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The Relation between Calcium Intake and Body Composition in a Dutch Population

The Amsterdam Growth and Health Longitudinal Study

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To investigate whether dietary calcium intake is related to body mass index and the sum of four skinfolds among subjects in the Amsterdam Growth and Health Longitudinal Study (the Netherlands), the authors followed a cohort of men and women from age 13 years in 1977 to age 36 years in 2000. Longitudinal linear regression analyses were performed with generalized estimating equations in continuous and categorical models, with adjustment for possible confounders. Results showed that calcium intake during adolescence is a weak predictor of calcium intake in adulthood. In this population, only a slight indication was found of a weak inverse relation of calcium intake with body composition. No differences were observed between the middle (800–1,200 mg/day) and high (>1,200 mg/day) groups of calcium intake, suggesting a threshold of approximately 800 mg/day above which calcium intake has no additional beneficial effect on body composition.

body composition; calcium, dietary; obesity; skinfold thickness

Abbreviations: AGAHLS, Amsterdam Growth and Health Longitudinal Study; BMI, body mass index; S4S, sum of four skinfolds.

The prevalence of obesity has increased markedly during the past two decades, making obesity an important risk factor for the development of type 2 diabetes, various types of cancer, and cardiovascular complications. The first indication of an inverse relation between calcium intake and body weight came from research by McCarron et al. in 1984 (1). Since then, this inverse relation between calcium intake and body composition or body weight has been observed in a large variety of populations (2–8). In a few other studies, however, no effects were found (9–11), while, in three studies, a gender-specific effect for an altered calcium intake was observed (12–14).

One possible mechanism for the relation between calcium intake and body weight has been suggested by various authors: in cell cultures of human adipocytes, increasing 1,25-OH_2-D_3 (calcitriol) levels can increase lipogenesis, decrease lipolysis, and increase messenger RNA expression of a number of fat-metabolism-related genes by stimulating calcium influx (15–20). The concentration of calcitriol increases when calcium intake is decreased (21). However, since most of the investigations studying the association of calcium intake and energy with substrate metabolism on the whole-body level were performed in humans or rodents during energy restriction (6, 11, 22–24), it is not clear whether it is possible to translate the results of these investigations to humans under free-living conditions.

Another mechanism that could explain the relation between calcium intake and body weight is fat binding in the gut. Increasing dietary calcium intake increases the calcium concentration in the intestine, which in turn induces formation of insoluble fatty acid and bile acid soaps that are excreted through the feces, thus decreasing the amount of dietary fat available for oxidation and/or storage. In randomized clinical trials, increasing dietary calcium intake by

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TABLE 1. Means (standard deviations) of dietary calcium intake, body mass index, and the sum of four skinfolds* at the eight follow-up measurements of men and women followed from age 13 to 36 years in the Amsterdam Growth and Health Longitudinal Study, the Netherlands, 1977–2000

Age (years)	Men (no.)	Women (no.)	Dietary calcium intake (mg/day)		Body mass index (kg/m^2)		Sum of four skinfolds (cm)	
			Men	Women	Men	Women	Men	Women
13	187	204	1,122 (408)	991 (396)	17.6 (1.7)	18.5 (2.2)	2.8 (1.2)	3.8 (1.4)
14	146	170	1,140 (461)	988 (412)	18.2 (1.8)	19.2 (2.3)	2.7 (1.0)	4.3 (1.6)
15	150	170	1,218 (491)	921 (382)	18.9 (1.9)	19.6 (2.2)	2.7 (0.9)	4.7 (1.6)
16	132	173	1,198 (467)	929 (388)	19.2 (1.9)	20.1 (2.3)	2.7 (0.9)	4.9 (1.6)
21	93	107	1,325 (562)	1,055 (446)	21.4 (2.0)	21.6 (2.7)	3.6 (1.4)	5.4 (1.9)
27	84	97	1,363 (549)	1,159 (418)	22.5 (2.2)	21.9 (2.5)	3.6 (1.4)	4.6 (1.6)
32	203	230	1,372 (616)	1,195 (411)	24.0 (2.6)	22.7 (3.0)	4.2 (1.7)	5.2 (2.0)
36	174	198	1,435 (606)	1,264 (418)	24.8 (2.7)	23.4 (3.3)	4.7 (1.5)	5.5 (1.9)

* Biceps, triceps, and subscapular and cresta iliaca.

905–4,000 mg per day increased fecal fat excretion by up to 8.2 g per day (25–27). However, a compensatory increase in energy intake in response to this decreased availability of dietary fat, to restore energy balance, cannot be excluded.

To our knowledge, all epidemiologic studies on the relation between calcium intake and body weight thus far are from cohorts whose median intake of calcium is relatively low. In the Netherlands, intake of this mineral is much higher; calcium intake levels are about 1,068 mg per day in young men and 963 mg per day in young women (28). It is possible that, to regulate body weight, calcium intake is optimal in the Dutch population.

Therefore, we wanted to test whether an inverse relation between dairy products/calcium intake and body weight was present in a population with a relatively high habitual intake of dairy products and calcium, such as the participants of the Amsterdam Growth and Health Longitudinal Study (AGAHLS) in the Netherlands. In addition, we investigated whether fiber and energy intake and physical activity confounded this relation.

MATERIALS AND METHODS

Subjects and study design

In 1977, boys and girls whose mean age was 13 (standard deviation, 0.7) years and who attended a secondary school in the Netherlands—more than 95 percent were Caucasian—were assessed regarding a wide range of characteristics including dietary calcium intake and body composition. Three measurements on the same subjects followed annually from 1978 through 1980. Additional follow-up measurements were performed in 1985, 1991, 1996, and 2000 when the subjects were an average age of 21, 27, 32, and 36 years, respectively. An equally large and same-aged cohort from another secondary school was assessed only once in the first 4 years of the study and was reassessed in 1996 and 2000 only. This difference between the two schools explains the increased number of participants for the follow-up measurements at ages 32 and 36 years (table 1). In total, 296 men and 333 women participated in the AGAHLS. The method used to measure dietary calcium intake and body composition remained the same over the 23 years of follow-up. The exact design and methods of the AGAHLS have been described in detail previously (29).

Calcium intake

An extensive cross-check dietary history interview was used to assess dietary calcium intake (30). This interview provides information about subjects' habitual dietary intake by using the 4 weeks preceding the interview as a reference. A traditional, face-to-face interview was conducted during the first seven measurements, whereas, during the last measurement in 2000, a computer-assisted method was used. This interview consisted of two parts. The first was focused on drawing a pattern of the subjects' eating habits and meal patterns; in the second, an extensive checklist was used to give a more detailed description of all food and drink items consumed. "Cross-check" means that an additional check was performed on the reported frequency of meals eaten and on eating habits during the first part and the food and drink items mentioned in the second part of the interview. The computer-assisted method was added during the measurement to reduce interview time and inter-interviewer variability. This computer-assisted cross-check dietary history interview has been validated against the traditional food history interview (31) and against the 3-day weighed food record and 24-hour dietary recall methods (32). From this interview, mean daily intake of various nutritional factors was calculated by using the Dutch Food and Nutrition Table (33).

Body composition

Anthropometric measurements of body height, body mass, and four skinfolds (biceps, triceps, and subscapular and cresta iliaca) were performed according to standard procedures (34). Body mass index (BMI), the quotient between body mass (in kilograms) and body height (in meters squared), was used as an indirect measure of fat mass. The

TABLE 2. Linear regression coefficients and 95% confidence intervals for the longitudinal association of dietary calcium intake (per 1,000 mg/day) with body mass index and the sum of four skinfolds† in men and women followed from age 13 to 36 years in the Amsterdam Growth and Health Longitudinal Study, the Netherlands, 1977–2000

	Adjusted for age		Adjusted for multiple factors‡	
	β	95% CI§	β	95% CI
Body mass index				
Men	0.07**	−0.22, 0.36	−0.06**	−0.35, 0.23
Women	−0.04	−0.37, 0.29	0.20	−0.17, 0.58
Sum of four skinfolds				
Men	−0.21*,***	−0.35, −0.06	−0.09*	−0.24, 0.07
Women	−0.17	−0.41, 0.07	0.11	−0.17, 0.40

* Negative interaction with age, $p < 0.05$; ** negative interaction with age, $p < 0.01$; *** significant at $p < 0.01$.

† Biceps, triceps, and subscapular and cresta iliaca.

‡ Regression coefficients were adjusted for age, dietary energy intake, fiber intake, and habitual physical activity.

§ CI, confidence interval.

sum of four skinfolds (S4S) was used as a more direct measure of fat mass (35).

Analyses

Longitudinal stability (tracking) of the variables of interest was analyzed using generalized estimating equations by regression of the initial value (age 13 years) to the values for all later measurements (ages 14, 15, 16, 21, 27, 32, and 36 years). This method results in one standardized regression coefficient, which can be interpreted as a longitudinal correlation coefficient (32). Generalized estimating equations take into account that repeated measurements on the same subject are not independent. Other advantages of analysis with generalized estimating equations are that time points do not have to be distributed evenly, and it copes with missing observations by using all available data (36). Generalized estimating equations were also used to study the gender-specific linear associations between dietary calcium intake and body composition (BMI and S4S). These longitudinal regression analyses were performed with continuous and categorical calcium data (<800 vs. 800–1,200 and >1,200 mg/day). The relation was estimated first by adjustment for age only and second with additional adjustment for total dietary energy intake, fiber intake, and level of habitual physical activity. Whether the magnitude of the associations was modified by age was studied by adding the interaction between age and calcium intake to the models. Generalized estimating equations were performed by using the Statistical Package for Interactive Data Analysis (37).

RESULTS

Table 1 presents the number of participants per measurement and the means and standard deviations of dietary calcium intake, BMI, and S4S. The values for all central variables increased with age for both men and women. Over the 23 years of follow-up, average calcium intake was 1,269 mg per day for men and 1,148 mg per day for women.

The results of the tracking analyses over the 23-year period indicate that dietary calcium intake had a relatively low stability, with coefficients of 0.38 for men and 0.41 for women. The stability of the body composition indicators BMI and S4S was higher: respectively, 0.84 and 0.70 for men and 0.82 and 0.87 for women.

The linear regression results for the longitudinal relation between dietary calcium intake and BMI and S4S are reported in table 2 for the continuous estimate of calcium and in table 3 for three categories of calcium intake. Only two significant inverse associations were found. For men, in the age-adjusted model shown in table 2, a 1,000-mg per day higher dietary calcium intake was related to a 0.21-cm lower S4S ($p = 0.004$). The negative interaction with age indicates that the magnitude of this inverse relation is larger (the relation is more negative) at older ages. For women, in the age-adjusted model shown in table 3, the highest dietary calcium intake group (>1,200 mg/day) had a significantly lower S4S than those consuming less than 800 mg of calcium per day ($p = 0.04$). A comparable trend was observed for BMI, but it was not statistically significant ($p = 0.15$). These two significant associations disappeared after adjustment for putative confounders.

DISCUSSION

In the present investigation, we used data on calcium intake and body composition from the AGAHLS cohort to investigate whether the inverse relation between calcium intake and body weight observed for children and adults in the United States existed in the Netherlands as well as in a cohort of healthy young men and women whose calcium intake was relatively high. For both men and women, only one significant inverse relation was observed between

TABLE 3. Linear regression coefficients and 95% confidence intervals for the longitudinal association of dietary calcium intake (three categories) with body mass index and the sum of four skinfolds† in men and women followed from age 13 to 36 years in the Amsterdam Growth and Health Longitudinal Study, the Netherlands, 1977–2000

Dietary calcium intake category (mg/day)	Adjusted for age		Adjusted for multiple factors‡	
	β	95% CI§	β	95% CI
Body mass index				
Men				
<800	Reference		Reference	
800–1,200	−0.14	−0.44, 0.15	−0.20	−0.49, 0.09
>1,200	0.03*	−0.38, 0.44	−0.07*	−0.60, 0.29
Women				
<800	Reference		Reference	
800–1,200	−0.18	−0.43, 0.08	−0.02	−0.29, 0.24
>1,200	−0.26	−0.62, 0.10	0.02	−0.35, 0.40
Sum of four skinfolds				
Men				
<800	Reference		Reference	
800–1,200	−0.08	−0.25, 0.10	−0.01	−0.20, 0.17
>1,200	−0.09*	−0.29, 0.12	0.09*	−0.13, 0.31
Women				
<800	Reference		Reference	
800–1,200	−0.15	−0.34, 0.05	−0.00	−0.19, 0.19
>1,200	−0.28**	−0.56, −0.01	0.04	−0.26, 0.34

* Negative interaction with age, $p < 0.01$; ** significant at $p < 0.05$.

† Biceps, triceps, and subscapular and cresta iliaca.

‡ Regression coefficients were adjusted for age, dietary energy intake, fiber intake, and habitual physical activity.

§ CI, confidence interval.

calcium intake and S4S, whereas nonsignificant trends were found for BMI. Although these associations were statistically significant, they were smaller than those found in the observational studies performed in the United States. For men but not women, negative interactions with age were observed in continuous and categorical models. This finding indicates that calcium intake and body composition are more strongly inversely related in the higher age groups. Men in the higher age groups also had a considerably higher BMI and S4S, so it could be possible that the effect of a higher calcium intake is stronger in subjects with a larger fat mass. There have been previous reports of different effects of calcium intake on body composition in men and women, but they were not consistent. In the study by Jacqmain et al. (12), after adjustment for protein intake, no relation was observed for men, but a negative relation was observed for women. Kamycheva et al. (14) saw no effect in men and a positive relation for women. Loos et al. (13) saw no effect in Black women but a negative relation in Black men and White men and in White women. Thus, from these data, no consistent pattern emerges about a possible gender-specific effect of calcium intake on body composition.

No differences in BMI or S4S were observed between the middle and highest groups of calcium intake, which could mean that if calcium intake is more than 800 mg per day, no additive beneficial effect of increasing the dietary calcium intake is present. Average calcium intake in the present study population was slightly higher than the average for the representative age groups in the Netherlands (28), and it was at least 200-mg per day higher than in studies from the United States. This finding indicates that, in a population such as the AGAHLS cohort, whose calcium intake in general meets the recommended daily intake of 1,000–1,200 mg per day in the Netherlands, no effects on body weight and body composition are to be expected. In other words, a suboptimal calcium intake may increase the risk of developing obesity, but, above a certain threshold, an increased calcium intake does not give any further protection.

A limitation of the present investigation is that we were not able to correct for the possible confounding effects of a higher protein intake because of the high covariance between protein and calcium intake in this cohort. Compared with fats or carbohydrates, protein is known to have a higher satiety per kilojoule and to produce a higher diet-induced thermogenesis per kilojoule. Therefore, this macronutrient has been used in studies on body-weight regulation (38–42). In an intervention study in which subjects received an ad libitum diet with a reduced fat concentration, Skov et al. (41) observed that subjects receiving a high-protein diet lost significantly more body weight than the group receiving a diet with a lower protein content. In obese subjects who had lost weight because of a 4-week very low energy diet, Westerterp-Plantenga et al. (43) saw that adding a protein supplement to an isocaloric diet resulted in less body weight regain than in those in a control group who did not receive the protein supplement. These trials show that an increase in protein intake may affect body weight in subjects consuming an ad libitum or isocaloric diet, at least during and after weight loss.

Underreporting of food intake by obese subjects is well established (44, 45). This problem may have caused a type I error in the present investigation because it could have led to underestimation of calcium intake among subjects with a higher BMI and S4S. The absence of significant inverse findings in the model adjusted for total energy intake supports this hypothesis. This underreporting is expected to be related more to fat than to calcium or protein intake, however (44, 45). On the other hand, the recall method used here to measure food intake is less accurate than those methods used in some intervention studies that report an inverse relation between calcium intake and body weight. Indirectly measuring food intake in the present study could have resulted in a relatively large amount of error in the calcium data and consequently may have caused type II errors. In other words, the relative absence of significant inverse findings in the present study may also be explained by the fact that we used a dietary history interview, whereas most epidemiologic investigations mentioned in this paper used food diaries to measure food intake.

In line with others (46), our tracking analyses show that dietary calcium intake has a low stability over time. This finding indicates that calcium intake during adolescence is a weak predictor of calcium intake later in life. From this finding it is hypothesized that the effects of a single dietary calcium intake intervention will not last a long time. In contrast, BMI and S4S show much higher tracking coefficients; therefore, assessments of BMI and S4S during adolescence will be quite good predictors of the relative levels of BMI and S4S at adulthood. This high stability of BMI and S4S shows the opportunity for early selection of subjects who have a high risk of becoming obese.

In conclusion, the results of this investigation of relatively healthy subjects followed from age 13 to 36 years indicate a weak inverse relation of calcium intake with body composition. This finding may seem to be in contrast with that of previous investigations, where stronger inverse relations were found, but it may be explained by the fact that average calcium intake is much higher in the present population than in those assessed in previous studies. There may be a threshold for calcium intake above which no additive beneficial effect exists. In the present investigation, this calcium intake threshold was about 800 mg per day.

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Conflict of interest: none declared.

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