ADA CE Program ARTICLE 4

Early childhood caries and intake of 100 percent fruit juice

Data from NHANES, 1999-2004

Clemencia M. Vargas, DDS, PhD; Bruce A. Dye, DDS, MPH; Catherine R. Kolasny, BS; Dennis W. Buckman, PhD; Timothy S. McNeel, BA; Norman Tinanoff, DDS, MS; Teresa A. Marshall, PhD; Steven M. Levy, DDS, MPH

ABSTRACT

Background. The results of several studies conducted in the United States show no association between intake of 100 percent fruit juice and early childhood caries (ECC). The authors examined this association according to poverty and race/ethnicity among U.S. preschool children.

Methods. The authors analyzed data from the 1999-2004 National Health and Nutrition Examination Survey (NHANES) for 2,290 children aged 2 through 5 years. They used logistic models for caries (yes or no) to assess the association between caries and intake of 100 percent fruit juice, defined as consumption (yes or no), ounces (categories) consumed in the previous 24 hours or usual intake (by means of a statistical method from the National Cancer Institute).

Results. The association between caries and consumption of 100 percent fruit juice (yes or no) was not statistically significant in an unadjusted logistic model (odds ratio [OR], 0.76; 95 percent confidence interval [CI], 0.57-1.01), and it remained nonsignificant after covariate adjustment (OR, 0.89; 95 percent CI, 0.63-1.24). Similarly, models in which we evaluated categorical consumption of 100 percent juice (that is, 0 oz; > 0 and ≤ 6 oz; and > 6 oz), unadjusted and adjusted by covariates, did not indicate an association with ECC.

Conclusions. Our study findings are consistent with those of other studies that show consumption of 100 percent fruit juice is not associated with ECC.

Practical Implications. Dental practitioners should educate their patients and communities about the low risk of developing caries associated with consumption of 100 percent fruit juice. Limiting consumption of 100 percent fruit juice to 4 to 6 oz per day among children 1 through 5 years of age should be taught as part of general health education.

Key Words. Caries; eating habits; pediatric dentistry; epidemiology; National Health and Nutrition Examination Survey.

JADA 2014;145(12):1254-1261.

doi:10.14219/jada.2014.95

Dental caries in young children often is referred to as early childhood caries (ECC). The American Academy of Pediatric Dentistry defined ECC as "the presence of 1 or more decayed (noncavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child under the age of six."[1] ECC is more likely to affect the most socially vulnerable children: those living in poverty and those from ethnic minority groups.[2] However, a recent increase in dental caries prevalence among children younger than 6 years shows that a higher proportion of traditionally low-risk children, such as those living in higher-income families, is being affected by dental caries.[3] No national data have been reported recently regarding the distribution of caries among children aged 2 through 5 years on the basis of poverty and race/ethnicity.

The U.S. Food and Drug Administration[4] defines the

Dr. Vargas is an associate professor, School of Dentistry, University of Maryland, 650 W. Baltimore St., Room 2217, Baltimore, Md. 21201, e-mail cvargas@umaryland.edu. Address correspondence to Dr. Vargas.
Dr. Dye is a dental epidemiology officer, National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Md.
Ms. Kolasny is a dental student, School of Dentistry, University of Maryland, Baltimore.
Dr. Buckman is a statistician, Information Management Services, Calverton, Md.
Mr. McNeel is a senior systems analyst, Information Management Services, Calverton, Md.
Dr. Tinanoff is a professor and chief, Division of Pediatric Dentistry, School of Dentistry, University of Maryland, Baltimore.
Dr. Marshall is an associate professor, Department of Preventive and Community Dentistry, College of Dentistry, The University of Iowa, Iowa City.
Dr. Levy is Wright-Bush Shreves Professor of Research and graduate program associate director, Dental Public Health, College of Dentistry, and a professor, Department of Epidemiology, College of Public Health, The University of Iowa, Iowa City.

term "100 percent fruit juice" as a beverage made from fruit; 100 percent fruit juice differs from "juice drinks," which are diluted with water and may contain added sugars or other ingredients. Researchers in a 2003 study about dental caries and beverage consumption found that 100 percent fruit juice was associated minimally with caries in participants from the Iowa Fluoride Study (IFS).[5] In 2005, an analysis of additional data from the IFS participants showed that consumption of 100 percent fruit juice was not associated with caries.[6] Similarly, researchers in a study focused on low-income African-American children in Detroit found that 100 percent fruit juice was protective against caries,[7,8] and data from the same study showed that milk and juice could be used together as the noncariogenic reference.[8] One important factor regarding the studies with findings that showed no association between consumption of 100 percent fruit juice and caries is that they were conducted in specific populations: white middle-income children in Iowa[5,6] and low-income black children in Detroit.[8] Investigators in a study involving the use of nationally representative data (National Health and Nutrition Examination Survey [NHANES] III) to ascertain the association between dental caries and consumption of 100 percent fruit juice presented results for all children with primary teeth and not for preschool-aged children specifically.[9] They found that consuming milk, 100 percent fruit juice or water was less likely to be associated with dental caries than was consuming other beverages.[8] The results of a small study of patients at children's medical centers showed that 100 percent fruit juice was not associated with severe ECC.[10]

Since the 1990s, the beverage consumption patterns of children have changed. More children are drinking beverages with added sugar, such as sodas and soda pop, juice drinks, and other sugary drinks instead of milk and water.[11,12] One hundred percent fruit juice is another beverage that has had a large increase in consumption.[11] Some of the factors linked to the increase in consumption of 100 percent fruit juice include the following: it is a convenient snack for children, it is considered a healthy beverage choice, it often costs less than milk, and marketing efforts to increase fruit and vegetable intake may promote juice as an alternative.[13]

Because of the increased consumption of juice beverages, the American Academy of Pediatrics[14] has recommended that young children limit their consumption of 100 percent fruit juice to 4 to 6 ounces per day. Despite this recommendation, intake of 100 percent fruit juice among young children remains high, with the average preschooler consuming twice the recommended amount of 100 percent fruit juice per day.[11,15] With passage of the 2010 Healthy Hunger-Free Kids Act, there has been a call for the U.S. Department of Agriculture to begin promoting whole fruit instead of 100 percent fruit juice in children's school meals to help prevent childhood obesity.[16]

Information regarding the association between consumption of 100 percent fruit juice and dental caries in young children is lacking at the national level. The purpose of this study was to assess the relationship between consumption of 100 percent fruit juice and caries among U.S. preschool children, adjusting for sociodemographic characteristics. In addition, we provide updated information about caries prevalence according to poverty level and race/ethnicity among U.S. children 2 through 5 years of age.

METHODS

Study population. Data for this study come from the 1999-2004 NHANES.[17] NHANES is a series of cross-sectional, nationally representative health examination studies conducted by the Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics (NCHS) to evaluate the health of the U.S. civilian noninstitutionalized population. Each survey period involves the use of a stratified, multistage probability sampling design to select participants. NHANES oversamples some population groups to provide an adequate sample size to improve estimate precision by reducing variances. Relevant to the children included in this study, the 1999-2004 NHANES oversampled non-Hispanic black children, Mexican-American children and low-income white children. The 1999-2004 NHANES is the most current data set that includes all of the variables of interest with sufficient sample size of children aged 2 through 5 years to allow multivariate analysis.

The study sample consisted of a total of 2,290 children aged 2 through 5 years for whom we had complete dental examination and dietary recall data. NHANES staff members collected data by means of a personal interview at the participant's home, a health examination at a mobile examination center (MEC) and laboratory analyses. Interviewers collected oral health data from participants 2 years and older during the home interview and by means of a detailed oral examination in the MEC by dentists who underwent calibration. Additional information detailing examination procedures is provided elsewhere.[18,19] A trained NHANES interviewer, using dietary interview software and visual aids, collected information about beverage consumption as part of the 24-hour dietary recall interview conducted at the MEC. Incomplete interviews were completed by telephone, and the 2003-2004 public-use data sets include dietary data from a second 24-hour recall interview conducted via

ABBREVIATION KEY. **CDC:** Centers for Disease Control and Prevention. **dft:** Decayed or filled teeth (primary). **ECC:** Early childhood caries. **FPG:** Federal poverty guideline. **IFS:** Iowa Florida Study. **MEC:** Mobile examination center. **NA:** Not applicable. **NCHS:** National Center for Health Statistics. **NHANES:** National Health and Nutrition Examination Survey. **PIR:** Poverty income ratio. **ZINB:** Zero-inflated negative binomial. **ZIP:** Zero-inflated poisson.

telephone. All NHANES study protocols were approved by the CDC/NCHS Institutional/Ethics Review Board, and written informed consent was obtained from participants or their legal guardians. The University of Maryland at Baltimore institutional review board considered our study to be exempt from IRB review because the study involved the use of previously collected data with no personal identifiers (exemption no. 4).

Variables. We analyzed dental caries experience as the prevalence (yes or no) of untreated caries or filled teeth by means of the dft index, which is the count of affected teeth, whereby "d" represents the number of primary teeth with carious lesions and "f" represents the number of filled (restored) primary teeth ("t"). The presence of caries in our study group was similar to that reported previously on the basis of NHANES data; the mean dft for children 2 through 5 years of age was 1.17.[20]

We defined consumption of 100 percent fruit juice as having a reported intake of 100 percent juice made from any fruit in the previous 24 hours. We analyzed juice consumption as the prevalence of consumption (yes or no) and the ounces of consumption recoded into three categories: 0 oz, more than 0 oz but less than or equal to 6 oz, and more than 6 oz.[14] Although a responsible adult reported beverage consumption for the child, we use the phrase "child reported" throughout this article.

Another independent variable was age (in years). Sex was self-reported as male or female. We included race/ethnicity and poverty because many study findings have shown that they are social determinants of health associated strongly with caries in preschool children.[2,3,21] Race/ethnicity was self-reported, and we recoded it as non-Hispanic white, non-Hispanic black, Mexican-American and others. We based poverty level on the poverty income ratio (PIR); a PIR of 1.00 is considered representative of a poverty level at 100 percent of the federal poverty guideline (FPG).[22] We grouped participants into three categories: less than 1.00 PIR (< 100 percent FPG [poverty]), 1.00-2.99 PIR (100-299 percent FPG) or 3.00 or higher PIR (≥ 300 percent FPG). We defined an annual dental visit (yes or no) as having had at least one dental visit within the previous 12 months.

Data analysis. We performed all statistical analyses by using statistical software (SAS Version 9.1.3, SAS Institute, Cary, N.C.; SUDAAN Version 10.0, RTI International, Research Triangle Park, N.C.; and Stata, Version 10.1, StataCorp, College Station, Texas). We used dietary sample weights to account for oversampling, nonresponse and other survey design features. SUDAAN and Stata account for the complex survey design, including design effects. We used SUDAAN to estimate weighted percentages and standard errors, and we used Taylor series linearization to calculate standard errors. We evaluated differences between percentages by using two-sided significance tests at the .05 level, with all comparisons made to the reference group within the selected variable. We also tested for trend within the age and poverty covariates by using the stratum-adjusted Cochran-Mantel-Haenszel test.[23,24] If we did not observe a linear relationship, we presented findings only for the comparisons to the reference group.

We assessed the relationship between dental caries and 100 percent fruit juice consumption by using two distinct modeling approaches. We fit logistic regression models to analyze caries prevalence (yes or no) by using SUDAAN software to account for the complex sample design. Caries prevalence among preschool children in the United States is below 50 percent,[2,3] resulting in a sizeable number of preschool children who have not experienced caries. Consequently, we fit zero-inflated poisson (ZIP) models and zero-inflated negative binomial (ZINB) models to analyze the number of teeth with caries (dft) and to allow for excess zeros in this count variable. We fit ZIP and ZINB models by using Stata software with appropriate options to account for the complex survey design. Because results from both ZIP and ZINB models essentially were the same as those obtained from logistic regression only, we present results from the logistic regression models. We used logistic regression models to test the associations between ECC and sociodemographic indicators (age, sex, race/ethnicity and poverty status).

We also assessed the relationship between dental caries and usual intake of 100 percent fruit juice by using a statistical method from the National Cancer Institute designed for 24-hour recall data for episodically consumed dietary components that corrects for the measurement error occurring in dietary variables.[25] An episodically consumed dietary component, such as 100 percent fruit juice, may or may not be consumed during a given 24-hour period; consequently, the 24-hour recall data consist of an excess number of zeros owing to nonconsumption days, and they consist of positive consumption amounts from consumption days. We used SAS macros[26] to fit the measurement error model and to predict usual intake for use in the logistic model to assess the relationship between caries and usual intake of 100 percent fruit juice, with correction for dietary measurement error. We used the jackknife method to estimate variance.

RESULTS

Children were distributed evenly, according to age and sex (Table 1[17,22]). Almost two-thirds were non-Hispanic white, 14 percent were non-Hispanic black, 14 percent were Mexican-American and less than 11 percent were from other groups. More than one-quarter of children lived in poverty (< 100 percent FPG) and one-third lived in families at or above 300 percent FPG. Just under one-half (45.8 percent) of the children reported having had a dental visit in the previous year.

Table 2[17,22] (page 1258) shows the consumption of 100 percent fruit juice in the previous 24 hours. Nearly

TABLE 1

Sociodemographic characteristics among children 2-5 years of age, according to NHANES* 1999-2004.†

CHARACTERISTICS	PERCENTAGE OF CHILDREN (SE‡)
Age, in Years	
2	25.8 (1.1)
3	24.2 (1.1)
4	24.1 (1.6)
5	26.0 (1.1)
Sex	
Male	49.3 (1.6)
Female	50.7 (1.6)
Race/Ethnicity	
Non-Hispanic white	62.0 (2.3)
Non-Hispanic black	13.9 (1.4)
Mexican-American	13.6 (1.4)
Other	10.5 (1.4)
Poverty Level, in Percentage FPG§	
< 100	26.8 (1.2)
100-299	41.0 (2.0)
≥ 300	32.2 (2.0)
Dental Visit Within Previous Year	
Yes	45.8 (1.6)
No	54.2 (1.6)

* NHANES: National Health and Nutrition Examination Survey.
† Source: Centers for Disease Control and Prevention.[17]
‡ SE: Standard error.
§ FPG: Federal poverty guideline.[22]

54 percent of children consumed 100 percent fruit juice during that period. Consumption decreased according to age. We found no significant difference in consumption of 100 percent fruit juice between children living in poverty and children living in families at or above 300 percent FPG; however, fruit juice consumption was significantly lower ($P \leq .05$) among children living in families at 100-299 percent FPG than it was among children living at higher levels of the FPG.

Approximately 39 percent of all children consumed more than 6 oz of 100 percent fruit juice in the previous 24 hours. This high level of consumption decreased with age ($P \leq .05$). We found no significant difference in the percentage of children consuming more than 6 oz of 100 percent fruit juice according to poverty level. In addition, we observed no significant difference in children's consumption of 100 percent fruit juice according to sex or race/ethnicity. Finally, we found no statistically significant difference between children who had dental caries (dft > 0) and reported consumption of 100 percent fruit juice (48 percent) and those who did not have caries (dft = 0) and reported consumption of 100 percent fruit juice (55 percent).

Table 3[17,22] (page 1259) shows the prevalence of ECC according to sociodemographic indicators. The prevalence of dental caries (dft) among 2- to 5-year-olds was 28.5 percent. Dental caries prevalence increased in magnitude as age increased ($P \leq .05$), ranging from 12 percent for 2-year-olds to nearly 40 percent for 5-year-olds. We found no difference in ECC prevalence according to sex. Mexican-American children had the highest prevalence of dental caries (42.6 percent) ($P \leq .05$) compared with that among non-Hispanic white children, non-Hispanic black children and children from "other" racial/ethnic groups, all of whom had a caries prevalence below 30 percent. Overall, as poverty increased, dental caries prevalence increased, from approximately 13 percent (≥ 300 percent FPG) to about 43 percent (< 100 percent FPG) ($P \leq .05$).

Table 4[17,22] (page 1260) shows the odds ratios (ORs) and 95 percent confidence intervals (CIs) for the association between consumption of 100 percent fruit juice and caries experience by means of the standard logistic regression modeling approach and the usual intake modeling approach, with correction for measurement error. Using standard regression modeling techniques, we found that the association between dental caries and consumption of 100 percent fruit juice was not significant for consumption determined dichotomously in either the unadjusted or the adjusted model when controlling for age, sex, race/ethnicity, poverty and dental visits. Likewise, in models evaluating consumption of 100 percent fruit juice according to the categorical amount consumed (0 oz, > 0 and ≤ 6 oz, and > 6 oz), neither the unadjusted nor the adjusted model—controlling for age, sex, race/ethnicity, poverty and dental visits—indicated an association with dental caries.

Results from modeling that involved the use of a technique to correct for potential measurement error for intake of 100 percent fruit juice and that was adjusted for age, sex, race/ethnicity, poverty and dental visits also did not show an association between intake of 100 percent fruit juice and dental caries (Table 4). Likewise, when comparing the results of an adjusted model in which we corrected for potential dietary measurement error for juice intake with the results of the other two adjusted models that involved the use of the more typical modeling approach, we observed little difference across the covariates and in the association of those covariates with dental caries.

DISCUSSION

Consistent with the findings of previous studies,[6-10] we found no association between consumption of 100 percent fruit juice in the previous 24 hours and dental caries among young children in NHANES 1999-2004. The crude ORs for the two variables representing consumption of 100 percent fruit juice—prevalence of consumption (yes or no) and categories for ounces consumed—

remained nonsignificant after we entered them in the adjusted models.

We used two different modeling approaches in analyzing dietary data from 24-hour recalls. As demonstrated by the reported zero values in Table 2, 100 percent fruit juice was not consumed daily by everyone in our study. Furthermore, dietary data from self-reported assessment methods, such as the 24-hour recall, may not accurately reflect intake, so we used an established statistical approach to evaluate the relationship between a health outcome and dietary data with excess zeros and measurement error.[25]

Our findings show no evidence of an association between dental caries and usual intake of 100 percent fruit juice when comparing the 10th and 90th percentiles of the usual intake distribution. Likewise, we observed little difference among the covariates evaluated between the other two adjusted models by using the more typical modeling approach and an adjusted model corrected for measurement error.

The risk of caries (that is, OR) adjusted for the sociodemographic factors did not vary considerably in the models that included one of the indicators (that is, prevalence or ounces consumed) of consumption of 100 percent fruit juice (data not shown). This is consistent with the lack of association between consumption of 100 percent fruit juice and ECC, as well as the overall lack of difference in consumption of 100 percent fruit juice according to sociodemographic indicators. Therefore, we presented the logistic models for juice consumption without presenting the sociodemographic factors.

TABLE 2

Consumption of 100 percent fruit juice in previous 24 hours by children aged 2-5 years, NHANES* 1999-2004.†

CHARACTERISTICS	PERCENTAGE (SE‡) OF ALL CHILDREN			
	Prevalence of 100 Percent Fruit Juice Consumption	Consumption of 100 Percent Fruit Juice, in Ounces		
	Yes	0	> 0 and ≤ 6	> 6
Total Percentage (SE)	53.6 (2.2)	46.4 (2.2)	15.1 (1.5)	38.5 (1.8)
Age, in Years				
2 (reference)	62.0 (2.9)§	38.0 (2.9)§	16.3 (1.8)	45.8 (2.6)§
3	55.6 (2.7)	44.4 (2.7)	14.6 (2.3)	41.0 (2.7)
4	53.8 (3.1)	46.2 (3.1)	16.6 (2.5)	37.2 (3.2)
5	43.0 (4.3)	57.0 (4.3)	13.0 (2.6)	30.0 (3.8)
Sex				
Male	54.7 (2.8)	45.3 (2.8)	16.3 (2.2)	38.4 (2.1)
Female (reference)	52.4 (2.7)	47.6 (2.7)	13.9 (1.8)	38.5 (2.5)
Race/Ethnicity				
Non-Hispanic white (reference)	53.0 (3.1)	47.0 (3.1)	14.8 (1.9)	38.2 (2.5)
Non-Hispanic black	53.3 (2.4)	46.7 (2.4)	14.3 (1.9)	39.0 (2.4)
Mexican-American	52.7 (2.5)	47.3 (2.5)	14.7 (1.4)	38.1 (2.2)
Other	58.0 (5.5)	42.0 (5.5)	18.4 (3.8)	39.6 (5.3)
Poverty Level, in Percentage FPG¶				
< 100	52.7 (2.8)	47.3 (2.8)	14.2 (1.8)	38.5 (2.9)
100-299	46.8 (3.2)#	53.2 (3.2)#	13.1 (1.6)	33.6 (3.0)
≥ 300 (reference)	60.3 (4.2)	39.7 (4.2)	18.5 (3.3)	41.8 (3.6)
Dental Visit Within Previous Year				
Yes	52.1 (3.2)	47.9 (3.2)	15.3 (2.1)	36.9 (2.5)
No (reference)	54.8 (2.4)	45.2 (2.4)	15.0 (1.7)	39.8 (2.2)
Dental Caries				
Yes	48.0 (3.2)	52.0 (3.2) (3.0)	13.0 (1.9)	35.0 (2.7)
No (reference)	54.8 (2.6)	45.2 (2.6)	16.0 (1.9)	38.9 (2.6)

* NHANES: National Health and Nutrition Examination Survey.
† Source: Centers for Disease Control and Prevention.[17]
‡ SE: Standard error.
§ $P \leq .05$ (linear trend test) for age and poverty only.
¶ FPG: Federal poverty guideline. FPG based on the poverty income ratio.[22]
# $P \leq .05$ for comparison with reference group.

Limitations of this study are related closely to limitations in the dietary data collection methods and cross-sectional nature of the data. There are several methods for collecting dietary data, and all of them have their limitations.[27] Analyses based on a single 24-hour recall period can be subject to recall and social desirability biases and measurement error. One also could argue that the 24-hour dietary recall may be an inadequate risk indicator for a disease that develops over many months. Therefore, the results presented in this report showing a lack of association between consumption of 100 percent fruit juice and ECC should be considered preliminary and indicate the need for further research. Furthermore, dietary measurement error often attenuates relationships between diet and health outcomes.[25] However, Tooze and colleagues[28] demonstrated that food intakes reported for two or more 24-hour recall periods can be used to estimate the usual intake distribution of an episodically consumed dietary component, such as 100 percent fruit juice. Kipnis and colleagues[25] extended this method to evaluate relationships between usual intake and health outcomes. As part of our analyses, we used this established statistical approach to correct for potential measurement error. Another limita-

TABLE 3

Caries prevalence, according to sociodemographic characteristics among children aged 2-5 years, NHANES* 1999-2004.†

VARIABLES	PERCENTAGE (SE‡) OF CHILDREN WITH CARIES
TOTAL	28.5 (1.5)
Age, in Years	
2 (reference)	11.9 (1.8)§
3	25.0 (2.7)
4	35.2 (4.0)
5	39.5 (3.6)
Sex	
Male	29.8 (2.4)
Female (reference)	27.3 (2.1)
Race/Ethnicity	
Non-Hispanic white (reference)	25.7 (2.2)
Non-Hispanic black	29.2 (2.2)
Mexican-American	42.6 (2.5)¶
Other	26.3 (4.2)
Poverty Level, in Percentage FPG#	
< 100	43.4 (3.3)
100-299	29.4 (2.4)
≥ 300	13.2 (2.4)§

* NHANES: National Health and Nutrition Examination Survey.
† Source: Centers for Disease Control and Prevention.[17]
‡ SE: Standard error.
§ $P \leq .05$ (linear trend test) for age and poverty only for caries prevalence.
¶ $P \leq .05$ for comparison with reference group for caries prevalence.
# FPG: Federal poverty guideline.[22]

tion associated with the NHANES design is the lack of information about fluoride exposures.

The finding of no association between consumption of 100 percent fruit juice and dental caries in younger children may seem counterintuitive given the general understanding of sugars and their influence on dental caries etiology. However, several factors may contribute to this lack of association, including biological, behavioral and social factors.

One of the major biological factors that could explain the lack of association between consumption of 100 percent fruit juice and caries is fluoride protection against caries owing to its ubiquitousness.[29] For example, Campain and colleagues[30] reported that low-caries-risk adolescents exhibited a very weak association between sugar consumption and caries, which was attributed to frequent exposure to fluoride, both in the water supply and in toothpastes. Gibson and Williams[31] reported that the association between caries and sugar consumption was present only among preschool-aged children who had their teeth brushed less than twice a day. They concluded that regular toothbrushing twice a day with fluoridated toothpaste may have a greater effect on caries prevention among young children than does limiting the consumption of sugary foods.[31] Duggal and colleagues[32] demonstrated that demineralization after consumption of foods high in carbohydrates can be prevented by brushing with fluoridated toothpaste compared with brushing with nonfluoridated toothpaste. In addition, 100 percent fruit juices contain numerous phytochemicals with known antibacterial activities; thus, 100 percent fruit juice could inhibit oral bacteria's growth and metabolic activities.[33-35]

Other factors related to the timing and frequency of sugar consumption also could explain the lack of association found between intake of 100 percent fruit juice and ECC. However, Burt and colleagues[36] found that the frequency and time of sugar consumption were not associated with caries increments among children 11 to 15 years old. In 2005, Marshall and colleagues[6] reported similar results. Their study findings also showed that the timing of consumption of 100 percent fruit juice had minimal impact on caries risk among children aged 1 through 5 years.[6] We also found that consuming 100 percent fruit juice with meals or with snacks did not have any influence on the association between consumption of 100 percent fruit juice and ECC (data not shown).

The findings of the Vipehölm study, the most influential study on the topic of sugar consumption frequency, are questionable in relation to the population studied (patients in a mental institution) and the extreme nature of the sugar ingested (24 sticky toffees that, because of the large size, had to be sucked).[37] It is unlikely that these conditions are similar to real-world sugar consumption.[27,29] Moreover, the widespread availability of fluoride today makes that study's results even less applicable. Another epidemiological factor relates to the overall high consumption of added sugar among U.S. children,[38] which makes it difficult to find children who have not been exposed to added sugars to serve as control participants in studies.

Behavioral factors also may contribute to the lack of association between dental caries in young children and consumption of 100 percent fruit juice. One hundred percent fruit juice, as opposed to fruit drinks with added sugar, is viewed by many parents as a healthy dietary option for children, particularly young children.[14] Consequently, more health-conscious and well-informed parents or caregivers might be more inclined to provide 100 percent fruit juice to their children along with other healthy foods and to instill other healthy behaviors.[7,8] Lim and colleagues[8] found that children who had high consumption of 100 percent fruit juice also had high consumption of milk. Therefore, consumption of 100 percent fruit juice by young children could be an indicator of overall healthy behaviors, which, considering the multifactorial etiology of caries, would result

TABLE 4

Logistic regression results for the association between consumption of 100 percent fruit juice in the previous 24 hours and caries prevalence, NHANES* 1999-2004.†

VARIABLES	ODDS RATIO (95 PERCENT CONFIDENCE INTERVAL)			
	Crude Odds Ratios	Adjusted Model With Prevalence of Consumption of 100 Percent Fruit Juice‡	Adjusted Model With Ounces of Consumption of 100 Percent Fruit Juice§	Adjusted Model, Measurement Error Correction for Intake of 100 Percent Fruit Juice¶#
Consumption of 100 Percent Fruit Juice				
Yes	0.76 (0.57-1.01)	0.89 (0.63-1.24)	NA**	NA
No (reference)	Reference	Reference	NA	NA
Consumption of 100 Percent Fruit Juice				
> 6 ounces	0.78 (0.56-1.09)	NA	0.90 (0.62-1.30)	NA
> 0 and ≤ 6 oz	0.71 (0.46-1.08)	NA	0.85 (0.51-1.42)	NA
0 oz (reference)	Reference	NA	Reference	NA
Consumption of 100 Percent Fruit Juice: 12.6 oz Versus 0.9 oz	NA	NA	NA	0.97 (0.44-2.12)
Child's Age, in Years				
2 (reference)	Reference	Reference	Reference	Reference
3	2.47 (1.54-3.97)	2.27 (1.43-3.61)	2.27 (1.43-3.62)	2.29 (1.44-3.63)
4	4.04 (2.48-6.58)	3.79 (2.26-6.36)	3.79 (2.26-6.35)	3.80 (2.24-6.45)
5	4.85 (2.98-7.90)	4.14 (2.44-7.02)	4.14 (2.45-7.02)	4.21 (2.37-7.48)
Sex				
Male	1.13 (0.81-1.58)	1.23 (0.85-1.77)	1.23 (0.85-1.77)	1.22 (0.85-1.75)
Female (reference)	Reference	Reference	Reference	Reference
Race/Ethnicity				
Non-Hispanic white (reference)	Reference	Reference	Reference	Reference
Non-Hispanic black	1.19 (0.87-1.63)	0.79 (0.55-1.15)	0.79 (0.55-1.15)	0.79 (0.55-1.14)
Mexican-American	2.15 (1.57-2.95)	1.56 (1.13-2.16)	1.56 (1.13-2.17)	1.56 (1.15-2.11)
Other	1.03 (0.63-1.69)	0.93 (0.56-1.55)	0.93 (0.56-1.56)	0.92 (0.56-1.52)
Poverty Level, in Percentage FPG††				
< 100	5.06 (3.05-8.41)	5.85 (3.50-9.77)	5.84 (3.51-9.69)	5.89 (3.51-9.89)
100-299	2.75 (1.71-4.42)	2.84 (1.76-4.56)	2.83 (1.76-4.55)	2.87 (1.79-4.59)
≥ 300	Reference	Reference	Reference	Reference
Dental Visit Within Previous Year				
Yes	2.00 (1.45-2.76)	1.51 (1.05-2.19)	1.52 (1.05-2.19)	1.51 (1.05-2.17)
No (reference)	Reference	Reference	Reference	Reference

* NHANES: National Health and Nutrition Examination Survey.
† Source: Centers for Disease Control and Prevention.[17]
‡ Covariates include consumption of 100 percent fruit juice (yes or no), age, sex, race/ethnicity, poverty level, dental visits.
§ Covariates include consumption of 100 percent fruit juice (ounces), age, sex, race/ethnicity, poverty level, dental visits.
¶ Covariates include usual intake of 100 percent fruit juice, age, sex, race/ethnicity, poverty level, dental visits.
# Ninetieth percentile versus 10th percentile of the usual intake distribution.
** NA: Not applicable.
†† FPG: Federal poverty guideline. FPG based on the poverty income ratio.[22]

in caries prevention.[8]

Our finding of a lack of association between ECC and consumption of 100 percent fruit juice suggests that oral health care providers and educators should recommend limiting consumption of 100 percent fruit juice to 4 to 6 oz per day for children 1 to 6 years of age[14] for its overall health benefit (that is, nutritional value) rather than as a means to prevent caries.

CONCLUSION

Our findings are consistent with those of other studies that show consumption of 100 percent fruit juice is not associated with ECC. ■

Disclosure. None of the authors reported any disclosures.

This research was funded by grant 5R03 DE 018389-02 from the National Institute of Dental and Craniofacial Research, National Institutes of Health, Bethesda, Md., to Dr. Vargas.

1. American Academy of Pediatric Dentistry. Policy on early childhood caries (ECC): classifications, consequences, and preventive strategies. Revised 2014. www.aapd.org/media/Policies_Guidelines/P_ECCClassifications.pdf. Accessed Oct. 15, 2014.

2. Vargas CM, Crall JJ, Schneider DA. Sociodemographic distribution of pediatric dental caries: NHANES III, 1998-1994. JADA 1998;129(9):1229-1238.

3. Dye BA, Arevalo O, Vargas CM. Trends in paediatric dental caries by poverty status in the United States, 1988-1994 and 1999-2004. Int J Paediatr Dent 2010;20(2):132-143.

4. U.S. Food and Drug Administration. CFR: Code of Federal Regulations Title 21. www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=101.30. Accessed Nov. 3, 2014.

5. Marshall TA, Levy SM, Broffitt B, et al. Dental caries and beverage consumption in young children. Pediatrics 2003;112(3, pt 1):e184-e191.

6. Marshall TA, Broffitt B, Eichenberger-Gilmore J, Warren JJ, Cunningham MA, Levy SM. The roles of meal, snack, and daily total food and beverage exposures on caries experience in young children. J Public Health Dent 2005;65(3):166-173.

7. Kolker JL, Yuan Y, Burt BA, et al. Dental caries and dietary patterns in low-income African American children. Pediatr Dent 2007;29(6):457-464.

8. Lim S, Sohn W, Burt BA, et al. Cariogenicity of soft drinks, milk and fruit juice in low-income African-American children: a longitudinal study. JADA 2008;139(7):959-967.

9. Sohn W, Burt BA, Sowers MR. Carbonated soft drinks and dental caries in the primary dentition. J Dent Res 2006;85(3):262-266.

10. Evans EW, Hayes C, Palmer CA, Bermudez OI, Cohen SA, Must A. Dietary intake and severe early childhood caries in low-income, young children. J Acad Nutr Diet 2013;113(8):1057-1061.

11. Wang YC, Bleich SN, Gortmaker SL. Increasing caloric contribution from sugar-sweetened beverages and 100% fruit juices among US children and adolescents, 1988-2004. Pediatrics 2008;121(6):e1604-e1614.

12. Harnack L, Stang J, Story M. Soft drink consumption among US children and adolescents: nutritional consequences. J Am Diet Assoc 1999;99(4):436-441.

13. Dennison BA. Fruit juice consumption by infants and children: a review. J Am Coll Nutr 1996;15(5)(suppl):4S-11S.

14. American Academy of Pediatrics: the use and misuse of fruit juice in pediatrics—Committee on Nutrition. Pediatrics 2001;107(5):1210-1213.

15. Gidding SS, Dennison BA, Birch LL, et al; American Heart Association. Dietary recommendations for children and adolescents: a guide for practitioners (published correction appears in Pediatrics 2006;118[3]:1323. Gilman, Matthew W [corrected to Gillman, Matthew W]). Pediatrics 2006;117(2):544-559.

16. Wojcicki JM, Heyman MB. Reducing childhood obesity by eliminating 100% fruit juice. Am J Public Health 2012;102(9):1630-1633.

17. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey. Questionnaires, datasets, and related documentation. www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm. Accessed Nov. 3, 2014.

18. Dye BA, Barker LK, Selwitz RH, et al. Overview and quality assurance for the National Health and Nutrition Examination Survey (NHANES) oral health component, 1999-2002. Community Dent Oral Epidemiol 2007;35(2):140-151.

19. Dye BA, Nowjack-Raymer R, Barker LK, et al. Overview and quality assurance for the oral health component of the National Health and Nutrition Examination Survey (NHANES), 2003-04. J Public Health Dent 2008;68(4):218-226.

20. Dye BA, Tan S, Smith V, et al. Trends in oral health status: United States, 1988-1994 and 1999-2004. Vital Health Stat 11 2007;(248):1-92.

21. Fisher-Owens SA, Gansky SA, Platt LJ, et al. Influences on children's oral health: a conceptual model. Pediatrics 2007;120(3):e510-e520.

22. U.S. Census Bureau. Poverty. Definitions. www.census.gov/hhes/www/poverty/methods/definitions.html. Accessed Nov. 3, 2014.

23. Landis JR, Heyman ER, Koch GG. Average partial association in three-way contingency tables: a review and discussion of alternative tests. Int Stat Rev 1978;46:237-254.

24. Agresti A. Categorical Data Analysis. 2nd ed. New York City: Wiley and Sons; 2002.

25. Kipnis V, Midthune D, Buckman DW, et al. Modeling data with excess zeros and measurement error: application to evaluating relationships between episodically consumed foods and health outcomes. Biometrics 2009;65(4):1003-1010.

26. National Cancer Institute. Usual dietary intakes: SAS macros for the NCI method. http://appliedresearch.cancer.gov/diet/usualintakes/macros.html. Accessed Oct. 24, 2014.

27. Burt BA, Pai S. Sugar consumption and caries risk: a systematic review. J Dent Educ 2001;65(10):1017-1023.

28. Tooze JA, Midthune D, Dodd KW, et al. A new statistical method for estimating the usual intake of episodically consumed foods with application to their distribution. J Am Diet Assoc 2006;106(10):1575-1587.

29. Burt BA, Eklund SA. Dentistry, Dental Practice, and the Community. 6th ed. St. Louis: Elsevier Saunders; 2005.

30. Campain AC, Morgan MV, Evans RW, et al. Sugar-starch combinations in food and the relationship to dental caries in low-risk adolescents. Eur J Oral Sci 2003;111(4):316-325.

31. Gibson S, Williams S. Dental caries in pre-school children: associations with social class, toothbrushing habit and consumption of sugars and sugar-containing foods—further analysis of data from the National Diet and Nutrition Survey of children aged 1.5-4.5 years. Caries Res 1999;33(2):101-113.

32. Duggal MS, Toumba KJ, Amaechi BT, Kowash MB, Higham SM. Enamel demineralization in situ with various frequencies of carbohydrate consumption with and without fluoride toothpaste. J Dent Res 2001;80(8):1721-1724.

33. Tabasco R, Sánchez-Patán F, Monagas M, et al. Effect of grape polyphenols on lactic acid bacteria and bifidobacteria growth: resistance and metabolism. Food Microbiol 2011;28(7):1345-1352.

34. Russell W, Duthie G. Plant secondary metabolites and gut health: the case for phenolic acids. Proc Nutr Soc 2011;70(3):389-396.

35. Del Rio D, Borges G, Crozier A. Berry flavonoids and phenolics: bioavailability and evidence of protective effects. Br J Nutr 2010;104(suppl 3):S67-S90.

36. Burt BA, Eklund SA, Morgan KJ, et al. The effects of sugars intake and frequency of ingestion on dental caries increment in a three-year longitudinal study. J Dent Res 1988;67(11):1422-1429.

37. Gustafsson BE, Quensel CE, Lanke LS, et al. The Vipeholm dental caries study: the effect of different levels of carbohydrate intake on caries activity in 436 individuals observed for five years. Acta Odontol Scand 1954;11(3-4):232-264.

38. Ervin RB, Kit BK, Carroll MD, Ogden CL. Consumption of added sugar among U.S. children and adolescents, 2005-2008. NCHS Data Brief 2012;(87):1-8.