

Dairy Intake Is Associated with Lower Body Fat and Soda Intake with Greater Weight in Adolescent Girls^{1,2}

Rachel Novotny,³ Yihe G. Daida, Sushama Acharya, John S. Grove,* and Thomas M. Vogt[†]

Department of Human Nutrition, Food and Animal Sciences, University of Hawaii at Manoa, Honolulu, HI 96822; *Department of Public Health Sciences, University of Hawaii at Manoa, Honolulu, HI 96822; and [†]Kaiser Permanente, Center for Health Research, Honolulu, HI 96817

ABSTRACT Body fat and weight of 9- to 14-y-old girls ($n = 323$) from Kaiser Permanente were studied in relation to age, ethnicity, and physical activity. Mean age, calcium intake, weight, and iliac skinfold thickness were 11.5 ± 1.4 y, 736.5 ± 370.7 mg/d, 44.6 ± 13.0 kg, and 12.4 ± 6.1 mm, respectively. Multiple regression with age, ethnicity, height, Tanner breast stage, physical activity, energy, soda, and calcium intake explained 17% of the variation in iliac skinfold thickness. Calcium intake, age, and physical activity were significantly negatively associated with iliac skinfold thickness whereas height, Tanner breast stage, and Pacific Islander ethnicity were significantly positively associated ($P < 0.0001$, $R^2 = 0.165$). Substituting total calcium with dairy and nondairy calcium in separate models accounted for 16 and 15% of the variance, respectively ($P < 0.0001$, both models); 1 mg of total and dairy calcium was significantly associated with 0.0025 mm ($P = 0.01$) and 0.0026 mm ($P = 0.02$) lower iliac skinfold thickness. Thus, 1 milk serving was associated with 0.78 mm iliac skinfold thickness. The interaction of Asian ethnicity and dairy intake was significant ($P = 0.027$). Nondairy calcium was not associated with weight or iliac skinfold thickness. Soda intake was significantly positively associated with weight in both models ($P = 0.01$, both models). Decreasing soda and increasing dairy consumption among Asians may help maintain body fat and weight during adolescence. *J. Nutr.* 134: 1905–1909, 2004.

KEY WORDS: • adolescent • dairy • calcium • weight • fat

Data from the National Health and Nutrition Examination Survey (1999–2000) indicate a prevalence of overweight of 15.5% among children 12–19 y, 15.3% among children 6–11 y, and 10.4% among children 2–5 y, compared with 10.5, 11.3, and 7.2% (respectively) in 1988–1994 (1). Because the prevalence of overweight among children in the United States has been increasing since the 1960s, it is of considerable interest to identify dietary and other factors that may influence body fat and weight to stop or reverse this trend. Milk consumption among adolescents has decreased by 36% between 1965 and 1996, whereas consumption of soft drinks and noncitrus juices has almost doubled (2). It was the purpose of this study to identify the role of dairy and calcium intake on body fat and weight among Asian and Caucasian young adolescents. The relation of dairy and calcium intake to body fat and weight has not been demonstrated in populations of these ages or of Asian and Pacific Islander ethnicities.

SUBJECTS AND METHODS

Design. This is a cross-sectional analysis of the baseline measures of an ongoing longitudinal study of female adolescent maturation. Data were collected from 323 girls from Kaiser Permanente Oahu from March 2000 to June 2001.

The study population consisted of healthy female adolescents, 9–14 y old who resided on the island of Oahu, Hawaii. Subjects with any chronic diseases or use of steroids, asthma, and antiepileptic medications were excluded. Prescreening calls were made to all girls to determine whether they met the requirement of 50% or more Asian or Caucasian ancestry. Despite prescreening, the Background Questionnaire completed by parents revealed that 11 girls (4%) were <50% Asian or Caucasian.

Measurements

Dietary intake. A 3-d dietary record that included 2 weekdays (Thursday and Friday) and 1 weekend day (Saturday) was completed by the girls with their parents' assistance. A measuring cup and spoon were provided to help girls estimate quantities of food items eaten. The nutrient analysis was performed at the Cancer Research Center of Hawaii using the Shared Nutrition Food Composition Data Base (version September 1999) (3). Nutrient means of the 3 d of diet record were used in the analysis. The mean serving size of 6 major food groups based on the USDA Food Guide Pyramid (4) was also calculated from the Food Composition Data Base (5). A calcium value of 400 mg was used if girls reported taking a calcium supplement and 100 mg if girls reported taking a multivitamin/mineral supplement.

¹ Presented in poster form at Experimental Biology 03, April 2003, San Diego, CA [Novotny, R., Acharya, S., Grove, J., Daida, Y. & Vogt, T. (2003) Higher dairy intake is associated with lower body fat during adolescence. *FASEB J.* 17: A746 (abs.)].

² Funded by the U.S. Department of Agriculture, Grant # 9900700.

³ To whom correspondence should be addressed.

E-mail: novotny@hawaii.edu.

ment. The calcium values were derived from the USDA W191 regional research project, which estimated multiethnic adolescent supplement use (1996–2002).

Ethnicity. The girls' ethnicity was based on the ethnic proportion of each biologic parent. The proportion of girls' ethnicity classified as Asian, White, Pacific Islander, and Other was based on the combination of both mother's and father's ethnicity. For example, if a girl's father was 50% Asian and 50% Caucasian while the mother was 50% Asian, 25% Pacific Islander and 25% African American, the girls' ethnicity would be determined as 50% Asian, 25% Caucasian, 12.5% Pacific Islander and 12.5% African American. The classification of ethnicity was based on NIH recommendations (6). Information on the girls' ethnicity, age, and menstrual status was obtained from their parents by questionnaire. Asian ethnicities included girls of Japanese, Korean, Chinese, Filipino, Indian, Thai, and Vietnamese origin; Pacific Islanders included Native Hawaiians, Tongans, and Samoans. "Other" ethnicities included African American and Native American.

Anthropometric measurements. Anthropometric measurements were taken during the visit to Kaiser Permanente and included weight, height, and iliac skinfold thicknesses. Weight was measured with a scale (Continental Scale) and height was measured using a stadiometer (Measurement Concepts). Skinfold thicknesses were measured with a Lange Caliper (Beta Technology). Each measurement was taken at least twice; a third measurement was taken if the 2 measures differed by more than one tenth of a unit, with the mean of the 2 closest values used in the analysis.

Tanner breast stages of development. Breast staging was done as described by Tanner (7) by 1 of 2 nurse practitioners in the Pediatrics department at the Kaiser Permanente Honolulu Clinic. Reproducibility between the 2 nurse practitioners on 5 adolescent girls had a correlation of $r = 0.80$ and was considered acceptable (8).

Physical activity. The girls completed a physical activity questionnaire that was validated for adolescents (9). They were asked to fill in activities that they engaged in >10 times in the past year. For each activity, they were asked how many months a year, how many days a week, and how many minutes each day they spent doing that particular activity. The mean hours per week doing a particular activity during the past year was calculated with the formula:

$$\text{mo} \times 4.3 \text{ (wk/mo)} \times \text{(d/wk)} \times \text{(min/d)} \\ \div (60 \text{ min/h}) \div (52 \text{ wk/y}) = \text{h/wk}$$

The metabolic equivalent (MET) values for all activities were calculated for the specified duration (MET of each activity \times duration of each activity) and the sum of all MET values was used as a proxy for physical activity in the past year in MET-h/wk.

Human research. Approval was obtained from the University of Hawaii and Kaiser Permanente Committees on the Use of Human Subjects. Each girl and a parent or guardian signed informed assent/consent.

Statistical methods. Study data were entered using Microsoft Access 97 and statistical analysis was performed using SAS, version 8.2 (SAS Institute) or SPSS version 11.5. The data are summarized as means \pm SD unless stated otherwise. Differences in 2 values were analyzed for significance using a paired sample t test. Simple linear regression analysis was done to identify the relative importance of calcium, dairy, and other factors influencing body weight and skinfold thickness. Differences were regarded as significant if the corresponding P -value was ≤ 0.05 or for some analyses, 0.10.

Multiple regression analyses were conducted with weight and iliac skinfold thickness as dependent variables. Independent variables included age, ethnicity, height, Tanner breast stages, physical activity, energy intake, soda intake, and a calcium intake variable, using total calcium, dairy calcium, or nondairy calcium intake and the interaction of the calcium intake variable and Asian ethnicity. To adjust for ethnic background, variables denoting the proportion of ancestry that was Asian, Pacific Islander, or other were included in regression models, with Caucasian ancestry used as the comparison group.

RESULTS

Ethnic contributions of the study participants averaged 43% Caucasian, 47% Asian, 7% Pacific Islander, and 3% "Other Ethnicities." The calcium intake from dairy products was higher than nondairy calcium intake (Table 1). Dairy and soda intakes were 1.4 ± 1.1 servings and 752.11 g, respectively. Of the 349 girls, 58 took supplements; calcium intake from the diet was higher than from supplements. Other descriptive characteristics are given in Table 1.

In multiple regression models, total calcium intake was negatively associated with both iliac skinfold thickness and weight (Table 2, $P = 0.01$ and $P = 0.09$, respectively). Pacific Islander ethnicity, height, and Tanner breast stage had significant positive associations with both iliac skinfold thickness and body weight (in separate regression models). Weight was positively associated with total energy ($P = 0.00$) and soda intake ($P = 0.01$). Iliac skinfold thickness was negatively associated with age ($P = 0.05$) and physical activity ($P = 0.03$).

Regression models with dairy calcium intake substituted for total calcium intake are presented in Table 3. The results are similar to Table 2, with iliac skinfold thickness negatively associated with age ($P = 0.05$) and physical activity ($P = 0.04$), and weight positively associated with soda intake ($P = 0.01$). A test of the variable effect of dairy calcium across ethnic groups was constructed by including cross-products of non-Caucasian ethnicities with dairy calcium intake in a regression model. (There were too few girls with Pacific Island or other heritage to have adequate power, but their cross-products are needed in the model for interpretability.) Interactions of Asian ethnicity with calcium and nondairy calcium intakes were not significant. The cross-product of Asian ancestry with dairy calcium was negative and significant ($\beta = -0.00606$, $SEE = 0.0027$, $P = 0.0027$), suggesting that the effect of dairy calcium on iliac skinfold thickness was greater among girls of Asian ancestry than Caucasian girls.

Thus, total calcium and dairy calcium intakes both had inverse associations with iliac skinfold thickness. There was a positive association of soda intake with weight. The regression model with either expression of calcium intake accounted for 57% of the variability in weight ($P = 0.001$, both models).

TABLE 1

Descriptive characteristics of 323 adolescent girls¹

Age, y	11.5 \pm 1.4
Weight, kg	44.6 \pm 13.0
Height, cm	147.9 \pm 11.8
Iliac skinfold thickness, mm	12.4 \pm 6.1
Activity, MET-h/wk	43.6 \pm 38.7
Energy, kJ/d	7537.9 \pm 2064.4
Total calcium, ² mg/d	736.5 \pm 370.7
Dietary calcium, ³ mg/d	713.1 \pm 358.8
Calcium from supplements, ⁴ mg/d	129.9 \pm 121.3
Dairy calcium, ⁵ mg/d	466.7 \pm 320.1
Nondairy calcium, mg/d	246.5 \pm 122.6
Dairy servings, n/d	1.4 \pm 1.1
Soda, ⁶ g/d	752.11 \pm 640.10

¹ Values are means \pm SD.

² Includes supplements.

³ Different from calcium supplements, paired sample t test ($P < 0.001$).

⁴ $n = 58$.

⁵ Different from nondairy calcium, paired sample t test ($P < 0.001$).

⁶ $n = 187$.

TABLE 2

Total calcium intake and other factors influencing body weight and iliac skinfold thickness in adolescent girls, as assessed by multiple regression¹

Model	Weight, ² kg			Iliac skinfold, ³ mm		
	β	SEE	P	β	SEE	P
Intercept	-28.671	7.319	0.00*	1.431	4.765	0.76
Age, y	-0.728	0.525	0.17	-0.650	0.341	0.05*
Ethnicity, ⁴ %						
Asian	-1.131	1.462	0.44	1.469	0.952	0.12
Pacific	10.117	3.915	0.01*	4.992	2.548	0.05*
Other	2.851	5.780	0.62	1.526	3.762	0.69
Height, cm	0.429	0.059	0.00*	0.087	0.038	0.02*
Breast, Tanner staging	4.900	0.607	0.00*	1.708	0.395	0.00*
Activity, MET-h/wk	-0.017	0.013	0.19	-0.019	0.008	0.03*
Energy, kJ/d	0.0008	0.000	0.00*	0.0003	0.000	0.10
Soda, g/d	0.0050	0.002	0.01*	0.0008	0.001	0.49
Total calcium, ⁵ mg/d	-0.0027	0.002	0.09	-0.0025	0.001	0.01*

¹ $n = 315$.

² Adjusted R^2 for weight model = 57%.

³ Adjusted R^2 for iliac skinfold model = 17%.

⁴ Caucasian is the reference group.

⁵ Dietary plus supplemental calcium intake.

* Significant at $P \leq 0.05$.

The regression with total calcium intake accounted for 17% of the variability in iliac skinfold thickness; with dairy calcium, it accounted for 16% of the variability in iliac skinfold thickness ($P = 0.001$, both models). Nondairy calcium was not associated with either dependent variable.

DISCUSSION

Energy intake and physical activity. The energy intake of the girls was 7537.9 kJ/d or 87% of the recommended dietary reference intake (DRI; active girls, 8665 kJ/d) (10), suggesting that not all intake was captured. The reported MET value was 44 h/wk, slightly higher than that reported by Kimm et al.

(11), of 31 h/wk among Caucasian adolescent girls. The DRI definition (12) of active children is at least 60 min of exercise daily, although no MET-equivalent activity level is mentioned. Harrell et al. (13) reported a MET activity level of 4.9 among 6th graders (comparable to the age of girls in this study, 11.5 ± 1.4 y). Thus, using a MET value of 4.9 and the DRI recommendation of 160 min of exercise daily, active adolescents are estimated to expend an average of 34 MET-h/wk. A limitation of the study is that physical activity was estimated using a retrospective questionnaire. However, this questionnaire was validated for use among adolescents (14).

The calcium intake was 736 mg/d, much lower than the

TABLE 3

Dairy calcium intake and other factors influencing body weight and iliac skinfold thickness in adolescent girls, as assessed by multiple regression¹

Model	Weight, ² kg			Iliac skinfold, ³ mm		
	β	SEE	P	β	SEE	P
Intercept	-28.344	7.332	0.00*	1.752	4.774	0.71
Age, y	-0.745	0.525	0.16	-0.667	0.342	0.05*
Ethnicity, ⁴ %						
Asian	-1.178	1.472	0.42	1.413	0.958	0.14
Pacific	10.392	3.897	0.01*	5.220	2.537	0.04*
Other	2.989	5.780	0.61	1.636	3.763	0.66
Height, cm	0.427	0.059	0.00*	0.086	0.039	0.03*
Breast, Tanner staging	4.904	0.607	0.00*	1.711	0.395	0.00*
Activity, MET-h/wk	-0.016	0.013	0.21	-0.018	0.008	0.04*
Energy, kJ/d	0.0008	0.000	0.01*	0.0002	0.000	0.18
Soda, g/d	0.0050	0.002	0.01*	0.0008	0.001	0.50
Dairy calcium, mg/d	-0.0027	0.002	0.11	-0.0026	0.001	0.02*

¹ $n = 315$.

² Adjusted R^2 for weight model = 57%.

³ Adjusted R^2 for iliac skinfold model = 16%.

⁴ Caucasian is the reference group.

* Significant at $P \leq 0.05$.

DRI of 1300 mg/d and somewhat lower than the 902 mg/d recently found among 10- to 13-y-old Asian, Caucasian, and Hispanic girls from Arizona, California, Hawaii, Idaho, Nevada, and Washington based on two 24-h recalls (15). If we adjust the 736 mg/d to the equivalent value for 8665 kJ/d intake, the calcium intake is still somewhat low at 846 mg/d. The dairy intake of 1.4 servings/d was half of that recommended by the food guide pyramid (3 servings/d) (4), but the same as that found recently among Caucasian children in Alabama (16). Soda intake among our participants was high at 752 g/d, compared with a study by Bowman et al. (17) reporting an average soda intake of 276 g/d among 12-y-old children.

Dairy and Asian ethnicity. The negative effect of dairy on iliac skinfold thickness was stronger in Asians than Caucasians. The effect of dairy calcium on iliac skinfold thickness was estimated to be $\beta = -0.0003$ (95% CI = -0.0035 to 0.0030), whereas its extrapolated effect for girls of Asian ancestry was $\beta = -0.0063$ (95% CI = -0.0010 to -0.0025). This may reflect a dose response by which there is less effect at the higher end of dairy intake. We tested for a possible nonlinear effect of dairy calcium on iliac skinfold thickness by including the square of dairy calcium intake in the model (data not shown); the squared term did not improve the fit of the model ($t = 0.11$, $P = 0.92$). In addition, we substituted the log (dairy calcium + 1) for dairy calcium and compared the t test values; dairy calcium (linear) had a slightly more extreme t test value than log (dairy calcium + 1) (-2.36 vs. -2.16 , respectively), again giving no indication of a nonlinear effect.

Although it is possible that this might be a Type I error, weight was significant at the 0.1 level, using the same model. However, because iliac skinfold thickness and weight were correlated, it is not a strong confirmation of our finding. Future testing among this cohort should provide an opportunity to confirm this finding and further investigate this issue. Additionally, there could be differences in the types of dairy food consumed by different ethnic groups, or patterns of dairy food consumption (such as eating small amounts of dairy throughout the day) that might influence fat patterning.

Total calcium, dairy calcium and body fat. In a model with ethnicity, stage of maturation, age, height, and soda intake (and adjusted for energy), higher dairy and total calcium intakes were associated with lower body fat. Dairy calcium had a stronger association than total calcium intake. One milligram of dairy calcium was associated with a 0.0026-mm decrease in iliac skinfold thickness (or a serving of milk with ~ 0.78 mm of iliac skinfold thickness). This effect was seen mainly with Asian ethnicity for which 1 mg of dairy calcium was associated with a 0.0063-mm decrease in iliac skinfold thickness or 1 serving of milk with 1.89 mm smaller iliac skinfold thickness. Similarly, 1 mg of total calcium intake from diet and supplements was associated with 0.0025 mm smaller iliac skinfold thickness (or calcium in a serving of milk with 0.75 mm).

The NIH identifies excess fat in the abdomen as an independent predictor of risk factors for chronic diseases and morbidity (18). Theoretically, the recommended 2–3 servings of milk would lead to a 1.6- to 2.3-mm decrease in iliac skinfold thickness, an amount equal to about one quarter of the total iliac skinfold thickness of our participants (or 3.8–5.7 mm among Asians). The lack of association of nondairy calcium with weight and iliac skinfold thickness suggests that the dairy portion of the calcium intake is the key factor. The calcium may require other components from milk for its activity or it may be a marker for other bioactive components of milk. However, nondairy calcium intake was significantly less than dairy calcium intake among our subjects, and it is possible

that the nondairy calcium intake was too small to have an effect.

Soda intake and weight. Soda intake was positively associated with weight in all 3 models. A 1-g increase in soda consumption was associated with a 0.005-kg increase in weight (or a 341.6 g can of soda with a 1.7-kg increase in weight). Soda consumption could influence weight by increasing energy intake or by replacing milk. Calcium intake was not associated with body weight. However, without soda intake in the model (data not shown), both total calcium and dairy consumption were associated with body weight ($P = 0.1$).

In Hawaii, fluid milk was 66% of adolescent dairy intake (19). Although milk contains a broad range of nutrients such as protein and fat and is, therefore, metabolized slowly, soda has only sugar, which leads to blood glucose swings, triggering hunger in the presence of excess energy (20). Hence, the substitution of soda for milk is likely to result in increased body weight.

Relation to other studies. Other authors found effects similar to ours in other age groups, and one longitudinal study demonstrated that dairy did not increase BMI among adolescents (21). In a longitudinal study with children aged 2 mo to 8 y, Skinner et al. (22) found calcium intake to be negatively associated with body fat as measured by DXA. Carruth and Skinner (23) found a 3.5% decrease in the percentage of body fat with 1 serving of dairy intake per day among preschoolers. Davies et al. (24) found a decrease in body weight of 0.82 kg/y in young women for each 100 mg calcium consumed each day. Summerbell et al. (25) found a mean weight loss of 11.2 kg with consumption of a “milk-only” diet consumed for 16 wk, the highest weight loss compared with a control group and a “milk plus group,” which included milk and limited additional food. All diets were isoenergetic. Participants were men and women > 17 y old. Zemel et al. (26) found that after controlling for energy intake, higher calcium intake was associated with lower body fat in 28-y-old women. Body fat was highest in women in the lowest quartile of calcium intake (odds ratio equal to 1) and the odds ratio was reduced to 0.75, 0.40, and 0.16 for those in the second, third, and fourth quartiles of calcium intake, respectively. Davies et al. found a decrease in body weight of 0.038 kg/y among middle-aged women with a calcium intake of 100 mg (24).

Zemel et al. (26) found that increased calcium intake in mice increased lipolysis and decreased lipogenesis in mice. This was tested among transgenic mice consuming a low-calcium, high-fat, high-sucrose diet, with no supplementation or supplemented with 25 or 50% replacement of nonfat milk or 1.2% calcium with calcium carbonate for 6 wk. These diets stimulated lipolysis 3.4- to 5.2-fold and inhibited adipocyte fatty acid synthase expression and activity by 51%.

Consumption of dairy and calcium-rich foods and nutrients was associated with decreased iliac skinfold thickness among Asian adolescents, whereas consumption of soda was associated with increased weight. The long-term effect of calcium intake during adolescence on body fat in later years will be determined in future analysis.

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