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The associations between dietary intakes from 36 to 60 months of age and primary dentition non-cavitated caries and cavitated caries

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Abstract

Objective—To examine risk factors for non-cavitated caries, as well as cavitated caries.

Methods—Subjects were participants in the Iowa Fluoride Study cohort. Dietary data were collected at 36, 48, and 60 months old using 3-day dietary diaries, and a dental examination was conducted at about age 5. We compared the frequencies of dietary intakes of three groups: a) children having only $d_1$caries (n = 41); b) children having only cavitated ($d_{2+}f$) caries (n = 46); and c) children having both d_1 and $d_{2+}f$ caries (n = 49) with a forth group; d) those of caries-free children (n = 257).

Results—Multinomial and binomial logistic regression was used, where the categorical outcome was based on the 4 caries groups, and the caries-free group was designated as the reference. In the final model, sevenvariables were associated with the caries outcome. Lower milk consumption frequency at meals and greater presweetened cereal consumption frequency at meals were significantly associated with a greater likelihood of being in the d_1 group. Greater regular soda pop consumption frequency and greater added sugar consumption frequency at snacks were significantly associated with being in the cavitated caries ($d_{2+}f$ and/or $d_1d_{2+}f$) groups. Lower socioeconomic status and less frequent toothbrushing increased the likelihood of being in the d_1 group.

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Conclusions—The results suggest that different food and beverage categories are associated with being in the d_1 group compared with the cavitated caries groups. More frequent toothbrushing, greater milk consumption at meals, and avoiding presweetened cereal consumption at meals might reduce the risk of developing non-cavitated caries.

Keywords

non-cavitated caries; cavitated caries; diet; primary dentition; preschool children; dental caries

Introduction

Prevention of dental caries in preschoolers has positive benefits on both the primary and permanent dentitions. A better understanding of caries initiation and progression is necessary for more successful caries prevention.

Generally, both non-cavitated and cavitated caries are assumed to have the same risk and protective factors. However, Mascarenhas (1) reported different risk indicators for enamel and dentin caries. She reported that increased frequency of toothbrushing was a significant risk indicator for dentin caries, while mother's educational level and nonvegetarian diet were significant risk indicators for enamel caries.

Few cohort studies (2–6) have assessed associations between dietary intakes and dental caries in the primary dentition. A review of the English language literature describing studies of preschoolers showed that most studies investigated associations between cavitated caries experience and specific types of diet. One study (6) found a significant association between new caries and starting consumption of soft drinks or sugary snacks at 9 months of age.

A small number of English language studies have reported the prevalence and/or number of non-cavitated lesions (initial enamel caries) in the primary dentition (2,7–11). However, only four studies used non-cavitated caries as an outcome variable for analytical purposes. The first study (7) categorized children with only incipient caries as a separate category from Early Childhood Caries, but associations of risk factors with incipient caries were not presented. Two studies (2,8) reported separately the prevalence of children with initial caries and the prevalence of children with cavitated caries. However, only overall caries, combining non-cavitated caries with cavitated caries, was assessed for association with dietary factors. One study (12) did not report the distribution of caries; however, the authors used the combination of non-cavitated and cavitated caries as an outcome variable. None of these four studies examined the relationships between dietary factors and non-cavitated caries individually or weighted non-cavitated caries relative to cavitated caries.

The main purpose of the present analysis was to examine risk factors for non-cavitated caries. The secondary purpose was to examine risk factors for cavitated caries. We compared dietary intakes, expressed as frequencies of consumption, between caries-free children and children having a) non-cavitated caries only; b) cavitated caries only; and c) both non-cavitated and cavitated caries in the primary dentition.

Materials and methods

Subjects in this study were part of the longitudinal Iowa Fluoride Study (IFS). Children and parents were recruited from 1992 to 1995. The details of the study population and recruitment of IFS subjects have been published elsewhere (13). This study was approved by the Human Subjects Committee at the University of Iowa, and parents provided informed consent.

Three-day diet diaries were sent to parents when children reached each of the ages 1.5, 3, 6, 9, and 12 months, and then every 4 or 6 months through 102 months of age (5). Parents were instructed to record all food and beverage consumption for 2 weekdays and 1 weekend day, along with the time of consumption. For these analyses, dietary diaries at 36, 48 (if available), and 60 months were abstracted by a trained registered dietitian or diet technician. If the designated diary was missing, then substitution was made using the diary either 4 or 6 months preceding (or succeeding) the yearly diary.

Frequencies of food and beverage consumption were abstracted from diaries. Foods and beverages consumed within a 30-minute interval counted as a single eating event. Multiple servings of the same beverage or food consumed within 30 minutes also were considered as one item (5).

The eating events then were categorized into meals or snacks based on the time of consumption and nature of the foods. There were only three meals per day allowed: one during the morning, one at the middle of the day, and one during evening hours. However, there were unlimited eating events allowed for snacks. Each beverage was categorized by type of beverage, while each food was categorized based on sugar and/or starch content (5). Relevant categories for beverages included milk, 100 percent fruit juice, juice drink, powdered sugared beverage, regular (sugared) soda pop, and water. Categories for foods were: presweetened cereals, unsweetened cereals, baked starch with sugar (e.g., cake, cookies), unprocessed starches (e.g., bread, baked potato), processed starches (e.g., potato chips, pretzels), sugar-based desserts (e.g., gelatin, ice cream, pudding), candy, and added sugar (e.g., table sugar, honey, brown sugar). More details related to the abstraction methods have been presented else-where (5). The frequencies of consumptions from the diaries of each child were averaged at each age across the 3 days, and then results were averaged across the 2 (36 and 60 months) or 3 (36, 48, and 60 months) ages.

IFS questionnaires were sent to parents at the same time as the diaries. Average daily toothbrushing frequency and composite water fluoride levels were determined based on the data from these questionnaires. Composite water fluoride levels were determined from all sources of water (i.e., home and child care bottled/filtered/tap water) at each time point for each individual child. Composite water fluoride levels and toothbrushing frequency from 36, 48, and 60 months (with substitutions similar to those of the diaries described previously) were averaged. Socioeconomic status (SES) was classified from baseline questionnaires into low, medium, and high categories based on family income and mother's education at recruitment (1992–1995). Specifically, children from families with annual incomes of less than $30,000/year whose mother had 2 years or less in college were categorized as low SES.

Children from families with annual incomes from $30,000 to $49,999/year whose mothers had a graduate/professional degree, or from families with annual incomes of more than $50,000/year (regardless of the mother's educational level) were categorized as high SES. All others were placed in the middle SES category.

Dental examinations were conducted by trained and calibrated examiners when the children were approximately 5 years old. The examiners used a portable chair and halogen headlight (9). The teeth were dried and a DenLite® mirror (Welsh Allyn Medical Products, Inc., Skaneatele Falls, NY, USA) was used for improved lighting and transillumination. The examination was primarily by visual, but any questionable caries condition was confirmed by explorer (9). The diagnostic criteria used in this study were with a d_1-d_3 system modified from the criteria of Pitts (14). The criteria used in this study did not differentiate cavitated enamel (d_2) and dentine lesions (d_{3-4}), so those lesions were categorized together as d_{2+}. The d_1 criteria for non-cavitated lesions were similar to d_1 criteria used by others (9).

There were 393 subjects who had dental examinations at about age 5 and dietary diaries at both 36 and 60 months (or their substitutions, see below), but not all of these subjects had a 48-month diary (or substitution). Sixteen subjects needed to be dropped from the analyses due to missing SES information or toothbrushing frequency, resulting in a sample size of 377. Children were categorized into discrete groups: a) the d_1 group for children with non-cavitated caries only (no cavitated caries); b) the $d_{2+}f$ group for children with only cavitated and/or filled caries (no non-cavitated caries); c) the d_1 $d_{2+}f$ group for children with both cavitated and non-cavitated caries; and 4) the caries-free group for children with neither non-cavitated nor cavitated caries. Repeat exams by different examiners were conducted on 67 children. Inter-examiner reproducibility of classification of these 67 children into the four subgroups was assessed (weighted Kappa = 0.72). In the multinomial logistic regression modeling, the four caries groups comprised the outcome categories, with the caries-free group serving as the baseline or reference category.

Univariable multinomial logistic regression was used to screen for potential risk factors. Since over 30 separate risk factors were screened and since our multinomial regression involved three separate comparisons for each risk factor, we chose a fairly conservative screening cutoff ($P < 0.15$). Those identified risk factors were then examined for colinearity. Among variables with moderate to high pair-wise correlations (Pearson coefficients > 0.3), the variable with a weaker relationship with the outcome was removed. All two-way interactions of these variables were assessed in bivariable models, except for those of two continuous variables. Interaction terms with *P*-values less than 0.15 were considered in the multivariable modeling. A backward elimination procedure using the Akaike information criterion (AIC) was performed to reduce the number of variables in the model. The model with smaller AIC was chosen during the variable elimination procedure. Hosmer and Lemeshow goodness of fit tests were used to assess the lack of fit in multinomial logistic regression model.

Additionally, multivariable binomial logistic regression modeling comparing risk factors between children in the d_1 group and children in the caries-free group was conducted using steps similar to those described for the multivariable multinomial logistic modeling. Then, variables significant in the binomial model but not in the multinomial model were identified and included in developing the final multinomial logistic regression model.

All data were processed in SAS 9.12 (SAS Institute Inc., Cary, NC, USA) and analyzed using PROC LOGISTIC.

Results

There were 377 children included in the analyses. About 52 percent of subjects were girls and most families were of middle or high SES (38 percent and 40 percent, respectively). The mean age at the primary dentition exam was 5.1 (±0.3) years old. The mean number of d_1 surfaces among those in the d_1 group was 2.27 (±1.78), the mean number of $d_{2+}f$ surfaces among those in the $d_{2+}f$ group was 4.89 (±5.14), and the mean number of d_1 and $d_{2+}f$ surfaces among those in the $d_1d_{2+}f$ group were 2.80 (±2.82) and 5.69 (±7.77), respectively.

Table 1 presents the percentages of children who had consumed the specific food item at any of the 2–3 available time points, and the medians, 25th and 75th percentiles of food and beverage consumption frequency data separately at snacks and meals for the four groups.

Means of age at dental examination, toothbrushing frequency and composite water fluoride level and distribution of SES level for the four groups are presented in Table 2. More caries-free children were in the high SES level. Toothbrushing frequency, age at dental examination, and SES level among the four groups were significantly different in the bivariate analyses.

For the multivariable multinomial logistic regression analyses assessing factors associated with being in the four caries outcomes groups, eight variables were considered in the initial multivariable model. The results for the model from the use of AIC results in conjunction with the backward elimination procedure are shown in Table 3. Consumption frequencies of regular soda pop consumption at snacks and sugar at snacks, toothbrushing frequency, age at primary dentition, and SES level were retained in the model.

For the multivariable binomial logistic regression analyses assessing factors associated with being in the d_1 group versus caries-free group, eight variables were then considered in the initial multivariable model. Consumption frequencies of milk at meals and presweetened cereal at meals, toothbrushing frequency, and SES level were significant in the model.

Consumption frequencies of milk at meals and presweetened cereal at meals were two variables that were not represented in the multinomial model (Table 3), but were significantly associated with being in the d_1 group in the binomial model (Table 4). These two variables and five other variables (from Table 3) were used to form an overall multivariable multinomial logistic regression model comparing the three caries groups with the caries-free group (Table 5). AIC results for models in Tables 3 and 5 showed that both models characterize the data about equally well, with neither clearly superior based on balancing parsimony and goodness of fit. Since the two additional variables were significantly associated with non-cavitated caries, which is our main emphasis, we chose the model including these two variables as our final model (Table 5).

Greater consumption frequency of regular soda pop at snacks significantly increased the likelihood of being in the $d_1d_{2+}f$ group (relative to the reference category, the caries-free group). Added sugar consumption at snacks significantly increased the likelihood of being in the $d_{2+}f$ group and the $d_1d_{2+}f$ group. Lower consumption frequency of the milk at meals and greater consumption frequency of presweetened cereal significantly increased the likelihood of being in the d_1 only group. Greater daily toothbrushing frequency significantly decreased the likelihood of being in the $d_1d_{2+}f$ group and moderately decreased (*P*-value = 0.058) the likelihood of being in the d_1 group. Older children were significantly more likely to be in the $d_1d_{2+}f$ group. Children from higher SES families generally had decreased likelihood of being in any of the three caries groups. However, these relationships were statistically significant for the d_{2+f} and d_1 groups, but not for the $d_1d_{2+}f$ group.

Discussion

In the multivariable modeling, the data were analyzed using both multinomial logistic regression analyses (Table 3) for four categorical outcomes and binary logistic regression analyses (Table 4) comparing the d_1 only group and caries-free group. Both variable screening and initial model selection in the multinomial regression analyses were based on the overall *P*-values. These *P*-values provide a composite characterization of the effect of a variable on the conditional odds defined by comparing each caries group to the caries-free reference group. Milk and presweetened cereal consumption frequencies at meals were the two variables that were not statistically significant in the multinomial logistic analysis (Table 3), but were significant in the binomial logistic analysis (Table 4), as these two variables have weaker associations with the cavitated caries groups.

The main purpose of these analyses was to examine risk factors for non-cavitated caries, but non-cavitated caries is only one stage of the caries process. Thus, conducting binomial logistic regression analysis alone (d_1 only versus caries-free) does not seem adequate, since it would exclude all subjects with cavitated caries. However, the final multinomial analysis (Table 5) needs to be considered within the limitations of the sample sizes, especially for the affected groups. More studies with larger and more diverse samples, which analyze both non-cavitated and cavitated caries, are needed.

There are no other studies that have assessed the association between SES and non-cavitated caries in the primary dentition. SES might represent some other health-related factors that are difficult to measure, such as effective oral home care and patterns of food choices. The present study found that higher SES levels were significantly associated with being less likely to be in both the d_1 only group and the $d_{2+}f$ group compared with the caries-free group. SES is also an important variable which should be considered along with other related factors in assessing associations with both cavitated and non-cavitated caries.

One study (1) reported no significant association between increased toothbrushing frequency and enamel caries (D_1 and D_2), but increased toothbrushing frequency was significantly associated with dentin caries. In contrast, our study showed that lower toothbrushing frequency was marginally associated (*P*-value = 0.058) with being in the d_1 group and was significantly associated (*P*-value = 0.014) with being in the $d_1d_{2+}f$ group, but was not significantly associated with being in the $d_{2+}f$ group. These results suggest that toothbrushing frequency might be a significant factor only for the d_1 caries component in both the d_1 group and $d_1d_{2+}f$ group. The reasons for this are unclear, but at 36 months of age, 98.7 percent of the subjects were using a fluoride dentifrice with brushing, and that percentage increased to at least 99 percent thereafter. Hence, toothbrushing frequency was actually a measure of topical fluoride exposure and mechanical cleaning. Since other studies did not find plaque levels or oral hygiene status to be associated with caries outcome (15,16), we assume that it was mostly the topical fluoride exposure that reduced caries initiation in the present analyses. This finding differs from the conclusion of Groeneveld (17), who found that water fluoridation had only a small preventive effect on initiation of caries (but a larger effect on dentinal caries). The relationship between daily toothbrushing frequency and prevalence of cavitated caries has been investigated extensively in preschoolers (18–22). Three of five studies (19,21,22) found a significant association between less frequent toothbrushing and increased risk of cavitated caries. One study (18) reported no association between toothbrushing frequency and caries, after adjusting for other variables in a logistic regression. Additionally, another study (20) reported higher toothbrushing frequency was associated with greater cavitated caries experience. Like the findings from the Douglass *et al.* (20) and the Al-Malik *et al.* (18) studies, the present analyses do not support a preventive effect of greater toothbrushing frequency on cavitated caries. One possible reason for this finding is that children with cavitated caries in these studies, especially those with substantial proportions of filled lesions as in the present study, could have brushed their teeth more often because they received more oral hygiene instruction from dental personnel during the treatment and/or prevention visits than did caries-free children. This could explain why frequent toothbrushing did not decrease the chance of being in the caries-free group in these observational studies.

Presweetened breakfast cereals have been available in the United States for more than 40 years. Such cereals are prepared by coating the cereal pieces with a slurry or solution of sweeteners and then drying the cereals in an oven or air current. There is an average of about 42 g of total sugar in 100 g of presweetened cereals (23). Thus, an association between increased exposures to presweetened cereals at meals and dental caries is highly plausible. One animal study (24) that examined the relationship between gross caries and presweetened cereals in hamsters reported that presweetened cereals were more cariogenic than non-presweetened cereals. Another study (25) examined the association between cavitated caries and presweetened cereals in humans. The author analyzed data from the 1995 UK National Diet and Nutrition Survey of children aged 1.5 to 4.5 years, and reported no association between presweetened cereal consumption frequency and cavitated caries prevalence. Presweetened cereal consumption frequency at meals was not significantly associated with being in either the $d_{2+}f$ group or the $d_1d_{2+}f$ group in the present analyses, but was associated with being in the d_1 group.

Children with greater milk consumption frequency at meals were significantly more likely to be in the caries-free group than in the d_1 group in the multivariable logistic regression model. No other published study has assessed the relationship between milk consumptions and non-cavitated caries. For cavitated caries, one study which assessed the effect of milk consumption on cavitated caries experience of both primary and permanent teeth in Italian children aged 6–11 years (26) found that milk consumption was a protective factor only in the group of children with high sucrose consumption. They did not find this association in the groups of children with moderate and low sucrose consumptions.

There are several studies that have assessed the association between regular soda pop consumption frequency and cavitated caries experience. Al-Malik *et al*. (18) and Sohn *et al*. (27), as well as an earlier publication from the IFS (5), reported a strong positive association between regular soda pop consumption frequency and cavitated caries experience in preschool children. The present analyses found that greater regular soda pop consumption at snacks increased the likelihood of being in the $d_{2+}f$ group and significantly increased the likelihood of being in the $d_1d_{2+}f$ group compared with being caries-free. However, the present analyses did not find a significant association between being in the d_1 group and regular soda pop consumption frequency either at snacks or at meals. Greater consumption frequencies of regular soda pop and foods with added sugar were significantly associated with being in the $d_{2+}f$ and/or in the $d_1d_{2+}f$ groups (more advanced dental caries) for snacks (but not at meals). The greater consumption of presweetened cereal and lower consumption of milk at meals, where they are consumed with some other foods and/or beverages, were significantly associated with being in the d_1 group (less advanced caries). Consumption of high cariogenicity foods and beverages at meals is believed to decrease the cariogenicity of such consumption (5).

Several studies (18,19,27,28) have found a significant association between age at dental examination and cavitated caries experience. The present analyses produced similar results. Cavitated caries experience is an irreversible state that results in increased prevalence and number of affected surfaces over time. On the other hand, non-cavitated caries is a reversible stage between a sound surface and cavitated lesion. Thus, time might not be the primary significant factor, but the factors that change the dynamics of demineralization and remineralization of non-cavitated caries could be more important factors.

While several studies used questionnaires to collect information about specific food types (3,7,28), several others collected dietary data using a frequency questionnaire that focused on a selected number of snacks and sugar-containing foods and beverages and the consumption frequency per time period (week or day) (8,18). The IFS, along with several other studies (4,19,27), had the advantage of using dietary records (3–5 days) to collect more complete records of food and beverage consumption frequency and/or quantity and time. This method of recording time of consumption, combined with the data abstraction method, provided detailed data separately for consumption at meals and snacks, whereas most of the published studies on this subject have assessed overall frequency of food and/or beverage consumption per day. For some foods and beverages, the combined consumption at meals and snacks together may not show an association with caries, but separate analyses of only meals or snacks may exhibit an association with dental caries (5).

The idea of separately assessing risk factors for different stages of caries is not new. However, there are a limited number of studies because most of the earlier studies used diagnostic criteria that did not separate enamel caries from dentin caries. There are two studies that have assessed the different risk (or protective) factors for enamel caries (D_1 and

D_2) and dentine caries (D_3, D_4, filled and missing due to caries) (1,17). The present study classified children into four discrete groups at the person-level; thus we could separately assess the risk factors for non-cavitated caries. However, we used a different stage as a cutoff, in which our criteria concentrated on cavitation status regardless of the depth of the lesions.

There are several limitations of the present study. First, the study group was predominantly white and mostly of middle and high SES, which is not representative of the general United States population. Second, no “activity level of caries” was measured or scored, thus the study cannot distinguish the association between diet and active versus inactive non-cavitated caries. Third, this study did not use radiographic examination; therefore, the caries prevalence would tend to be underestimated due to undiagnosed proximal carious lesions. Fourth, only one examination of primary teeth was used in the analyses. This report did not investigate rates of progression for non-cavitated carious lesions. Fifth, the present study had a fixed sample size, with only a small number of subjects in the d_1 only group and so statistical power was limited. Indeed, using *t*-tests based on the means and standard deviations in Table 2, the power to detect the observable differences in toothbrushing frequency at a significance level of 0.05 for each of the three individual caries groups (versus caries-free) was only 21–60 percent. Larger studies with detailed dietary data and examination criteria that could separately identify non-cavitated and cavitated/filled caries are needed. Lastly, the present study did not conduct microbiological assays and did not collect information concerning dental insurance status or dental utilization rates. These omissions somewhat limit the interpretation and discussion of the results.

Most studies of caries and risk factors, even those published this decade, have focused on cavitated caries as the only outcome variable. Selection of preventive measures to treat non-cavitated caries based on information from those cavitated caries studies may not be appropriate for prevention of non-cavitated caries. Thus, a better understanding of risk factors for non-cavitated caries could provide the framework for the development of preventive programs to substantially decrease the initiation of dental caries in children. In the future, more in-depth, longitudinal studies of caries progression over time should analyze the data using both cavitated and non-cavitated caries definitions.

In summary, the present study suggests frequent toothbrushing, milk consumption at meals, and avoiding presweetened cereal consumption at meals might reduce the risk of developing non-cavitated caries. Future research studies need to place more emphasis on investigation of risk factors for non-cavitated caries as part of assessing caries risk factors overall.

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Table 1

Descriptive Analysis of Dietary Variables (Age 36–60 Months Old) by Caries Category

Parameter		% Children with some consumption* (n = 377)	Median (25th, 75th percentile)			
			Caries-free (n = 248)	d_1 (n = 38)	$d_{2+}f$ (n = 45)	$d_1d_{2+}f$ (n = 46)
Beverage (occasions/day)						
Powdered sugared beverages	Snack	36	0.0 (0.0, 0.1)	0.0 (0.0, 0.2)	0.0 (0.0, 0.3)	0.0 (0.0, 0.2)
	Meal	34	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.0 (0.0, 0.2)	0.0 (0.0, 0.1)
Regular soda pop	Snack	52	0.0 (0.0, 0.2)	0.0 (0.0, 0.2)	0.1 (0.0, 0.2)	0.1 (0.0, 0.3)
	Meal	71	0.2 (0.0, 0.3)	0.2 (0.1, 0.4)	0.2 (0.1, 0.4)	0.2 (0.1, 0.4)
Juice drinks	Snack	52	0.0 (0.0, 0.2)	0.1 (0.0, 0.3)	0.1 (0.0, 0.2)	0.1 (0.0, 0.3)
	Meal	56	0.1 (0.0, 0.2)	0.1 (0.0, 0.3)	0.1 (0.0, 0.2)	0.1 (0.0, 0.2)
100% Juice	Snack	80	0.3 (0.1, 0.7)	0.3 (0.1, 0.4)	0.3 (0.1, 0.7)	0.3 (0.0, 0.6)
	Meal	85	0.4 (0.1, 0.8)	0.4 (0.2, 0.7)	0.4 (0.1, 0.7)	0.3 (0.1, 0.8)
Milk	Snack	84	0.3 (0.1, 0.7)	0.2 (0.1, 0.6)	0.3 (0.1, 0.8)	0.3 (0.1, 0.7)
	Meal	99.7	1.8 (1.2, 2.2)	1.5 (1.0, 2.0)	1.7 (1.3, 2.1)	1.7 (0.9, 2.0)
Water	Snack	91	0.8 (0.3, 1.3)	0.6 (0.2, 1.1)	0.6 (0.2, 1.1)	0.4 (0.2, 0.9)
	Meal	65	0.1 (0.0, 0.3)	0.1 (0.0, 0.3)	0.1 (0.0, 0.3)	0.1 (0.0, 0.3)
Food (occasions/day)						
Presweetened cereals	Snack	29	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.0 (0.0, 0.0)
	Meal	86	0.3 (0.1, 0.6)	0.3 (0.2, 0.7)	0.3 (0.2, 0.7)	0.3 (0.1, 0.4)
Unsweetened cereals	Snack	20	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
	Meal	59	0.1 (0.0, 0.2)	0.1 (0.0, 0.3)	0.1 (0.0, 0.2)	0.1 (0.0, 0.2)
Baked starch with sugar	Snack	98	0.6 (0.4, 0.9)	0.7 (0.3, 0.9)	0.6 (0.3, 0.8)	0.6 (0.4, 1.0)
	Meal	86	0.3 (0.2, 0.6)	0.2 (0.0, 0.4)	0.3 (0.1, 0.6)	0.3 (0.1, 0.6)
Unprocessed starches	Snack	77	0.1 (0.0, 0.3)	0.2 (0.1, 0.3)	0.2 (0.1, 0.3)	0.2 (0.1, 0.4)
	Meal	100	2.6 (2.2, 2.8)	2.4 (2.0, 2.8)	2.3 (2.0, 2.8)	2.4 (2.2, 2.7)
Processed starches	Snack	77	0.2 (0.1, 0.4)	0.2 (0.1, 0.6)	0.2 (0.0, 0.3)	0.2 (0.0, 0.4)
	Meal	88	0.3 (0.1, 0.6)	0.3 (0.2, 0.4)	0.2 (0.1, 0.4)	0.3 (0.2, 0.4)
Sugar-based desserts	Snack	81	0.2 (0.1, 0.3)	0.2 (0.1, 0.4)	0.3 (0.1, 0.4)	0.2 (0.1, 0.4)
	Meal	68	0.2 (0.0, 0.3)	0.1 (0.0, 0.2)	0.1 (0.0, 0.2)	0.1 (0.0, 0.3)
Candy	Snack	72	0.2 (0.0, 0.4)	0.2 (0.0, 0.4)	0.2 (0.0, 0.4)	0.2 (0.0, 0.6)

Parameter		% Children with some consumption* (n = 377)	Median (25th, 75th percentile)			
			Caries-free (n = 248)	d_1 (n = 38)	$d_{2+}f$ (n = 45)	$d_1d_{2+}f$ (n = 46)
	Meal	34	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
Added sugar	Snack	36	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.0 (0.0, 0.2)	0.1 (0.0, 0.2)
	Meal	79	0.3 (0.1, 0.5)	0.2 (0.0, 0.4)	0.2 (0.0, 0.4)	0.2 (0.1, 0.4)

* Percentage of children with some consumption from diaries (among two or three annual time points per child).

Table 2

Descriptive Analysis of Other Related Factors (Age 36–60 Months Old) by Caries Category (n = 377)

Parameter	Caries-free (n = 248)	d_1 (n = 38)	$d_{2+}f$ (n = 45)	$d_1d_{2+}f$ (n = 46)	P-value*
	Mean (SD)				
Toothbrushing frequency (36 to 60 months)	1.4 (0.5)	1.2 (0.5)	1.3 (0.5)	1.2 (0.4)	0.01
Average composite water fluoride level from age 36 to 60 months (ppm F)	0.8 (0.4)	0.9 (0.5)	0.8 (0.3)	0.8 (0.4)	0.69
Age	5.1 (0.3)	5.1 (0.3)	5.2 (0.4)	5.2 (0.5)	0.05
	Percent distribution (%)				
SES					0.001
• Low	16.9	31.6	31.1	28.3	
• Middle	34.7	52.6	42.2	41.3	
• High	48.4	15.8	26.7	30.4	

* *P*-values from Kruskal–Wallis tests and chi-square test (SES only).

SD, standard deviation; SES, socioeconomic status.

Table 3

Multivariable Multinomial Logistic Regression Model to Estimate the Odds of Being in the d_1 Group (n = 38) Relative to the Caries-Free Group (n = 248), in the $d_{2+}f$ Group (n = 46) Relative to the Caries-Free Group and the $d_1d_{2+}f$ Group (n = 45) Relative to the Caries-Free Group

	d_1 only versus caries-free		$d_{2+}f$ versus caries-free		$d_1d_{2+}f$ versus caries-free		
Parameter	**Odds ratio (95% CI)**	***P*-value**	**Odds ratio (95% CI)**	***P*-value**	**Odds ratio (95% CI)**	***P*-value**	**Overall *P*-value**
Regular soda pop at snacks (occasions/week)	1.058 (0.792, 1.412)	0.704	1.137 (0.889, 1.455)	0.306	1.345 (1.083, 1.671)	0.008	0.063
Added sugar at snacks (occasions/week)	0.920 (0.550, 1.536)	0.749	1.588 (1.152, 2.190)	0.005	1.623 (1.181, 2.230)	0.003	0.005
Daily toothbrushing frequency (36–60 months)	0.465 (0.216, 0.999)	0.050*	0.755 (0.393, 1.452)	0.400	0.402 (0.198, 0.819)	0.012	0.030
Age at primary dentition exam	0.701 (0.230, 2.142)	0.534	2.001 (0.814, 4.921)	0.131	3.756 (1.551, 9.092)	0.004	0.013
SES level	0.460 (0.286, 0.740)	0.002	0.574 (0.369, 0.893)	0.014	0.710 (0.449, 1.122)	0.143	0.003

Note: The initial, full model additionally included frequencies of consumptions of powdered sugared beverages at snacks, sugar-based dessert at meals, candy at meals, and unprocessed starches at snacks. Added sugar at snacks includes table sugar, honey, and brown sugar.

*P-value = 0.0498.

CI, confidence interval; SES, socioeconomic status.

Table 4

Multivariable Binomial Logistic Regression Model to Estimate the Odds of Being in the d_1 Group Relative to the Caries-Free Group

Parameter	Odds ratio (95% CI)	*P*-value
Milk at meals (occasions/week)	0.906 (0.834, 0.984)	0.020
Presweetened cereal at meals (occasions/week)	1.344 (1.096, 1.649)	0.005
Daily toothbrushing frequency (36–60 months)	0.430 (0.263, 0.702)	0.001
SES level	0.472 (0.224, 0.996)	0.049

Note: 1) The initial, full model additionally included frequencies of consumptions of powdered sugared beverages at snacks, regular soda pop at meals, juice drinks at meals, unprocessed starches at meals, age at primary tooth dental exam, gender, composite water fluoride level, and the interaction between powdered sugared beverage consumption frequency at snacks and SES level. These variables were removed in the backward elimination (P-value < 0.05 to remain). 2) Included subjects are caries-free children (n = 248) or those with d_1 caries experience only (n = 38); those with d_2+f experience are excluded.

CI, confidence interval; SES, socioeconomic status.

Table 5

Multivariable Multinomial Logistic Regression Model Including Two Variables* (from Table 4) to Estimate the Odds of Being in the d_1 Group ($n = 38$) Relative to the Caries-Free Group ($n = 248$), in the $d_{2+}f$ Group ($n = 46$) Relative to the Caries-Free Group and the $d_1d_{2+}f$ Group ($n = 45$) Relative to the Caries-Free Group

	d_1 only versus caries-free		$d_{2+}f$ versus caries-free		$d_1d_{2+}f$ versus caries-free		
Parameter	**Odds ratio (95% CI)**	***P*-value**	**Odds ratio (95% CI)**	***P*-value**	**Odds ratio (95% CI)**	***P*-value**	**Overall *P*-value**
Regular soda pop at snacks (occasions/week)	1.007 (0.745, 1.359)	0.966	1.116 (0.869, 1.433)	0.390	1.315 (1.055, 1.639)	0.015	0.101
Added sugar at snacks (occasions/week)	0.926 (0.556, 1.541)	0.767	1.579 (1.142, 2.182)	0.006	1.630 (1.183, 2.245)	0.003	0.006
Milk at meals* (occasions/week)	0.911 (0.840, 0.988)	0.025	0.969 (0.899, 1.045)	0.416	0.962 (0.890, 1.045)	0.328	0.137
Presweetened cereal at meals* (occasions/week)	1.304 (1.072, 1.586)	0.008	1.134 (0.947, 1.358)	0.173	1.002 (0.825, 1.216)	0.987	0.042
Daily toothbrushing frequency (36–60 months)	0.469 (0.214, 1.025)	0.058	0.762 (0.395, 1.468)	0.417	0.407 (0.200, 0.830)	0.014	0.035
Age at primary dentition exam	0.631 (0.200, 1.991)	0.432	1.913 (0.773, 4.732)	0.161	3.779 (1.558, 9.167)	0.004	0.012
SES level	0.432 (0.264, 0.709)	0.001	0.561 (0.358, 0.878)	0.012	0.719 (0.453, 1.140)	0.161	0.002

* These two variables that were significant in the binomial logistic regression model for d_1 versus caries-free (Table 4), but did not meet the screening criterion (P-value < 0.15) for the multinomial regression models.

CI, confidence interval; SES, socioeconomic status.