Journal of Clinical Psychology in Medical Settings, Vol. 13, No. 2, June 2006 (© 2006)
DOI: 10.1007/s10880-006-9017-8

Relations Among Milk and Non-Milk Beverage Consumption, Calcium, and Relative Weight in High-Weight Status Children

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Published online: 3 June 2006

Relations among weight, calcium, and milk have received considerable attention, but inconsistencies remain regarding strength and direction of associations. Calcium, milk, other beverages, and weight status associations were examined among children >75th BMI percentile from three studies. Results indicated negative relations between *z*-BMI and non-whole milk and calcium in one sample, with lower *z*-BMI and percent body fat among older children drinking any non-whole milk. In one older child sample, *z*-BMI and percent body fat were higher for whole milk consumers. The only significant relation observed for other beverages was the negative association between juice and percent body fat in younger children. Milk, calcium, and child weight status associations are inconsistent, and appear dependent on milk type and child age.

KEY WORDS: Childhood obesity; calcium; milk; body fat; sugar-added beverages.

Childhood obesity is becoming increasingly prevalent in the United States (Ogden, Flegal, Carroll, & Johnson, 2002; Strauss & Pollack, 2001). No single factor is the predominant contributor to this epidemic, but dietary behaviors clearly impact weight status and interventionists are seeking dietary recommendations that would lead to better child weight management.

Calcium, and particularly milk, has recently received considerable popular press and empirical attention as a nutrient (and food item) potentially associated with better weight control. Zemel and colleagues propose a cellular mechanism by which a high-calcium diet inhibits adiposity through suppression of circulating concentrations of the active form of Vitamin D (Zemel, Shi, Greer, Dirienzo, & Zemel, 2000). Calcium may also act in the gut to reduce fat absorption by increasing fecal fat excretion (Parikh & Yanovski, 2003). Some cross-sectional evidence finds that adults' higher calcium intake is related to lower body mass index (BMI), lower body fat, and lower risk of being overweight, especially in White women (Davies et al., 2000; Lovejoy, Champagne, Smith, de Jonge, & Xie, 2001; Zemel et al., 2000). The inverse relationship between calcium intake and adiposity has been shown to persist after adjustment for total energy intake (Lovejoy et al., 2001) or total protein intake (Davies et al., 2000). Estimates of variance explained by calcium intake in adults' weight status or body fat range from approximately 3 to 6% (Davies et al., 2000). One clinical trial suggests that adding calcium supplementation results in greater weight loss among adults than energy restriction alone (Davies et al., 2000). There is some evidence that lower body fat accumulation or fat loss

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is augmented when the increased calcium intake is derived specifically from dairy products (Parikh & Yanovski, 2003).

Heaney's (Heaney, Davies, & Barger-Lux, 2002) review of the calcium–weight observational literature suggests some consistency of the association across the lifespan. Higher average calcium intake and dairy servings from 2 to 5 years of age was associated with lower percent body fat and absolute body fat mass measured at 70 months of age (Carruth & Skinner, 2001), with further follow-up documenting a continued relation between earlier calcium intake and body fat at 8 years of age (Skinner, Bounds, Carruth, & Ziegler, 2003). Skinner et al. (2003) report that calcium explains 4.5–9% of the variance in 8-year-old children's body fat. Barba, Troiano, Russo, Venezia, and Siani (2005) report decreasing BMI *z*-scores and decreased overweight prevalence with increasing whole milk consumption in a large sample of 3–11-year-old children, but only when the small percentage of children who drink skim milk were excluded from analysis (Barba et al., 2005).

The relations between calcium, milk, and weight status are far from definitively established however. Some investigators have failed to find an association between calcium and/or milk intake and child weight status, whereas others have found a positive association indicating greater dairy intake is related to higher weight status. For example, there was no significant association found between beverage consumption type (e.g., milk, fruit juice) or change in beverage consumption and short-term weight or BMI change in 2–5-year-old children enrolled in a WIC program (Newby et al., 2004). Another study among toddler and pre-school children also failed to find a milk/obesity association (Dennison, Rockwell, & Baker, 1997). Among 10-year-old children in the Bogalusa Heart Study, neither milk nor the more global dairy serving consumption was related to overweight prevalence (Nicklas, Yang, Baranowski, Zakeri, & Berenson, 2003). Others found no prospective relations from middle childhood to adolescence between either BMI *z*-score or percent body fat and dairy food consumption (Phillips et al., 2003). Berkey, Rockett, Willett, and Colditz (2005) recently found that higher milk consumption and increases in milk consumption were related to higher average yearly BMI increases among a large U.S. sample of 9–14–year-olds, although these relations were weakened after controlling for total energy intake (Berkey et al., 2005).

Clinical trials have failed to clarify whether calcium is a potent contributory factor in better weight control, with a dearth of studies among children. In an empirical literature review up to October 2001, Barr found that only 1 out of 17 clinical trials involving calcium supplementation in children or adults had documented greater weight loss among participants randomized to a higher calcium condition (Barr, 2003). These trials were limited in being designed primarily to examine bone outcomes, and thus perhaps under-powered to detect adiposity effects, but subsequent trials specifically to examine adiposity outcomes have found conflicting effects. Zemel and colleagues found that higher calcium was related to better body fat losses in obese adults, when matched with calorically similar low calcium dietary interventions (Zemel, Richards, Milstead, & Campbell, 2005; Zemel, Thompson, Milstead, Morris, & Campbell, 2004). However, calcium source may be an important moderating factor of body fat reduction, as calcium supplementation does not appear to be as effective in weight management as higher dairy consumption at the same overall level of calcium (Zemel, 2002; Zemel et al., 2004). Other recent randomized trials have failed to find differences in diet-induced weight loss among adult participants randomly assigned to different calcium levels (Gunther et al., 2005; Jensen, Kollerup, Quaade, & Sorensen, 2001; Shapses, Heshka, & Heymsfield, 2004; Thompson et al., 2005).

One potential mechanism by which milk consumption may be related to weight status is through displacement by other beverages. Even though across milk types the caloric range is similar to these other beverages, some have proposed that milk is being displaced by greater volumes of less nutrient-dense beverages during childhood that themselves contribute to higher weight status, particularly beverages such as soft drinks, juice, and other fruit flavored drinks. The specific reasons for higher volume (and therefore caloric) consumption of non-milk sweetened beverages is unknown, but could be associated with such things as taste preference, cost, availability, and usual serving presentation. It is noteworthy in a recent study that the percentage of children consuming sweetened beverages has actually declined over the past 20 years in some locations, but children consuming any sweetened beverages have increased the quantity of their consumption (Nielsen & Popkin, 2004; Rajeshwari, Yang, Nicklas, & Berenson, 2005). Negative relations have been observed between children's consumption of carbonated and other sugar-added beverages and calcium intake at age 8 (Skinner et al., 2003). Similarly, others found higher odds of low milk consumption (<8 oz/day) among higher soft drink consumers from pre-school age through adolescence (Harnack, Stang, & Story, 1999). Other reports by this group find no association between fruit juice and milk consumption, but significant negative relations between soda/pop consumption and both milk and juice consumption (Harnack et al., 1999; Skinner, Carruth, Moran III, Houck, & Coletta, 1999). In a camp setting where numerous beverage options were available to 6–13–year-old children, sweetened drink and juice consumption was inversely related to milk consumption, although the juice/milk association appeared to be the result of different availability of these beverages (Mrdjenovic & Levitsky, 2003). Like the calcium–weight relation, there is not universal consistency in these negative relations between beverage types. For example, Dennison and colleagues failed to find an inverse association between juice and milk consumption in young children (Dennison et al., 1997). Storey, Forshee, and Anderson (2004) found that non-dairy beverage consumption (e.g,. cola, fruit drinks) was only weakly inversely related to overall calcium and milk consumption across various child age groups (Storey et al., 2004).

The present study extends prior findings by examining the relation between children's calcium intake, milk consumption, and weight status, while also considering the influence of non-milk beverage consumption. To test the consistency of these relations among these variables, we examine these relations in samples from three distinct projects on which beverage consumption was assessed similarly. Further, we examine these relations among children with already high-weight status, based on the intervention need to identify weight management strategies for this group and on the hypothesis that even within this at-risk group, children with higher milk and calcium consumption will have lower relative weight status.

METHOD

Participants

Adiposity Rebound Study

Pre-school aged children were recruited from pediatrician offices, day care centers, and newspapers in the greater Cincinnati area to participate in an observational study about early growth and development and the identification of factors related to adiposity rebound. Children were required to not have a medical condition or be involved with treatment that would interfere with their normal growth or development.

Child Health and Natural Growth Evaluation Study (CHANGES)

Children within 3 months of their 8th birthday in the greater Cincinnati area were invited to participate in a study about the natural course of growth and development among children above average in weight status relative to their peers. Children were required to be: (1) Above the 75th body mass index percentile for age and gender, (2) have at least one parent who had a BMI >25.0, and (3) have no medical conditions or be involved with any medical treatment that would be contributing to high-weight status.

Cholesterol Clinic Study

Children between the ages of 8 and 16 years with diagnosed hypercholesterolemia (total cholesterol >170 mg/dl) who were referred to the Cincinnati Children's Hospital Cholesterol Treatment Center (CTC) were considered for participation. Children with causes of secondary hypercholesterolemia, homozygous LDL-cholesterol receptor deficiency, or those taking cholesterol-lowering medications were excluded. For the purpose of this manuscript, baseline cross-sectional data were used. Data from the cholesterol clinic sample was collected at the subject's enrollment visit at the CTC, prior to receipt of any dietary education.

Across Samples

For comparative purposes across studies and to isolate relations among beverages and weight status among only high-weight status children, only children with BMI values above the 75th percentile BMI for age and gender are included in analyses. Participant characteristics are provided in Table I for each sample. All of these studies were approved by the Cincinnati Children's Hospital Medical Center Institutional Review Board. Informed consent was obtained from parents for children's participation in

Table I. Descriptives for Samples

	Adiposity rebound sample ($n = 122$)	CHANGES sample ($n = 41$)	Cholesterol clinic sample ($n = 44$)
Age (years)			
Mean ± *SD*	3.7 ± 0.3	8.0 ± 0.1	11.2 ± 1.7
Range	2.9–4.3	7.8–8.3	8.0–15.8
Gender (%)			
Female	50.0	48.8	61.4
Race (%)			
White	80.3	68.3	90.9
Black	19.7	26.8	6.8
Other	0	4.9	2.3
BMI			
Mean ± *SD*	17.4 ± 1.0	22.4 ± 4.0	26.7 ± 5.1
Range	16.2–21.8	17.3–34.0	17.6–39.7
z-BMI			
Mean ± *SD*	1.3 ± 0.5	1.8 ± 0.6	1.9 ± 0.6
Range	.70–2.94	.72–2.8	.78–2.6
Body fat (%)			
Mean ± *SD*	25.3 ± 5.3	33.6 ± 6.1	N/A
Range	12.2–40.3	20.2–44.9	N/A

Note. *z*-BMI is a better measure of weight status in children than absolute BMI as it is relative to median BMI (where *z*-BMI = 0) for age and gender.

these studies, with no additional consent required for the present analyses. Children provided either verbal (<12 years old) or written (12 years old or older) assent.

Procedures

Weight and Height Measurement

Weight was measured to the nearest 0.1 kg using a Scaletronic electronic scale and height was measured with a stadiometer to the nearest 0.1 cm. BMI was calculated as kg/m^2. Values for *z*-BMI were calculated using the LMS method and Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS) 2000 growth curves (Kuczmarski et al., 2000).

Dual Energy X-ray Absorptiometry

Fan-beam dual energy X-ray absorptiometry (DXA; Hologic QDR 4500A; Bedford, MA) was used to measure body composition in children in the Adiposity Rebound and CHANGES projects. This is a non-invasive procedure, requiring minimal radiation dose (3.6 μSv) and short scan time (~3 min), and provides accurate and precise (<1–2%) estimates of whole body fat, lean, and bone masses (Koo, Hammami, & Hockman, 2002; Mazess, Barden, Bisek, & Hanson, 1990). DXA allows for consideration of whole body adiposity in both absolute (kg) and relative (%) terms. The whole body percentage fat measure (whole body fat mass/whole body mass) provides more information about degree of adiposity than the simpler measures of weight and weight relative to height (BMI or BMI *z*-scores for age and sex). This may be particularly important in children because of variability in whole body lean mass accumulation among children of similar ages.

Dietary Data

In each study, families were given a 3-day food record form to take home and were instructed to record foods/beverages eaten by the child for 2 week days and one weekend day. Children older than 8 were asked to complete the food record with the help of the parent. Parents of children 8 and younger were instructed to complete the food record with the help of the child. Food records were analyzed by a registered dietitian using the Minnesota Nutrition Data Systems software (NDS system 2.92) or through Nutritionist-V software. Beverages were classified into milk by fat level (skim milk, 1% milk, 2% milk, whole milk; including milkshakes, malts, and milk prepared with flavoring), 100% juice, sugar-added drinks, and other and volumes per day calculated within each type. Sugar-added drinks included non-diet pop/soda, juice drinks that were not 100% juice (e.g., juice cocktails, sugar-added fruit punch), and other beverages sweetened with added sugar (e.g., "sports" drinks, iced tea). Average daily calcium and an estimate of daily caloric consumption were derived from only beverage and food sources (e.g., vitamin supplementation was not included).

Data Analysis

Data were examined for normality. Given the high kurtosis of milk servings by fat level, milk was classified into whole or non-whole (skim + 1% + 2%) milk volume, with the individuals also dichotomized into drinking any or no whole and non-whole milk. Pearson product–moment correlations were calculated among the beverage types and between beverage consumptions and child weight status variables, z-BMI and percent body fat. Based on the small sample sizes in two of the examined samples, significance values of $p < .05$ and $<.10$ are reported. The magnitude and statistical significance of findings with beverage consumption were only minimally changed after controlling for average total caloric intake.

RESULTS

Calcium Intake and Beverage Consumption

Mean consumption of calcium and different beverage types are reported in Table II. Average calcium intakes among young subjects in the Adiposity Rebound and CHANGES studies were above the recommended dietary reference intake (DRI) for children less than 8 years of age (800 mg/day), but the older children in the Cholesterol Clinic Study failed to achieve the DRI appropriate for their age group (1300 mg/day) (Institute of Medicine of the National Academies, 1999). Average total milk consumption was higher in the younger sample than the older samples and, as indicated in Table III, there are strong positive associations between total milk consumption and calcium intake.

The majority of total milk consumption among children across all the samples appears derived from skim, 1% or 2% milk, not whole milk, with non-whole milk sources particularly prominent among older children. Average 100% juice consumption did not differ much across the samples, but the average sugar-added drink consumption was almost twice as high in the Cholesterol Clinic than the Adiposity Rebound sample. Sugar-added drink consumption was negatively related to calcium intake in two of the three samples. However, with the exception of the significant negative relations between 100% juice consumption and non-whole and total milk consumption in the Adiposity Rebound sample, milk consumption was not significantly negatively related to consumption of juice or sugar-added beverages (see Table III).

Relations between Child Weight Status, Calcium Intake, and Beverage Consumption

Significant negative associations were found among the CHANGES sample for child z-BMI and calcium intake, non-whole milk, and total milk (see Table IV). These associations were smaller and non-significant for the outcome of percent body fat. As seen in Table IV, all relations among child weight status and calcium and milk consumption were smaller

Table II. Descriptives for Average Daily Calcium, Total Caloric Intake, and Beverage Consumption (mean ± *SD*)

	Adiposity rebound sample ($n = 122$)	CHANGES sample ($n = 41$)	Cholesterol clinic sample ($n = 44$)
Calcium (mg/day)	830.7 ± 344.4	993.3 ± 434.7	773.7 ± 293.4
Range	186.6–1922.1	430.9–2201.5	333.2–1564.0
Total caloric intake (kcal/day)	1401.2 ± 310.8	2164.9 ± 579.7	1780.9 ± 489.8
Range	742.4–2594.9	1125.8–3552.1	843.1–3477.3
Calcium per kcal (mg/kcal/day)	0.60 ± 0.23	0.46 ± 0.16	0.44 ± 0.12
Range	.16–1.43	0.23–0.88	0.23–0.72
Non-whole milk[a] (oz/day)	9.85 ± 9.9	8.3 ± 10.5	7.0 ± 5.7
Range	0–40.0	0–42.7	0–25.0
% of children consuming any non-whole milk	76.2	61.0	81.8
Whole milk (oz/day)	2.0 ± 3.8	3.4 ± 5.7	0.9 ± 2.1
Range	0–18.0	0–27.0	0–10.7
% of children consuming any whole milk	31.3	48.8	25.0
Total milk (oz/day)	12.0 ± 9.1	11.7 ± 9.9	7.9 ± 6.0
Range	0–40.0	0–42.7	0–25.0
100% juice (oz/day)	3.9 ± 4.5	3.5 ± 3.3	2.8 ± 4.1
Range	0–25.0	0–12	0–16
Sugar-added drinks[b] (oz/day)	6.9 ± 7.2	9.0 ± 8.5	11.8 ± 10.1
Range	0–30.3	0–34.7	0–52.0

[a]Non-whole milk = skim milk + 1% milk + 2% milk.
[b]Sugar-added drinks include soda/pop and non-100% juice drinks or other flavored drinks wherein non-low calorie sweeteners are used.

Table III. Pearson-Product Moment Correlations Among Average Daily Calcium and Beverage Consumption in the Adiposity Rebound, CHANGES, and Cholesterol Clinic Samples

	1	2	3	4	5	6	7
1. Calcium/kcal	—						
2. Non-whole milk	.76**	—					
	.53**						
	.47**						
3. Whole milk	−.11	−.38**	—				
	.20	*−.38***					
	.33**	**−.07**					
4. Total milk	.80**	.92**	.00	—			
	.68**	*.85***	*.17*				
	.57**	**.93****	**.29***				
5. 100% Juice	−.20**	−.22**	−.03	−.24**	—		
	−.02	*−.09*	*.05*	*−.06*			
	.16	**−.04**	**−.01**	**−.04**			
6. Sugar-added drinks	−.28**	.01	−.03	−.02	.01	—	
	−.23	*−.07*	*−.09*	*−.12*	*−.31**		
	−.30**	**−.15**	**−.09**	**−.17**	**−.10**		
7. Total non-dairy drinks with sugar	−.34**	−.11	−.04	−.15	.54**	.85**	—
	−.24	*−.10*	*−.07*	*−.15*	*.09*	*.92***	
	−.23	**−.16**	**−.09**	**−.18**	**.29**	**.92****	

Note. Values for the Adiposity Rebound sample are in *plain font*; values for the CHANGES sample are in *italics*; values for the Cholesterol Clinic sample are in **bold**.
$^{*}p < .10$.
$^{**}p < .05$.

and non-significant in the other samples. Indeed, the only significant association in the Adiposity Rebound sample was the negative relation between 100% juice consumption and percent body fat. There were no significant correlations between child weight status and calcium or beverage consumption in the Cholesterol Clinic sample.

When dichotomizing milk consumption (yes/no) by milk category however, there were significant differences in child weight status in the two samples of older children. Both child z-BMI and percent body fat were significantly lower among CHANGES children consuming any (z-BMI = 1.7; % body fat = 32.1) versus no (z-BMI = 2.0; % body fat = 35.8) non-whole milk (both $p < .065$). Similarly, the Cholesterol Clinic children who consumed any non-whole milk had a lower z-BMI than children who consumed no non-whole milk (1.8 versus 2.3; $p < .05$). There were no z-BMI or percent body fat differences between Adiposity Rebound children who did or did not consume any non-whole milk. The only significant difference in weight status between children who consumed any versus no whole milk was observed in the CHANGES sample. CHANGES children who consumed no whole milk had lower average z-BMI (1.6 versus 2.0) and percent body fat values (31.4 versus 35.8) than children consuming at least some whole milk (both $p < .05$).

DISCUSSION

Average milk consumption by volume was lower in older than younger children across the three studies examined in this analysis, but average sugar-added drink consumption by volume was higher. Whereas there was no evidence of linear displacement between milk and sugar-added beverage consumption and only evidence of displacement between milk and juice among younger children, higher sugar-added drink consumers had lower calcium intake per caloric intake. There have been significant changes in beverage consumption among children over the past few decades, with decreases in milk consumption from 13.2 to 8.3% of caloric intake, and increases in soft drink (3.0 to 6.9% of caloric intake) and fruit drink consumption (1.8 to 3.4% of caloric intake) (Nielsen & Popkin, 2004). The Bogalusa Heart Study demonstrated similar average gram consumption declines in milk and increases in fruits/fruit juices and sugar-added beverages in children from 1973 to 1994 (Nicklas et al., 2004), despite declines in the percentage of children consuming sweetened beverages (Rajeshwari et al., 2005). Studies examining individual children's change in beverage consumption find trends of increasing sugar-added beverage consumption with age, but decreasing milk consumption (Berkey, Rockett, Field, Gillman, &

Table IV Pearson-Product Moment Correlations Between Child Weight Status and Calcium and Beverage Consumption in the Adiposity Rebound, CHANGES, and Cholesterol Clinic Samples

	z-BMI	% Body fat
Calcium/kcal	.01	−.06
	*−.28**	*−.07*
	.11	**N/A**
Non-whole milk	.09	.00
	*−.33***	*−.25*
	−.09	**N/A**
Whole milk	−.11	−.06
	.11	*.20*
	−.17	**N/A**
Total milk	.06	−.04
	*−.29**	*−.15*
	−.15	**N/A**
100% Juice	−.08	−.21**
	−.02	*.04*
	.20	**N/A**
Sugar-added drinks	.02	.08
	.12	*−.13*
	.05	**N/A**

Note. Values for the Adiposity Rebound sample are in *plain font*; values for the CHANGES sample are in *italics*; values for the Cholesterol Clinic sample are in **bold.**
*$p < .10$.
**$p < .05$.

Colditz, 2004). This decline in milk consumption and increase in sugar-added beverage consumption with age perhaps results from increased availability of alternatives to milk in later grades in school (Cullen & Zakeri, 2004).

Findings regarding milk-adiposity associations were mixed in these high-weight status children, with only significant correlations obtained in one of the samples of older children and consistency in findings across both older samples only found when dichotomizing milk consumption (yes/no) by type (non-whole, whole). Greater non-whole milk consumption was the beverage factor most consistently related to lower *z*-BMI and percent body fat, although not always in a linear fashion. The lack of significant correlations between calcium, whole milk, non-whole milk and the more precise measure of adiposity, percent body fat measured by DXA, is problematic for the argument that calcium specifically targets fat loss or prevents fat accumulation. Further, the contrasting differences between weight status based on type of any milk consumed (greater weight status among whole milk drinkers versus lower weight status among non-whole milk drinkers) suggests that calcium source may be an important moderator of the calcium–weight status relation. Alternatively, recognizing the limitations of the dietary assessment methods used herein, non-whole milk drinking among older school-aged children may be a proxy for a more healthful diet overall that could be leading to better weight management than for similarly aged whole milk drinkers. The lack of findings between calcium, milk, and weight status among the younger children is consistent with some prior literature in this age group (Dennison et al., 1997; Huston, Wright, Marquis, & Green, 1999; Newby et al., 2004).

Although many juices now offer calcium fortified versions, among the studies reported here, juice consumption was weakly or not associated with calcium intake. In the present study, a negative association was found between juice consumption and percent body fat, but only in the 2–4-year-old child sample. Prior evidence regarding fruit juice consumption and child overweight is mixed, with three studies finding no association and one finding a positive association. Skinner et al. (1999, 2001) did not find significant associations between 100% fruit juice intake over time in early childhood and child BMI among a Caucasian sample. Similar to the present study, they found a negative relation between juice intake and child relative weight status at 72 months of age (Skinner & Carruth, 2001; Skinner et al., 1999). A lack of association between juice and obesity was found in a low income, predominantly African-American sample (Kloeblen-Tarver, 2001). In contrast, higher fruit juice consumption has been reported to be associated with higher overweight prevalence (Dennison et al., 1997).

The present findings failed to show any significant associations between sugar-added beverages, such as soft drinks and other flavored drinks, and child weight status in any of the studied samples. The relatively low, but increasing volumes, in the age groups studied could have contributed to low overall variability in sugar-added drink consumption, particularly among the youngest children. Greater sugar-added beverage intake in European-American 10-year-olds has been found to be related to greater overweight prevalence (Nicklas et al., 2003). Higher baseline sugar-added beverage consumption and increases in such consumption were found to be related to later BMI among elementary school children, with consumption increases also related to higher subsequent obesity incidence (Ludwig, Peterson, & Gortmaker, 2001). Nine to fourteen-year-olds in the Growing Up Today Study at baseline who drank more milk were leaner and girls in this study who consumed more sugar-added beverages had higher BMIs (Berkey et al., 2004). In the same study however, both sugar-added beverage and milk consumption at baseline and the change in these consumptions over time were positively and significantly related to subsequent increased BMI over time, with these relations becoming non-significant after adjusting for total energy intake (Berkey et al., 2004).

Findings from the present analysis should be considered in the context of the limitations of these projects to evaluate beverage–weight status associations. This analysis was a cross-sectional assessment of calcium, beverage intake, and relative weight status, so causality cannot be determined. As in this study in which all correlations between total milk consumption and calcium intake adjusted for caloric intake were above .50, prior studies have found that milk product consumption is highly correlated with calcium intake (Storey et al., 2004). This appears to be especially true with younger children. However, the contribution of non-food or beverage sources (e.g., multivitamins) to overall calcium was not examined. Dietary intake was self-reported, with likely underestimates of intake (Champagne, Baker, DeLany, Harsha, & Bray, 1998), although the types of foods and beverages on which individuals and children in particular misreport is not clear.

The present study included only children above the 75th BMI percentile for age and gender. As expected, the average DXA-derived body fat percentage, which was available for two of samples, was higher than that of similarly aged child samples not selected for high-weight status (Cameron et al., 2004; Eisenmann, Heelan, & Welk, 2004; Goran, Driscoll, Johnson, Nagy, & Hunter, 1996; Ogle, Allen, & Humphries, 1995; Sopher et al., 2004) and similar to overweight child samples (Bray, DeLany, Harsha, Volaufova, & Champagne, 2001). This is an important target group, given they would likely be the focus of weight management intervention, but this limits the weight status range over which the associations between calcium, beverage consumption, and weight status were examined. Randomized clinical trials that manipulate and control all sources and amount of calcium and milk beverages in order to evaluate the impact on children's weight status are clearly needed. Unlike the present study in which vitamin supplementation was not included in estimates of calcium intake, such a trial would need to manipulate and control calcium source (calcium pill supplement, low-fat dairy, pill placebo) and amount, while being isocaloric, and examine change in weight and body fat. Adding measurement of biologic markers hypothesized to be affected by calcium, including fecal excretion of lipids, parathyroid hormone, and 1,25-dihydroxyvitamin D, would allow for testing of whether proposed mechanisms of calcium action differ across conditions.

ACKNOWLEDGMENTS

This project was supported in part by NIH DK60476, HL064022, and the Ohio Valley Affiliate of the American Heart Association.

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