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## Increased sweetened beverage intake is associated with reduced milk and calcium intake in 3–7 y. old children at multi-item laboratory lunches

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### Abstract

Dietary survey data show that intake of sugar-sweetened beverages is negatively associated with intake of milk, but these findings have yet to be confirmed by laboratory feeding studies. The objectives of the present study were to analyze children's intake across 2 laboratory-based *ad libitum* lunches to 1) investigate the relationships between intake of sweetened beverages, milk, and calcium and 2) explore relationships between beverage consumption and child age and weight status. Data were extracted from a cohort of 126, 3–7 year (y.)-old twins from diverse ethnic backgrounds who participated in a cross-sectional study (conducted from November 1999 – September 2002) designed to determine the genetic and environmental contributions to eating and body weight. At 2 visits, children ate *ad libitum* from lunches that offered a variety of sugar-sweetened and calcium-rich beverages. Total beverage and nutrient intakes were computed from the test meals. Weight, height, and waist circumference were assessed on the final visit. Regression analyses tested the associations among intake of sweetened beverages, calcium, and milk (primary aim) and whether these variables were associated with child age and weight status (secondary aim). Sweetened

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beverage intake was negatively correlated with both milk ( $p < 0.01$ ) and calcium ( $p < 0.01$ ) intakes, and these relationships remained after controlling for age, gender, and ethnicity ( $p < 0.01$ ). Child age was negatively associated with milk intake ( $r = -0.22$ ,  $p < 0.01$ ) but positively associated with intake of sweetened beverages ( $r = 0.27$ ,  $p < 0.01$ ). Results support the notion that sugar-sweetened beverages displace milk in a single meal, and this phenomenon may vary with child age. Due to the cross-sectional nature of this study, future investigations are needed to determine the long-term implications of this consumption pattern. The possibility that limiting sweetened beverages may help optimize dietary calcium during childhood is a topic that merits further research.

## Keywords

Beverage intake; sugar-sweetened beverages; milk intake; childhood obesity

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## Introduction

Cross-sectional data find that calcium intake in United States (US) children is lower than recommended (1,2), and tends to decrease with age, while intake of sweetened beverages such as soft drinks and juices tends to increase, particularly among adolescents (3,4). Decreases in calcium intake among children can in part be attributed to declines in milk consumption over the past several decades (5). Some investigators have hypothesized that sweetened beverages displace intake of milk in children's diets (6,7). If this displacement begins in early childhood, children might suffer from inadequate intakes of calcium through adolescence, a dietary pattern which can potentiate the development of osteoporosis (8,9) or possibly obesity (10,11) in adulthood. To date, there have been no reports using direct measures of food intake from controlled laboratory settings to support findings from cross-sectional surveys. The present laboratory feeding study is warranted to more rigorously test the reported inverse associations between intake of milk and sweetened beverages.

The primary aim of this study was to test the hypothesis that increased sweetened beverage intake is associated with decreased milk and calcium intake in laboratory-based meal data previously collected from a twin cohort. The secondary objective was to test the hypothesis that sweetened beverage intake at meals is positively associated with child age, while the inverse is true for milk intake. Because several recent studies have found that intake of high-calcium dairy products may be inversely correlated to body weight (12–15), the associations between beverage consumption and weight status were also assessed.

## Methods

Children's data were obtained from a cross-sectional laboratory study designed to test genetic and environmental influences on child eating and body composition. The original study was conducted during the period of November 1999 to September 2002. Participants ( $n = 126$ , 54 boys, 72 girls) in this convenience sample were same-sex identical and fraternal twins, 3–7 y. old with a mean ( $\pm$  standard deviation) – (SD) age of 4.5 ( $\pm 1.5$ ) y. Recruitment was done by advertising in local parent-targeted circulations and was ongoing over the course of the 3 year study. Twins were excluded if they had any medical problems or were taking any medications, had any food allergies, or were lactose intolerant. All parents signed consent for their children's participation and research authorization forms as defined by the Health Insurance Portability and Accountability Act (HIPAA). The Institutional Review Board of St. Luke's Roosevelt Hospital approved this study.

For the full study protocol, children came to the child feeding laboratory for 4 lunch-time visits (16). Data for the present study came from the last two visits where children consumed multi-

item *ad libitum* lunches. Each twin ate alone with his or her mother and the lunch was videotaped in order to capture parental feeding interactions associated with the meal (16,17), but these variables were not analyzed in the present study.

Children were given 30 minutes to consume meals that consisted of a variety of age-appropriate foods listed in Table 1. Foods were selected based on their familiarity to most children in this age group. Although they were not selected for the purposes of studying beverage and calcium intake, per se, the variety of foods was such to allow some exploration of beverage choice.

Anthropometric measures (height, weight, and waist circumference) were performed by a trained technician with experience taking such measures in children. Waist circumference was measured to the nearest 1 centimeter (cm), midway between the lowest point of the ribcage and the iliac crest. Weight was measured to the nearest 0.1 kg by a digital scale (Weight-Tronix, Scale Electronics Development, New York, NY). Height (without shoes) was measured to the nearest 0.5 cm using a stadiometer (Holtain, Crosswell, Wales, UK). Height and weight were converted to body mass index ( $BMI = kg/m^2$ ), and BMI z-scores, using the Centers for Disease Control growth charts conversion program for Statistical Analysis Software (version 9.1, 2002, SAS Institute Inc, Cary, NC).

## Statistics

Energy consumption across meals was determined by first calculating the difference between the pre- and post-weights of all foods. Total energy and percent of calories from fat, carbohydrate, and protein were calculated from food label information.

Micronutrient intakes at the meals, in particular calcium and vitamin D, were calculated using *FoodWorks* (Version 8.0, 2000, The Nutrition Company, LongValley, NJ). *FoodWorks* contains over 30,000 foods and determines adequacy of each nutrient based on current dietary standards. To attain these values for each child, grams consumed of each food were entered into the program database and micronutrient outputs were extracted for further analyses.

Descriptive statistics (means and standard deviations) were generated for quantitative data, including beverage parameters (ie, calories from sweetened beverages and milk), as well as total energy, macro- and micronutrients (calcium and vitamin D). Pearson's correlation coefficients were calculated to test the hypotheses that sweetened beverage intake was negatively associated with intake of milk, calcium, and vitamin D. The above analyses were also performed after adjusting for key descriptive variables (ie, age, gender, and ethnicity). Secondary objectives were assessed by determining the Pearson's correlation coefficients between beverage intake, child age, and weight status.

To account for family dependencies in the data structure, significant correlations were retested using the degrees of freedom (*df*) from twin pairs instead of individual children in the analyses. Any relationships that were no longer significant after accounting for the family dependency were noted in the results.

Power calculations were not performed prior to these secondary data analyses. For all statistical tests, a p-value of less than or equal to 0.05 was the cut-off for significance, and all hypotheses were two-tailed. Descriptive statistics were reported as means  $\pm$  SD. All analyses were done using SPSS software program (version 14.0, 2005, SPSS Inc, Chicago, IL).

## Statement of Ethics

All applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research.

## Results & Discussion

Children in this study were on average lean, with a mean (SD) BMI z-score of 0.2 ( $\pm$  1.4), and waist circumference of 52.2 ( $\pm$  6.0) cm. Fifty-three percent were non-Hispanic white, 16.2% were African-American, 14.0% were Hispanic-American, 2.9% were Asian-American, and 13.2% identified themselves as “other.” Across meals, children consumed 23.9 ( $\pm$ 31.1) kcals from milk (both white and chocolate) and 37.6 ( $\pm$ 38.0) kcals from sweetened beverages (all juices, juice drinks, and cola).

The primary aim of the study was to determine if sweetened beverage and milk/calcium intakes are inversely correlated with one another in a laboratory meal setting. Findings from these test meals show that intake of sweetened beverages (cola, juice, and juice drink) was negatively associated with intake of not only milk, but also calcium and vitamin D, two essential micronutrients. Specifically, sweetened beverage intake was negatively associated with intakes of both milks together (chocolate and white) ( $r = -0.32$ ,  $p < 0.01$ ), and with intake of just white milk ( $r = -0.20$ ,  $p = 0.02$ ). Also, sweetened beverage intake was negatively associated with total calcium consumed at the test meals ( $r = -0.24$ ;  $p < 0.01$ ). This relationship was stronger after adjusting sweetened beverage intake for total calories consumed at the meals ( $r = -0.38$ ;  $p < 0.001$ ) [Figure 1].

In addition to having a negative relationship to calcium intake, sweetened beverages were also negatively associated with amount of vitamin D consumed ( $r = -0.28$ ;  $p < 0.05$ ). All of the above relationships remained after adjusting for child age, gender, and ethnicity.

While these findings are cross-sectional and do not demonstrate a causal relationship, they lend support to the notion that sweetened beverages displace intake of milk in children’s diets. The possibility that children who over-consume sugar-sweetened beverages may do so at the detriment of essential nutrients such as calcium and vitamin D warrants further investigation. In other reports, increased soft drink consumption, in particular, has been associated with lower intakes of calcium and other micronutrients in children and adolescents (7,18–20). This is of great nutritional concern because calcium and vitamin D work together as key nutrients in achieving optimal bone health (8–9). Further, Zemel and colleagues have observed that adding calcium to the diet can enhance weight loss (10) and improve metabolic profiles (21) in adults. In addition to its potential to displace calcium, consumption of sweetened beverages alone has been proposed as an independent risk factor for obesity because some studies have found that children do not compensate for energy consumed in these highly palatable sources of liquid calories (22). Taken together, one can hypothesize that sweetened beverage consumption might be a contributing risk factor to poor overall diet quality and, potentially, obesity.

Previous reports have demonstrated that intake of sweetened beverages increases as children grow older, while intake of milk tends to decrease (3,23,24). Accordingly, a secondary aim of this project was to test for these associations in the laboratory. Indeed, child age was positively associated with sweetened beverage intake ( $r = 0.27$ ;  $p < 0.01$ ) and this association remained after adjusting for total energy intake ( $r = 0.19$ ;  $p < 0.05$ ). Further, after adjusting for total energy intake, age was negatively correlated with calories from both milks (white and chocolate) ( $r = -0.22$ ;  $p < 0.01$ ). While these relationships were expected, it was surprising that such low intakes of milk were seen in children that were, on average, not yet 5 y. old and who consumed the meal with their mothers present. Average caloric consumption from milk at the meal was around 24 kcal (~15 milliliters) and intake of calcium was around 200 mg. If this is representative of children’s usual consumption, the recommended adequate intake of 800 mg/day for this age group (25) would not be achieved. While other reports have noted similar results, most studies have identified this trend in adolescents (3) or children older than 5 y. of age (23). Results from the present study suggest that younger children may be at risk

for this dietary trend as well, but additional studies are warranted to determine how well this test meal predicts children's usual intakes.

Previous cross-sectional (12–15) and experimental (10,11,21) studies have suggested that calcium can be protective against obesity, despite a lack of relationship in this study. Neither calcium nor milk intake was inversely associated with BMI z-score (p-values ranging from 0.30–0.80), or with waist circumference (p-values ranging from 0.13–0.53). However, children were young and positive effects of calcium on body weight may not be evident yet. Also, sweetened beverage intake (adjusted for milk intake) was not associated with BMI z-score ( $p = 0.61$ ) but showed a modest positive association with child waist circumference ( $r = 0.18$ ,  $p = 0.05$ ). These intriguing findings should be interpreted with caution. Intake of a test meal may not reflect children's usual intake, and thus foods and nutrients consumed at these meals may not be good predictors of long-term consumption or health risk.

### Limitations

There are several factors that might have influenced children's food choices at the test meal that were not taken into account in this study, but should be noted. First, maternal beverage consumption patterns may influence children's beverage choices, but these were not factored into the present study design. Fisher *et al.* found that maternal milk consumption is positively associated with daughters' milk intakes (26). It is possible that children's beverage choices in the present study were in part mediated by mothers' habitual beverage consumption, thus future studies might wish to control for this variable. Furthermore, Birch and colleagues have hypothesized that parental feeding styles that are overly restrictive can encourage overeating of "restricted" foods in free access situations, particularly in young girls (27,28). It may be that children preferred to drink sweetened beverages at the laboratory because they were not regularly offered these beverages at home. The fact that calcium intakes in these meals were low is concerning, given that mothers were present, and this suggests the need to conduct future research on assessing level of parental concern and awareness about this important nutrient.

In addition to the parental variables mentioned above, there were other limitations. First, a laboratory meal might not reflect children's usual intakes, as discussed above. Although the lab setting provided was comfortable for families, the laboratory cannot substitute for children's natural eating environments. Furthermore, day-to-day and meal-to-meal fluctuations in calcium intake are common in children. Because this study presents data from only two meals, results may not reflect overall patterns of calcium consumption. Second, while children were offered a range of foods, intakes were limited by the choices available. The number of calcium-rich foods offered to children was minimal, and the possibility that greater calcium intake would have been seen with a greater variety of calcium-containing foods cannot be eliminated. Finally, power analyses were not performed on the reported relationships, so it is not possible to rule out the presence of a Type II error in the data. Despite the limitations, this is one of the only laboratory feeding studies to corroborate a wealth of cross-sectional data. Further, there is a lack of observational food intake data on children this age, so the contribution to the literature is thought to be meaningful.

### Conclusion

These findings support previous cross-sectional data, and suggest that intake of sweetened beverages and intake of micronutrients such as calcium may be inversely correlated with each other during meals. Because this study was not designed to test causality, future investigations are warranted to determine the implications for consumption of sweetened beverages in the overall diet. Reducing consumption of sweetened beverages in children's diets might be one strategy for increasing milk and calcium intake, a notion that warrants future testing.



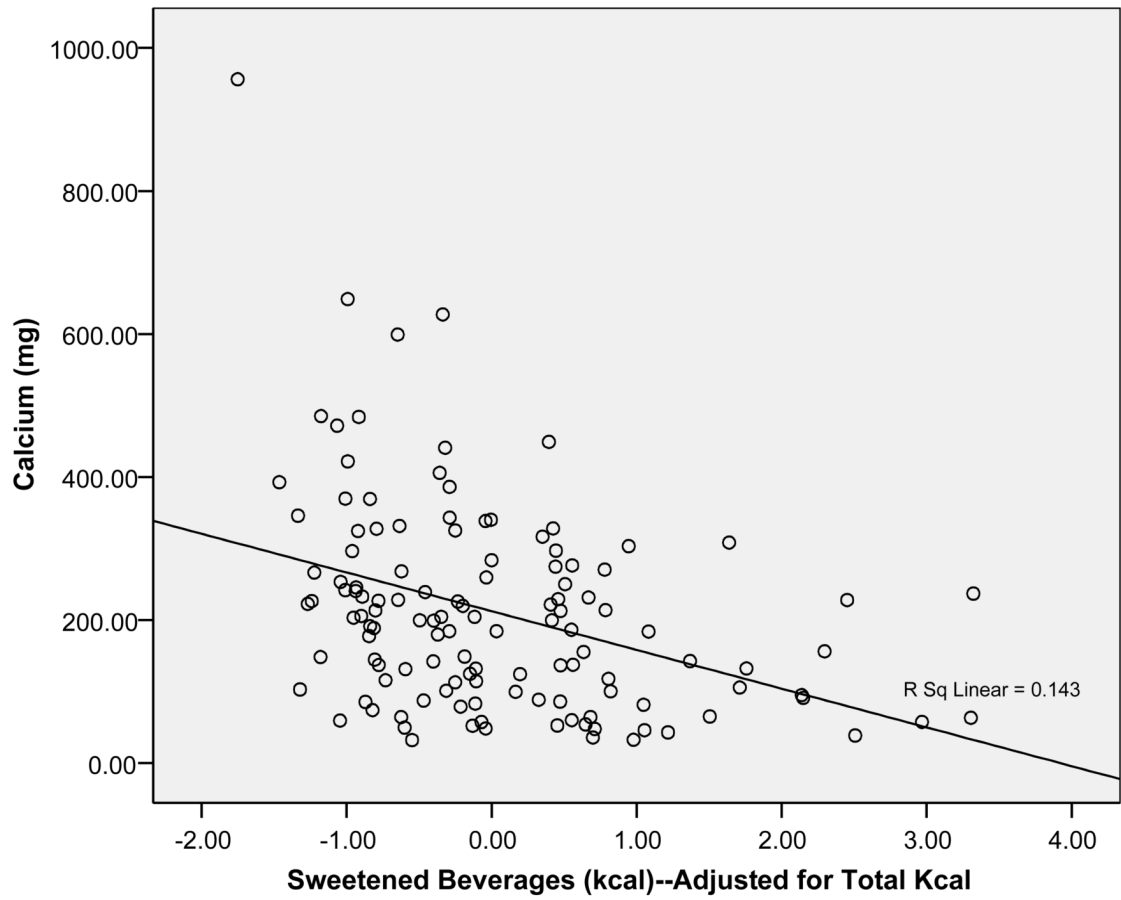
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**Figure 1.** Intake of sweetened beverages (kcal), adjusted for total kcal consumed at the test meals, was negatively associated with total meal calcium (mg) ( $r = -0.38$ ;  $p \leq 0.001$ ).



**Table 1**  
Foods Served in Buffet Lunch, Serving Sizes, and Nutrient Information

Food	Approximate Serving Size (g)	Calories; Calcium (mg)
Chicken Nuggets	372 g (5 chicken nuggets)	951 kcal; 43 mg
Bologna on Wheat	150 g (1 small sandwich)	292 kcal; 58 mg
Bologna on White	150 g (1 small sandwich)	247 kcal; 59 mg
Turkey on Wheat	100 g (1 small sandwich)	225 kcal; 56 mg
Turkey on White	100 g (1 small sandwich)	178 kcal; 57 mg
Canned Peas	40 g	28 kcal; 8 mg
Canned Corn	40 g	32 kcal; 2 mg
Baby Carrots	35 g	13 kcal; 8 mg
Cheese and Crackers	195 g	312 kcal; 94 mg
Strawberry Yogurt	120 g	118 kcal; 176 mg
Raisins	18 g	54 kcal; 9 mg
Applesauce	120 g	91 kcal; 5 mg
Potato Chips	47 g (1 small bag)	257 kcal; 13 mg
Regular Fat Chocolate Milk (3.75 % fat)	260 g	217 kcal; 292 mg
Whole White Milk (3.75 % fat)	400 g	257 kcal; 476 mg
Apple Juice	255 g (1 small juice box)	120 kcal; 18 mg
Orange Juice	220 g (1 small can)	92 kcal; 18 mg
Fruit Punch	260 g (1 small juice box)	122 kcal; 21 mg
Caffeine Free Cola	275 g (1 can)	151 kcal; 0 mg
Banana	90 g (1 half banana)	83 kcal; 5 mg
Graham Crackers	25 g	106 kcal; 20 mg
Oreos	36 g (3 cookies)	100 kcal; 0 mg
Chocolate Cupcakes	90 g (2 packaged cupcakes)	275 kcal; 32 mg
Hershey Kisses	50 g	257 kcal; 96 mg
Fruit Cocktail	145 g	67 kcal; 12 mg
Jello	110 g	65 kcal; 2 mg
Chocolate Pudding	120 g	157 kcal; 119 mg
Fruit Roll-up	15 g	56 kcal; 0 mg
Granola Bar	30 g	126 kcal; 28 mg

<sup>a</sup>Beverage options are shaded.