Obesity and Dental Caries in Children Aged 2-6 Years in the United States: National Health and Nutrition Examination Survey 1999-2002

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Abstract

Objective: *This study assessed the associations between obesity and dental caries in young children participating in a national survey.* ***Methods:*** *Participants included 1,507 children aged 2-6 years who received dental examinations and had at least 10 primary teeth in the National Health and Nutrition Examination Survey 1999-2002. Decayed/filled teeth (dft) counts of primary dentition were obtained, and weight and height were measured. Body mass index (BMI; kg/m^2) was calculated, and participants were categorized using age- and gender-specific criteria as underweight (<5th percent), normal (5th-85th percent), at risk for overweight (>85th and <95th percent), and overweight (≥95th percent). With appropriate sample weighting, relationships between dft and BMI were assessed using the Kruskal–Wallis test and multivariable logistic regression.* ***Results:*** *Seventy-four percent of children were classified as normal weight, 11 percent as at risk for overweight, and 11 percent as overweight; 58 percent did not have caries; 30 percent had 1-5 dft and 12 percent had >5 dft. When caries experience was compared across BMI categories stratified by age and race characteristics, statistically significant association between caries and obesity was found only for 60-<72-month age group. In the comparison between children with normal and at-risk BMI only, significant associations were also found in the Hispanic and non-Hispanic Black strata. In multivariable logistic regression models to predict caries experience, family income and age were statistically significant predictors for severe early childhood caries only.* ***Conclusions:*** *There appears to be no significant association between childhood obesity and caries experience after controlling for age, race, and poverty/income ratio. However, further studies are needed to better understand this relationship.*

Key Words: obesity, dental caries, childhood, primary teeth

Introduction

Although the prevalence of dental caries has declined in the past several decades, it continues to be a significant public health problem among children in the United States (1). In particular, racial and ethnic minority children and children living in poverty have a disproportionately higher burden of dental caries (2). Dental caries is the most common chronic childhood disease—in some age groups it is five times more prevalent than asthma (1). Early childhood caries, which affects primary teeth during early stages of life, can have a profound impact on a child's oral and general health, and quality of life. Twenty-eight percent of the children in the United States aged 2-6 years old have caries, and the prevalence increased by 15 percent during the past decade (3). Among the children with caries, three-quarters of tooth decay remain untreated (3).

Childhood obesity is currently the most prevalent nutritional condition of children in the U.S and is increasingly being cited as a growing epidemic and public health crisis (4,5). One study estimated that 25 percent of 10-year-old children were at risk for overweight and 11 percent were obese. Nationally, the proportion of overweight children aged 6-11 years has more than doubled, and the rate for overweight adolescents has tripled since 1980 (5).

There has been a growing interest in the relationship between dental caries and childhood obesity. Some studies have identified a positive association between these two common childhood conditions and have suggested that obese children are at an increased risk for dental caries (6,7). Other studies, however, have reported a negative association based on the failure to thrive among children with early childhood caries and the corresponding lower body mass index (BMI) (8,9). Additional studies have also reported no association between dental caries and childhood obesity (10,11). A recent systematic review of the literature published between 1984 and 2004 found only one study with a sufficient level of evidence for direct association between obesity and dental caries (12). The association between dental caries and obesity is complicated because both are complex conditions with multiple contributing factors, including biological, genetic, socioeconomic, cultural, dietary,

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environmental, and lifestyles issues. Nevertheless, childhood obesity and caries may share some common risk factors. For example, children at the highest risk for dental caries are disproportionately from minority households and/or live in poverty (1), and childhood obesity is also associated with low socioeconomic status (SES) in the United States (13).

Since very few studies have explored this issue using large-scale national samples, the aim of our study was to assess the associations between obesity and dental caries in children aged 2-6 years (24 to <72 months) who participated in the National Health and Nutrition Examination Survey (NHANES) 1999-2002.

Methods

Data from NHANES 1999-2002 were used for this cross-sectional study. The survey, which entailed interviews and physical and laboratory examinations, is based on a nationally representative sample of approximately 5,000 persons each year from 1999 to 2002. Over the 4 years of data collection 21,004 persons were selected and interviewed. Of those, oral health examinations were completed on 1,904 children aged 2-6 years. More detailed information on the sample design and operation of NHANES 1999-2002 can be found elsewhere (14). Our study was limited to children who were 2-6 years old with at least 10 primary teeth present in the mouth at the time of the oral examination. This age group was chosen to focus the analysis on primary tooth caries. The number of children meeting the eligibility criteria of this study was 1,507 – among those, 71 percent had all 20 primary teeth.

Household interviews provided information on demographic variables, medical history, and health-related behaviors of the 2- to 6-year-old children. Demographic variables included gender, ethnicity, age at examination, and the poverty index (PI). The PI was computed as a ratio between the midpoint of the reported family income category and the poverty threshold value determined by the Census Bureau. Consequently, a PI value below 1 indicates that the family income is below the poverty threshold. Medical history was obtained in the interview, including information on asthma, arthritis, cancer or malignancy, chronic bronchitis, coronary heart disease, ear infection, diabetes, hay fever, and stroke. Since few children had arthritis, cancer or malignancy, chronic bronchitis, coronary heart disease, diabetes, and/or stroke, only asthma was included in our analysis.

Oral health examinations were conducted in the mobile examination centers (MEC) and included dentition and periodontal assessments. Each quadrant was dried with air and examined with a surface reflection mirror and a No.23 explorer. The dentition assessment included tooth count, coronal caries, root caries, dental sealants, incisor trauma, and enamel fluorosis. Coronal caries was assessed by trained and calibrated dentists using a visual-tactile method with standardized equipment and supplies. Since this study was limited to children 2-6 years old, only coronal caries was included in the analysis. The number of decayed and filled teeth (dft) was calculated for each participant. Participant's caries status was categorized into three groups: 0 dft, 1-5 dft, and >5 dft. The filling component represented a tooth surface that has been restored with either a permanent or a temporary restoration as a result of caries. Because of difficulty of correctly distinguishing among teeth extracted for caries and other reasons, such as exfoliation and trauma, missing teeth count was not included in this analysis. Further, using criteria from the American Academy of Pediatric Dentistry, severe early childhood caries (S-ECC) was defined as follows: any sign of smooth surface decay in children younger than 3 years of age; one or more decayed or filled surfaces in primary maxillary anterior teeth from ages 3 to 5 years; or dfs ≥4 (age 3), ≥5 (age 4), or ≥6 (age 5) (14).

Weight and height were measured during a physical examination. Weight was measured when the child stood on a digital scale that was connected to the Integrated Survey Information System (ISIS) and standing height was measured with an electronic stadiometer that was also connected to the ISIS. BMI was calculated using the standard formula: weight in kilograms (kg) divided by height in meter squared (m^2). Children were classified into four categories using age- and gender-specific criteria recommended by the Centers for Disease Control and Prevention (15): underweight – less than 5th percentile; normal weight – 5th percentile to less than 85th percentile; at risk of overweight – 85th to less than 95th percentile; and overweight – equal to or greater than the 95th percentile. Dietary variables included in this analysis were daily total energy (kcal) intake, daily total carbohydrate intake, daily total fat intake, and daily total sugar intake. Dietary data were collected by trained and calibrated registered dietitians through 24-hour recall interviews to estimate the intake of food energy, nutrients, and nonnutrient food components from foods and beverages consumed during the 24-hour period (from midnight to midnight) prior to the MEC examinations (16).

Individual characteristics were categorized and presented as percentages or means (standard error). χ^2 analyses and Kruskal–Wallis tests were used to compare social-demographic, dietary, medical, and dental variables between caries experience categories and among BMI categories. χ^2 test was used to test for categorical associations between caries prevalence and BMI categories after stratifying by age and race. Further, BMI categories were compared between caries-free children and those with S-ECC using χ^2 test after stratifying by age, race, and gender. Logistic regression models were developed to predict caries experience (yes/no). The model included the variables that were significant in bivariate analyses or thought to be potentially important: child's BMI category, child's age,

Table 1
Characteristics of Study Sample, National Health and Nutrition Examination Survey 1999-2002, Age 2-6 Years

	Percentages (SE), mean (SE), or quantiles
Gender (%)	
Male	48.0% (1.5%)
Female	52.0% (1.5%)
Race (%)	
Non-Hispanic White	60.7% (2.5%)
Non-Hispanic Black	13.9% (1.9%)
Hispanic	19.5% (2.1%)
Other	5.9% (1.1%)
Poverty index (PI)	
Mean	2.2 (0.1)
<2.0	56% (2.3%)
≥2.0	44% (2.3%)
Body mass index (BMI)	
Mean	16.2 (0.1)
Underweight	4.2% (0.7%)
Normal	73.9% (1.4%)
At risk	11.3% (0.9%)
Overweight	10.6% (1.1%)
Daily total energy (kcal)	
Median (25th, 75th percentile)	1823.0 (1330.0, 2407.0)
Daily total carbohydrate intake (gram)	
Median (25th, 75th percentile)	236.3 (162.3, 323.2)
Daily total fat intake (gm)	
Median (25th, 75th percentile)	64.2 (43.5, 94.0)
Daily total sugar intake (gm)	
Median (25th, 75th percentile)	122.5 (71.4, 176.9)
Asthma (%)	14% (1.4%)
Dental caries	
Mean dft	1.79 (0.09)
0 dft	58.0% (1.5%)
1-5 dft	30.0% (1.5%)
>5 dft	12.0% (0.9%)
Dental visit in last year (%)	
Yes	65.2% (1.5%)
No	34.8% (1.5%)

dft, decayed/filled teeth; SE, standard error.

child's carbohydrate intake, race, and family income. All statistical tests were conducted in SAS 9.1 at the 0.05 level of significance. The NHANES Analytic and Reporting Guidelines were followed to apply appropriate weighting methodology for adjustment for the complex sample design and the unequal probability of selection; the variables SDMVSTRA, SDMVPSU, and WTMEC4YR provided with the NHANES 1999-2002 data were used for this purpose (14).

Results

Characteristics of the 2- to 6-year-old children are summarized in Table 1. About 4.2 percent were underweight, 73.9 percent had normal weight, 11.3 percent were at risk of overweight, and 10.6 percent were obese; 42.0 percent had at least one decayed and/or filled tooth – 30.0 percent had one to five dft and 12.0 percent had more than five dft; the mean number of dft was 1.8 (SE 0.09).

Table 2 presents caries experience and BMI categories according to social-demographic, dietary, medical, and dental visit characteristics. Overall, there was no statistically significant difference in percentage distribution of caries experience and BMI categories by gender, PI, race, asthma condition, dental visit in the previous 12 months, daily total energy intake, daily carbohydrate intake, daily fat intake, or daily total sugar intake. Caries experience (both percent of children with caries and the mean dft score) was compared across the BMI categories stratified by age and race (Table 3). Generally, children with at-risk BMI or overweight BMI had a higher percentage of caries and higher mean dft than children with normal BMI, although percentages and mean dft for BMI categories varied in different strata. Most of these differences across BMI categories were not statistically significant, except for percentages in the 60- <72-month age group ($P = 0.049$) and mean dft among African-American race ($P = 0.02$). When the comparison was only between the children with at risk BMI and the children with normal BMI, those with at-risk BMI had a significantly higher percentage with caries and higher mean dft in the 60-<72-month age group and significantly higher mean dft in the African-American ($P = 0.01$) and Hispanic ($P = 0.02$) strata (last column in Table 3).

No statistically significant difference was found in the comparison of BMI category distribution – stratified by age and race – between caries-free children and those with S-ECC (Table 4). The majority of children in both groups had a normal BMI and only a few were underweight. The results comparing percentage distribution of only normal and at risk BMI between caries-free children and those with S-ECC showed a similar pattern (last column in Table 4). Four dietary variables including daily total carbohydrate intake, daily total sugar intake, daily total fat intake, and daily total energy intake were examined for individual relationship with caries experience using Spearman correlation analysis. The correlation coefficients were 0.01 ($P = 0.71$) for carbohydrate intake, 0.04 ($P = 0.28$) for sugar intake, 0.002 ($P = 0.92$) for fat intake, and 0.02 ($P = 0.51$) for total energy intake.

A logistic regression model predicting caries experience (any

Table 2
Caries Experience and Body Mass Index (BMI) Categories According to Characteristics of Children Aged 2-6 Years

		Caries experience		BMI categories*			
		Caries-free	Caries present	Underweight BMI	Normal BMI	At-risk BMI	Overweight BMI
		Percent		Percent			
Gender	Male	58.3 (1.7)	41.7 (1.2)	4.2 (0.5)	72.3 (1.9)	12.4 0.7)	11.6 (0.9)
	Female	58.2 (1.3)	41.8 (1.3)	4.3 (0.5)	75.6 (1.9)	9.9 (0.6)	10.1 (0.8)
Poverty index†	<2	57.8 (1.6)	42.2 (1.5)	5.7 (0.6)	71.0 (1.9)	11.7 (0.6)	11.6 (1.0)
	≥2	58.2 (1.6)	41.8 (1.5)	3.2 (0.4)	77.9 (1.9)	11.4 (0.8)	7.5 (0.8)
Race	Non-Hispanic White	56.4 (1.3)	43.6 (1.1)	3.7 (0.2)	75.7 (1.5)	11.4 (0.5)	9.2 (0.6)
	Non-Hispanic Black	58.9 (1.1)	41.1 (0.9)	6.3 (0.6)	71.9 (2.3)	14.3 (0.8)	7.5 (1.0)
	Hispanic	55.4 (1.6)	45.6 (2.0)	2.8 (0.2)	66.3 (1.5)	12.9 (0.3)	17.0 (0.2)
	Others	68.1 (0.8)	31.9 (0.5)	5.2 (0.2)	77.9 (1.1)	6.3 (0.2)	10.6 (0.5)
Has asthma	No	57.6 (0.9)	42.4 (0.7)	4.3 (0.2)	74.2 (1.2)	11.0 (0.4)	10.5 (0.4)
	Yes	58.1 (1.9)	41.9 (1.4)	1.8 (0.7)	71.8 (1.4)	14.3 (0.8)	12.1 (1.0)
Dental visit in previous year	No	56.4 (1.1)	43.6 (1.4)	4.6 (0.4)	75.0 (1.5)	11.4 (0.8)	9.0 (0.6)
	Yes	58.1 (1.3)	41.9 (1.9)	3.8 (0.7)	73.4 (1.2)	10.7 (0.8)	12.1 (1.1)
		Median (25%, 75% percentile)			Median (25%, 75% percentile)		
Daily total energy intake		1986.7 (1357.0, 2339.0)	1991.0 (1285.5, 2447.5)	1887.9 (1309.3, 2327.2)	1948.0 (1318.7, 2459.5)	2006.0 (1402.8, 2426.0)	2209.3 (1332.7, 2208.0)
Daily total carbohydrate intake (gm)		257.9 (163.7, 322.9)	259.2 (159.4, 323.9)	237.7 (153.2, 320.2)	261.4 (163.5, 323.7)	259.0 (173.4, 302.5)	289.1 (150.3, 311.1)
Daily total fat intake		72.1 (46.2, 94.3)	74.3 (44.5, 96.0)	71.2 (46.2, 84.6)	70.0 (42.9, 98.1)	74.9 (44.8, 87.1)	80.7 (42.0, 96.2)
Daily total sugar intake (gm)		134.5 (77.6, 175.3)	134.4 (73.9, 178.2)	118.0 (67.0, 177.4)	146.7 (76.4, 178.2)	137.8 (88.1, 178.3)	136.8 (79.5, 165.2)

* BMI was calculated using weight in kilograms (kg) divided by height in meter squared $(m)^2$.
Children were classified into four categories using age- and gender-specific criteria.
† Poverty index was computed as a ratio between the midpoint of the family income category reported by the participant and the poverty threshold value determined by the Census Bureau.
BMI, body mass index.

decayed/filled tooth: yes/no) was fitted using five predictor variables: age (years), poverty (PI; <2 or ≥2), obesity (BMI ≥95 percentile), race (non-Hispanic White, non-Hispanic Black, Hispanic, or others), and carbohydrate intake (tertiles: <187 mg, 187- <288 mg, ≥288 mg). In this multivariable logistic regression model (Table 5), none of these factors was a statistically significant predictor of caries experience. Using the same five predicator variables, a logistic regression model was also fitted for predicting S-ECC (yes/no in Table 5). Age [odds ratio (OR) = 1.82, $P < 0.01$] and PI (OR = 0.59, $P = 0.01$) were statistically significant in predicting severe early childhood caries.

Discussion

Using data from NHANES 1999-2002, the relationship between childhood obesity and dental caries was assessed. In this sample of 1,507 2- to 6-year-old children, dental caries was a prevalent disease. Most children had normal BMI; however, about 11 percent were at risk of overweight and 10 percent were actually overweight. The observation is consistent with other studies related to childhood obesity (17-18). After stratifying by age, gender, race, and family income, the relationships between childhood obesity and dental caries were not statistically significant, except among children aged 60-72 months. It is unclear why the dental caries-obesity relationship for the 60-72 month group differs from the other age groups. One possible explanation is that both are age-related cumulative conditions and thus the older group is more likely to exhibit a stronger relationship. In the comparison between children with at risk BMI and those with normal BMI, a significant association was detected not only for the 60-<72 months age group, but also for the African-American and Hispanic children. This is consistent with some studies that have reported higher prevalence of both obesity and dental caries among children from minority groups and/or low SES families (1, 13, 19). The observed association

Table 3
Percentage with Caries and dft by Body Mass Index (BMI)* Category Among Children Aged 2-6 Years

			Normal BMI	At-risk BMI	Overweight BMI	*P*-value (3 groups)†	*P*-value (2 groups)‡
Percent of children with caries (SE)	Age	24-<36 months (417)	39.2 (4.5)	38.4 (2.2)	54.4 (3.6)	0.42	0.23
		36-<48 months (276)	34.6 (4.6)	47.0 (1.5)	41.4 (2.7)	0.42	0.97
		48-<60 months (295)	44.8 (5.3)	39.5 (2.5)	41.9 (1.9)	0.88	0.64
		60-<72 months (276)	41.6 (3.4)	68.3 (2.1)	50.6 (2.1)	0.04	0.01
	Race	Non-Hispanic White (355)	40.8 (2.4)	47.8 (1.2)	54.5 (1.5)	0.38	0.39
		Non-Hispanic Black (351)	39.2 (2.3)	50.3 (1.2)	47.9 (1.0)	0.26	0.13
		Hispanic (445)	43.1 (2.5)	51.1 (1.5)	37.0 (1.3)	0.24	0.32
		Others (62)	20.4 (5.1)	29.4 (0.9)	32.8 (3.6)	0.77	0.60
dft mean (SE)	Age	24-<36 months (417)	1.5 (0.7)	1.7 (0.2)	2.4 (0.4)	0.22	0.71
		36-<48 months (276)	1.4 (0.4)	1.8 (0.2)	1.4 (0.5)	0.63	0.31
		48-<60 months (295)	1.8 (0.6)	1.8 (0.2)	2.2 (0.7)	0.68	0.89
		60-<72 months (276)	1.9 (0.6)	3.6 (0.3)	2.6 (0.9)	0.27	0.01
	Race	Non-Hispanic White (355)	1.7 (0.2)	1.9 (0.4)	2.5 (0.7)	0.21	0.56
		Non-Hispanic Black (351)	1.5 (0.2)	2.4 (0.4)	2.6 (0.6)	0.02	0.01
		Hispanic (445)	1.9 (0.2)	3.0 (0.9)	1.6 (0.3)	0.83	0.02
		Others (62)	0.8 (0.3)	1.6 (0.5)	1.6 (1.2)	0.52	0.92

* BMI was calculated using weight in kilograms (kg) divided by height in meter squared $(m)^2$. Children were classified into four categories using age- and gender-specific criteria recommended by the Centers for Disease Control and Prevention: underweight – less than 5th percentile; normal weight – 5th percentile to less than 85th percentile; at risk of overweight – 85th to less than 95th percentile; and overweight – equal to or greater than the 95th percentile.
† *P*-value from χ^2 test for proportions or ANOVA for means, comparing normal, at risk, and overweight groups.
‡ *P*-value from χ^2 test for proportions or *t*-test for means, comparing only normal and at-risk groups.
SE, standard error; dft, decayed/filled teeth.

Table 4
Percentage Distribution of Body Mass Index (BMI)* Categories in Caries-Free and Severe Early Childhood Caries (S-ECC)† Children

			Underweight BMI	Normal BMI	At-risk BMI	Overweight BMI	*P*-value‡	*P*-value¶
Age	24-<36 months	Caries Free	5.3 (1.1)	79.8 (3.0)	11.2 (1.6)	3.7 (0.9)	0.97	0.69
		S-ECC	4.7 (0.8)	82.1 (2.7)	9.0 (0.9)	4.2 (0.6)		
	36-<48 months	Caries Free	6.8 (1.9)	74.7 (3.8)	10.3 (2.2)	8.2 (2.1)	0.44	0.17
		S-ECC	3.5 (0.5)	64.1 (1.9)	21.4 (1.3)	11.0 (0.5)		
	48-<60 months	Caries Free	2.0 (1.2)	73.3 (4.1)	10.6 (2.4)	14.1 (2.8)	0.51	0.05
		S-ECC	3.3 (0.4)	81.5 (4.1)	3.4 (0.2)	11.8 (0.8)		
	60-<72 months	Caries Free	5.3 (1.9)	73.0 (4.6)	7.7 (2.1)	14.0 (1.9)	NA§	0.40
		S-ECC	0	94.3 (3.0)	3.8 (0.4)	1.9 (0.2)		
Race	Non-Hispanic White	Caries Free	3.4 (0.7)	66.7 (3.2)	11.3 (1.6)	18.6 (2.7)	0.54	0.44
		S-ECC	2.6 (0.4)	75.5 (2.0)	8.6 (0.5)	12.3 (0.8)		
	Non-Hispanic Black	Caries Free	5.5 (1.2)	77.6 (2.8)	10.3 (1.7)	6.6 (1.4)	0.69	0.76
		S-ECC	3.9 (0.5)	83.0 (2.0)	9.4 (1.7)	3.7 (0.7)		
	Hispanic	Caries Free	6.5 (1.2)	73.8 (2.8)	11.7 (1.6)	8.0 (1.4)	0.97	0.92
		S-ECC	4.8 (0.5)	75.0 (2.1)	11.8 (0.8)	8.4 (0.4)		
	Others	Caries Free	0	84.7 (6.2)	5.4 (2.6)	9.9 (5.1)	NA	0.27
		S-ECC	6.5 (0.5)	78.4 (2.8)	15.1 (0.7)	0		

* BMI was calculated using weight in kilograms (kg) divided by height in meter squared $(m)^2$. Children were classified into four categories using age- and gender-specific criteria.
† S-ECC was defined using criteria from American Academy of Pediatric Dentistry.
‡ *P*-value from χ^2 test comparing percentage distribution of normal, at risk, and overweight groups.
¶ P-value from χ^2 test comparing percentage distribution of only normal and at-risk groups.
§ No *P*-value was calculated due to zero observations in the cell.

between BMI and caries among African-American and Hispanic children might be a reflection of the role of SES in both conditions.

Considering the results from this analysis, it is not surprising that different studies (6-11) have observed different relationships, particularly when samples consisted of local, specific groups of children. Our findings, together with those of other investigators, suggest an intricate

Table 5
Logistic Models Predicting Children's Caries Experience

Outcome variable	Predictor variables	Odds ratio (95% CI)	*P*-value
Any decayed and/or filled tooth (yes/no)	Age (years)	1.09 (0.81-1.23)	0.28
	Poverty index*	0.84 (0.62-1.17)	0.33
	Overweight†	1.20 (0.67-1.03)	0.08
	Race	1.10 (0.99-1.23)	0.08
	Carbohydrate intake‡	1.02 (0.82-1.17)	0.83
Severe early childhood caries (S-ECC)¶ (yes/no)	Age (years)	1.82 (1.43-2.31)	<0.01
	Poverty index	0.59 (0.41-0.88)	0.01
	Overweight	1.08 (0.81-1.43)	0.62
	Race	1.11 (0.98-1.26)	0.11
	Carbohydrate intake	1.10 (0.86-1.38)	0.44

* Poverty index was computed as a ratio between the midpoint of the family income category reported by the participant and the poverty threshold value determined by the Census Bureau.
† Overweight was defined as having a body mass index of ≥95 percentile.
‡ Carbohydrate intake was categorized into tertiles based on frequency distribution: <187mg, 187-288 mg, ≥288mg).
¶ S-ECC was defined using criteria from American Academy of Pediatric Dentistry.

picture in which many factors may simultaneously influence the relationship between caries and obesity.

Both obesity and dental caries are complex conditions and many biological, genetic, environmental, and behavioral factors are known to be involved in these conditions (19-21). In some developed countries, dental caries has been linked to SES factors, such as family income, parents' education and occupation, with low SES individuals being at higher risk of caries (2, 17-18, 22). In the United States childhood obesity is also associated with low SES (14, 23). Marshall et al. identified measures of SES (parents' education and family income) that were predictive of both caries experience and obesity among children in an Iowa cohort (19). In our analysis, family income was identified as an important predictor of caries experience, after controlling for age, race, and BMI category. Additionally, relationships between health outcomes and contextual characteristics – particular aspects of places where people live – have been documented in a number of empirical studies of various health conditions (24).Therefore, characteristics of the population, including a broader set of socioeconomic and contextual characteristics, must be considered when the relationship between childhood obesity and dental caries is assessed.

One of the important findings of this study was that children at risk of being overweight generally had higher caries experience than their normal weight peers. This observation is consistent with what other investigators reported (6, 7, 10, 19). Although the mechanism is not clear, caries co-existed with the risk of being overweight in these studies. Marshall et al. (19) suggested that neither "obesity increases risk of caries" nor "caries increases risk of obesity," but rather a common risk factor increased the likelihood of both diseases. Dietary factors and SES were hypothesized to be common risk factors that potentially link obesity and dental caries. A dietary habit that contributes to obesity could also increase caries risk. It is well established that a dietary component is necessary for the caries disease process. Dietary habits (how much and how often the beverage or food is consumed) can modify caries risk, with frequent consumption of sugars considered to increase the risk. Energy-dense, highly refined food choices and dietary habits have been identified as important contributors to the obesity epidemic (25-27). Identification of children at risk of being overweight early in life may give health care providers and parents the opportunities for early intervention to decrease risk for both obesity and caries. Furthermore, educational interventions addressing dietary issues should highlight both consequences (overweight and dental caries) simultaneously.

This analysis utilized a nationally representative sample and thus allowed for greater examination of complexity in the relationship between obesity and dental caries. However, some limitations must be observed. Since the data was cross-sectional, causal relationships cannot be established and the observed association could be due to other unexplored factors. Part of the data was based on self-reports and thus subject to recall bias. Furthermore, since the reasons for missing teeth could not be explicitly sought, missing teeth were excluded from the analysis. This may have excluded a certain number of teeth lost due to caries.

In conclusion, within study limitations, results from this analysis of a large national sample of young children suggest a complex multifactorial relationship between childhood obesity and dental caries. This demands carefully defined research designs, including longitudinal studies, to identify the particular pathways through which different factors influence dental caries and obesity.

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References

1. US Department of Health and Human Services. Oral in America: a report of the surgeon general – executive summary. Rockville (MD): US Department of Health and Human Services, National Institute of Dental and Craniofacial Research, National Institutes of Health; 2000.
2. Vargas CM, Crall JJ, Schneider DA. Sociodemographic distribution of pediatric dental caries: NHANES III, 1988–1994. J Am Dent Assoc. 1998;129:1229-38.
3. CDC. CDC morbidity and mortality weekly report 2005. Atlanta (GA): CDC; 2005 [cited 2006 April 12]; 54(03):[44 p.]. Available from: http://www.cdc.gov/MMWR/preview/mmwrhtml/ss5403a1.htm

4. Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. Lancet. 2002;360: 473-82.
5. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999-2000. JAMA. 2002;288: 1728-32.
6. Reifsnider E, Mobley C, Mendez DB. Childhood obesity and early childhood caries in a WIC population. J Multicult Nurs Health. 2004;10:24-31.
7. Willerhausen B, Haas G, Krummenauer F, Hohenfellner K. Relationship between high weight and caries frequency in German elementary school children. Eur J Med Res. 2004;9:400-4.
8. Ayhan H, Suskan E, Yildirim S. The effect of nursing or rampant caries on height, body weight and head circumference. J Clin Pediatr Dent. 1996;20:209-12.
9. Acs G, Shulman R, Ng MW, Chussid S. The effect of dental rehabilitation on the body weight of children with early childhood caries. Pediatr Dent. 1999;21:109-13.
10. Tuomi T. Pilot study on obesity in caries prediction. Community Dent Oral Epidemiol. 1989;17:289-91.
11. Chen W, Chen P, Chen SC, Shih WT. Lack of association between obesity and dental caries in three-year-old children. J Chin Pediatr Dent. 1998;39:109-11.
12. Kantovitz KR, Pascon FM, Rontani RM, Gaviao MB. Obesity and dental caries – a systematic review. Oral Health Prev Dent. 2006;4:137-44.
13. Wang Y. Cross-national comparison of childhood obesity: the epidemic and relationship between obesity and socioeconomic status. Int J Epidemiol. 2001; 30:1129-36.
14. American Academy of Pediatric Dentistry (AAPD). Policy on early childhood caries (ECC): classifications, consequences, and preventive strategies. Chicago (IL): AAPD; 2006 [cited 2006 April 12]. Available from: http://www.aapd.org/media/Policies_Guidelines/P_ECC Classifications.pdf
15. Centers for Disease Control and Prevention, U.S. Department of Health and Human Services. National Center for Health Statistics Clinical Growth Charts. Atlanta (GA): Centers for Disease Control and Prevention, U.S. Department of Health and Human Services; 2006 [cited 2006 April 12]. Available from: http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/clinical_charts.htm.
16. Centers for Disease Control and Prevention, U.S. Department of Health and Human Services. NHANES. Atlanta (GA): Centers for Disease Control and Prevention, U.S. Department of Health and Human Services; 2006 [cited 2006 April 12]. http://www.cdc.gov/nchs/about/major/nhanes/datalink.htm
17. Schou L, Uitenbroek D. Social and behavioural indicators of caries experience in 5-year-old children. Community Dent Oral Epidemiol. 1995;23:276-81.
18. Slade GD, Spencer JA, Davies MJ, Stewart JF. Influence of exposure to fluoridated water on socioeconomic inequalities in children's caries experience. Community Dent Oral Epidemiol. 1996;24:89-100.
19. Marshall TA, Eichenberger-Gilmore JM, Broffitt BA, Warren JJ, Levy SM. Dental caries and childhood obesity: roles of diet and socioeconomic status. Community Dent Oral Epidemiol. 2007;35:449-58.
20. Palmer CA. Dental caries and obesity in children: different problems, related causes. Quint Int. 2005;36:457-61.
21. Kantovitz KR, Pascon FM, Rontani RM, Gaviao MB. Obesity and dental caries – a systematic review. Oral Health Prev Dent. 2006;4:137-44.
22. Thomson WM, Poulton R, Milne BJ, Caspi A, Broughton JR, Ayers AMS. Socioeconomic inequalities in oral health in childhood and adulthood in a birth cohort. Community Dent Oral Epidemiol. 2004;32:345-53.
23. Danielzik S, Czerwinski-Mast M, Langnäse K, Dilba B, Müller MJ. Parental overweight, socioeconomic status and high birth weight are the major determinants of overweight and obesity in 5-7 y-old children: baseline data of the Kiel Obesity Prevention Study (KOPS). Int J Obes. 2004;28:1494-592.
24. Hillemeier MM, Lynch J, Harper S, Casper M. Measuring contextual characteristics for community health. Health Serv Res. 2003;38:1645-717.
25. Nicklas TA, Baranowski T, Cullen KW, Berenson G. Eating patterns, dietary quality and obesity. J Am Coll Nutr. 2001;20:599-608.
26. Ludwig DS, Peterson KE, Gortmaker SL. Relationship between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. Lancet. 2001;357:505-8.
27. Berkey CS, Rockett HRH, Field AE, Gillman MW, Colditz GA. Sugar-added beverages and adolescent weight change. Obes Res. 2004;12:778-88.