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Obesity and Sugar-sweetened Beverages in African-American Preschool Children: A Longitudinal Study

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A representative sample of 365 low-income African-American preschool children aged 3–5 years was studied to determine the association between sugar-sweetened beverage consumption (soda, fruit drinks, and both combined) and overweight and obesity. Children were examined at a dental clinic in 2002–2003 and again after 2 years. Dietary information was collected using the Block Kids Food Frequency Questionnaire. A BMI score was computed from recorded height and weight. Overweight and obesity were defined by national reference age-sex specific BMI: those with an age-sex specific BMI ≥85th, but <95th percentile as overweight and those with BMI ≥95th age-sex specific percentile as obese. The prevalence of overweight was 12.9% in baseline, and increased to 18.7% after 2 years. The prevalence of obesity increased from 10.3 to 20.4% during the same period. Baseline intake of soda and all sugar-sweetened beverages were positively associated with baseline BMI *z*-scores. After adjusting for covariates, additional intake of fruit drinks and all sugar-sweetened beverages at baseline showed significantly higher odds of incidence of overweight over 2 years. Among a longitudinal cohort of African-American preschool children, high consumption of sugar-sweetened beverages was significantly associated with an increased risk for obesity.

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INTRODUCTION

Data from the National Health and Nutrition Examination Survey (NHANES) indicate that 14.0% of US children aged 2–5 years were overweight in 2006, compared with 4.0% in 1980 (ref. 1). Data such as these have hastened the recognition of obesity in US preschool children as a serious public health problem, and identifying its causes has become a major public health challenge for researchers, educators, and policy makers (2). Diet is naturally seen as a key determinant in the development, prevention, and treatment of childhood obesity (3). Because the consumption of sugar-sweetened beverages has substantially increased in the past 30 years, and these beverages are a major source of added sugars in children's diet, excess energy from the increased intakes of sugar-sweetened beverages may result in energy imbalance, further leading to obesity (4,5).

Previous studies provide conflicting evidence for a relationship between sugar-sweetened beverage consumption and childhood obesity. Several studies have identified a positive relationship (6–11), others have not (12–20), and still others have mixed findings (21–24). The current literature is limited by (i) inconsistent definition of sugar-sweetened beverages; and (ii) a lack of longitudinal studies examining association (15,16,23,25,26). In addition, there have been fewer studies targeting preschool children aged 2–5 years (9,12,16,19,25,27) compared to the number of studies targeting school-aged children 5–18 years of age (6–8,13–15,17,18,20,23). Although African-American children are represented in several of the national studies (15,17,19,27), results for low-income African-American children are generally limited in the literature.

The overall aim of the longitudinal study was to examine the association between consumption of sugar-sweetened beverages and obesity in a cohort of low-income African-American preschool children. In the investigation of these children, there were three basic questions addressed: (i) what is the relationship between consumption of sugar-sweetened beverages and BMI; (ii) what is the relationship between changes in consumption of sugar-sweetened beverages and change in

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BMI over a 2-year period; and (iii) what factors are related to the incidence (the occurrence of new cases) of overweight.

The first question adds to the literature on consumption of sugar-sweetened beverages and BMI findings from a group that has been under-studied. It is a particularly important group because obesity in adulthood are increasingly linked to childhood behaviors (28,29), and obesity in an African-American population, particularly women, is a public health concern (30,31).

The second and third questions are examinations of potential underlying causes of overweight and obesity. Each addresses the same issue, but from two different perspectives. The second question examines whether there is direct evidence among these young children whether increased or decreased consumption of sugar-sweetened beverages causes change in BMI. Such causal linkage is examined using the temporal aspect of these unique longitudinal data. The third question examines essentially the same issue, but does so from an "incidence of disease" perspective. The longitudinal features of the data allow the identification of new cases of overweight. Incidence can then be regressed on potential causal factors to determine whether an incidence investigation uncovers associations not observed in an analysis of change.

METHODS AND PROCEDURES

Study population

Data for this study were obtained from the Detroit Dental Health Project, a 2-year longitudinal cohort study focusing on the oral health of low-income African-American children and their caregivers. This study protocol was approved by the Institutional Review Board for Health Sciences at the University of Michigan and the caregivers of all participants gave written consent for inclusion in this study.

The sampling design consisted of a stratified two-stage area probability sample of households from the 39 census tracts with the highest proportion of low-income residents in the city of Detroit. Power calculations indicated that a sample of 1,000 eligible children completing examinations would meet precision requirements for the project. To be eligible for the study, households needed to comprise at least one caregiver of a child aged 0–5 years. Among contacted households, 1,386 families were eligible. Among these, 1,021 dyads of child and caregiver completed baseline data collection using face-to-face interviews and dental examinations in 2002–2003 (baseline; response rate = 74.0%). Details of the sampling and data collection procedures have been described in previous reports (32,33). At 2-year follow-up in 2004–2005 (follow-up), 77.0% ($n = 790$) returned to complete an interview and receive a clinical oral examination. There was no significant difference between children who participated in follow-up and those who dropped out in terms of baseline BMI, beverage consumption, and demographic characteristics. This study focused on those children aged ≥3 years at baseline ($n = 522$) and from whom follow-up data were collected ($n = 403$). Portion size information was not collected for children initially aged ≤2 years, so these children were omitted from the analyses. Daily intakes of energy and nutrients were screened to identify outliers, including 37 children excluded from study who had daily energy intake <750 kcal or >6,500 kcal, daily protein intake <19 g, or daily calcium intake >4,000 mg. Also, one child was found to have dietary vitamin C intake 20% higher than the other children. These exclusions left a final sample of 365 children.

Study variables

Data were collected by interview and clinical examination at a central facility in Detroit. The structured questionnaire, administered by trained interviewers in face-to-face interviews with the caregivers, was used to obtain the information on sociodemographic and behavioral characteristics of the participants, as well as their general health histories.

Dietary information for children aged ≥3 years was collected by trained interviewers using the Block Kids Food Frequency Questionnaire (Kids FFQ) as developed by Block Dietary Data Systems, Berkeley, CA. The reliability of the FFQ instrument is widely accepted after its use in field studies (34), and the validity of the Kids FFQ in the estimates of beverage intakes has been established for children aged 7–9 years (35). The Kids FFQ asks the caregivers frequency and portion consumption of a wide variety of food and drink items. The collected dietary data were quantified as the daily intake in grams (or ml for liquids) and further summarized into daily intakes of energy and nutrients using an algorithm from Block. For the purpose of this study, information on sugar-sweetened beverage consumption was selected from these quantified data, and then converted to ounces to make it more clinically relevant.

In this study, soda (excluding diet soda) and fruit drinks (including Kool-Aid, Gatorade, Sunny Delight, Hi-C, Hawaiian Punch, Ocean Spray; though excluding 100% fruit juice) were separately measured and analyzed. In a successive analysis, all sugar-sweetened beverages were defined by combining soda and fruit drinks. To measure changes in beverage intake, we first subtracted the baseline intakes from the follow-up intakes, and then categorized them into decrease, no change, and increase groups. In separate analyses, both baseline beverage intake as well as three groups of changes in beverage intake were treated as independent variables. Plain water and beverages sweetened by low-caloric sweetener were not measured in the Kids FFQ.

All participating children and caregivers were weighed on a calibrated digital scale, and their heights were measured from a wall-mounted tape measure. Both procedures followed a standard protocol from the NHANES (36). BMI (kg/m^2) was computed for each child and caregiver. It was further converted to a BMI z-score using BMI percentiles for each child obtained from Centers for Disease Control and Prevention 2000 growth charts (37). Thus, a BMI z-score is a measure of each child's relative BMI value compared to national averages. BMI z-score was then used to identify children as not overweight (BMI <85th percentile), overweight (85th percentile ≤ BMI <95th percentile), or obese (BMI ≥95th percentile). Furthermore, the incidence of overweight was determined as whether the children's normal weight at baseline became overweight (or obese) at follow-up (BMI ≥85th percentile). Similarly, the incidence of obesity was determined as new events of obesity at follow-up (BMI ≥95th percentile) among children who were not obese (which includes children's overweight at baseline). Measures of childhood obesity included baseline BMI z-scores, change in BMI z-score from baseline to follow-up, incidence of overweight, and incidence of obesity.

Statistical analysis

Descriptive statistics were computed to illustrate characteristics of the sampled children and the overall trends of beverage intakes and obesity. The baseline association between children's BMI z-scores and beverage intakes was examined by using linear regression analysis. This cross-sectional association was evaluated separately for soda, fruit drinks, and all sugar-sweetened beverages, regressing baseline BMI z-score on the predictors. Two additional sets of regression analyses were conducted to examine longitudinal associations. First, change in BMI z-score from baseline to follow-up was regressed on indicators of changes in beverage intakes (decrease, no change, increase). Appropriate control variables were added as predictors to these regression models to adjust for potential confounding. The second regression sets were logistic regression models to examine the association between sugar-sweetened beverage intakes (baseline intake and changes in intakes) and incidence of overweight and obesity, again with adjustments for important potential confounding variables. Potential confounding variables include children's age, sex, and energy intake, and child's caregiver's education, income, and BMI. Statistical significance was at the conventional level ($P < 0.05$).

Statistical analyses were conducted in STATA version 10 software (Stata, College Station, TX). All analyses were adjusted with weights developed to account for unequal selection probabilities and differential nonresponse. There was a small number of missing values on baseline weight and height of child and caregiver (0.6–1.6%), caregiver's education (1.4%), and income (3.5%) variables. To minimize potential bias resulting from excluding children with these missing data, missing values were imputed by sequential regression procedures in the *IVEware* software system (38).

RESULTS

Table 1 shows the sociodemographic characteristics, mean daily consumption of beverages and dietary energy, and obesity status of the children. Between baseline and follow-up, the prevalence of overweight in the study population increased from 12.9 to 18.7%, and the prevalence of obesity almost doubled. Incidence of overweight and obesity occurred among 26.3 and 13.4% of baseline nonoverweight (n = 275) and nonobese children (n = 325), respectively. Mean consumption of fruit drinks and all sugar-sweetened beverages increased from baseline to follow-up. By contrast, during the same period, average soda consumption slightly decreased, indicating that increased consumption of all sugar-sweetened beverages came from the increase in consumption of fruit drinks.

Table 2 shows the outcomes of baseline cross-sectional analyses of associations among intakes of soda, fruit drinks, and all sugar-sweetened beverages and BMI z-score. From the unadjusted model (model 1), baseline intakes of soda and sugar-sweetened beverages were positively associated with BMI z-scores. The addition of sociodemographic characteristics, dietary energy intake, and caregiver's BMI (model 2) did not change the association observed in model 1 between intakes and BMI z-score.

In longitudinal analyses, change in BMI z-scores was regressed on change in beverage intakes (decrease, no change, increase), with and without control variables. Although a positive trend was observed for soda, fruit drinks, and all sugar-sweetened beverages, these associations failed to achieve statistical significance (data not shown).

Finally, a second set of longitudinal analyses was conducted among 275 children who were normal weight at baseline. **Table 3** shows the results of logistic regression models in which the incidence of overweight at the 2-year follow-up was regressed on baseline consumption of soda, fruit drinks, and all sugar-sweetened beverages. After adjusting for sociodemographic characteristics, dietary energy intake, and caregiver's BMI, the odds of becoming overweight increased by 1.04 per ounce of fruit drink consumption per day and 1.04 per ounce of all sugar-sweetened beverage consumption per day (see model 3). However, the longitudinal associations among changes in beverage intake and incidence of overweight were not significant (data not shown).

Logistic regression analyses for incidence of obesity among 325 children who were not obese at baseline were performed using baseline beverage intakes as well as change in beverage intakes as predictors (data not shown). The direction of associations was similar to the one in the model for incidence of overweight although the associations were not significant.

Table 1 Characteristics of the sampled children at baseline and follow-up (n = 365)

	Baseline	Follow-up
Child-level characteristics		
Baseline age (weighted %)		
3 years old	119 (30.2%)	—
4 years old	126 (36.6%)	—
5 years old	120 (33.2%)	—
Gender (weighted %)		
Male	165 (48.4%)	—
Female	200 (51.6%)	—
Weight and height: weighted mean (s.e.)		
Weight in kg	18.4 (0.3)	24.9 (0.3)
Height in cm	106.8 (0.6)	119.9 (0.4)
BMI z-scores: weighted mean (s.e.)	0.14 (0.08)	0.56 (0.1)
Change in BMI z-scores	—	0.43 (0.1)
Weight status (weighted %)		
Nonoverweight (BMI < 85%)	275 (76.8%)	213 (60.9%)
Overweight (85% ≤ BMI < 95%)	50 (12.9%)	71 (18.7%)
Obesity (BMI ≥ 95%)	40 (10.3%)	81 (20.4%)
Incidence of overweight[a] (BMI ≥ 85%)	—	75 (26.3%)
Incidence of obesity[b] (BMI ≥ 95%)	—	51 (13.4%)
Beverage intake (oz/day): weighted mean (s.e.)		
Soda	6.1 (0.5)	5.2 (0.4)
Fruit drinks	13.0 (0.7)	16.5 (1.0)
All sugar-sweetened beverages[c]	19.2 (1.0)	21.6 (1.1)
Change in soda	—	-0.9 (0.7)
Change in fruit drinks	—	3.5 (1.0)
Change in all sugar-sweetened beverages[c]	—	2.6 (1.4)
Dietary energy intake (kcal/day): weighted mean (s.e.)	2243.3 (81.0)	2565.3 (62.6)
Caregiver-level characteristics		
Caregiver's education (weighted %)		
<high school	163 (43.7%)	—
≥high school diploma	202 (56.3%)	—
Caregiver's annual income (weighted %)		
<$10,000	159 (44.1%)	—
≥$10,000	206 (55.9%)	—
Caregiver's BMI (kg/m^2): weighted mean (s.e.)	31.1 (0.61)	—

[a]Incidence of overweight means the event that nonoverweight children at baseline (n = 275) became overweight or obese at follow-up. [b]Incidence of obesity means the event that nonobese children at baseline (n = 325) became obese at follow-up. [c]All sugar-sweetened beverages = soda + fruit drinks.

Table 2 Baseline relationship between beverage intakes and BMI *z*-scores (*n* = 365)

	Soda		Fruit drinks		All sugar-sweetened beverages[a]	
	Coefficients (s.e.)	*P* values	Coefficients (s.e.)	*P* values	Coefficients (s.e.)	*P* values
Model 1[b]						
Beverage intake (oz/day)	**0.02 (0.01)**	**0.002**	0.01 (0.01)	0.27	**0.11 (0.004)**	**0.02**
Model 2[c]						
Beverage intake (oz/day)	**0.02 (0.01)**	**0.003**	0.01 (0.01)	0.43	**0.01 (0.005)**	**0.03**
Caregiver's BMI	**0.02 (0.01)**	**0.02**	**0.02 (0.01)**	**0.02**	**0.02 (0.01)**	**0.02**

Estimates in boldface indicate statistical significance at $P < 0.05$.
[a]All sugar-sweetened beverages = soda + fruit drinks. [b]Model 1 only includes baseline beverage intakes as an independent variable. [c]Model 2 includes baseline beverage intakes, caregiver's BMI, age, gender, caregiver's education and income, and child's baseline dietary energy intake as covariates.

Table 3 Odds ratios and 95% confidence intervals for incidence of overweight[a] by baseline beverage intake (*n* = 275[b])

	Soda	Fruit drinks	All sugar-sweetened beverages[c]
	Odds ratios (95% CI)	Odds ratios (95% CI)	Odds ratios (95% CI)
Model 1[d]			
Beverage intake (oz/day)	1.04 (1.00–1.08)	1.01 (0.98–1.04)	1.02 (1.00–1.04)
Model 2[e]			
Beverage intake (oz/day)	1.04 (1.00–1.09)	**1.04 (1.01–1.07)**	**1.04 (1.01–1.06)**
Ref: gender: male	—	—	—
Gender: female	**0.41 (0.21–0.80)**	**0.38 (0.19–0.73)**	**0.38 (0.20–0.74)**
Ref: 3 years old	—	—	—
4 years old	**0.41 (0.18–0.94)**	**0.42 (0.19–0.94)**	**0.40 (0.18–0.89)**
5 years old	0.52 (0.24–1.16)	0.54 (0.25–1.17)	0.51 (0.24–1.11)
Ref: dietary energy intakes: low[f]	—	—	—
Dietary energy intakes: middle low[f]	1.13 (0.45–2.85)	0.95 (0.36–2.51)	0.89 (0.33–2.39)
Dietary energy intakes: middle high[f]	**0.34 (0.13–0.85)**	**0.28 (0.11–0.72)**	**0.24 (0.10–0.60)**
Dietary energy intakes: high[f]	0.47 (0.17–1.33)	**0.26 (0.08–0.83)**	**0.23 (0.07–0.76)**
Child's baseline BMI-scores	**2.49 (1.56–3.97)**	**2.53 (1.57–4.09)**	**2.52 (1.55–4.09)**
Model 3[g]			
Beverage intake (oz/day)	1.04 (0.99–1.10)	**1.04 (1.01–1.07)**	**1.04 (1.01–1.07)**
Ref: gender: male	—	—	—
Gender: female	**0.43 (0.21–0.88)**	**0.40 (0.19–0.84)**	**0.40 (0.19–0.83)**
Ref: 3 years old	—	—	—
4 years old	**0.40 (0.16–0.99)**	**0.41 (0.17–0.97)**	**0.39 (0.16–0.91)**
5 years old	0.52 (0.23–1.21)	0.53 (0.23–1.23)	0.51 (0.22–1.16)
Ref: dietary energy intakes: low[f]	—	—	—
Dietary energy intakes: middle low[f]	1.13 (0.49–2.61)	0.93 (0.36–2.41)	0.88 (0.34–2.25)
Dietary energy intakes: middle high[f]	**0.35 (0.14–0.83)**	**0.28 (0.12–0.69)**	**0.24 (0.10–0.62)**
Dietary energy intakes: high[f]	0.51 (0.18–1.46)	**0.27 (0.08–0.89)**	**0.24 (0.07–0.88)**
Child's baseline BMI-scores	**2.47 (1.55–3.94)**	**2.53 (1.54–4.15)**	**2.52 (1.53–4.15)**
Caregiver's BMI	1.03 (0.99–1.08)	**1.04 (1.00–1.08)**	1.03 (0.99–1.08)

Estimates in boldface indicate statistical significance at $P < 0.05$.
CI, confidence interval.
[a]Incidence of overweight means the event that nonoverweight children at baseline became overweight or obese at follow-up. [b]The sample size decreased to 275 from 365 because the analysis only focused on nonoverweight children at baseline. [c]All sugar-sweetened beverages = soda + fruit drinks. [d]Model 1 only includes baseline beverage intakes as an independent variable. [e]Model 2 includes baseline beverage intakes, BMI, age, gender, caregiver's education and income, and child's baseline dietary energy intake as covariates. [f]Four categories of dietary energy intakes were defined by quartiles of dietary energy intake (kcal) as low (~25th % quartile), middle low (25th–50th % quartiles), middle high (50th–75th % quartiles), and high (~75th % quartile). [g]Model 3 includes all the covariates in model 2 plus caregiver's BMI.

DISCUSSION

In this longitudinal cohort of low-income African-American preschool children, we found that baseline consumption of soda and all sugar-sweetened beverages was positively associated with BMI *z*-scores. The odds of becoming overweight at follow-up among the baseline normal weight children increased by 4% for each additional ounce of fruit drinks consumed at baseline and by 4% for each additional ounce of all sugar-sweetened beverages consumed at baseline. This 4% increased risk for each ounce of sugar-sweetened beverages is put in perspective when considering the ~20 oz of all sugar-sweetened beverages consumed by this population is about 6 oz more per day than found among children aged 3–7 years in the 2003–2004 NHANES data (39).

The baseline association between BMI and the consumption of soda, fruit drinks, or all sugar-sweetened beverages can be compared to previous cross-sectional studies. In a study of 354 two-year-old Mexican American children, Warner and colleagues found that children who drank one or more soda per day were 3.4 times more likely to be overweight when compared with those with no soda consumption (9). In contrast to our findings, the majority of other studies targeting preschool children did not find an association between sugared-beverages consumption and weight status. For example, two studies based on nationally representative samples of 2–5-year-old children did not find an association between intakes of soda or fruit drinks and weight status (19,27). In a study using NHANES 1999–2002 data, the quantity of fruit drinks or soda consumption was not significantly associated with the increased BMI (19). The other study identified high fruit juice drinkers from beverage clusters using NHANES 2001–2002 data, but adjusted mean BMI of these children were not significantly different from the one of the other children (27). However, the population from the first study had a mean daily soda intake of 3.3 oz, and fruit drink intake of 5.0 oz, approximately one-half and one-third of the quantity in our population.

Unlike the baseline association, we found that the associations between change in beverage consumption and change in BMI *z*-scores were not significant. Other studies have mixed findings examining the same type of association. For example, Newby and colleagues found no significant association between change in soda or fruit drinks intake and change in BMI among 1,379 low-income Caucasian and Native American preschool children in North Dakota (16). The two other studies found associations with increased sugar-sweetened beverage consumption from baseline and greater weight gains at follow-up; however these studies targeted children aged 9–14 years (6,23). Several additional studies targeting preschool children have focused on naturally sweet juice or 100% fruit juice in their analyses, making comparisons with our study difficult (25,40,41).

Several additional findings from this study are noteworthy. First, the estimated 260 empty calories and 65 g of sugar from the ~20 oz of all sugar-sweetened beverages consumed each day is of great concern, as previous studies have found that this level of consumption of sugar-sweetened beverages displaces more nutritious foods (6,42). Because obesity-influencing dietary behaviors developed at an early age may continue throughout adolescence and adulthood, this study illustrates concerns for the developing unhealthy beverage consumption patterns in these preschool children (19,43). Second, the fact that the caregiver's BMI was a significant predictor of childhood obesity in all of our analyses supports previous evidence of genetic, environmental, and parental influences on early development of obesity. The genetic contribution to obesity was observed in several studies of adults (44,45), and the significant association between mother's BMI and child's BMI was interpreted as evidence of high heritability (46,47). In a previous study supporting high heritability, the authors found that the odds of overweight among children from overweight mothers were 15.7 higher compared to children from lean mothers (46). Along with heritability, home environment and parental role modeling may also contribute to the relationship between caregiver's BMI and child's BMI in our study, as children are known to adopt eating behaviors modeled from caregivers in home environment (45). Although recent policy efforts have focused on reducing the availability of sugar-sweetened beverages in school-aged children (48), our findings clearly indicate that school-based policies alone will not be sufficient in reversing sugar-sweetened beverage intake or retarding the escalating rise in childhood obesity in these young African-American children.

Higher dietary energy intake appeared to have a protective effect in the model for incidence of overweight. However, physical activity levels may be confounding this finding, as both dietary intake and physical activity levels contribute to weight status. It is feasible to suggest that children with high dietary energy intake may have also been more physically active; hence the physical activity levels contribute to the protective effect of overweight in these models. Since the primary focus of this longitudinal cohort study was on oral health outcomes, physical activity was not assessed. The lack of physical activity data is a limitation of this study and future studies examining associations between sugar-sweetened beverage consumption and weight status among children should assess and account for the potential confounding effects of physical activity. In addition to this limitation, our models accounted for energy intake, but other dietary covariates were not considered. Furthermore, data on children's food intake came from the caregivers. This could lead to reporting inaccuracies as children who were 3–5 years old at baseline became 5–7 years olds at follow-up, and spent more time out of the home, e.g., at school or kindergarten. Caregivers may become less able to track what their children actually eat.

This longitudinal study of low-income African-American preschool children supports the hypothesis that baseline consumption of sugar-sweetened beverages is positively associated with baseline BMI and the incidence of overweight over 2 years. As future researchers improve our understanding of the impact of beverage intake on obesity, it will be important to refine our use of longitudinal analyses to better capture changes in both beverage intake and weight over time. This is especially so among preschool- and school-aged children because lifestyle patterns are still being developed (49,50). It is equally as important to account for contributions and variability from all sources of sugared beverages.

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DISCLOSURE

The authors declared no conflict of interest.

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