Calcium supplementation for 1 y does not reduce body weight or fat mass in young girls

Janne K Lorenzen, Christian Mølgaard, Kim F Michaelsen, and Arne Astrup

ABSTRACT
Background: Accumulating evidence from observational studies indicates that a high calcium intake may reduce body weight and body fat. However, few randomized trials have been conducted.

Objective: We examined whether calcium supplementation affects body weight and body fat in young girls and whether a relation exists between habitual calcium intake and body weight and body fat.

Design: A randomized, double-blind, placebo-controlled intervention study was conducted in 110 young girls. The subjects were randomly assigned to receive 500 mg Ca/d as calcium carbonate or placebo for 1 y. Two groups of girls were selected according to habitual calcium intake from a large group; one group consumed 1000–1304 mg/d (40th–60th percentile; n = 60) and the other group consumed <713 mg/d (<20th percentile; n = 50). Height, body weight, body fat, and calcium intake were measured at baseline and after 1 y.

Results: At baseline a significant negative correlation was observed between habitual dietary calcium intake and percentage of body fat (r = −0.242, P = 0.011). However, calcium supplementation had no effect on height, body weight, or percentage body fat.

Conclusions: Habitual dietary calcium intake was inversely associated with body fat, but a low-dose calcium supplement had no effect on body weight, height, or body fat over 1 y in young girls. It is possible that the effect of calcium on body weight is only exerted if it is ingested as part of a meal, or the effect may be due to other ingredients in dairy products, and calcium may simply be a marker for a high dairy intake.


KEY WORDS Children, adolescents, calcium supplementation, habitual calcium intake, body weight, body fat

INTRODUCTION
It is well known that optimal intake of dietary calcium is essential for bone health, but there is accumulating evidence that the dietary intake of calcium may also play an important role in body weight regulation. Several studies found inverse associations between calcium intake or intake of dairy products and body weight (1–8). Using data from the third National Health and Nutrition Examination Survey, Zemel et al (2) found an inverse association between relative risk of obesity and calcium intake in adults. Davies et al (1) reanalyzed data from 5 studies (1 intervention and 4 observational studies), which were originally designed to examine the effect of calcium intake on bone health in adults. In 2 of those studies (cross-sectional studies on young women) they observed that a difference in the dietary calcium-to-protein ratio of 1.0 mg/g was associated with a 0.186 decrement in body mass index (in kg/m²). Including all 4 observational studies, they concluded that differences in calcium intake could explain ≈3% of the variation in body weight. Similar observations were made in studies on children and adolescents. Carruth and Skinner (5) examined food consumption in children aged 24–60 mo (n = 53) and related these findings to body composition at 70 ± 2 mo. They found that a high intake of calcium and dairy products was associated with lower body fat. In a case-control study, Tanasescu et al (4) found that a low intake of dairy products was associated with obesity in Puerto Rican children aged 7–10 y (n = 53), but observational studies have failed to find an association between calcium intake and body weight in children and adolescents (9).

In those observational studies there is a risk of unaccounted confounding factors, such as other components of the dairy products (eg, protein). It was previously shown that a high protein intake from skimmed milk stimulates the secretion of the anabolic hormones insulin-like growth factor I and insulin in 8-y-old boys (10, 11). Insulin is also involved in appetite regulation, and several studies have confirmed that protein increases the sensation of satiety (12). Data on habitual calcium intake are based on self-reported data, which are always connected with a certain degree of uncertainty. Therefore, it cannot be established from those studies whether a causal relation exists between calcium intake and body weight or composition; that is, that a change in calcium intake will produce a change in body weight or composition.

Few intervention studies to examine the effect of calcium intake on body weight and composition in children and adolescents have been conducted, and the results are inconsistent (13–17). Most studies examined the effect of calcium intake from natural foods or foods fortified with calcium.

In the present study we examined whether a calcium supplement (500 mg/d) had an effect on change in body weight and...
body fat during a period of 1 y in young girls. Furthermore, we examined whether there was a relation between habitual calcium intake and body weight and body fat.

SUBJECTS AND METHODS

Subjects
A randomized, double-blind, intervention study of young girls designed to examine whether the effect of calcium supplement on bone accretion depends on habitual calcium intake gave us the opportunity to perform a secondary analysis to examine whether a calcium supplement has an effect on change in body weight and fat mass. Girls were recruited through the National Central Person Register. All girls aged 12 y ± 6 mo from the Frederiksberg and Copenhagen municipalities with Danish names were contacted by mail. The girls were sent a food-frequency questionnaire (FFQ) and asked about their height, weight, and health. The FFQ was identical to that used during the intervention. A total of 608 girls responded. The median calcium intake was 1161 mg/d (10th percentile: 543 mg/d; 90th percentile: 2129 mg/d), estimated from the FFQ. Two groups were selected according to their intake of dietary calcium. The median-calcium (MC) group had intakes between the 40th and 60th percentiles (1000–1304 mg/d) and the low-calcium (LC) group had intakes <20th percentile (<713 mg/d). One hundred thirteen girls were eligible for and agreed to participate in the present study. One hundred ten girls completed the study; 60 from the MC group and 50 from the LC group. Only data on subjects who completed the study are included in the analysis. For a more detailed description on recruiting, see Mølgaard et al (18, 19). The study was approved by the Ethics Committee for Copenhagen and Frederiksberg [case no. (KF) 01-033/95].

Design
Girls from each of the 2 groups (MC and LC) were randomly assigned to receive either a daily calcium supplement of 500 mg given as calcium carbonate (calcium group) or a placebo tablet containing microcrystalline cellulose (placebo group) for 1 y. The calcium supplement was given as tablets containing 250 mg calcium. Both calcium supplement and placebo were chewable. The girls were instructed to consume the supplement together with the evening meal. The tablets were delivered to the subject’s private address every third month, and surplus tablets from the previous period were collected. Compliance was evaluated by tablet counting and was expressed as

\[
\text{Compliance} = \frac{\text{tablets eaten}}{\text{tablets that should have been eaten}} \times 100
\]

Dietary intake
Dietary intake of calcium and protein was estimated by using an FFQ at recruitment, at baseline, and after 1 y. The FFQ contained 88 questions about usual daily intake of calcium, phosphorus, and protein during the past month. The FFQ had been validated against food records, and its reproducibility and validity were previously described in detail (20). Calcium intake was expressed as intake of total dietary calcium and intake of dairy calcium. In addition, calcium was expressed as calcium:protein. Because data on energy intake were not collected in the present study, protein intake was used as an indicator for energy intake and adjustment for protein intake as an approximate adjustment for energy intake.

Anthropometric measures and body composition
Height, body weight, and pubertal development were measured at baseline and at 1 y. Height and body weight were measured before dual energy X-ray absorptiometry (DXA). Height was measured to the nearest millimeter by using a stadiometer. Body weight was measured in kilograms with one decimal by a digital electronic scale. Subjects wore only panties and a cotton T-shirt when weighed.

DXA measurements [Hologic QDR-1000/W (S/N 1108 P) whole-body version 5.61; Hologic Inc, Waltham, MA] were performed as whole-body scans, with separate assessment of the 3 compartments: fat mass, lean body mass, and total bone mineral content (BMC). Fat-free mass was calculated as lean body mass plus BMC. Subjects wore only panties and a cotton T-shirt during the scan. A spine phantom was scanned each morning as a quality control and for instrument calibration. In adults examined during an 8-wk period reproducibility CV was 2.3% for percentage body fat (D Hansen and A Astrup, unpublished observations, 1998). The entrance radiation dose was 15 μSv, equal to ≈1 d background radiation in Denmark. The same skilled technician performed all DXA scans.

Blood analysis
Blood samples were collected at baseline and at 1 y. 25-hydroxyvitamin D was analyzed by radioimmunoassay (25-hydroxyvitamin D125I radioimmunoassay kit; DiaSorin, Stillwater, MN).

Statistical methods
Data were analyzed with the use of SPSS 12.0 for WINDOWS (SPSS Inc, Chicago, IL). Data are reported as mean ± SE unless otherwise indicated. Comparisons between 2 groups were made by using independent-samples t test. Analyses of covariance (ANCOVAs) were used to examine the effect of calcium supplementation. In such analyses the 2 intervention groups (calcium or placebo) and the 2 dietary groups (MC or LC) were included as independent variables, and either baseline values alone, or baseline values and protein intake at 1 y were included as covariates. Protein intake was previously shown to be negatively associated with weight loss and loss of body fat and was therefore included as a covariate (21, 22). Furthermore, as previously described, protein intake was used as a proxy adjustment for energy intake. Correlations between 2 variables were evaluated by using Pearson correlation coefficient or linear regression. Adjusted \( R^2 \) was used to assess how well the linear regression model predicted the dependent variable. A P value < 0.05 was considered significant.

RESULTS
Effect of the intervention on body weight and composition
The subjects’ characteristics at baseline and at 1 y according to intervention (calcium or placebo) and dietary group (MC or LC) are presented in Table 1. No significant differences were observed between the calcium intervention and the placebo...
The calcium intervention group received calcium carbonate. The MC group \((n = 30\) in each intervention group) had calcium intakes between 1000 and 1304 mg/d, and the LC group \((n = 24\) calcium intervention; \(n = 26\) placebo intervention) had calcium intakes <713 mg/d.

# TABLE 1

<table>
<thead>
<tr>
<th></th>
<th>Calcium</th>
<th>1 y</th>
<th>Placebo</th>
<th>1 y</th>
<th>Intervention group</th>
<th>Dietary group</th>
<th>Intervention group × dietary group</th>
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</thead>
<tbody>
<tr>
<td><strong>Age (y)</strong></td>
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<tr>
<td>MC group</td>
<td>13.1 ± 0.06(^1)</td>
<td>14.1 ± 0.6</td>
<td>13.2 ± 0.08</td>
<td>14.2 ± 0.08</td>
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<td>LC group</td>
<td>13.3 ± 0.06</td>
<td>14.3 ± 0.06</td>
<td>13.2 ± 0.08</td>
<td>14.2 ± 0.08</td>
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<td><strong>Height (cm)</strong></td>
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<tr>
<td>MC group</td>
<td>162.5 ± 1.1</td>
<td>166.2 ± 1.0</td>
<td>161.9 ± 1.2</td>
<td>165.9 ± 1.1</td>
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<tr>
<td>LC group</td>
<td>159.6 ± 1.3</td>
<td>163.2 ± 1.3</td>
<td>160.1 ± 1.5</td>
<td>163.2 ± 1.4</td>
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<td><strong>Weight (kg)</strong></td>
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<tr>
<td>MC group</td>
<td>51.8 ± 1.7</td>
<td>56.9 ± 1.8</td>
<td>50.7 ± 1.6</td>
<td>55.6 ± 1.6</td>
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<td>0.031</td>
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<tr>
<td>LC group</td>
<td>52.2 ± 1.7</td>
<td>56.3 ± 1.8</td>
<td>49.5 ± 1.7</td>
<td>52.5 ± 1.6</td>
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<td><strong>Body fat (%)</strong></td>
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<tr>
<td>MC group</td>
<td>22.6 ± 0.9</td>
<td>23.2 ± 0.9</td>
<td>21.7 ± 0.7</td>
<td>22.3 ± 0.8</td>
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<tr>
<td>LC group</td>
<td>24.6 ± 1.0</td>
<td>25.2 ± 1.1</td>
<td>24.5 ± 1.1</td>
<td>24.4 ± 1</td>
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<td><strong>Lean body mass (%)</strong></td>
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<tr>
<td>MC group</td>
<td>74.0 ± 0.9</td>
<td>73.3 ± 0.8</td>
<td>74.9 ± 0.7</td>
<td>74.2 ± 0.8</td>
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<tr>
<td>LC group</td>
<td>72.0 ± 0.9</td>
<td>71.3 ± 1.0</td>
<td>72.1 ± 1.1</td>
<td>72.0 ± 1.0</td>
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<td><strong>Menarche (+/-; n)</strong></td>
<td>17/13</td>
<td>24/6</td>
<td>17/13</td>
<td>22/8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC group</td>
<td>15/9</td>
<td>23/1</td>
<td>18/8</td>
<td>23/3</td>
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</table>

\(^1\) The calcium intervention group received calcium carbonate. The MC group \((n = 30)\) in each intervention group had calcium intakes between 1000 and 1304 mg/d, and the LC group \((n = 24\) calcium intervention; \(n = 26\) placebo intervention) had calcium intakes <713 mg/d.

\(^2\) Baseline values were included as covariates. Calculated with the use of analysis of covariance.

\(^3\) \(\bar{x} ± SE\) (all such values).

intervention at baseline either when the MC group and the LC group were analyzed separately or when the 2 dietary groups were united. An ANCOVA, with baseline values included as covariates, showed that calcium supplementation had no effect on height \((P = 0.868)\), body weight \((P = 0.249)\), body fat \((P = 0.384)\), or lean body mass \((P = 0.358)\). The results were not affected by inclusion of protein intake as a covariate as well.

Dietary intakes at baseline and at 1 y are presented in Table 2. No significant differences were observed between the calcium intervention and the placebo intervention at baseline either when the MC group and the LC group were analyzed separately or when the 2 dietary groups were united. An ANCOVA with baseline values included as covariates showed that calcium supplementation (intervention group) had a positive effect on total calcium intake at 1 y \((P < 0.0001)\) but not on intake of dietary calcium, intake of dairy calcium, dietary protein, or intake of dietary calcium and protein.

Compliance in the calcium and placebo intervention groups was 80 ± 18% and 82 ± 13%, respectively. No significant difference in compliance was observed between the 2 groups.

No significant correlation was observed between change in calcium intake from baseline to 1 y and change in percentage of body fat. However, a nonsignificant tendency toward a positive correlation was observed between change in calcium intake and change in body weight \((r = 0.169, P = 0.077)\).

**Effect of habitual calcium intake on body weight and composition**

At baseline the MC group had a significantly \((P = 0.009)\) lower percentage of body fat than the LC group when the 2 intervention groups were united. No significant differences were observed in age, height, and body weight between the 2 dietary groups. In addition to a significantly higher intake of dietary calcium \((P < 0.0001)\), the MC group had a significantly higher protein intake than the LC group \((P < 0.0001)\). The main source of calcium was dairy products, accounting for 85 ± 7% and 68 ± 22% in the MC group and the LC group, respectively.

At baseline, a negative correlation was observed between intake of dietary calcium and percentage of body fat \((r = −0.242, P = 0.011)\) when all subjects were included (Figure 1). Similar associations were found between percentage of body fat and intake of dietary calcium \((r = −0.218, P = 0.022)\) and calcium: protein \((r = −0.274, P = 0.004)\). A linear regression model showed that intake of dietary calcium could explain 5% of the variation in percentage of body fat \(( constant = 25.585 ± 1.016, P < 0.001; calcium intake = −0.002 ± 0.001, P = 0.011; R\(^2\) adjusted = 0.05)\). No significant correlation was observed between body weight and intake of dietary calcium \((r = 0.072, P = 0.453)\), intake of dairy calcium \((r = 0.077, P = 0.424)\), or dietary calcium:protein \((r = 0.041, P = 0.674)\) at baseline.

**DISCUSSION**

The important findings of the present study are that a daily calcium supplement of 500 mg/d does not reduce body weight or body fat mass in young girls. However, we confirmed the previously reported inverse association between habitual intake of dietary calcium and body fatness.

**Effect of the intervention on body weight and composition**

In the present study we found that a daily calcium supplement of 500 mg/d had no effect on body weight or body fat during 1 y
in young girls. Few intervention studies on children and adolescents have been performed. In a study on preschool children \( n = 50 \). Chan and McNaught (15) found that increasing intake of dairy calcium by \( \approx 400 \) mg/d prevented fat gain during a period of 6 mo in comparison to a control group of children who consumed their habitual diet. Such a clear effect was not found in 2 other intervention studies. In an intervention study \( n = 82 \) the effect of increased milk intake was examined (14). The subjects in the treatment group were given 568 mL milk/d, and by the end of the study their daily calcium intake was \( \approx 400 \) mg higher than that of the subjects in the control group \( 1125 \) compared with \( 703 \) mg/d. No significant differences were observed in the changes in body weight or fat mass between the groups. However, the treatment group had a higher energy intake \( \approx 1000 \) kJ; NS) without increasing their habitual diet. The present study differs from earlier studies in that we used calcium supplementation rather than foods with naturally high calcium content or calcium-fortified foods, or to their habitual diet. Such a clear effect was not found in 2 other intervention studies. In an intervention study \( n = 82 \) the effect of increased milk intake was examined (14). The subjects in the treatment group were given 568 mL milk/d, and by the end of the study their daily calcium intake was \( \approx 400 \) mg higher than that of the subjects in the control group \( 1125 \) compared with \( 703 \) mg/d. No significant differences were observed in the changes in body weight or fat mass between the groups. However, the treatment group had a higher energy intake \( \approx 1000 \) kJ; NS) without increasing their weight. Lappe et al (17) examined the effect of high calcium intake on body weight and body composition in 9-y-old girls \( n = 59 \) randomly assigned either to a diet with a high content of calcium-rich foods, including calcium-fortified foods, or to their habitual diet. No difference in increase in body weight, height, or fat mass was observed between the 2 groups. The results of those studies all indicate that calcium has either no effect or that it has a positive effect on body weight and body composition.

The present study differs from earlier studies in that we used calcium supplementation rather than foods with naturally high calcium content or calcium-fortified foods. In agreement with the present study Englert et al (16) found that 1-y supplementation with 1 g Ca/d did not influence change in body fat in children aged 3–5 y \( n = 178 \). Few intervention studies have examined the effect of a calcium supplement on body weight changes in adults. Of those studies, 2 have found that calcium supplementation has no effect on body weight and body composition (23, 24). Shapses et al (24) found that supplementation with 1 g calcium citrate malate or calcium citrate/d during a 25-wk weight-loss intervention did not affect body fat or body weight.

![FIGURE 1](https://academic.oup.com/ajcn/article-lookup/83/1/18/4649535)
loss in women (n = 100). In contrast a randomized controlled trial (n = 216) found that subjects assigned to 1200 mg calcium carbonate/d for nearly 4 y had a small but significantly greater weight loss (0.346 kg/y) than subjects assigned to placebo (1). Thus, in agreement with our study, the above-mentioned studies all indicate that calcium from supplements either has no effect on body weight and composition or that the effect is small and therefore only reaches statistical significance in studies with high statistical power. Contrastingly, Zemel et al (25) found that supplementation with calcium carbonate (800 mg/d) compared with placebo during energy restriction resulted in greater weight loss (8.58 compared with 6.60 kg, P < 0.01) and loss of fat mass (5.61 compared with 4.81, P < 0.01). It is therefore possible that energy restriction is prerequisite for calcium supplementation to exert its effect on energy balance.

The present study was designed to examine whether a relatively small supplement of calcium had an effect on bone accretion. The subjects in the present study were given a daily dose of 500 mg, which is half of the dose used in most of the other studies cited here. Although it cannot be excluded that we would have seen a loss of weight or body fat if the dose were higher, it seems unlikely because the trend was in the opposite direction.

It was previously suggested that the source of calcium (dairy or supplement) influences the effect on body weight. In studies in both rodents and humans it was found that calcium from dairy products has a more profound effect than calcium from supplements (2, 25). The mechanism of this additional dairy effect is not yet clear, but it was suggested that other bioactive components in dairy products may contribute to the effect on body weight (26). Another possibility is the chemical form of calcium. In dairy products calcium is largely found as calcium phosphate, and it is possible that phosphate contributes to the effect on body weight. In the present and other studies calcium was given as calcium citrate, calcium citrate-malate, or calcium carbonate (1, 23, 24). To our knowledge no studies have examined the effect of calcium phosphate on body weight and composition.

Several different mechanisms were suggested to be responsible for the effect of a high calcium intake on energy balance. One possible explanation is reduced absorption of fat in the gut; another is that intracellular calcium has a regulatory role in fat metabolism by influencing lipolysis, fat oxidation, and lipogenesis (2, 27–32). Several studies in both animals and humans have shown that calcium increases the excretion of fat, presumably by formation of insoluble calcium fatty acid soaps or by binding of bile acids that impair the formation of micelles (27–31). Whether one or both of these mechanisms takes place, it is a condition that fat and calcium are present in the intestine at the same time. In many of the studies that used supplements it is not stated when the subjects consumed the tablets; therefore, it is possible that the tablets were not consumed with the meals. In the present study the subjects were instructed to consume the tablets with the evening meal, but compliance with this instruction was not examined. This may explain, at least partly, why calcium from supplements seems to have a less pronounced effect than calcium from dairy products. Future studies should take into account when the supplement is consumed.

Effect of habitual calcium intake on body weight and composition

In the present study an inverse association was observed between habitual calcium intake and body fat. Other observational studies found a similar association. In an analysis that used data from the Framingham Children’s Study and the third National Health and Nutrition Examination Survey, it was found that a high calcium intake was associated with low body fat in adolescents (8). In agreement with this, Tanasescu et al (4) found, in a case-control study in prepubertal children, that a low daily intake of dairy products was associated with obesity. Similar findings were observed in 2 longitudinal studies; one included preschool children and one included 8-y-old children (5, 7). Others have failed to find such an association (9). The results from the different studies are not consistent, and more research is needed.

In the present study habitual calcium intake was found to explain ≈5% of the variation in percentage of body fat. This is similar to the observation by Davies et al (1), who found that among adults habitual calcium intake could explain ≈3% of the variation in body weight.

Study limitations

The present study was not originally designed to evaluate the effect of calcium on body weight and body composition and has therefore some limitations that should be underscored. Because of the relatively few subjects who participated in the study, statistical power is limited. On the basis of baseline data, it was calculated that the sample size was sufficient to detect a difference in percentage of body fat of ≥3% (with a confidence level of 95% and a power of 90). To detect a smaller difference, a larger sample size should be included. Data on energy intake were not collected in the present study; therefore, it was not possible to adjust for energy intake. Protein intake was used as an indicator for energy intake and adjustment for protein intake as an approximate adjustment for energy intake. However, it cannot be excluded that part of the effect found in the present study was due to differences in energy intake. The subjects in the present study were all of normal weight. It is possible that an effect of the intervention would be seen if the subjects were overweight or obese.

Summary

Habitual intake of dietary calcium was inversely associated with body fat, but a low-dose calcium supplementation had no effect on body weight, height, or body fat during a period of 1 y in young girls. It is possible that the effect of calcium on body weight is only exerted if it is ingested as part of a meal. Alternatively, the effect may be due to other ingredients in dairy products, and calcium may simply be a marker for a high dairy intake.

We thank Birgitte Hermansen for performing most of the practical work in the study. CM and KFM designed the study. CM was responsible for the data collection. The idea for the data analysis reported originated with AA and JKL and was performed by JKL. All authors participated in the discussion of the results and commented on the manuscript. None of the authors had any financial or personal interest in the company sponsoring the research project.

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