

# Milk, Dairy Fat, Dietary Calcium, and Weight Gain

## A Longitudinal Study of Adolescents

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**Background:** Milk is promoted as a healthy beverage for children, but some researchers believe that estrone and whey protein in dairy products may cause weight gain. Others claim that dairy calcium promotes weight loss.

**Objective:** To assess the associations between milk, calcium from foods and beverages, dairy fat, and weight change over time.

**Design, Subjects, and Outcome Measure:** We followed a cohort of 12 829 US children, aged 9 to 14 years in 1996, who returned questionnaires by mail through 1999. Children annually reported their height and weight and completed food frequency questionnaires regarding typical past-year intakes. We estimated associations between annual change in body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared) and our dietary factors, adjusted for adolescent growth and development, race, physical activity, inactivity, and (in some models) total energy intake.

**Results:** Children who drank more than 3 servings a day of milk gained more in BMI than those who drank smaller amounts (boys:  $\beta \pm SE$ ,  $0.076 \pm 0.038$  [ $P = .04$ ] more than

those who drank 1 to 2 glasses a day; girls:  $\beta \pm SE$ ,  $0.093 \pm 0.034$  [ $P = .007$ ] more than those who drank 0 to 0.5 glass a day). For boys, milk intake was associated with small BMI increases during the year ( $\beta \pm SE$ ,  $0.019 \pm 0.009$  per serving a day;  $P = .03$ ); results were similar for girls ( $\beta \pm SE$ ,  $0.015 \pm 0.007$  per serving a day;  $P = .04$ ). Quantities of 1% milk (boys) and skim milk (girls) were significantly associated with BMI gain, as was total dietary calcium intake. Multivariate analyses of milk, dairy fat, calcium, and total energy intake suggested that energy was the most important predictor of weight gain. Analyses of year-to-year changes in milk, calcium, dairy fat, and total energy intakes provided generally similar conclusions; an increase in energy intake from the prior year predicted BMI gain in boys ( $P = .003$ ) and girls ( $P = .03$ ).

**Conclusions:** Children who drank the most milk gained more weight, but the added calories appeared responsible. Contrary to our hypotheses, dietary calcium and skim and 1% milk were associated with weight gain, but dairy fat was not. Drinking large amounts of milk may provide excess energy to some children.

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**D**ISTURBING INCREASES IN the prevalence of childhood and adolescent obesity in recent decades are extensively documented,<sup>1-7</sup> as are the associated health and social consequences.<sup>2,5-25</sup> This rapid increase in obesity prevalence implicates environmental factors.<sup>21,26-30</sup> Physical activity among adolescents has declined, whereas time spent in sedentary activities such as watching television or videos and playing computer games has increased.<sup>3,4</sup> Furthermore, in nationally representative samples of US adolescents, many changes in dietary patterns have taken place.<sup>31-35</sup>

Studies suggest that dairy products and dietary calcium may help prevent weight

gain and promote weight loss.<sup>36-43</sup> However, a review of randomized trials of dairy products or calcium supplementation in adults did not support a benefit, with 2 studies showing weight gain in older adults randomized to dairy groups and only 1 of 17 trials demonstrating more weight loss in calcium-supplemented groups.<sup>44</sup> Another review article concluded that existing data support the need for large clinical trials of supplemental calcium and dairy products in overweight adults.<sup>45</sup> A recent study of 178 normal-weight girls, aged 8 to 12 years at enrollment and followed up through adolescence, found no evidence of a relationship between body fat and dairy food or calcium consumption.<sup>46</sup>

Also found in dairy products is the hormone estrone, which may promote in-

creases in body weight.<sup>47</sup> Furthermore, whey protein is often added during processing to reduced-fat milk,<sup>48</sup> estrone is found in whey,<sup>49</sup> and whey protein itself may promote weight gain.<sup>50-53</sup>

Using data from the Growing Up Today Study,<sup>54</sup> an ongoing cohort study of more than 10 000 US children, we analyzed the relationship between milk, dietary calcium and fats, and body mass index (BMI) change over time.

## METHODS

### STUDY POPULATION

Established in the fall of 1996, the Growing Up Today Study consists of 16 771 children residing in 50 states who are offspring of Nurses' Health Study II (NHSII) participants.<sup>55</sup> The study, approved by the Human Subjects Committees at Harvard School of Public Health and Brigham and Women's Hospital, is described in detail elsewhere.<sup>54</sup> These children were aged 9 through 14 years in 1996. In 1997, 1998, and 1999, we mailed the participants follow-up questionnaires to update their information. Response rates to 1 or more follow-ups were 94.12% (girls) and 89.45% (boys). More relevant to our longitudinal analyses, 86.73% of girls and 79.27% of boys responded to at least 1 pair of adjacent surveys (1 year apart).

### OUTCOME MEASURE

Children self-reported their height and weight annually on our questionnaire, which provided specific measuring instructions but suggested that they ask someone for assistance. Since their mothers are nurses who biennially self-report their own height and weight as part of NHSII, assistance is available to each child. A previous study reported high validity for self-reported heights and weights for children aged 12 to 16 years.<sup>56</sup> We assessed relative weight status by computing BMI (calculated as weight in kilograms divided by height in meters squared). The International Obesity Task Force supports the use of BMI to assess fatness in children and adolescents.<sup>57</sup> Childhood BMI is strongly related to measures of adiposity that were not feasible to collect in our study.<sup>58,59</sup> A recent study<sup>60</sup> supported the validity of BMI computed from self-reported height and weight, providing a correlation of 0.92 between BMI computed from measured values and self-reports by youths in grades 7 through 12.

Before computing BMI, we excluded any height that was more than 3 SDs away from the sex- and age-specific mean height (0.50% of heights excluded) and any 1-year height change that declined more than 1 inch or increased by more than the 99.7th percentile of the sex- and age-specific height growth distribution (1.36% excluded). (Using additional rules based on external information<sup>61</sup> that excluded another 3% of the 1-year height changes did not materially alter our findings.) We excluded any BMI less than 12.0 as a biological lower limit (clinical opinion) and any BMI more than 3 SDs above or below the sex- and age-specific mean (log scale, 0.97% excluded). We then estimated our outcome, annual change in BMI, by  $BMI_{1997} - BMI_{1996}$ ,  $BMI_{1998} - BMI_{1997}$ , and  $BMI_{1999} - BMI_{1998}$ , dividing each by the exact interval between the pair of measurements. We excluded any annualized BMI changes that were more than 3 SDs above or below the mean change (0.84% excluded); 7553 girls and 5961 boys provided BMI changes.

We grouped children based on their 1996 BMI using the Centers for Disease Control and Prevention (CDC) sex- and age-specific BMI percentiles.<sup>62</sup> Children between the 85th and 95th percentiles were designated as overweight, those higher than the 95th percentile were obese, and those lower than the fifth

percentile were very lean.<sup>62</sup> The CDC standards were also used to assign z scores to BMIs.

## INDEPENDENT VARIABLES

### Dietary Intakes

We designed a self-administered, semiquantitative food frequency questionnaire (FFQ) specifically for older children and adolescents that was inexpensive and easy to administer to large populations.<sup>63</sup> This FFQ for youth was shown to be valid and reproducible with children aged 9 through 18 years<sup>63,64</sup>; the mean correlation for nutrients from the FFQ compared with three 24-hour recalls was  $r = 0.54$ , comparable with the performance of the adult FFQ. A similar youth FFQ provided estimates of milk and dairy food consumption (by adolescent girls) that correlated well with 7-day dietary records.<sup>46</sup> Our youth FFQ included questions regarding usual frequency of intake of 132 specific food items during the past year. Beverage questions indicated that the serving size was a can, glass, bottle, or cup (specific to the beverage). For dairy milk (white, in a glass or on cereal; chocolate milk), we derived typical past-year intake (servings per day) and change in intake between years (we did not include soy milk). Children also reported the fat content of the milk they usually drink (whole/2%/1%/skim). We derived total dietary calcium, dairy fat, vegetable fat, other fat (from meat/fish/eggs), and energy (kilocalories per day) intakes. Dairy fat was calculated from milk, butter, and cheese as a whole food and as ingredients in other foods on the FFQ. We excluded as implausible total energy intakes less than 500 kcal/d or greater than 5000 kcal/d (0.53% excluded).

Because we used an abbreviated FFQ in 1999, we do not have estimates of total energy, dietary fats, and calcium intakes from that year. For analyses that included these variables, we used data through 1998.

### Physical Activity

We developed a physical activity questionnaire specifically for youth, which asked the participants to recall the typical amount of time spent within each season during the past year in 17 activities and team sports (outside of gym class); response categories ranged from 0 to 10 or more hours per week. From each child's responses, we computed his or her typical hours of weekly physical activity within each season and during the entire year. Evaluation of an earlier nonseasonal version of this instrument found that total physical activity was moderately reproducible and reasonably correlated with cardiorespiratory fitness, thus providing evidence of validity.<sup>65</sup> Another validation study reported a correlation of  $r = 0.80$  between survey self-reports and 24-hour recalls in sixth- to eighth-grade children.<sup>66</sup> We developed the seasonal format used in this study to further improve reliability and validity.<sup>67</sup> Estimates of total physical activity that exceeded 40 h/wk were deemed implausible and excluded (3.60%).

### Inactivity

Another series of questions were designed to measure weekly hours of recreational inactivity: "watching TV," "watching videos or VCR," and "Nintendo/Sega/computer games (not homework)." For each of these items, children reported their usual number of hours per week, separate for weekdays and weekends, from options ranging from 0 to 31 or more hours. From this information, we computed each child's typical hours per week of recreational inactivity. Gortmaker et al<sup>66</sup> reported moderate reproducibility, for children in grades 6 to 8, for recalled total inactivity from a similar instrument. We excluded totals exceeding 80 hours per week as implausible (0.89%).

## Race/Ethnicity

At baseline, children reported their race or ethnic group by marking any of 6 options that applied to them. We assigned each child to 1 of 5 racial or ethnic groups following US Census definitions, except we retained Asian children as a separate group rather than pooled with "other."<sup>1</sup>

## Tanner Stage, Menarche, and Age

Each year, children reported their Tanner maturation stage, a validated self-rating<sup>68</sup> of sexual maturity that uses 5 illustrations for stage of pubic hair development. Girls reported whether or when their menstrual periods had begun. We derived a menstrual history variable that had 3 categories: premenarche before and after the 1-year BMI change, periods began during the interval, and postmenarche both years. We computed each child's age from the dates of birth and questionnaire return.

## STATISTICAL ANALYSES

To assess the potential for selection bias, we compared the baseline (1996) values of age, BMI, and milk, calcium, dairy fat and energy intakes of those children who returned surveys in consecutive follow-up years with those who did not. All models throughout were fit separately for boys and girls.

## LONGITUDINAL ANALYSES

All longitudinal models were adjusted for race and ethnicity. To account for changes in BMI (the dependent variable) that typically occur during adolescent growth and development, we included (as independent variables) height growth during the same year, menstrual history (girls), Tanner stage, prior-year BMI *z* score, and nonlinear age trends.<sup>28,69-72</sup> We also adjusted for physical activity and inactivity during the year of BMI change. Activity and inactivity were previously shown (in this cohort) to be associated with changes in BMI.<sup>54,73</sup>

To study change in BMI and milk intake during the year, we related the past-year milk intake reported in 1997 to change in BMI from 1996 to 1997, milk intake reported in 1998 to BMI change from 1997 to 1998, and milk intake reported in 1999 to BMI change from 1998 to 1999. Because each child can have up to 3 outcomes (BMI changes), the assumption of independent observations required by ordinary linear regression models is not met. To take these within-child correlations into account, we used mixed linear regression models<sup>74</sup> of BMI change, estimated with SAS statistical software (Proc Mixed; SAS Institute, Cary, NC).<sup>75</sup> Milk intake was a continuous independent variable in some models (servings per day), but we also analyzed it as a 5-group categorical variable. We further looked at the (per-serving) effects for milk of different fat contents, comparing children who drank the same type of milk but different quantities. In separate models, total energy intake, dairy fat, and dietary calcium were studied as independent variables. We fit models to compare the estimates for dairy fat with estimates for nondairy fats. Additional models of milk, dietary calcium, or dairy fat (individually) included total energy intake as a hypothesized intermediary in the pathway between dietary intake and weight gain. Multivariate models included milk, calcium, dairy fat, and energy intake together.

We also studied the association between 1-year change in milk intake (the difference between milk intakes reported in 1996 and 1997, between 1997 and 1998, and between 1998 and 1999) and same-year change in BMI. We adjusted for the prior-year (1996, 1997, or 1998) milk intake in these mixed regression models. Annual changes in calcium, dairy fat, and energy intake were analyzed similarly.

To estimate the net impact of health promotion efforts that encourage youths to replace soda with milk, we predicted BMI change from 1-year changes in intakes of white milk, chocolate milk, and soda, adjusting for prior-year intakes of these beverages. We included only children who did not change milk type (fat) between years.

A final analysis estimated the cumulative effect of milk intake on BMI change from 1996 through 1999 using children who provided longitudinal data all 4 years.

## RESULTS

The children we studied, whose mothers were in the NHSII,<sup>55</sup> were mostly white (94.68%). At baseline, 14.55% of the boys and 12.67% of the girls were overweight (85th to 95th percentile on CDC BMI charts), 8.71% of boys and 4.79% of girls were obese (>95th percentile), and 4.16% of boys and 4.68% of girls were very lean (<fifth percentile). Boys consumed (baseline means) 2.2 servings of milk, 2290 kcal, 20.6 g of dairy fat, and 1291 mg of dietary calcium per day. Girls consumed 1.9 servings of milk, 2050 kcal, 18.0 g of dairy fat, and 1145 mg of dietary calcium per day.

Children who did not return surveys in adjacent years (required for inclusion in our longitudinal analyses) were slightly older (girls by 0.3 year; boys by 0.4 year;  $P < .05$  for both). At baseline they drank less milk (girls by 0.2 serving per day; boys by 0.1 serving per day; age-adjusted  $P < .05$  for both) and, owing to their lower milk intake, consumed less dietary calcium (girls by 60 mg/d; boys by 47 mg/d; age-adjusted  $P < .05$  for both). There were no significant baseline differences in age-adjusted BMI or total energy or dairy fat intake.

## LONGITUDINAL RESULTS

Milk intake declined as these children grew older. Among children who completed the FFQ all 4 years, boys consumed (on average) 2.3 servings per day in 1996 but only 2.0 by 1999, and girls consumed 2.0 servings per day in 1996, which declined to 1.7 by 1999.

We related milk intake during each year to BMI changes during the same period. Boys who drank more than 3 servings per day had significantly larger BMI gains during the year ( $\beta \pm SE$ ,  $0.076 \pm 0.038$ ;  $P = .04$ ) than those who drank more than 1.0 but less than or equal to 2.0 servings per day. Similarly, girls who drank more than 3 servings per day had significantly larger BMI gains ( $\beta \pm SE$ ,  $0.093 \pm 0.034$ ;  $P = .007$ ) than girls consuming half a glass or less each day (**Table 1**). The continuous milk  $\beta$  (boys:  $\beta = .019$ ;  $P = .03$ ; girls:  $\beta = .015$ ;  $P = .04$ ; Table 1) represents the 1-year change in BMI expected per usual daily serving of milk.

Skim and 1% milk appeared more strongly linked (per serving) to weight gain than whole or 2% milk (**Table 2**), although the number of children consuming whole milk was small. For girls, the association between skim milk and weight gain ( $\beta = .020$ ;  $P = .04$ ) persisted somewhat after energy adjustment ( $\beta = .021$ ;  $P = .09$ ). Excluding the children who changed milk type from the previous year (<18%) provided similar results (Table 2, right column).

**Table 1. Association Between Milk Consumption and 1-Year Change in BMI, Estimated Using Annual Data From 1996 Through 1999\***

	Milk Category, Servings per Day					Continuous Milk, per Serving	
	0 to ≤0.5 (Referent)	0.5 to ≤1.0	1.0 to ≤2.0	2.0 to ≤3.0	>3.0	β	P Value
Boys (n = 5550)							
Percentage of boys in each category	9	23	16	30	23		
BMI change, β ± SE	0.0	0.052 ± 0.049	0.005 ± 0.051	0.022 ± 0.047	0.081 ± 0.048†‡	0.019 ± 0.009	.03
Girls (n = 7279)							
Percentage of girls in each category	16	27	13	29	15		
BMI change, β ± SE	0.0	0.058 ± 0.031†	0.072 ± 0.036§	0.056 ± 0.029†	0.093 ± 0.034§	0.015 ± 0.007	.04

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

\*Models adjusted for race/ethnicity, age, same-year height growth, prior BMI z score, Tanner stage, menstrual history (girls), and same-year physical activity and inactivity (television/videos/computer games).

†P < .10 (different from those drinking 0 to ≤0.5 serving per day).

‡P < .05 (different from those drinking 1 to ≤2.0 servings per day).

§P < .05 (different from those drinking 0 to ≤0.5 serving per day).

**Table 2. Association Between Milk Intake (per Daily Serving) and 1-Year Change in BMI, Estimated Using Annual Data From 1996 Through 1999\***

Type of Milk	Percentage of Children Drinking Each Type of Milk	1-Year Change in BMI per Daily Serving	
		For Milk Type During BMI Change, β (95% CI)	For Same Milk Type Before and During BMI Change, β (95% CI)
Boys (n = 5388)			
Whole	5	-0.001 (-.046 to .043)	0.008 (-.040 to .057)
2%	38	0.006 (-.016 to .027)	0.006 (-.017 to .028)
1%	25	0.027† (.003 to .050)	0.027† (.002 to .053)
Skim	32	0.020‡ (-.002 to .041)	0.020‡ (-.002 to .042)
Girls (n = 6943)			
Whole	4	0.009 (-.037 to .055)	0.021 (-.032 to .075)
2%	32	0.004 (-.016 to .024)	-0.001 (-.023 to .020)
1%	26	0.016 (-.004 to .037)	0.021‡ (-.001 to .044)
Skim	39	0.020†§ (.001 to .039)	0.021†§ (.001 to .040)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval.

\*Estimates are shown for past-year milk type reported at the end of BMI change and separately for milk type that was identical before and after the BMI change.

Adjustment variables are the same as those shown for Table 1.

†P < .05.

‡P < .10.

§P < .10 with energy intake in model (1996-1998 data).

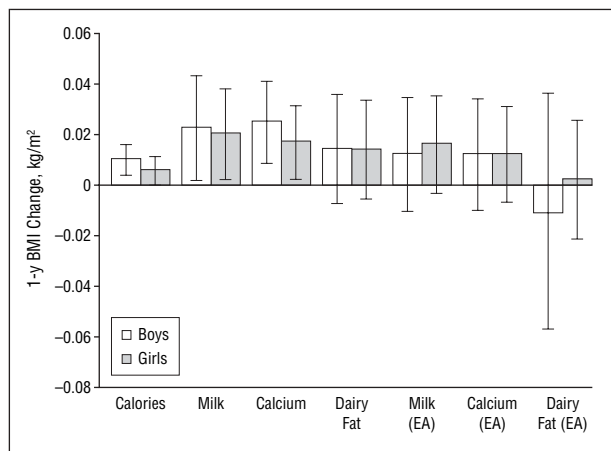
The **Figure** shows the estimated effects on weight gain of total energy intake (per 150 kcal), milk intake (per daily serving), dietary calcium (per 290 mg), and dairy fat intake (per 8 g); each factor was in a separate model. These per-serving units correspond roughly to the quantity of calcium, energy, or dairy fat in 8 oz (244 g) of whole milk. Taking energy into account, only milk intake (in girls) retains a marginally significant association ( $\beta = .016$ ;  $P < .10$ ) (Figure). In the fully adjusted model (dairy fat, dietary calcium, milk, and total energy intakes), nothing remains statistically significant, although energy intake has the smallest P value (boys:  $\beta = .008$  per 150 kcal;  $P = .16$ ; girls:  $\beta = .007$ ;  $P = .16$ ). In a separate model (not energy adjusted), the association between BMI gain and butter intake (pats per day) was not significant for boys ( $P = .44$ ), consistent with our null dairy fat results, but achieved borderline significance for girls ( $\beta = .04$  per pat;  $P = .07$ ).

These analyses included calcium only from dietary sources, not from supplements (eg, multivitamins or

TUMS [GlaxoSmithKline, Research Triangle Park, NC]). In additional models (not shown), supplemental calcium was not associated with weight change (girls:  $P = .72$ ; boys:  $P = .19$ ). However, supplemental calcium intake was low in this cohort.

We also compared different types of dietary fats. Dairy fat was not a stronger predictor of weight gain than other types of fat, and no fat (dairy, vegetable, or other) intake was significantly associated with weight gain after energy adjustment, nor was total fat intake.

Our models provided comparable estimates when we instead analyzed 1-year change in dietary intake. An increase from the prior year of 1 serving per day of milk was associated with a BMI gain of 0.023 ( $P = .08$ ) in boys and 0.023 ( $P = .05$ ) in girls (adjusted for prior milk intake but not energy). A 150-kcal/d increase in total energy from the prior year predicted a BMI gain of 0.012 ( $P = .003$ ) for boys and 0.008 ( $P = .03$ ) for girls (adjusted for prior energy intake). One-year changes in milk, calcium, dairy fat, veg-



**Figure.** The estimated gain in body mass index (BMI) during 1 year associated with (same-year) total energy (per 150 kcal/d), milk (per daily serving), dietary calcium (per 290 mg/d), and dairy fat (per 8 g/d) intakes. Energy, milk, calcium, and dairy fat were each in a separate model that adjusted for age, Tanner stage, race, prior BMI z score, height growth, menarche (girls), activity, and inactivity. Energy-adjusted (EA) estimates included total energy intake in each model. Data were collected in 1996, 1997, and 1998 from 5109 boys and 6723 girls. Error bars indicate 95% confidence intervals.

etable fat, and other fat intakes were not significant after adjusting for change in total energy intake.

Analyzing change in milk and change in sugar-sweetened soda in the same model, for children who did not change milk fat between years, we estimated the net effect of replacing soda with white milk. Among boys, omitting a daily serving of soda was related to a BMI loss of 0.032, whereas adding a daily serving of white milk was related to a BMI gain of 0.014, suggesting a nonsignificant net BMI loss ( $\beta \pm SE$ ,  $-0.018 \pm 0.028$ ;  $P = .52$ ). For girls, omitting a serving of soda ( $-0.039$ ) and adding a serving of white milk ( $+0.023$ ) suggested a similar nonsignificant net BMI loss ( $\beta \pm SE$ ,  $-0.016 \pm 0.028$ ;  $P = .57$ ).

An analysis of children ( $n=9166$ ) who returned surveys all 4 years addressed the cumulative effects of high milk intake on BMI from 1996 through 1999. Girls ( $n=129$ ) who reported consuming more than 3 servings per day of white milk every year gained 0.213 ( $P = .24$ ) more BMI than girls ( $n=652$ ) who consistently consumed 2 to 3 servings per day (not energy adjusted). Boys ( $n=129$ ) who consumed more than 3 servings per day every year similarly gained more BMI (0.262;  $P = .19$ ) than boys ( $n=499$ ) who consistently consumed 2 to 3 servings per day. Because these estimated 3-year effects are more than 3 times the magnitude of the 1-year effects (compare with 0.037 for girls and 0.059 for boys, derived from Table 1), this suggests that these effects accumulate over time.

We did not present an analysis of incident overweight (crossing the 85th percentile of BMI during a year) because we believe that the effects of these dietary factors should influence the full range of body mass. Thus, many more children beyond those who cross the 85th percentile are affected. As an extreme example, one child may gain considerable weight, moving from the 30th percentile to the 70th percentile, but does not become overweight, yet another child who gains far less weight (moves from 84th to 86th percentile) does become overweight. The analysis of incident overweight excludes those who

were initially overweight (although they are also affected by these dietary factors), so the analytic sample size is smaller as well. Recognizing that risk estimates are more interpretable to many readers than the BMI  $\beta$ , we present findings from logistic models (adjusted for the same factors as Table 1; estimated using SAS statistical software [Proc Genmod; SAS Institute Inc, Cary, NC]).<sup>75</sup> Boys who drank more than 3 servings per day of milk were 35% more likely to become overweight (relative risk [RR] = 1.35; 95% confidence interval [CI], 0.96-1.90) during 1 year than boys who drank more than 1.0 but less than or equal to 2.0 servings and were 26% more likely to become overweight than boys who drank more than 2.0 but less than or equal to 3.0 servings (RR = 1.26; 95% CI, 0.95-1.66). Girls who drank more than 3 servings per day were 36% more likely to become overweight (RR = 1.36; 95% CI, 0.92-2.01) than those who drank more than 1.0 but less than or equal to 2.0 servings and were 25% more likely (RR = 1.25; 95% CI, 0.91-1.72) than those who drank more than 2.0 but less than or equal to 3.0 servings.

## COMMENT

Contrary to our hypotheses, we found that (1) children who reported higher total milk intake experienced larger weight gains; (2) children who drank more 1% and skim milk had larger weight gains than those who drank smaller amounts of 1% and skim milk; (3) dietary calcium intake was positively correlated with weight gain; and (4) dairy fat was not. The effects of milk and dietary calcium appear to be explained by energy intake, since the associations were attenuated when adjusted for energy. However, skim milk in girls remained marginally significant after adjustment for energy intake. Models fit to explore whether type of milk consumed was associated with physical activity suggested no association ( $P = .18$  to  $.81$ ). Although the magnitudes of our estimated dietary effects (on 1-year BMI change) were small, they may accumulate over time and become clinically important if high intakes persist for multiple years.

The US Department of Agriculture Food Guide Pyramid recommends 2 to 3 servings per day from the milk, cheese, and yogurt group, primarily to promote adequate calcium intake for the prevention of osteoporosis in old age. Milk is a valuable source of protein, vitamins (A and D), and minerals (calcium and phosphorus), has a low glycemic index, and may prevent prepubertal bone fractures.<sup>76</sup> However, there is considerable controversy about whether high intakes of dairy products are necessary, and the evidence is weak regarding the health benefits of a large calcium intake.<sup>77</sup> Given the high prevalence of lactose intolerance, the energy content and saturated fat in milk, and evidence that dairy products may promote both male (prostate)<sup>78</sup> and female (ovarian)<sup>79-82</sup> cancers, we should not assume that high intakes are beneficial. Furthermore, these cancers may be linked to consumption during adolescence.<sup>80</sup>

Some studies have suggested that dairy products, and dietary calcium in particular, may help prevent weight gain and promote weight loss.<sup>36-43,83-86</sup> However, a review of randomized trials of dairy products or calcium supplementa-

tion in adults did not support a benefit, with 2 studies showing weight gain in older adults randomized to dairy foods and only 1 of 17 trials demonstrating more weight loss in calcium-supplemented groups.<sup>44</sup> This review<sup>44</sup> included 7 randomized controlled trials of calcium supplementation and 3 of dairy food supplementation<sup>87-89</sup> in children; these trials also did not support weight loss, although some benefits for bone density were demonstrated. More recently, a longitudinal study of low-income preschool children in North Dakota found no association between milk intake and weight change,<sup>90</sup> and a longitudinal study of normal-weight girls followed up from ages 8 to 12 years through adolescence similarly found no relationship between dairy food or calcium intake and body fat.<sup>46</sup>

A school-based milk intervention trial in Chinese girls<sup>91</sup> demonstrated benefits for bone growth, including significantly greater height growth during 2 years of follow-up. They further reported body weight increases for the milk intervention group, but these were not adjusted for height growth and so may not reflect increases in adiposity. A longitudinal study of 92 Japanese children found more (3-year) height growth among children who drank more milk, but weight changes (taking height growth into account) were not significant.<sup>92</sup> Our own data also show significantly greater 1-year height growth for boys (0.023 in per daily serving of milk, reported at the time of earlier height measurement;  $P = .008$ ) and girls (0.017 in per serving;  $P = .004$ ).

In our study, dairy fat intake was not predictive of weight gain, consistent with a body of evidence from long-term randomized trials in adults that failed to link dietary fat to body fat.<sup>93</sup>

Because our estimated effects became smaller (and lost statistical significance) after adjusting for total energy intake, as illustrated in the Figure, the energy in dairy products probably explains most of our associations between milk and dietary calcium and weight gain. However, we do not differentiate between energy from milk or from foods or beverages providing calcium and energy from other foods typically consumed with them.<sup>94</sup> Also, compensation for energy consumed in liquid form (including milk) may be less complete (owing to lower satiety) than energy consumed in solid form.<sup>95,96</sup> The inclusion of sweetened soda in our models had little impact on the associations between milk and BMI gain (boys:  $\beta = 0.020$  per daily milk serving;  $P = .02$ ; girls:  $.016$  per daily serving;  $P = .03$ ; compare with the continuous milk  $\beta$ s in Table 1).

Dietary estrone increases fat mass in rats, and in humans 67% of estrone intake is estimated to be from dairy products (mostly whole milk and butter).<sup>47</sup> Remesar et al<sup>47</sup> suggested that a typical human might consume each day an amount of estrone comparable with the daily estrogen production in women. In a randomized trial designed to study risk factors for breast cancer, preadolescent girls with low dietary fat intakes had significantly lower blood estrone, estrone sulfate, and other sex hormone concentrations,<sup>97</sup> suggesting that hormones in (foods containing) dietary fat could modify serum hormone levels. On the other hand, whey protein, which is added to reduced-fat milk during processing,<sup>48</sup> promotes weight gain in male patients with AIDS,<sup>50</sup> increases fat mass in female patients with AIDS,<sup>51</sup> and promotes weight gain in healthy formula-fed in-

fants<sup>52</sup> and in children who are unable to gain weight.<sup>53</sup> In a trial that compared high-protein diets in overweight men, the whey protein (+ exercise) group lost far less body fat than did the casein protein (+ exercise) group.<sup>98</sup> Also, recombinant bovine growth hormone (rBGH), which elevates levels of insulinlike growth factor I (IGF-I) in commercial milk, is widely used to increase milk production in cows.<sup>99</sup> Adult intakes of dairy foods (including whole and nonfat milk) are associated with higher plasma levels of IGF-I,<sup>100-102</sup> which may contribute to weight gain. However, we have no data on whether any of the milk consumed by this cohort was from rBGH-treated cows, although even in milk from treated cows, most of the IGF-I is from endogenous production.

A major strength of our analysis is the longitudinal design, which allowed us to study changes over time in dietary intakes and BMI while accounting for adolescent growth and maturation. Longitudinal observational studies like ours cannot infer causality as definitively as randomized trials, but our study design is considerably stronger than cross-sectional studies, in which associations between the outcome and factors that can change over time may reflect reverse causality. Even though our models adjusted extensively for many important covariates, including race or ethnicity, sex, age and maturational stage, height growth, physical activity, and recreational inactivity (television/videos/computer games), some residual and unmeasured confounding may remain. Because we included together (in certain models) various components of dairy products, as well as sweetened soda, we reduced confounding by these other dietary variables, although most of our associations between weight gain and dietary variables were attenuated after adjusting for total energy intake. Another limitation of our study was the necessity to collect data on youths by self-report using mailed questionnaires, but with our large, geographically dispersed cohort, alternatives were not feasible. Random reporting errors in these data will bias estimates of true associations toward the null, possibly explaining why our estimates were quite small even when statistically significant. Even if the heavier children systematically underreported their weight, this should bias our estimates toward the null. Recent increases in beverage serving sizes have been documented; this complicates the reporting of intakes by children and encourages overconsumption.<sup>103</sup> Milk and dairy fat intakes on our youth FFQ have not specifically been validated, but serving sizes should be less problematic for milk than for soda and other beverages. Finally, although our cohort of children of nurses is not representative of US children, the associations among factors within our cohort should still be valid. In the 1994-1996 Continuing Survey of Food Intakes by Individuals,<sup>104</sup> 9- to 13-year-old children consumed a mean of 9.7 oz (295.8 g) per day of milk, considerably less than the 2 servings per day consumed by our cohort in 1996.

In conclusion, increases in milk consumption are widely promoted as a way of controlling weight gain, but long-term studies in children are few. Our analysis of a very large prospective cohort of children from all 50 states, who provided annual data from 1996 to 1999, suggests that high intakes of milk, including skim and 1% milk, may provide some children with excess energy that re-

sults in an increase in body weight. Total dietary calcium, but not dairy fat, was associated with weight gain. Our findings did not support theories that greater milk intake will contribute to the control of overweight.

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