11-2006

Fat Mass Gain is Lower in Calcium-supplemented than in Unsupplemented Preschool Children with Low Dietary Calcium Intakes

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Published in final edited form as:
Am J Clin Nutr. 2006 November ; 84(5): 1123–1127.

Fat mass gain is lower in calcium-supplemented than in unsupplemented preschool children with low dietary calcium intakes[1,2,3]

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Abstract

Background—Dietary calcium may play a role in the stimulation of lipolysis and the inhibition of lipogenesis, thereby reducing body fat.

Objective—The aim was to determine whether an association existed between change in percentage body fat (%BF) or fat mass and calcium intake in children aged 3–5 y.

Design—A secondary analysis of a 1-y randomized calcium and activity trial in 178 children was conducted. Three-day diet records and 48-h accelerometer readings were obtained at 0, 6, and 12 mo. Body composition was measured by dual-energy X-ray absorptiometry at 0 and 12 mo.

Results—The decrease in %BF was less in girls (−0.6 ± 2.8%) than in boys (−1.5 ± 2.6%; $P = 0.03$) and correlated with age ($r = 0.19$, $P = 0.01$) and maternal body mass index ($r = 0.19$, $P = 0.02$). Changes in fat mass were not significantly different by activity group or between children randomly assigned to receive calcium or placebo (0.5 ± 0.9 and 0.6 ± 0.8 kg, respectively; $P = 0.32$). Similar findings were observed for the change in %BF. No correlations between %BF and fat mass changes and dietary calcium ($r = -0.01$, $P = 0.9$ and $r = -0.05$, $P = 0.5$) or total (dietary + supplement) calcium intake ($r = -0.02$, $P = 0.8$ and $r = -0.06$, $P = 0.4$) were observed. Among children in the lowest tertile of dietary calcium (<821 mg/d), fat mass gain was lower in the calcium group (0.3 ± 0.5 kg) than in the placebo group (0.8 ± 1.1 kg) ($P = 0.04$) but was not correlated with mean total calcium intake ($r = -0.20$).

Conclusion—These findings support a weak relation between changes in fat mass gain and calcium intake in preschool children, who typically consume below recommended amounts of dietary calcium.

Keywords

Preschool children; calcium; obesity; body fat; activity; diet

INTRODUCTION

Data have emerged to support an inverse relation between body fat mass and calcium intake in both animal and human studies. Zemel et al (1) reported a 26% and 29% reduction in weight gain in aP2-transgenic-agouti mice that were assigned diets containing high amounts of calcium and medium amounts of dairy products, respectively, compared with a 24% increase in aP2-transgenic-agouti mice with a high-fat, high-sucrose basal diet. A further 39% reduction in

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[2]Supported in part by a grant from the National Institutes of Health (RO1-AR45310).

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weight gain was found in aP2-transgenic-agouti mice who consumed a diet containing a high amount of dairy products.

An inverse relation between percentage body fat and dairy intake also was found when Zemel et al (1) analyzed data collected between 1988 and 1994 in the third National Health and Nutrition Examination Survey (NHANES III). Results from the analysis showed that the odds ratio for women being in the highest quartile of body fat was reduced from 1.00, for the lowest quartile of calcium intake, to 0.75, 0.40, and 0.16 for increasing quartiles of calcium intake.

Several studies found a relation between body weight and calcium intake in population subsets only. Davies et al explored the association between body weight and calcium intake among women in their third, fifth, and eighth decades of life by reviewing data collected from 2 cross-sectional studies, 2 longitudinal studies, and 1 randomized trial (2). They reported a negative association between weight and calcium intake, but only for young women in the lower half of the calcium intake distribution. Lin et al (3), in a retrospective analysis of data from a 2-y exercise intervention study among women aged 18–31 y, found an association between greater weight and fat mass loss and calcium intake, but only among women with lower energy intakes (<1876 kcal/d)

Carruth and Skinner (4,5), in a study of 52 children, found an inverse correlation between percentage body fat at 6 and 8 y of age and calcium intake, which was determined prospectively between 2 and 8 y. However, no baseline measures of percentage body fat were obtained. To our knowledge, no studies of young children who had longitudinal measures of both body composition and dietary intake have been conducted. The present study tested whether an inverse relation existed between change in percentage body fat or fat mass and dietary or total calcium intake in preschool children using data previously collected from a randomized trial of calcium supplementation and physical activity. Analyses were also performed among children in the lowest tertiles of dietary calcium intake and energy intake because of previous findings that suggested that additional calcium is associated with low body fat in persons who typically consume low amounts of calcium or energy (2,3).

SUBJECTS AND METHODS

Participants were 178 children aged 3–5 y who were enrolled in a longitudinal, partially blinded trial of physical activity and calcium supplementation, which is described in detail elsewhere (6). Briefly, children who were free of any disorder known to influence bone metabolism and enrolled in 1 of the 11 participating childcare centers were eligible to participate. Children were randomly assigned, after stratification by center and sex, to participate in either fine motor or gross motor activities for 30 min/d, 5 d/wk, for 12 mo. Children in the fine motor group performed activities designed to keep them sitting quietly. Children in the gross motor group performed activities designed to provide 5 min of warm-up, which were followed by 20 min of jumping, hopping, and skipping activities and concluded with 5 min of cool-down. Significant activity group differences were observed in the percentage of time in moderate plus vigorous activities at 6 and 12 mo (6).

Within each supplement group, the children received either calcium (2 tablets of TUMS containing 500 mg elemental Ca as calcium carbonate each, 1000 mg Ca/d; Smith-Kline-Beecham, Parsippany, NJ) or placebo, which was administered by study personnel. Parents were asked not to provide additional dietary supplements containing calcium. All other supplemental vitamins were included in the dietary intake calculations. Measures of dietary intake and physical activity were obtained at baseline and at 6 and 12 mo by 3-d diet diaries and 48-h accelerometer readings. Mean dietary and total (dietary plus supplements) calcium intakes (mg/d) over the study period (at baseline and at 6 and 12 mo) were calculated.

Body fat was measured by dual-energy X-ray absorptiometry (Hologic QDR-4500A; Experimental Pediatric Whole Body Version 8.2 software, Waltham, MA) at baseline and at 12 mo. Body fat measures at both baseline and 12 mo were available for 177 of the 178 children. One boy in the placebo group with a body fat increase of 8.7% (3.8 SD above the mean change) was excluded from the analysis. Therefore, 176 of the 178 children were included in the analyses. The protocol was approved by the South Dakota State University Human Subjects Committee, and parental informed consent was obtained.

The number of weeks of intervention were similar among groups, with an average of 50 wk (range: 38–58 wk) (6). Children were present in the childcare centers for an average of 78% of the 5-d workweek. Children randomly assigned to the calcium group consumed fewer supplements on the days they were present than did the children who were randomly assigned to receive placebo. The mean (±SD) overall compliance rates, taking into account the number of days present in the center, were 56 ± 25% and 74 ± 12% in the calcium and placebo groups, respectively, ($P = 0.01$). The overall compliance rates with the gross motor and fine motor programs, taking into account the number of days the children were present, were 72% and 75%, respectively.

Descriptive statistics were compared between supplement groups by using JMP statistical software (SAS Institute, Cary, NC). General linear models were used to determine the significance of total calcium intake on changes in the percentage of total body fat and body composition after control for covariates. Sex-by-supplement and activity-by-supplement interactions were also tested. Because of previous reports of associations between body fat and calcium intake only among individuals with low calcium or low energy intakes, these variables were categorized into tertiles and subset analyses were performed within the lowest tertile of either calcium or energy intake. Potential covariates and activity group assignment were screened, and those variables associated with changes in total percentage body fat or changes in fat or lean mass were included. The data presented are means ± SDs unless otherwise specified.

RESULTS

Subject characteristics and univariate analyses

Anthropometric and dietary characteristics of the population are given in Table 1 by sex and supplementation group. Body weight, total fat mass, and lean mass increased in all groups over the study period. Total percentage body fat at baseline ranged from 17% to 39% and decreased over the 12-mo study (−1.2 ± 2.6%, different from 0 at $P = 0.01$). The change (12 mo–baseline) in total-body fat mass correlated with maternal BMI ($r = 0.20$, $P = 0.008$) and with age ($r = 0.22$, $P = 0.004$), with a greater increase in fat mass among children of mothers with higher BMI and among older children. Change in fat mass was not associated with the percentage of time engaged in moderate plus vigorous activity ($r = -0.10$, $P = 0.18$) and did not differ by activity group (0.5 ± 0.8 and 0.5 ± 0.8 kg in fine and gross motor groups, respectively; $P = 0.99$). Changes in fat mass did not differ between children in the calcium and placebo groups (0.5 ± 0.9 and 0.6 ± 0.8 kg, respectively; $P = 0.32$). Similar findings were observed for changes in percentage body fat. No significant correlations between changes in body composition and dietary calcium intake ($r = -0.01$ and $P = 0.9$ for the change in percentage body fat; $r = -0.05$ and $P = 0.5$ for the change in fat mass; and $r = 0.05$ and $P = 0.5$ for the change in lean mass) or total calcium intake ($r = -0.02$ and $P = 0.8$ for the change in percentage body fat; $r = -0.06$ and $P = 0.4$ for the change in fat mass; and $r = 0.004$ and $P = 0.9$ for the change in lean mass) were observed. The inclusion of age or age and maternal BMI in the model did not change the results.

Sex-specific effects of calcium supplementation

The sex-by-supplementation group interaction was not significant for either changes in total-body fat mass (*P* = 0.32) or changes in total-body lean mass (*P* =0.32), even when adjusting for age and maternal BMI. The sex-by-supplementation group interaction was nearly significant for changes in total percentage body fat in a model that controlled for age and maternal BMI (*P* = 0.08; Figure 1). In the calcium-supplemented group, the boys tended to have a greater decrease in percentage body fat than did the girls (−2.0 ± 0.4% and −0.5 ± 0.4%; least-squares means ± SE); however, this was not observed in the placebo group (−1.2 ±0.4 and −1.0 ±0.4%, respectively). The activity-by-supplementation group interaction was not significant for either change in total percentage body fat (*P* = 0.12) or change in fat or lean mass (*P* = 0.29 and *P* = 0.66, respectively). The inclusion of age and sex or age, sex, and maternal BMI produced similar results.

Influence of calcium on body-composition changes in children with a low dietary calcium intake or a low energy intake

To determine whether the relation between body-composition changes and total calcium intake was more apparent if a low dietary calcium intake was consumed, the analyses were limited to children in the lowest tertile of dietary calcium intake (<821 mg/d; *n* = 25 boys and 32 girls; Table 2). There were no differences in changes in percentage body fat or lean mass by calcium supplementation group. The change in fat mass was lower in the calcium-supplemented group than in the placebo group (0.3 ± 0.5 and 0.8 ± 1.1 kg; *P* = 0.04), but the group-by-tertile interaction (lowest versus highest 2 tertiles) was only of borderline significance (*P* = 0.08; Table 2). However, no significant correlations were observed between the changes in body composition and total calcium intake within the lowest tertile of dietary calcium intake (Table 3). The inclusion of age or age and maternal BMI in the regression models did not alter these findings.

To determine whether the relation between body-composition changes and either supplementation group or mean total calcium intake was more apparent if a low dietary calcium intake was consumed by a specific sex, the analyses were limited to the girls with a calcium intake <783 mg Ca/d (*n* = 27) and to the boys with a calcium intake <865 mg Ca/d (*n* = 29) using the lowest tertile of dietary calcium intake for each sex. No significant differences in body-composition changes by calcium supplementation group were observed for either sex, and no significant correlations between changes in body composition and total calcium intake were observed for either boys or girls in the lowest tertile of dietary calcium intake. The inclusion of age or age and maternal BMI did not alter these findings. The sex-by-supplementation group and sex-by-total calcium intake interactions were not significant for any of the changes in body composition (percentage body fat, fat mass, and lean mass; *P* > 0.3 for all interactions).

To determine whether the relation between body-composition changes and total calcium intake was more apparent among children with a low energy intake, the analyses were limited to children in the lowest tertile of energy intake (<1435 kcal/d; Table 2). No significant differences in the changes in body composition by calcium supplementation group and no significant correlations between changes in body composition and total calcium intake were observed (Table 3). Similar nonsignificant findings were observed in subsets of the lowest tertile of energy intake for boys (<1482 kcal/d) and girls (<1373 kcal/d).

DISCUSSION

The results of the current study are from a secondary analysis of a randomized activity and calcium supplementation trial in preschool children. Wide ranges in both mean dietary calcium

(306–1799 mg/d) and percentage body fat (17–39%) were observed in our population, which provided sufficient variation to observe a relation. This analysis found no consistent relation between changes in total percentage body fat in young children and either dietary calcium intake or total calcium intake, even when the analyses were limited to the children in the lowest tertile of calcium intake or the lowest tertile of energy intake. We did find, among children in the lowest tertile of dietary calcium intake, a smaller gain in fat mass among children randomly assigned to receive calcium supplements than in children randomly assigned to receive placebo. However, the correlation between change in fat mass and total calcium intake, from both diet and supplements, was not significant in this group of children and did not support the hypothesis that changes in fat mass were associated with increased calcium intake.

In a population similar in age to ours, Carruth and Skinner (4) found that total percentage body fat at 6 y of age was negatively associated with the number of servings per day of dairy products consumed between 2 and 5 y of age. We could not replicate these findings when we looked at changes in percentage body fat over the 1-y study. Although, theoretically, early calcium intake may affect body composition later in life, we are unaware of any other studies other than the one conducted by Carruth and Skinner that have reported this finding.

BMI decreases between the ages of 2 to 5 y, with a nadir at approximately 4 y, and then rebounds after the age of 5 y. We found that percentage body fat decreased significantly in this age range in both boys and girls, and perhaps the effect of high calcium intakes would be more apparent at ages when percentage body fat is increasing. The mean age of the subjects in the other published study (2) in young children was significantly greater than in ours (6 y compared with 4 y of age).

It has been hypothesized that dietary calcium from dairy sources, and not calcium from nondietary sources, is associated with decreases in body fat (7). Other components of dairy products, not analyzed in this study, could be the factor that influences body weight. Conjugated linoleic acid (CLA) has been suggested as one factor responsible for the effects of dairy products on body weight and adiposity. Mice fed CLA-supplemented diets have lower body weights (8), lower amounts of body fat (9), and higher amounts of lean mass (10) than do controls. However, studies by Zemel et al (1) indicate that nonfat dairy products, which do not contain CLA, also prevent increases in body fat in genetically obese mice; this finding suggests that the effect of dairy products on body fat changes are not due to CLA content. Although we did not specifically identify the amount of calcium that came from dairy sources, in this age group and at the time this study was conducted (1997–2001) a large percentage of dietary calcium was likely to have come from dairy products because foods consumed by this age group were not typically fortified with calcium. The finding of a significant difference in fat mass gain between the calcium and the placebo groups suggests that calcium was responsible for this effect rather than some other component of dairy foods.

High calcium intakes suppress 1,25-dihydroxyvitamin D concentrations, which has been reported to play a role in lipolysis and in the regulation of thermogenesis (7). Studies in obesity-prone genetic mice have found that suppression of 1,25-dihydroxy-vitamin D with the feeding of high-calcium diets leads to increased thermogenesis (10), and a recent study reported that higher calcium intakes are associated with higher rates of whole-body fat oxidation (11). These findings indicate that the effect of increased calcium intakes on changes in total body fat is likely to be observed in persons who typically have low calcium intakes. Although we observed a difference in fat mass gain between calcium and placebo groups, we could not detect a relation between changes in total percentage body fat or fat mass and total calcium intake in children who were in the lowest tertile of dietary calcium intake.

Some individuals have proposed that the beneficial effect of calcium intake on body weight and fat mass is limited to those with low energy intakes. In their retrospective analysis of data from a 2-y prospective study of exercise among women aged 18–31 y, Lin et al (3) found that calcium intake predicted a greater weight and fat mass loss only in those women who had lower energy intakes. We were not able to discern such a relation in young children in the current study. Although we observed a significant decrease in mean total percentage body fat in this age group, all children gained weight over the 1-y study.

In summary, we found that children in the lowest tertile of dietary calcium intake who were randomly assigned to receive supplemental calcium had lower gains in fat mass than did children randomly assigned to receive placebo. However, we did not observe a significant correlation between changes in fat mass and total calcium intake in these children, which suggests that if calcium intake is important, it is a weak relation that exists only among children with low dietary calcium intakes. If children consume the recommended dietary intakes of calcium to optimize bone health, additional calcium is not likely to prevent fat mass accumulation.

Acknowledgements

We acknowledge the assistance of the study coordinators and research assistants who were involved with this study and the parents and children who willingly gave their time to participate in the research.

EDD contributed to the data analyses and writing of the manuscript. TLB provided significant advice and contributed to the data collection and writing of the manuscript. BLS was responsible for the study design and contributed to the data collection and analyses and writing of the manuscript. None of the authors had any potential sources of conflict.

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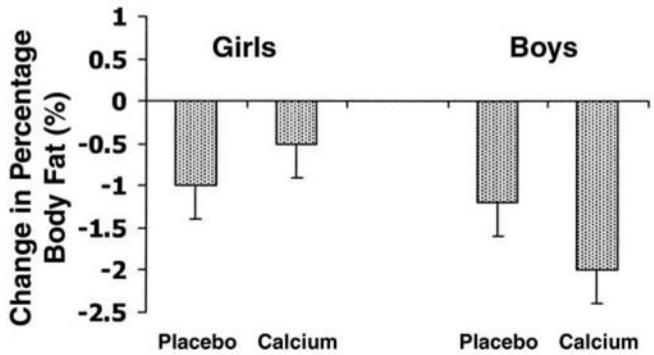

FIGURE 1.
Least-squares mean (±SEM) changes in percentage body fat in girls and boys supplemented or unsupplemented with calcium. The values were derived from a model that controlled for age and maternal BMI. Sex-by-group interaction: $P = 0.08$.

TABLE 1

Population characteristics by supplement group[1]

	Boys		Girls	
	Placebo group (*n* = 46)	**Calcium group (*n* = 47)**	**Placebo group (*n* = 42)**	**Calcium group (*n* = 41)**
Anthropometric characteristics				
Age at baseline (y)	3.9 ± 0.6[2]	3.9 ± 0.6	3.9 ± 0.5	4.0 ± 0.6
Height (cm)	102.3 ± 5.5	102.8 ± 5.3	100.8 ± 6.0	102.4 ± 6.4
Baseline				
50th Percentile[3]	102		101	
Weight (kg)				
Baseline	16.9 ± 2.2	16.6 ± 2.0	16.2 ± 2.3	16.4 ± 2.9
50th Percentile[3]	16.5		16.0	
Change	2.6 ± 1.1[4]	2.4 ± 1.0[4]	2.9 ± 1.2[4]	2.6 ± 1.2[4]
Total body fat (%)				
Baseline	23.1 ± 3.5	24.0 ± 3.6	27.8 ± 4.6	27.8 ± 4.1
Change	−1.1 ± 2.2[4]	−2.0 ± 2.5[4]	−0.8 ± 2.4[4]	−0.5 ± 3.1[4]
Total-body fat mass (kg)				
Baseline	4.0 ± 1.0	4.2 ± 0.9	4.7 ± 1.2	4.8 ± 1.3
Change	0.4 ± 0.8[4]	0.2 ± 0.7[4]	0.7 ± 0.8[4]	0.7 ± 1.0[4]
Total-body lean mass (kg)				
Baseline	12.8 ± 1.5	12.6 ± 1.4	11.5 ± 1.6	11.6 ± 1.8
Change	2.0 ± 0.6[4]	2.0 ± 0.7[4]	2.0 ± 0.6[4]	1.8 ± 0.6[4]
Dietary characteristics				
Baseline intake (mg/d)	968 ± 252	961 ± 309	866 ± 196	925 ± 346
Calcium intake (mg/d)[5]				
Diet	1028 ± 277	969 ± 247	860 ± 197	936 ± 282
Supplements	0	425 ± 164[6]	0	375 ± 192[6]
Total	1028 ± 277	1395 ± 237[6]	860 ± 197	1310 ± 356[6]
Energy intake (kcal)[5]	1608 ± 300	1621 ± 235	1475 ± 234	1512 ± 257
Total fat intake (g)	57 ± 16	57 ± 11	52 ± 10	56 ± 11
Protein intake (g)[5]	58 ± 18	58 ± 12	52 ± 11	53 ± 12
Carbohydrate intake (g)[5]	220 ± 42	223 ± 30	206 ± 36	205 ± 37

[1]The sex-by-supplementation group interaction term was nearly significant for changes in total-body percentage fat (*P* = 0.08) after control for age and maternal BMI. This interaction term was not significant for changes in total-body fat mass (*P* = 0.32) or in total-body lean mass (*P* = 0.32).

[2]$\bar{x}$ ± SD (all such values).

[3]50th Percentiles based on sex-specific Centers for Disease Control and Prevention 2000 growth charts (Vital and Health Statistics, National Center for Health Statistics, no. 314, 8 June 2000) for mean age of study population.

[4]Change significantly different from 0, *P* = 0.05.

[5]Mean intake was based on baseline, 6-mo, and 12-mo 3-d diet records.

[6]Significantly different from placebo within sex group, *P* = 0.01.

TABLE 2

Body-composition changes (12 mo–baseline) by lowest tertile and highest 2 tertiles of mean dietary calcium or energy intake[1]

	Change in body fat %	Change in fat mass kg	Change in lean mass kg
Mean dietary calcium intake[2,3]			
Lowest tertile, −821 mg/d			
Placebo group (*n* = 28)	−0.7 ± 2.7[4]	0.8 ± 1.1	1.9 ± 0.5
Calcium group (*n* = 29)	−1.7 ± 2.1	0.3 ± 0.5	1.8 ± 0.6
P[5]	0.11	0.04	0.80
Highest 2 tertiles, ≥821 mg/d			
Placebo group (*n* = 59)	−1.2 ± 2.1	0.5 ± 0.6	2.1 ± 0.6
Calcium group (*n* = 56)	−1.1 ± 3.2	0.5 ± 1.0	1.9 ± 0.7
P[5]	0.96	0.87	0.19
Mean dietary energy intake[2]			
Lowest tertile, <1435 kcal/d			
Placebo group (*n* = 31)	−1.0 ± 2.4	0.6 ± 0.8	2.0 ± 0.5
Calcium group (*n* = 26)	−1.2 ± 3.0	0.6 ± 1.0	2.1 ± 0.5
P[5]	0.77	0.73	0.54
Highest 2 tertiles, ≥1435 kcal/d			
Placebo group (*n* = 56)	−1.0 ± 2.3	0.6 ± 0.8	2.1 ± 0.6
Calcium group (*n* = 59)	−1.4 ± 2.9	0.4 ± 0.8	1.8 ± 0.7
P[5]	0.43	0.30	0.08

[1] The group-by-tertile interaction was not significant for any of the outcome variables at $P = 0.05$.

[2] Mean intake was based on baseline, 6-mo, and 12-mo 3-d diet records.

[3] Group-by-tertile (low vs highest 2) interaction, $P = 0.07$.

[4] $\bar{x} \pm$ SD (all such values).

[5] Represents the significance of the main effect of calcium supplementation group.

TABLE 3

Correlation coefficients (r) for changes in body composition (12 mo–baseline) by mean total (diet–supplement) calcium intake for the lowest and highest 2 tertiles of mean dietary calcium intake and energy intake[1]

Total calcium intake versus	Change in body fat	Change in fat mass	Change in lean mass
	%	*kg*	*kg*
Mean dietary calcium intake[2]			
Lowest tertile, <821 mg/d	−0.18	−0.20	0.05
P[3]	0.18	0.13	0.70
Highest 2 tertiles, ≥821 mg/d	0.04	−0.00	−0.13
P[3]	0.71	0.98	0.18
Mean dietary energy intake[2]			
Lowest tertile, <1435 kcal/d	0.02	0.02	0.15
P[3]	0.91	0.88	0.27
Highest 2 tertiles, ≥1435 kcal/d	−0.02	−0.07	−0.02
P[3]	0.81	0.48	0.85

[1] The mean total calcium intake-by-tertile of mean dietary calcium intake (lowest vs highest 2 tertiles) interaction was not significant for any of the changes in body composition.

[2] Mean intake was based on baseline, 6-mo, and 12-mo 3-d diet records.

[3] Represents the significance of the main effect of calcium supplementation group.