differences associated with the longitudinal intake pattern with regard to the number of new d_1, d_2 and m surfaces were not statistically significant (data not shown).

TABLE 4

Daily beverage consumption for longitudinal intake patterns.

VARIABLE	WEIGHTED MEAN CONSUMPTION, IN MILLILITERS (WEIGHTED MEAN PERCENTAGE OF TOTAL BEVERAGE INTAKE)			
	High-High Milk-Juice* (n = 158)	Low-High Soft Drinks† (n = 104)	High-Low Soft Drinks‡ (n = 31)	High-High Soft Drinks§ (n = 76)
Baseline				
Soft drinks¶	399.3 (33)	567.4 (41)	699.1 (69)	930.1 (73)
Milk#	374.0 (34)	307.3 (28)	162.7 (21)	185.2 (16)
Fruit juice**	401.2 (33)	445.8 (31)	122.4 (10)	150.2 (11)
Follow-up				
Soft drinks††	330.2 (26)	1032.4 (67)	389.8 (30)	930.5 (69)
Milk‡‡	458.3 (42)	300.1 (22)	363.6 (34)	236.5 (19)
Fruit juice§§	415.0 (32)	205.9 (11)	414.6 (36)	186.7 (12)

* High-high milk-juice: High intake of milk or 100% fruit juice at baseline and at two-year follow-up.
† Low-high soft drinks: Low intake of soft drinks at baseline and high intake at two-year follow-up.
‡ High-low soft drinks: High intake of soft drinks at baseline and low intake at two-year follow-up.
§ High-high soft drinks: High intake of soft drinks at baseline and two-year follow-up.
¶ Mean soft drink intake (%) in children with high-low and high-high soft drink patterns was significantly different from that in children with high-high milk-juice and low-high soft drink patterns at $P < .05$.
\# Mean milk intake (%) in children with high-high milk-juice pattern was significantly different from that in children with other patterns at $P < .05$.
** Mean 100% fruit juice intake (%) in children with high-high milk-juice and low-high soft drink patterns was significantly different from that in children with high-low and high-high soft drink patterns at $P < .05$.
†† Mean soft drink intake (%) in children with low-high and high-high soft drink patterns was significantly different from that in children with high-high milk-juice and high-low soft drink patterns at $P < .05$.
‡‡ Mean milk intake (%) in children with high-high milk-juice and high-low soft drink patterns was significantly different from that in children with low-high and high-high soft drink patterns at $P < .05$.
§§ Mean 100% fruit juice intake (%) in children with high-high milk-juice and high-low soft drink patterns was significantly different from that in children with low-high and high-high soft drink patterns at $P < .05$.

DISCUSSION

This study presents findings regarding the cariogenicity of sugared drinks from a two-year follow-up of a cohort of low-income black children in Detroit. Cariogenicity of sugared drinks is difficult to determine in human studies, and Burt and Ismail[11] proposed definitions to guide human studies in this area. They defined "cariogenic potential" as the ability of foods to cause a significant drop in plaque pH, to cause demineralization of enamel or to result in more caries (than that without the food) in animals under controlled experimental conditions. They suggested that researchers should consider the frequency and manner of consumption along with the cariogenic potential to determine the "effective cariogenicity" of foods. Thus, effective cariogenicity of foods can be determined only in longitudinal studies such

TABLE 5

Associations between longitudinal intake patterns and covariates.

VARIABLE	NO. OF CHILDREN OR CAREGIVERS	PERCENTAGE OF CHILDREN OR CAREGIVERS*			
		High-High Milk-Juice†	Low-High Soft Drinks‡	High-Low Soft Drinks§	High-High Soft Drinks¶
Children's Age (Years)					
3	120	33	29	22	28
4	128	36	37	32	42
5	121	31	34	46	30
Childrens' Sex					
Male	168	54	39	46	50
Female	201	46	61	54	50
Children's Baseline Total Sugar Intake#					
Low (0 - 119.2 grams)	123	35	27	46	21
Middle (119.4 - 194.4 g)	123	36	29	31	32
High (196.6 - 680.8 g)	123	29	44	23	47
Caregiver's Education					
Less than high school	167	42	48	45	45
High school diploma or higher	202	58	52	55	55
Caregiver's Annual Income					
≤ $10,000	163	36	55	47	48
> $10,000	206	64	45	53	52
Fatalistic Belief About Children's Oral Health**					
No	77	19	17	11	18
Yes	292	81	83	89	82
Reasons for Dental Visits					
Reference: no dental visit or no Medicaid record	149	48	32	42	38
Preventive care–only visit	129	29	50	34	29
Restorative/surgical visit	91	23	18	24	33
Brushing Frequency During Previous Week††					
< 7 times	101	26	19	38	39
≥ 7 times	268	74	81	62	61
Baseline Caries ($d_t$mfs‡‡)					
None	92	28	33	19	18
1- 8	147	39	35	53	36
> 8	130	33	32	28	46
New Dental Caries, Weighted Mean (Standard Error)					
No. of new d_1 surfaces	—§§	2.6 (0.2)	2.5 (0.2)	2.3 (0.5)	2.8 (0.4)
No. of new d_2 surfaces	—	1.9 (0.3)	1.8 (0.2)	1.7 (0.4)	2.7 (0.5)
No. of new filled surfaces¶¶	—	0.7 (0.2)	1.0 (0.3)	0.3 (0.1)	2.4 (0.8)
No. of new missing teeth owing to caries	—	0.3 (0.1)	1.2 (0.4)	0.9 (0.5)	0.5 (0.2)
No. of new $d_t$mfs##	—	5.6 (0.4)	6.5 (0.7)	5.2 (0.8)	8.1 (1.2)
No. of new $d_2$mfs***	—	3.0 (0.4)	3.9 (0.7)	2.9 (0.7)	5.5 (1.1)

* Unless otherwise specified.
† High-high milk-juice: High intake of milk or 100% fruit juice at baseline and at two-year follow-up.
‡ Low-high soft drinks: Low intake of soft drinks at baseline and high intake at two-year follow-up.
§ High-low soft drinks: High intake of soft drinks at baseline and low intake at two-year follow-up.
¶ High-high soft drinks: High intake of soft drinks at baseline and two-year follow-up.
# Children's baseline total sugar intake was categorized as low, middle and high, according to tertiles.
** This is the caregiver's belief that most children eventually develop dental caries.
†† Children's toothbrushing frequencies were associated significantly with the longitudinal intake pattern at $P < .05$.
‡‡ $d_t$mfs: Noncavitated surfaces (d_1), cavitated/dentinal surfaces (d_2), missing owing to caries (m), filled (f) surfaces (s).
§§ Dash indicates not applicable.
¶¶ The mean number of new filled surfaces in children with high-high soft drink pattern was significantly different from that in children with high-low soft drink pattern at $P < .05$.
Mean new $d_t$mfs in children with high-high soft drink pattern was significantly different from that in children with high-high milk-juice pattern at $P < .05$.
*** Mean new $d_2$mfs in children with high-high soft drink pattern was significantly different from that in children with high-high milk-juice pattern at $P < .05$.

as the one described in this report.[11]

Study limitations. This study had several limitations. First, there were not enough children to achieve statistical significance for all of the outcome measures. Second, the Kids FFQ did not collect data regarding detailed eating patterns (for example, between meals) or intake of water. This absence of information prevented a detailed analysis of frequency of consumption and fluoride exposure. Accordingly, it also meant that our results could not be compared directly with those from other studies that reported the importance of frequent exposure to cariogenic foods. Third, to obtain data regarding the dietary intake of these young children, interviewers questioned the caregivers. Consequently, reporting accuracy could have been compromised as the children grew up and spent more time out of the home. To adjust for this potential reporting error, we used relative measures (for example, percentage of total beverage intake) instead of absolute amounts of beverages consumed, as an earlier study suggested.[29]

Another methodological difficulty is the large number of zero counts in measuring caries incidence; 57.0 percent of the children developed no new cavitated surfaces between baseline and follow-up. If we had used a Poisson model, the observed dispersion likely would have been underestimated, which would have resulted in large discrepancies between observed and expected counts.[30] To model this skewed distribution, some authors have suggested the use of a zero-inflated Poisson or negative binomial model (ZINB).[26,30] We also found that the ZINB model provided a better fit when the nonzero counts were overdispersed with respect to a Poisson distribution.[31] After examining the distribution of nonzero counts, we decided to use a ZINB model.

Study strengths. The study also had a number of

TABLE 6

Adjusted incidence rate ratio (IRR) for caries increment (new $d_2$mfs* and new filled surfaces).†‡

VARIABLE	NEW D_2MFS		NEW FILLED SURFACES	
	IRR	95% CI§	IRR	95% CI
Longitudinal Intake Pattern				
Reference: high-high milk-juice¶	—‡‡	—	—	—
Low-high soft drinks#	**1.75**	**1.16 - 2.64**	**2.67**	**1.36 - 5.23**
High-low soft drinks**	1.11	0.60 - 2.08	0.50	0.17 - 1.53
High-high soft drinks††	1.29	0.86 - 1.93	**2.68**	**1.44 - 4.96**
Children's Age (Years)				
Reference: 3	—	—	—	—
4	**0.54**	**0.38 - 0.79**	**0.37**	**0.20 - 0.69**
5	0.79	0.55 - 1.15	1.02	0.35 - 3.03
Caregiver's Annual Income				
Reference: ≤ $10,000	—	—	—	—
> $10,000	1.04	0.74 - 1.48	0.88	0.48 - 1.62
Education				
Reference: less than high school	—	—	—	—
High school diploma or higher	0.99	0.71 - 1.39	1.62	0.92 - 2.84
Oral Health Behavior§§				
Reference: fatalistic oral health belief = no	—	—	—	—
Fatalistic oral health belief = yes	1.03	0.66 - 1.61	1.48	0.79 - 2.75
Reason for Dental Visit				
Reference: no dental visit or no Medicaid record	—	—	—	—
Preventive care–only visit¶¶	**0.65**	**0.42 - 0.99**	—	—
Restorative/surgical visit	**2.49**	**1.79 - 3.45**	**13.82**	**7.22 - 26.47**
Brushing Frequency				
Reference: < 7 times per week	—	—	—	—
≥ 7 times per week	0.77	0.52 - 1.15	1.34	0.71 - 2.51
Baseline Caries				
None	—	—	—	—
1 - 8	**4.04**	**2.06 - 7.94**	**4.26**	**1.16 - 15.71**
> 8	**11.17**	**5.52 - 22.61**	**7.00**	**1.73 - 28.29**
Total Sugar Intake##				
Reference: low	—	—	—	—
Middle	1.13	0.78 - 1.64	0.74	0.31 - 1.75
High	1.15	0.79 - 1.65	0.60	0.31 - 1.17

* $d_2$mfs: Cavitated/dentinal surfaces (d_2), missing (m), filled (f) surfaces (s).
† The authors used an intercept-only logit model to account for the large number of zero counts.
‡ Numbers in bold indicate statistical significance at $P < .05$.
§ CI: Confidence interval.
¶ High-high milk-juice: High intake of milk or 100% fruit juice at baseline and at two-year follow-up.
\# Low-high soft drinks: Low intake of soft drinks at baseline and high intake at two-year follow-up.
** High-low soft drinks: High intake of soft drinks at baseline and low intake at two-year follow-up.
†† High-high soft drinks: High intake of soft drinks at baseline and two-year follow-up.
‡‡ Dash indicates not applicable.
§§ This is the caregiver's belief that most children eventually develop dental cavities.
¶¶ No new filled surfaces among children who had a preventive-care–only visit.
\## The authors categorized baseline total sugar intake as low, middle and high, according to tertiles.

strengths. It consisted of a longitudinal design and included a clinical assessment, interviews and use of Medicaid dental care records. To test our hypothesis, we combined the data from examinations and interviews at baseline and follow-up with data from Medicaid dental records. The cluster analysis, which yielded some intake patterns of sugared drinks over time, has construct validity on the basis of the findings of the ZINB models. However, the intake patterns were not associated with demographic characteristics, which is not consistent with results of other studies of children's beverage intake patterns.[1,32] This finding probably reflects the sociodemographic homogeneity of the study population.

This study found that low-income black children with a high intake of soft drinks over time, or those who changed from low to high consumption of soft drinks, had a higher risk of receiving new fillings than did those with a relatively higher intake of milk and 100 percent fruit juice at baseline and follow-up. We did not find any significant difference in the numbers of new noncavitated (d_1) or cavitated (d_2) tooth surfaces. Given that a majority of children (59.0 percent) had visited a dentist during the two years of the study, we interpret the significant increase in f surfaces in children in the low-high soft drink group as a rapid progression of caries to a stage at which restorative care is necessary. Caries progresses rapidly under conditions of high sugar exposure[5]; thus, symptoms of sensitivity and pain may have led caregivers to seek dental care for these children.

These results support the American Dietetic Association's dietary guideline for children that discourages a high intake of soft drinks.[33] While total elimination of soft drinks is unrealistic for most children, clinicians should recommend to caregivers that they limit children's exposure to a few times per week, followed by toothbrushing with fluoridated dentifrice, in the interest of caries prevention.[34]

Milk. Milk is a good alternative to soft drinks because of its potential protective factors: calcium, phosphorus and proteose-peptone fractions 3 and 5.[35] Milk has many of the physical and chemical properties of saliva, which could make it a suitable substitute for saliva.[36] Studies with animals have concluded that bovine milk is noncariogenic,[37,38] and several authors also have found evidence of the noncariogenic potential of bovine milk in human studies.[1,3,8,9,39] One study contains a cluster analysis of data from the Third National Health and Nutrition Examination Survey, in which children with a high intake pattern of milk were found to have lower caries severity in the primary dentition.[1] Another study is the longitudinal Iowa Fluoride Study, which found that routine milk consumption was protective in the primary dentition.[39]

Fruit juice. Kolker and colleagues[6] conducted a cross-sectional study of the same population in this study, and they found that consumption of 100 percent fruit juice (excluding orange juice) was associated with a low prevalence and severity of caries. Other studies have reported that consumption of 100 percent fruit juice by young children was not associated with dental caries.[3,22] It may be that high consumption of 100 percent fruit juice is a marker for more health-conscious caregivers in this population.[6] In this study, we found a parallel between high consumption of milk and 100 percent fruit juice in the follow-up assessment (Table 3).

CONCLUSION

This two-year longitudinal study of low-income black children supports the hypothesis that children with a high consumption of soft drinks over time, or those who increase their consumption of soft drinks relative to consumption of milk and 100 percent fruit juice, are at a higher risk of developing dental caries. Soft drinks are potentially cariogenic; however, young children still can consume them more safely if the exposure is reduced and dental plaque is removed regularly with a fluoridated dentifrice. It is important for health care providers to emphasize in health promotion programs the need to maintain a balance between exposure to soft drinks and preventive oral hygiene behaviors. ■

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