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Dietary calcium intake is associated with less gain in intra-abdominal adipose tissue over 1 yr

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Abstract

Calcium intake is reported to enhance weight loss with a preferential loss in trunk fat. Discrepant findings exist as to the effects of calcium intake on longitudinal changes in total fat mass and central fat deposition. Therefore, the purpose of this study was to determine associations between dietary calcium intake and 1-yr change in body composition and fat distribution, specifically intra-abdominal adipose tissue (IAAT). 119 healthy, premenopausal women were evaluated at baseline and 1 yr later. Average dietary calcium was determined via 4-day food records. Total fat was determined by dual-energy X-ray absorptiometry and subcutaneous abdominal adipose tissue (SAAT) and IAAT by computed tomography. Over the study period, participants' reported daily calcium and energy intakes were 610.0 ± 229.9 mg and 1623.1 ± 348.5 kcals, respectively. The mean change in weight, total fat, IAAT, and SAAT were $+4.9 \pm 4.4$ kg, $+5.3 \pm 4.0$ kg, $+7.7 \pm 19.5$ cm², and $+49.3 \pm 81.1$ cm², respectively. Average calcium intake was significantly, inversely associated with 1-yr change in IAAT (standardized β : -0.23 , $P < 0.05$) after adjusting for confounding variables. For every 100 mg/day of calcium consumed, gain in IAAT was reduced by 2.7 cm². No significant associations were observed for average calcium intake with change in weight, total fat, or SAAT. In conclusion, dietary calcium intake was significantly associated with less gain in IAAT over 1 yr in premenopausal women. Further investigation is needed to verify these findings and determine the calcium intake needed to exert beneficial effects on fat distribution.

INTRODUCTION

In general, research supports the notion that high dietary calcium intake will augment weight loss, possibly with a preferential loss of trunk fat (1–3). Likewise, longitudinal studies generally support an inverse correlation between measures of calcium and dairy intake and increases in body weight and fat over time (4–9). Findings, however, are equivocal as to the association of calcium or dairy intake with longitudinal changes in central fat with little research, if any, focusing on associations with changes in intra-abdominal adipose tissue (IAAT), the depot most often linked to poor metabolic outcomes (10). Previous studies have primarily relied on indirect measures of IAAT such as waist circumference or trunk fat derived from dual energy X-ray absorptiometry [DXA (2,3,11–14)].

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DISCLOSURE

The authors have no conflict of interest to declare.

The purpose of this study was to investigate the association between dietary calcium intake and 1-yr changes in body composition and fat distribution in healthy, premenopausal women. We hypothesized that calcium intake would be inversely associated with weight and body fat gain, and in particular, with IAAT gain.

METHODS AND PROCEDURES

Subjects were 119 healthy, premenopausal women (20–41 yrs) who participated in two studies at the University of Alabama at Birmingham (UAB). Design of the two parent studies has been previously described in detail (15,16). Briefly, however, all subjects were non-smokers, consumed <400 g of alcohol a week, and were not taking medications known to affect body composition or metabolism. Both studies recruited overweight women to take part in a controlled, supervised weight loss intervention. The intervention consisted of either an 800 kcal/day diet alone or in combination with structured exercise. In addition, one of the parent studies also recruited a group of never overweight women who received no intervention. For the purposes of this sub-study, baseline data were collected while all women were in a normal weight state (BMI <25 kg/m²), which for some of the women (n=99) was after they had lost ~10 kg following the weight loss intervention. The remainder of the women (n=20) were part of the never overweight group that did not receive weight loss intervention. Weight status (previously overweight/never overweight) and diet/exercise group assignment in the parent studies were explored in preliminary statistical analyses as potential covariates, and included in final models where relevant. Follow-up testing was performed 1 yr after baseline. Prior to clinical evaluation, all subjects underwent a 4-week weight stabilization period with food provided by UAB's General Clinical Research Center during the last 2 weeks. The study was approved by UAB's Institutional Review Board for Human Use, and all subjects were consented before any testing was performed.

Dietary Intake

Only subjects who completed at least 3 days of a 4-day food record both prior to the start of the parent study and at the 1-yr follow-up visit were included in the present analyses. The food records were analyzed for total caloric and calcium intake using the Nutrition Data System for Research software, developed by the Nutrition Coordinating Center, University of Minnesota, MN, Database versions 4.04_32 and 4.05_33, release date 2001–2002 (17). The mean values for calcium and caloric intake from both visits were used to estimate total nutrient intake throughout the study period.

Body Composition and Fat Distribution

Total and regional body composition (fat mass) measures were obtained by DXA using either a Lunar DPX-L densitometer (LUNAR Radiation Corp, Madison, WI) or a LUNAR Prodigy densitometer in the department of Nutrition Sciences at UAB. Body composition assessed by these instruments differs by 4% or less (18). IAAT and subcutaneous abdominal adipose tissue (SAAT) were analyzed via computed tomography using a HiLight/Advantage Scanner (General Electric, Milwaukee) as previously described (19). In brief, adipose tissue cross-sectional area (cm²) was obtained using attenuation ranges of –30 to –190 Hounsfield units from a single 5 mm scan taken at the umbilical region. Subjects were weighed (Scale-tronix 6702W; Scale-tronix, Carol Stream, IL) to the nearest 0.1 kg in minimal clothing without shoes.

Statistical Methods

Means and standard deviations were computed for all variables of interest. Differences in baseline and 1-yr means for age, weight, BMI, total fat, IAAT and SAAT were compared using the paired t-test. The relationships of average calcium intake with change in weight, total fat mass, IAAT, and SAAT were assessed using multiple linear regression analyses. To assess

change in the outcomes over 1 yr, the models were set up with the 1-yr value as the dependent variable and the baseline value as an independent variable. The following covariates were included in all models: total energy intake, ethnicity, age, and weight status group (i.e. previously overweight or never overweight). These models were also examined in sub-group analyses for weight maintainers (<3 kg weight gain over the 1-yr period) and weight gainers (≥ 3 kg weight gain over the 1-yr period). Continuous variables with distributions deviating from normal were logarithmically transformed using a $\log_{10}$ scale. Not all data were available on all subjects, resulting in a sample size ranging from 110–119 subjects for individual analyses. Data from one subject was removed due to the IAAT value being three standard deviations above the mean. Statistical analyses were performed using the SAS software package (Version 9.1; SAS Institute Inc., Cary, NC). All statistical tests were two-sided and were performed using a 5% significance level.

Post-hoc power calculations were performed for the final sample size of 119 women using nQuery Advisor, version 7 (Janet D. Elashoff, Cork, Ireland). Results indicated that we had at least 80% power to detect pair-wise correlations of 0.26 and greater, and at least 90% power to detect pair-wise correlations of 0.30 and greater, as being statistically significant. Power calculations for multiple linear regression models indicated that we had at least 80% power to detect an R^2 of 0.11 and greater, and at least 90% power to detect an R^2 of 0.13 and greater, in a 5-parameter regression model as being statistically significant. Using the baseline and one-year means, and also the baseline standard deviations (as standard deviations of the differences), for weight, total fat, IAAT, and SAAT as presented in Table 1, we had 89% power to detect differences in weight and IAAT as being statistically significant and greater than 95% power to detect baseline to one-year differences in total fat and SAAT as being statistically significant.

RESULTS

Fifty-one percent of the participants were African American and 49% were European American. Subjects' average reported daily calcium and energy intakes over the study period were 610.0 ± 229.9 mg and 1623.1 ± 348.5 kcals, respectively. Descriptive statistics for weight and body composition variables at baseline and 1-yr follow-up are presented in Table 1. Over the 1-yr period, subjects' weight, total fat mass, IAAT and SAAT increased by an average of 4.9 ± 4.4 kg, 5.3 ± 4.0 kg, 7.7 ± 19.5 cm², and 49.3 ± 81.1 cm², respectively.

Average calcium intake was not significantly associated with change in weight, total fat, or SAAT (standardized β : -0.07 , $P = 0.28$; -0.08 , $P = 0.34$; -0.18 , $P = 0.13$, respectively). However, average calcium intake was significantly and inversely associated with change in IAAT (standardized β : -0.23 , $P < 0.05$, Figure 1) after adjusting for baseline IAAT, total energy intake, ethnicity, age, and weight status group. In subgroup analyses, the significant association of calcium intake on change in IAAT was observed among weight maintainers but not weight gainers (parameter estimate $\pm$ SE: -0.52 ± 0.16 , $P < 0.01$ vs. -0.14 ± 0.19 , $P = 0.46$, respectively). Calcium intake was not significantly associated with change in weight, total fat, or SAAT among either group.

DISCUSSION

The goal of this study was to determine if dietary calcium intake was associated with changes in body composition and fat distribution over 1 yr in healthy, premenopausal women. We hypothesized that greater dietary calcium intake would be inversely associated with gain in weight, total body fat, and abdominal fat, specifically IAAT. Although average calcium intake was not associated with 1-yr change in weight, total fat, or SAAT in our population, it was significantly, inversely associated with change in IAAT such that subjects with greater calcium

intake had less gain in IAAT, which was especially true for individuals who maintained their weight over the 1-yr period.

To our knowledge, this is the first report of a significant inverse association between dietary calcium intake and gain in IAAT over 1 yr. Previous investigations have primarily focused on dairy and/or dietary calcium intake and longitudinal changes in total abdominal fat determined via waist circumference measurements or DXA. Of the few studies that have addressed this issue, findings have been inconsistent. Dairy intake was shown to have an inverse association with 6-yr change in waist circumference in men, but a positive association in women (11), and in a separate study, no association between dairy intake and change in waist circumference was observed (13). Low dairy intake (1 serving/day) among women has also been associated with greater gains in DXA-derived trunk fat compared to the recommended number of dairy servings [3 servings/day, (14)]. Cross-sectionally, dietary calcium intake was shown to be inversely associated with total abdominal adipose tissue, IAAT, and SAAT in a group of white women and black men (20) as well as with waist circumference and sagittal diameter in women and men, respectively (3,21). Dairy and/or dietary calcium has also been shown to enhance trunk fat loss as part of a weight loss program (1,2,12). As we are the first to investigate the relationship between dietary calcium intake and change in IAAT over 1 yr, further research is needed to verify our results. However, in our group of premenopausal women, results indicate that calcium intake may specifically impede IAAT accrual.

It is important to consider whether the influence of calcium intake on IAAT accrual is clinically relevant. The slope of the relationship between calcium intake and change in IAAT can be used to estimate the impact that changes in calcium intake may have on changes in IAAT. The regression slope shows that, within the range of weight change observed in this study (-5.6 to $+19.1$ kg), for every 100 mg/day increase in calcium intake, the gain in IAAT would be reduced by 2.7 cm^2 . Thus, consumption of the recommended dietary allowance of calcium (1000 mg/day) may reduce IAAT accrual by $\sim 27 \text{ cm}^2$, an amount that may be clinically relevant given that the detrimental effects of IAAT on cardiovascular disease risk factors such as poor lipid profile and elevated blood pressure in women become significant at a threshold of $\sim 110 \text{ cm}^2$ (22).

Although our findings are congruous with studies showing no significant associations of calcium and/or dairy intake with changes in weight or fat indices over time (11,13,23–26), they contrast with a number of investigations indicating that calcium and/or dairy intake is inversely associated with weight and fat gain over time (4–9). Reasons for lack of consistency among studies are likely varied and may include differences in populations, study design (e.g. examining dairy intake vs. dietary calcium intake vs. calcium supplementation), and methods for assessing dietary intake, among others. Additionally, it is possible that the lack of significant associations in our study was due to minimal 1-yr changes in weight and total fat in conjunction with suboptimal calcium intake among our participants. The average calcium intake among our participants was $610.0 \pm 229.9 \text{ mg/day}$, which is considerably lower than the recommended 1000mg/day for adults 19–50 yrs of age (27). Given the low standardized β coefficients for the association of calcium intake with change in weight, total fat and SAAT, a much larger sample size would be needed to see a significant effect. However, even with our relatively small sample size, we were still able to detect a significant association of dietary calcium with changes in IAAT over 1 yr.

To our knowledge, the significant, inverse effect of calcium intake on change in IAAT among weight maintainers vs. weight gainers has not been reported. However, a previous study by Lin et al. (8) found that calcium intake predicted change in body weight and fat mass among low energy intake participants but not high energy intake participants. In addition, many calcium intervention studies showing significant effects of calcium or dairy intake on weight

loss also include a reduced calorie diet (1,2,12). Therefore, it is possible that the influence of calcium intake on fat metabolism may require a metabolic environment associated with negative energy balance, which may be more likely to occur in leaner women or women undergoing weight loss.

Although the exact mechanism by which calcium intake regulates visceral adiposity is unclear, two potential mediators include estrogen and cortisol. Estrogen is associated with less central fat deposition including less IAAT compared to subcutaneous fat deposition (28,29), and studies have shown dietary calcium to be associated with the metabolism of estrogens to relatively more active forms (30,31). Additionally, cortisol is known to promote IAAT accumulation (32). It has been suggested that high dietary calcium intake may result in lower cortisol production by inhibiting 1,25-dihydroxyvitamin D₃-mediated expression of adipocyte 11- β -hydroxysteroid dehydrogenase type 1, the enzyme that converts cortisone to cortisol (33). However, the level of calcium intake needed to influence estrogen and cortisol effects on IAAT accumulation and whether this differs by gender or age is not known.

The strengths of our study include the ability to assess longitudinal changes in fat distribution, specifically IAAT, via robust measurement and the inclusion of healthy, premenopausal women who were non-smokers and consumed minimal amounts of alcohol, which could affect both calcium homeostasis and IAAT (34–36). Our study is limited by the retrospective nature of the analyses and that average dietary calcium intake for the duration of the study was determined from 4-day food records collected at only two time points. An additional limitation of the study is that information regarding calcium supplementation was not obtained. General vitamin and mineral intake, however, was not found to be associated with the main outcome variables (data not shown).

In conclusion, we show that greater dietary calcium intake is significantly associated with lesser gain in IAAT over 1 yr in healthy, premenopausal women. Additional research is needed to verify these findings and to determine the appropriate levels of calcium intake necessary to impede the accrual of IAAT.

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Figure 1.

Average calcium intake vs. intra-abdominal adipose tissue (IAAT). The figure represents IAAT at 1 yr adjusted for baseline IAAT, average energy intake, age, ethnicity, and weight status group. Standardized β : -0.23 , $P < 0.05$.

Table 1

Descriptive statistics at baseline and 1 yr

	Baseline	1 yr
Age (yr)	34.6 ± 6.1	—
Weight (kg)	63.9 ± 6.0	68.7 ± 8.1 *
BMI (kg/m ²)	23.6 ± 1.2	25.4 ± 2.3 *
Total Fat (kg)	20.9 ± 4.1	26.5 ± 6.0 *
IAAT (cm ²)	51.9 ± 25.8	59.5 ± 31.0 *
SAAT (cm ²)	214.2 ± 70.6	267.3 ± 96.4 *

Mean ± SD. Sample sizes range from 110–119 subjects for the individual analyses.

IAAT, intra-abdominal adipose tissue; SAAT, subcutaneous abdominal adipose tissue.

* $P < 0.001$ for difference from baseline