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# Caries status and overweight in 2- to 18-year-old US children: findings from national surveys

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Abstract – *Background:* The prevalence of overweight children in the United States continues to increase. *Objectives:* To examine the relationship between being overweight and caries in primary and permanent dentition in a nationally representative sample of children. *Methods:* Data from the NHANES III (1988–1994) were analyzed using logistic regression and controlling for potential confounders for 10 180 children 2–18 years of age and from the NHANES 1999–2002 for 7568 children 2–18 years of age. *Results:* For children 2–5 years of age, there was no difference in caries experience among normal weight, at risk for overweight or overweight children for NHANES III and for NHANES 1999–2002. For children 6–11 years of age (NHANES III), at risk for overweight and overweight children were less likely to have caries experience in the primary dentition than normal weight children; overweight children were less likely to have caries experience in the permanent dentition than normal weight children. For children 12–18 years of age (NHANES III), overweight children were less likely to have caries experience in the permanent dentition than normal weight children. For children 6–11 years of age and 12–18 years of age (NHANES 1999–2002), there was no difference in having caries experience among normal, at risk for overweight and overweight children. *Conclusions:* The data from NHANES III and NHANES 1999–2002 provide no evidence to suggest that overweight children are at an increased risk for dental caries. Although no differences in caries rates by weight were found in younger children, interestingly results from NHANES III suggest that being overweight may be associated with decreased rates of caries in older children.

Key words: body mass index; cotinine levels; dental caries; NHANES III; NHANES 1999–2002; overweight status

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The prevalence of overweight and at risk for overweight children in the United States has been increasing steadily in recent years (1). The number of children with a body mass index (BMI) greater than the 95th percentile has doubled in the last two decades and there has been a 50% increase in the prevalence of children with a BMI greater than the 85th percentile (2). Data from the National Health and Nutrition Examination Survey (NHANES 1999–2000) have shown that the prevalence of overweight children (BMI > 95th percentile) among 12–19 year olds is 15.5%. The prevalence of overweight among non-Hispanic Black and Mexican–American children increased more than 10% points between 1988–1994 and 1999–2000 (1). More than 23% of non-Hispanic Black and Mexican–American children were overweight in 1999–2000.

Childhood overweight status carries with it much co-morbidity: type II diabetes, metabolic syndrome, hyperadrogenism, acanthosis nigricans, orthopedic problems, sleep apnea, and psychological and behavioral problems (3–5). Overweight is recognized as a multifactorial disease (6). However, while there are numerous social, medical, and behavioral factors that contribute to overeating and under exercising, overweight status is usually a result of an imbalance between energy intake and energy expenditure.

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It is thought that the increase in children's overweight status has occurred because of an increase in caloric intake and also because of a lack of physical activity among children and adolescents. Increasingly, leisure time activities are more sedentary for US children. Television, video games, and computer activities are replacing outside play, especially among non-Hispanic African–American and Mexican–American children. Results from NHANES III show that 25% of all US children watch 4 or more hours of television each day, as do 43% of African–American children (7). Increased television viewing may result in the decline of fruit and vegetable consumption and an increase of less-nutritious food consumption (8).

The amount of carbohydrates in children's diet has been increasing over the last 10 years as a consequence of recommendations to decrease dietary fat. Overweight in children has been associated with increased carbohydrate intake and may be related to prolonged exposure to carbohydrates (9–10).

The intake of refined carbohydrates, especially sugars and the prevalence of dental caries are well documented in the literature (11–13); however, studies assessing the relationship between obesity and tooth decay in children have been limited (14–17). A recent study investigated the relationship between being overweight and dental caries in children from Kentucky (18). The authors of the three of the aforementioned studies found a positive correlation between caries experience in the permanent dentition and overweight status, suggesting that overweight children had higher caries scores than children with normal weight (15, 17–18). Dye et al., however, found no relationship between weight status and caries experience in the primary dentition of US children 2–5 years of age (16).

Although caries prevalence and severity has declined substantially over the past 40 years, dental caries is still the most common chronic childhood disease, five times more common than asthma and seven times more common than hay fever (19). Although an increasing percentage of preschool and school-aged children are caries free, caries remains a major national public health problem. Nearly 20% of children between the ages of 2 and 4 have clinically detectable caries, and by age 17, nearly 80% of young people have had one or more teeth with caries (20). Data from the Centers for Disease Control and Prevention show that the prevalence of untreated caries in the primary dentition among US children, 6–11 years of age, is 25% (21). Almost 60% of 12- to 15-year-old study participants have had at least one carious tooth or a restoration and this increases to 78% by age 16 (21). Fewer than one in five Medicaid-covered children have seen a dentist during the previous year (19).

The purpose of this study was to examine the association between dental caries and being at risk of overweight and being overweight in children 2–18 years of age using data collected in the Third National Health and Nutrition Examination Survey (NHANES III) and the 1999–2002 National Health and Nutrition Examination Survey (NHANES 1999–2002).

## Methods

Data from the Third National Health and Nutrition Examination Survey (NHANES III) conducted from 1988–1994 and from NHANES 1999–2002 were used in the analyses. NHANES is a series of cross-sectional, nationally representative examination surveys of the civilian noninstitutionalized US population conducted by the Centers for Disease Control and Prevention. In addition to completing a survey questionnaire, a standardized physical examination and dental examination component and various laboratory tests were performed on the study participants. A detailed description of the sample design and methods used in these surveys is reported elsewhere (22).

Children 2–18 years of age who participated in the NHANES III and the NHANES 1999–2002 formed the basis for this analysis. As the oral health examination of NHANES and the CDC growth charts for BMI percentiles are not available for study participants younger than 2 years of age; these children were excluded from the analyses. A total of 10 180 study participants (95% response rate) from the NHANES III and 7568 (93% response rate) from the NHANES 1999–2002 were identified, who received a complete dental examination and were within the targeted age range (2–18 years of age) and for whom weight and height measurements were available. Caries experience in the primary (dfs) and permanent dentition (DMFS) was defined as the dependent variable. For study participants aged 2–5 years, decayed and filled surfaces in the primary dentition (dfs) were estimated. For study participants aged 6–11 years, decayed and filled surfaces in the primary

dentition (dfs) and decayed, missing and filled surfaces in the permanent dentition (DMFS) were estimated. For study participants aged 12–18 years, decayed, missing and filled surfaces in the permanent dentition (DMFS) were analyzed.

In this phase of the analysis, the dependent variables were dichotomized; study participants were categorized as either having caries experience (dfs > 0 and DMFS > 0) or having no caries experience (dfs = 0 and DMFS = 0), i.e. subjects were categorized as either having the disease or not having the disease which is consistent with the presentation of the data describing caries experience reported by the Centers for Disease Control and Prevention (21). Each study participant was the unit of analysis for assessing caries experience and weight status.

The primary explanatory variable of interest was BMI percentile. Overweight and at risk for overweight status were defined based on the age and sex-specific 2000 CDC growth charts for the United States (23). Overweight was defined as at or above the 95th percentile of BMI for age and sex, at risk for overweight was defined as at or above the 85th percentile and less than 95th percentile of BMI for age and sex. Normal weight was defined as less than 85th percentile of BMI for age and sex. Other potential explanatory variables with dental caries were analyzed including the subjects' age (2–5 years, 6–11 years, 12–18 years), sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican–American and Other), poverty status [based on family income and family size compared with the federal poverty level (FPL) for that year defined by three categories: family income <100% of the FPL, ≥100% but <200% of the FPL, and ≥200% of the FPL], region of residence (not available for NHANES 1999–2002 defined by four categories: Northeast, Midwest, South and West), education level of head of the household (not available for NHANES 1999–2002; defined by three categories: less than high school, high school graduate, and greater than high school graduate), blood lead level (>median and ≤median), serum cotinine level [nonexposed (<0.2 ng/ml), passive (0.2–10 ng/ml) and active exposure (>10 ng/ml)] and use of dental services (categorized as time since last dental visit: ≤1 year and >1 year). Blood lead and cotinine levels were included in the analyses as previous studies had found statistically significant associations between caries experience and elevated blood lead and cotinine levels in US children (24–25). Use of dental services was determined by the length of time since the last visit to the dentist.

Bivariate analyses with chi-square statistics were conducted to determine associations between weight status, demographics, time since the last dental visit, and serum lead and cotinine levels with dental caries-experience. Logistic regression analyses were performed to determine associations with caries-experience. Additionally, interactions were assessed between sex and race/ethnicity by weight status. Variables in the logistic regression models were assessed for colinearity by examining Spearman correlation coefficients in bivariate analyses. SUDAAN (Research Triangle Park, NC) software was used to account for the complex multistage sampling design of the survey (26). Sample weights were used to produce national estimates by adjusting for the oversampling of specific age and race/ethnic groups in each survey. Data from the NHANES III and NHANES 1999–2002 were analyzed separately. The level of significance was set at a *P*-value of less than 0.05.

## Results

A total of 10 180 study participants aged 2–18 years were included in the NHANES III analyses and a total of 7568 study participants aged 2–18 years were included in the NHANES 1999–2002 analyses. The association between caries experience and BMI and other potential risk factors with occurrence of caries in the primary and permanent dentition (Table 1 for NHANES III, Table 2 for NHANES 1999–2002) was examined in bivariate analyses.

As presented in Table 1, there were statistically significant associations found between caries prevalence and weight status in the permanent dentition in 6–11 year olds ($P = 0.02$). There were no statistically significant associations found in the primary dentition in 2–5 year olds ($P = 0.57$), in the primary dentition in 6–11 year olds ($P = 0.09$) and in the permanent dentition in 12–18 year olds ($P = 0.20$).

As shown in Table 2, there were no statistically significant associations found between caries prevalence and weight status in the NHANES 1999–2002: in the primary dentition in 2–5 years olds ($P = 0.42$), in the primary dentition in 6–11 year olds ($P = 0.06$), in the permanent dentition in 6–11 year olds ($P = 0.33$) and in the permanent dentition in 12–18 year olds ($P = 0.83$).

Table 1. Prevalence of 2- to 18-year-old children with caries-experience by child characteristics in bivariate analyses (NHANES III, 1988–1994)

| | 2–5 years | | | 6–11 years | | | | | | 12–18 years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $n$[a] | % with any primary caries (SE)[b] | $P$-value | $n$ | % with any primary caries (SE) | $P$-value | $n$ | % with any permanent caries (SE) | $P$-value | $n$ | % with any permanent caries (SE) | $P$-value |
| Overall | 4167 | 23.8 (1.4) | | 2869 | 49.5 (1.6) | | 3164 | 25.9 (1.7) | | 2777 | 66.3 (1.9) | |
| Weight status | | | | | | | | | | | | |
| Overweight (≥95th percentile) | 370 | 23.0 (3.6) | 0.57 | 368 | 40.6 (4.7) | 0.09 | 438 | 17.6 (2.9) | 0.02 | 380 | 57.7 (4.6) | 0.20 |
| At-risk (BMI ≥ 85th–<95th percentile) | 484 | 26.4 (3.0) | | 360 | 45.5 (4.6) | | 426 | 29.9 (4.0) | | 437 | 67.8 (4.7) | |
| Normal (BMI < 85th percentile) | 3313 | 23.5 (1.4) | | 2141 | 51.4 (1.6) | | 2300 | 26.5 (1.7) | | 1960 | 67.2 (2.2) | |
| Sex | | | | | | | | | | | | |
| Male | 2048 | 23.2 (1.5) | 0.44 | 1502 | 48.7 (2.5) | 0.63 | 1596 | 23.5 (2.0) | 0.06 | 1304 | 65.1 (3.2) | 0.49 |
| Female | 2119 | 24.4 (1.7) | | 1367 | 50.3 (1.9) | | 1568 | 28.3 (2.2) | | 1473 | 67.5 (1.8) | |
| Race/ethnicity | | | | | | | | | | | | |
| Non-Hispanic White | 1178 | 18.1 (1.9) | <0.001 | 805 | 46.3 (1.8) | 0.001 | 838 | 24.2 (1.9) | 0.01 | 720 | 66.5 (2.9) | 0.21 |
| Non-Hispanic Black | 1333 | 28.8 (2.1) | | 927 | 49.2 (2.0) | | 1089 | 23.4 (2.0) | | 989 | 61.5 (2.3) | |
| Mexican–American | 1449 | 40.1 (1.8) | | 1023 | 60.8 (3.3) | | 1106 | 28.7 (1.8) | | 928 | 67.8 (2.7) | |
| Other | 207 | 34.8 (4.3) | | 114 | 63.3 (6.7) | | 131 | 40.3 (6.7) | | 140 | 70.8 (5.5) | |
| Region of the country | | | | | | | | | | | | |
| Northeast | 463 | 19.7 (2.6) | 0.01 | 299 | 46.4 (2.1) | 0.22 | 339 | 29.3 (5.7) | 0.37 | 314 | 68.4 (6.6) | 0.56 |
| Midwest | 712 | 18.2 (1.5) | | 517 | 46.3 (2.8) | | 563 | 28.7 (2.6) | | 515 | 64.0 (3.8) | |
| South | 1800 | 25.1 (2.6) | | 1198 | 52.8 (2.6) | | 1341 | 26.0 (2.1) | | 1254 | 68.4 (2.3) | |
| West | 1192 | 30.4 (92.6) | | 855 | 49.9 (4.6) | | 921 | 20.6 (3.2) | | 694 | 63.2 (3.2) | |
| Poverty status | | | | | | | | | | | | |
| <100% poverty | 1611 | 34.3 (2.4) | <0.001 | 1059 | 62.0 (2.6) | <0.001 | 1185 | 26.8 (3.6) | 0.26 | 921 | 70.6 (3.0) | 0.18 |
| 100–<200% poverty | 1045 | 28.8 (2.5) | | 703 | 54.9 (2.8) | | 783 | 30.1 (3.3) | | 703 | 65.4 (3.7) | |
| ≥200% poverty | 1175 | 14.1 (1.3) | | 877 | 40.8 (2.6) | | 951 | 23.5 (2.0) | | 873 | 64.1 (2.4) | |
| Head of household education | | | | | | | | | | | | |
| <High School | 1645 | 34.6 (2.8) | <0.001 | 1218 | 64.0 (2.0) | <0.001 | 1331 | 29.0 (2.8) | 0.06 | 1577 | 73.9 (1.6) | <0.001 |
| High School | 1324 | 23.7 (2.1) | | 891 | 51.7 (2.9) | | 995 | 28.6 (2.9) | | 670 | 61.9 (3.8) | |
| >High School | 1198 | 17.3 (1.6) | | 760 | 39.5 (2.5) | | 838 | 22.0 (2.3) | | 530 | 58.4 (3.8) | |
| Time since last dental visit | | | | | | | | | | | | |
| ≤1 year | 4008 | 23.5 (1.4) | 0.14 | 2396 | 49.2 (1.8) | 0.51 | 2607 | 26.8 (1.8) | 0.10 | 2024 | 67.3 (1.9) | 0.21 |
| >1 year | 114 | 35.2 (8.4) | | 454 | 52.3 (4.2) | | 536 | 20.9 (3.1) | | 723 | 62.5 (4.0) | |
| Lead level ($\mu$g/dl) | | | | | | | | | | | | |
| >Median | 2161 | 27.8 (1.9) | 0.01 | 1604 | 56.5 (2.0) | <0.001 | 1767 | 30.2 (2.4) | 0.01 | 1495 | 68.0 (2.7) | 0.51 |
| ≤Median | 1286 | 21.0 (2.1) | | 955 | 42.8 (2.0) | | 1065 | 22.0 (2.0) | | 1094 | 66.2 (2.4) | |
| Cotinine level (ng/ml) (≥4 years only) | | | | | | | | | | | | |
| Non-exposed (<0.2) | 463 | 27.8 (3.4) | 0.01 | 1099 | 40.5 (2.4) | <0.001 | 1220 | 25.3 (2.7) | 0.64 | 990 | 61.3 (2.9) | 0.01 |
| Passive exposure (0.2–10) | 660 | 39.7 (3.5) | | 1277 | 57.9 (2.2) | | 1424 | 27.6 (1.6) | | 1222 | 66.4 (2.6) | |
| Active (>10) | 5 | 8.0 (8.6) | | 14 | 66.3 (15.9) | | 17 | 22.5 (13.4) | | 297 | 78.2 (3.6) | |

[a]$n$ = unweighted sample size.
[b]SE = standard error of the percent.

Table 2. Prevalence of 2- to 18-year-old children with caries-experience by child characteristics in bivariate analyses (NHANES 1999–2002)

| | 2–5 years | | | 6–11 years | | | | | | 12–18 years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $n$[a] | % with any primary caries (SE)[b] | $P$-value | $n$ | % with any primary caries (SE) | $P$-value | $n$ | % with any permanent caries (SE) | $P$-value | $n$ | % with any permanent caries (SE) | $P$-value |
| Overall | 1449 | 28.2 (1.8) | | 1917 | 49.0 (2.5) | | 2120 | 20.3 (1.4) | | 3954 | 56.8 (1.1) | |
| Weight status | | | | | | | | | | | | |
| Overweight (≥95th percentile) | 157 | 35.7 (5.8) | 0.42 | 326 | 52.3 (3.0) | 0.06 | 405 | 23.0 (2.4) | 0.33 | 792 | 56.6 (2.7) | 0.83 |
| At-risk (BMI ≥ 85th–<95th Percentile) | 184 | 24.3 (5.4) | | 282 | 42.5 (4.1) | | 326 | 23.1 (3.2) | | 649 | 58.2 (2.9) | |
| Normal (BMI < 85th percentile) | 1108 | 27.7 (1.8) | | 1309 | 49.7 (2.9) | | 1389 | 19.1 (1.7) | | 2513 | 56.6 (1.2) | |
| Sex | | | | | | | | | | | | |
| Male | 724 | 29.2 (2.9) | 0.56 | 998 | 51.5 (2.8) | 0.21 | 1072 | 19.2 (1.6) | 0.33 | 1973 | 54.2 (1.7) | 0.01 |
| Female | 725 | 27.2 (2.0) | | 919 | 46.3 (3.5) | | 1048 | 21.5 (1.9) | | 1981 | 59.6 (1.4) | |
| Race/ethnicity | | | | | | | | | | | | |
| Non-Hispanic White | 446 | 26.2 (2.4) | <0.001 | 531 | 45.6 (3.2) | 0.002 | 561 | 17.7 (2.3) | 0.003 | 1013 | 54.6 (1.8) | <0.001 |
| Non-Hispanic Black | 434 | 32.6 (2.9) | | 605 | 51.3 (2.4) | | 718 | 19.1 (1.7) | | 1176 | 53.3 (2.0) | |
| Mexican–American | 440 | 41.7 (2.1) | | 652 | 63.2 (3.4) | | 703 | 29.9 (2.5) | | 1469 | 62.5 (1.5) | |
| Other | 129 | 16.9 (4.0) | | 129 | 49.6 (7.8) | | 138 | 25.7 (4.3) | | 296 | 65.8 (3.0) | |
| Poverty status | | | | | | | | | | | | |
| <100% poverty | 476 | 41.6 (3.1) | <0.001 | 559 | 63.6 (4.3) | <0.001 | 639 | 27.6 (2.9) | 0.01 | 1092 | 65.1 (1.9) | <0.001 |
| 100–<200% poverty | 364 | 28.2 (4.3) | | 482 | 55.4 (3.9) | | 529 | 21.6 (3.5) | | 954 | 62.9 (2.2) | |
| ≥200% poverty | 456 | 18.0 (2.2) | | 664 | 38.9 (3.0) | | 717 | 15.7 (1.9) | | 1494 | 49.6 (1.6) | |
| Time since last dental visit | | | | | | | | | | | | |
| ≤1 year | 634 | 36.7 (3.3) | <0.001 | 1364 | 50.3 (2.5) | 0.08 | 1504 | 21.8 (1.3) | 0.001 | 2591 | 58.2 (1.3) | 0.003 |
| >1 year | 751 | 19.2 (1.8) | | 299 | 41.7 (4.8) | | 333 | 13.5 (2.0) | | 833 | 48.6 (2.6) | |
| Lead level ($\mu$g/dl) | | | | | | | | | | | | |
| >Median | 652 | 37.4 (2.7) | 0.003 | 915 | 56.2 (3.5) | 0.01 | 1012 | 20.6 (2.0) | 0.87 | 2166 | 60.7 (1.7) | 0.001 |
| ≤Median | 444 | 23.5 (2.4) | | 751 | 44.8 (2.6) | | 841 | 21.1 (2.4) | | 1535 | 52.8 (1.6) | |
| Cotinine level (ng/ml) (≥3 years only) | | | | | | | | | | | | |
| Non-exposed (<0.2) | 414 | 29.2 (2.0) | 0.03 | 1005 | 45.9 (3.0) | 0.02 | 1098 | 19.3 (1.8) | 0.13 | 2120 | 50.9 (2.4) | 0.001 |
| Passive exposure (0.2–10) | 288 | 45.4 (4.6) | | 566 | 59.1 (4.0) | | 652 | 24.4 (3.4) | | 1084 | 61.3 (2.2) | |
| Active (>10) | 6 | 37.4 (23.3) | | 4 | 83.0 (17.5) | | 6 | 9.5 (9.8) | | 399 | 68.8 (3.2) | |

[a]$n$ = unweighted sample size.
[b]SE = standard error of the percent.

In multivariable analyses, the independent association between caries and weight status was examined. The results of these analyses are presented in Table 3 for NHANES III and in Table 4 for NHANES 1999–2002.

For NHANES III, the logistic regression analyses were adjusted for sex, race/ethnicity, geographic region of the country, poverty status, level of education of the household head, time since last dental visit, and blood lead and cotinine levels. For children 2–5 years of age, there was no difference in having dfs > 0 (having caries experience) among normal weight, at risk for overweight or overweight children. Poverty and Mexican–American ethnicity were significantly associated with increased risk of having caries experience in the primary dentition. Serum cotinine levels were included in the analysis only for 4- to 5-year-old children, as blood specimens were collected only from children 4 years of age and older.

There was a statistically significant relationship found between cotinine levels, indicative of second hand smoke exposure, and having caries experience in the primary dentition of 4- to 5-year-old children (OR = 1.6, 95% CI 1.04–2.5).

For children 6–11 years of age, both at risk for overweight (OR = 0.7, 95% CI 0.5–0.98, $P = 0.04$) and overweight children (OR = 0.7, 95% CI 0.5–0.98, $P = 0.04$) were less likely to have caries experience in the primary dentition (dfs > 0) and overweight children also were less likely to have caries experience in the permanent dentition (DMFS > 0) (OR = 0.6, 95% CI 0.4–0.95, $P = 0.03$) compared with normal weight children.

Additionally, poverty, low level of education of household head and serum cotinine levels were significantly associated with increased risk of having caries experience in the primary dentition. Low level of education of household head, blood lead level above the median and other race/ethnicity were significantly associated with increased risk of having caries experience in the permanent dentition for these children, as presented in Table 3.

For children 12–18 years of age, overweight children were less likely to have caries experience in the permanent dentition (DMFS > 0) (OR = 0.5, 95% CI 0.3–0.9, $P = 0.02$) compared with normal weight children. Low level of education of household head and time since last dental visit were significantly associated with an increased risk of having caries experience in the permanent dentition.

The results of the logistic regression analyses for NHANES 1999–2002 are presented in Table 4. The logistic regression analyses were adjusted for sex, race/ethnicity, last dental visit, poverty status, blood lead levels (below and above median) and serum cotinine levels. For children 2–5 years of age, there was no difference in having dfs > 0 (having caries experience) among normal weight, at risk for overweight or overweight children. Mexican–American ethnicity, poverty, time since the last dental visit and blood lead levels above median were significantly associated with increased risk of having caries experience in the primary dentition, as shown in Table 4. For children 6–11 years of age, there was no difference in having caries experience in the primary dentition among normal, at risk for overweight and overweight children. Mexican–American ethnicity, time since the last dental visit, poverty and serum cotinine levels were significantly associated with increased risk of having caries experience in the primary dentition. For children 6–11 years of age, there was no difference in having caries experience in the permanent dentition among normal, at risk for overweight and overweight children. Mexican–American ethnicity, time since the last dental visit and poverty were significantly associated with increased risk of having caries experience in the permanent dentition.

For children 12–18 years of age, there was no difference in having caries experience in the permanent dentition among normal, at risk for overweight and overweight children. Mexican–American ethnicity, time since the last dental visit, poverty and serum cotinine levels were significantly associated with an increased risk of having caries experience in the permanent dentition.

Additionally, interactions were assessed between sex and race/ethnicity by weight status in the analyses. Sex by weight status interactions were significant for the permanent dentition in 6- to 11-year-old children examined in the NHANES III and for the primary dentition in 6- to 11-year-old children examined in the NHANES 1999–2002 ($P < 0.05$). Race/ethnicity by weight status interactions were not statistically significant for any of the models.

## Discussion

The purpose of our study was to examine a possible association between dental caries and

Table 3. Multivariable logistic regression models for the presence of caries in 2- to 18-year-old children (NHANES III, 1988–1994)

| | 2–5 years | | | 6–11 years | | | | | | 12–18 years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Any primary caries | | | Any primary caries | | | Any permanent caries | | | Any permanent caries | | |
| | Odds ratio | 95% CI | *P*-value | Odds ratio | 95% CI | *P*-value | Odds ratio | 95% CI | *P*-value | Odds ratio | 95% CI | *P*-value |
| Weight status | | | | | | | | | | | | |
| Overweight | 0.8 | 0.5–1.3 | 0.30 | 0.7 | 0.5–0.98 | 0.04 | 0.6 | 0.4–0.95 | 0.03 | 0.5 | 0.3–0.9 | 0.02 |
| At-risk | 1.0 | 0.7–1.5 | 0.98 | 0.7 | 0.5–0.98 | 0.04 | 1.2 | 0.8–1.8 | 0.43 | 1.0 | 0.6–1.6 | 0.92 |
| Normal | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Sex | | | | | | | | | | | | |
| Male | 0.9 | 0.7–1.0 | 0.10 | 0.9 | 0.7–1.2 | 0.52 | 0.8 | 0.6–1.1 | 0.16 | 0.9 | 0.6–1.3 | 0.60 |
| Female | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Race/ethnicity | | | | | | | | | | | | |
| Non-Hispanic White | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Non-Hispanic Black | 1.3 | 0.9–1.8 | 0.20 | 0.7 | 0.5–0.9 | 0.01 | 0.9 | 0.6–1.3 | 0.42 | 0.8 | 0.5–1.1 | 0.17 |
| Mexican–American | 1.7 | 1.04–2.7 | 0.04 | 1.5 | 0.96–2.2 | 0.08 | 1.5 | 0.9–2.6 | 0.12 | 1.1 | 0.8–1.7 | 0.56 |
| Other | 1.8 | 0.9–3.7 | 0.10 | 1.5 | 0.7–3.2 | 0.35 | 2.3 | 1.3–4.1 | 0.004 | 1.5 | 0.7–3.6 | 0.33 |
| Region of the country | | | | | | | | | | | | |
| Northeast | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Midwest | 1.2 | 0.7–2.1 | 0.52 | 0.9 | 0.6–1.4 | 0.52 | 1.0 | 0.6–1.8 | 0.98 | 0.8 | 0.4–1.7 | 0.57 |
| South | 1.6 | 0.9–2.8 | 0.13 | 1.1 | 0.7–1.6 | 0.68 | 0.8 | 0.5–1.3 | 0.28 | 1.0 | 0.5–2.0 | 0.95 |
| West | 2.0 | 1.1–3.7 | 0.03 | 0.9 | 0.6–1.4 | 0.75 | 0.6 | 0.3–1.1 | 0.12 | 0.8 | 0.4–1.5 | 0.44 |
| Poverty status | | | | | | | | | | | | |
| <100% poverty | 2.6 | 1.7–4.0 | <0.001 | 1.5 | 0.99–2.3 | 0.05 | 0.8 | 0.5–1.3 | 0.29 | 1.4 | 0.8–2.2 | 0.22 |
| 100–<200% poverty | 2.6 | 1.8–3.9 | <0.001 | 1.5 | 1.01–2.2 | 0.04 | 1.3 | 0.8–1.9 | 0.26 | 1.0 | 0.7–1.6 | 0.85 |
| ≥200% poverty | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Head of household education | | | | | | | | | | | | |
| <High School | 1.2 | 0.9–1.7 | 0.27 | 1.9 | 1.3–2.8 | 0.002 | 1.6 | 1.03–2.6 | 0.04 | 1.8 | 1.2–2.8 | 0.01 |
| High School | 1.2 | 0.8–1.6 | 0.47 | 1.3 | 0.9–1.8 | 0.16 | 1.7 | 1.1–2.5 | 0.02 | 1.1 | 0.6–1.8 | 0.77 |
| >High School | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Time since last dental visit | | | | | | | | | | | | |
| ≤1 year | 0.5 | 0.2–1.1 | 0.10 | 0.9 | 0.6–1.5 | 0.76 | 1.3 | 0.8–1.9 | 0.28 | 1.7 | 1.2–2.4 | 0.004 |
| >1 year | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Lead level (μg/dl) | | | | | | | | | | | | |
| >Median | 1.2 | 0.9–1.7 | 0.27 | 1.3 | 0.9–1.7 | 0.14 | 1.4 | 1.03–2.0 | 0.03 | 1.0 | 0.7–1.4 | 0.94 |
| ≤Median | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Cotinine level (ng/ml) | | | | | | | | | | | | |
| Non-exposed (<0.2) | [a] | | | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Passive exposure (0.2–10) | | | | 1.7 | 1.3–2.4 | 0.001 | 1.0 | 0.7–1.4 | 0.89 | 1.3 | 0.9–1.8 | 0.12 |
| Active (>10) | | | | 2.3 | 0.6–9.1 | 0.24 | 0.8 | 0.2–3.9 | 0.74 | 1.7 | 0.9–3.2 | 0.08 |

CI = confidence interval.
[a]Cotinine level not included in the model since not collected for all ages.
. Referent group for comparison within each independent variable.

Table 4. Multivariable logistic regression models for the presence of caries in 2- to 18-year-old children (NHANES 1999–2002)

| | 2–5 years | | | 6–11 years | | | | | | 12–18 years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Any primary caries | | | Any primary caries | | | Any permanent caries | | | Any permanent caries | | |
| | Odds ratio | 95% CI | *P*-value | Odds ratio | 95% CI | *P*-value | Odds ratio | 95% CI | *P*-value | Odds ratio | 95% CI | *P*-value |
| Weight status | | | | | | | | | | | | |
| Overweight | 1.3 | 0.7–2.3 | 0.36 | 1.1 | 0.8–1.6 | 0.58 | 1.0 | 0.7–1.5 | 0.90 | 1.0 | 0.8–1.4 | 0.84 |
| At-risk | 0.9 | 0.5–1.7 | 0.66 | 0.7 | 0.5–1.1 | 0.14 | 1.6 | 0.96–2.7 | 0.07 | 1.1 | 0.8–1.4 | 0.61 |
| Normal | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Sex | | | | | | | | | | | | |
| Male | 0.9 | 0.5–1.4 | 0.69 | 1.1 | 0.8–1.6 | 0.42 | 0.7 | 0.5–1.1 | 0.09 | 0.9 | 0.7–1.1 | 0.20 |
| Female | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Race/ethnicity | | | | | | | | | | | | |
| Non-Hispanic White | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Non-Hispanic Black | 0.8 | 0.5–1.2 | 0.30 | 0.7 | 0.5–0.99 | 0.049 | 0.9 | 0.6–1.4 | 0.63 | 0.8 | 0.6–1.2 | 0.27 |
| Mexican–American | 1.7 | 1.2–2.6 | 0.01 | 1.6 | 1.1–2.4 | 0.02 | 1.7 | 1.1–2.8 | 0.03 | 1.5 | 1.02–2.1 | 0.04 |
| Other | 0.4 | 0.2–1.01 | 0.052 | 0.9 | 0.4–1.8 | 0.68 | 1.2 | 0.6–2.6 | 0.60 | 1.3 | 0.8–2.1 | 0.30 |
| Poverty status | | | | | | | | | | | | |
| <100% poverty | 2.4 | 1.3–4.3 | 0.01 | 2.4 | 1.3–4.5 | 0.01 | 1.7 | 1.1–2.5 | 0.01 | 1.8 | 1.4–2.4 | <0.001 |
| 100–<200% poverty | 1.4 | 0.7–2.7 | 0.38 | 1.6 | 1.02–2.6 | 0.04 | 1.5 | 0.9–2.4 | 0.10 | 1.6 | 1.2–2.3 | 0.01 |
| ≥200% poverty | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Time since last dental visit | | | | | | | | | | | | |
| ≤1 year | 2.8 | 1.7–4.6 | <0.001 | 2.3 | 1.5–3.5 | 0.001 | 2.2 | 1.4–3.4 | 0.001 | 2.3 | 1.7–3.0 | <0.001 |
| >1 year | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Lead level ($\mu$g/dl) | | | | | | | | | | | | |
| >Median | 1.9 | 1.2–3.0 | 0.01 | 1.3 | 0.9–1.8 | 0.14 | 0.8 | 0.5–1.4 | 0.46 | 1.4 | 1.04–1.8 | 0.03 |
| ≤Median | 1.0 | | . | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Cotinine level (ng/ml) | | | | | | | | | | | | |
| Non-exposed (<0.2) | [a] | | | 1.0 | | . | 1.0 | | . | 1.0 | | . |
| Passive exposure (0.2–10) | | | | 1.8 | 1.1–2.8 | 0.02 | 1.5 | 0.9–2.5 | 0.08 | 1.6 | 1.1–2.2 | 0.01 |
| Active (>10) | | | | . | . | . | 0.6 | 0.1–6.9 | 0.65 | 2.1 | 1.3–3.4 | 0.004 |

CI = confidence interval.

[a]Cotinine level not included in the model since not collected for all ages.

. Referent group for comparison within each independent variable.

overweight in children 2–18 years of age using data collected from two nationally representative cross-sectional surveys, NHANES III and NHANES 1999–2002.

Our analyses provide no evidence to suggest that overweight children are at increased risk for dental caries. Indeed, while not entirely consistent, the data from these two nationally representative surveys suggest that overweight status may be associated with a somewhat decreased risk for caries. Although no differences in rates of caries by weight status were found in younger children in both data sets (NHANES III and NHANES 1999–2002), results from NHANES III suggest that childhood overweight is associated with decreased rates of caries in older children. However, results from NHANES 1999–2002 do not indicate any difference in caries rates by weight status in older children.

Additionally, the results of the logistic regression analyses show a statistically significant association between elevated serum cotinine levels (NHANES III) in children 4–5 years old and an increased risk of having caries in the primary dentition. Similar results were reported by Aligne and colleagues (25). Elevated serum cotinine levels were also associated with an increased caries rate in the primary dentition in children 6–11 years old (NHANES III and NHANES 1999–2002) and in children 12–18 years old in the permanent dentition (NHANES 1999–2002). Poverty was significantly associated with increased risk of caries in the primary dentition for children 2–5 years old and 6–11 years old (NHANES III). Moreover, poverty and elevated blood lead levels were significantly associated with increased risk of being caries active in the primary dentition in children 2–5 years old and in the permanent dentition in children 12–18 years old (NHANES 1999–2002). These associations indicate that US children are still exposed to harmful environmental agents and that poverty and low parental education remain a predictor for suboptimal dental health in US children.

Published studies that examined the relationship between BMI or weight status and caries have been sparse and inconclusive (14–17). Larson et al. found a univariate moderate correlation between BMI and DMFS in a cohort of 15-year-old Swedish adolescents from an urban community in Northern Sweden (15). In the multiple regression model, BMI was the variable that contributed significantly to explain variations in the caries score; BMI explained 5.5% of the variation in caries scores.

A Finnish study explored the possibility of predicting future caries using weight status and past caries experience as predictor variables in 5- to 13-year-old children (14).

When obesity was used as the predicting factor for caries, sensitivity was low but specificity was high. When past caries experience was used as a predicting factor for caries, sensitivity and specificity was in the middle range for different age groups. This latter study used growth charts that were outdated, according to the author, and the cohort of children in the study did not represent a national sample of Finnish adolescents.

A descriptive analysis of possible association between being overweight and caries frequency was conducted in Germany in 6- to 11-year-old elementary school children. The authors concluded that children with normal weight had significantly lower caries scores in the primary and permanent dentition than overweight children (17). Weight status, sex, and caries status were the only variables that were included in the analysis.

The results from our study indicate no relationship between weight status (BMI) and dental caries in children 2–5 years of age, and are in agreement with a report using NHANES III data to examine the relationship between eating practices and dental caries in children age 2–5 years (16).

We are aware of only one publication that examined the association between caries and BMI in US children older than 5 years of age. In that study, the association between childhood obesity and smooth-surface caries in posterior teeth in US children was examined (18). Caries scores were calculated for a convenience sample of 178 children, aged 8–11 years, who participated in the 'Smile Kentucky' program. Caries severity averages were analyzed with children's BMI, sex, and age. The results of the study indicated that children with a high BMI had significantly higher caries scores in the permanent molars than normal weight children. However, only interproximal caries was evaluated; pit and fissure caries was not assessed and only 29 subjects in this sample were at or above a BMI of 25.

Our results are inconclusive for older children. Data from the NHANES III survey suggest that older children who are overweight or at risk for overweight experience less caries than children who are at normal weight. However, results from NHANES 1999–2002 provide no evidence of this phenomenon. These findings surprised us; *a priori*, we posited that overweight should be associated

with dental caries, as obesity and caries are, in principle, influenced by similar factors. Our analyses are inconclusive as to whether or not there is a relationship between increased BMI and decreased caries in US children and adolescents. We can only speculate as to why this is. NHANES III was conducted between the years 1988 and 1994. As our results suggest, in the NHANES III survey, the percentage of overweight children in the 6–11 age group was 12.8% and in the 12–18 year olds was 13.7%. In the NHANES 1999–2002 survey there was a significant increase in being overweight in the above age categories (17% in the 6–11 year olds and 20% in the 12–18 year olds). However, dietary practices are not the only possible factors that contribute to the obesity epidemic among US children and adolescents. Sedentary lifestyles combined with excess energy intake are primary factors responsible for the dramatic increase in being overweight during the past two decades (27). According to Slyper, a dramatic decrease in self-reported activity levels in adolescents could be to blame. A relationship between television viewing and being overweight has also been evident in longitudinal studies (9).

Limitations of our study are related to the use of cross-sectional data to examine possible relationships between caries experience and weight status in US children. Additionally, the 24-hour dietary recall was not included in the analysis as it is not a good measure of long-term nutrition intake. The strength of our study; however, is the use of a large, nationally representative sample of US children to explore and control for multiple risk factors. In addition, the NHANES data sets are unique in providing detailed oral health information obtained from comprehensive dental exams performed on a nationally representative sample of children and adults. Caries experience estimates derived from our study are consistent with the estimates reported by the Centers for Disease Control and Prevention in August 2005 (21). For example: prevalence of caries experience in the primary dentition in 2- to 5-year-old study participants reported by CDC was 24.23%; our estimate was 23.8% (NHANES III). The prevalence of caries experience in the primary dentition in 6- to 11-year-old study participants reported by CDC was 49%; our estimate was 49% as well (NHANES 1999–2002).

In conclusion, these data from two separate, nationally representative samples of children and youth provide no evidence that overweight or at risk for overweight children and youth are at increased risk for dental caries and provide some, but inconsistent, evidence that overweight status may be associated with a decreased risk for dental caries.

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