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Prospective association between milk intake and adiposity in preschool age children

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Abstract

Objective—To determine whether the quantity and type of milk (whole, 2%, or 1%/skim) consumed at age 2 is associated with adiposity at age 3.

Design—We assessed milk and dairy intake at age 2 with food frequency questionnaires completed by mothers. Our primary outcomes were body mass index (BMI) z-score and overweight at age 3 years, defined as BMI (kg/m²) for age and sex $\geq$ 85th percentile.

Subjects—852 preschool-aged children in the prospective US cohort Project Viva.

Statistical Analysis—We used linear and logistic regression models, adjusting for maternal BMI and education, paternal BMI, and child age, sex, race/ethnicity, intake of energy, non-dairy beverages, TV-viewing, and BMI z-score at age 2 years.

Results—At age 2 years, mean (SD) milk intake was 2.6 (1.2) servings per day. Higher intake of whole milk at age 2, but not low-fat milk, was associated with a slightly lower BMI z-score (−0.09 unit per daily serving [95% CI −0.16, −0.01]) at age 3; when restricted to children with a normal

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BMI (5th to < 85th %ile) at age 2, the association was null (−0.05 unit per daily serving [95%CI −0.13, 0.02]). Intake of milk at age 2, whether full or low-fat, was not associated with risk of incident overweight at age 3. Neither total milk nor total dairy intake at age 2 was associated with BMI z-score or incident overweight at age 3.

Conclusion—Neither consuming more dairy products, nor switching from whole milk to low-fat milk at age 2, appears likely to prevent overweight in early childhood.

Keywords

obesity; dairy; child

Introduction

Obesity is epidemic among American children, with recent nationally representative data indicating 31.9% are either overweight (>85th to <95th percentile for BMI) or obese (>95th percentile for body mass index (BMI) (1, 2). Obesity is prevalent even among preschool-age children(1), placing these children at risk for associated comorbid conditions (3). Furthermore, an elevated BMI in childhood predicts obesity and related complications in adulthood (4–6). Identification of modifiable risk factors early in childhood is therefore a crucial step in preventing lifelong morbidity due to obesity.

It is possible that increasing intake of milk or dairy products may lower the risk of obesity. Several authors have noted that the rise in childhood obesity has coincided with a secular rise in sweetened beverage consumption and a decline in dairy consumption (7–9). In children and adolescents, some(10–12) but not all(13–16) studies have reported an inverse association between milk or dairy intake and adiposity. Among the few studies examining dairy intake and the development of adiposity in preschool-aged children (11–14), limitations have included cross-sectional design (14), small study size (11, 12), and lack of adjustment for key confounders (11, 12).

In addition, it is possible that consumption of low-fat milk could result in less weight gain than whole milk. The American Academy of Pediatrics (AAP) and the American Heart Association (AHA) have recommended that children age 2 and older drinking whole milk should be transitioned to 1% or skim milk, as part of a population-based approach to dietary changes targeting obesity prevention (3, 17). Recent national data(18) show that almost half of preschool-aged children drink whole milk (14), yet few studies have examined whether consumption of low-fat milk is associated with lower adiposity in this age group.

If dairy intake as a whole, or switching from whole to low-fat milk, protects against adiposity development among preschool-aged children, this finding would have important public health implications for several reasons. Milk and dairy products remain a prominent component of diet in the preschool age group (19, 20); yet mean daily child dairy intake in the U.S. is around 1.5 to 2 servings (16 fluid oz milk) per day (8, 14, 20), indicating that many children consume less than the 2 daily servings recommended in the USDA MyPyramid (21). Food preferences may be formed early in life (22), and because parents exert control over offered food and drinks (23), dietary intervention at this age may be more feasible than later in childhood. Furthermore, an intervention early in childhood has the potential to reduce obesity prevalence throughout the childhood years and beyond.

The goal of this study was to examine the relationship between milk and dairy intake at age 2 years and adiposity at age 3 years, using data from a prospective cohort of mothers and their offspring (Project Viva). We examined the relationships of both quantity and type of milk (whole, 2%, or 1%/skim) consumed at age 2 with adiposity at age 3.

Methods

Study Population: Project Viva

From April 1999 to July 2002, we enrolled participants into Project Viva, a longitudinal pre-birth cohort of mother-offspring pairs in the Boston, Massachusetts, USA area (24).

Recruitment for Project Viva was conducted at eight obstetric practices within Harvard Vanguard Medical Associates, a multi-specialty, managed-care group practice. Women with singleton pregnancies were study-eligible if they entered prenatal care within the first 22 weeks of gestation, intended to continue their obstetric care at HVMA, and were able to answer questionnaires in English. Human Subjects Committees of Harvard Pilgrim Health Care, Brigham and Women's Hospital, and Beth Israel Deaconess Medical Center approved study protocols. All participants provided written informed consent (24).

We have previously described in detail study population, enrollment and follow up procedures (24). Of 2128 newborns born to Project Viva mothers, 1579 children were eligible for this analysis because their mother had completed prenatal nutritional assessments and had consented to follow-up of their children beyond age 6 months. Of 1579 eligible children, 1258 completed a 3 year research visit including valid BMI-z score, and 1030 of them had valid food frequency questionnaires completed at age 2 years (plausible energy intake, with available milk servings per day and milk type). We excluded 46 children who did not drink milk, 36 who reported drinking predominantly formula or non-dairy milk (soy, breast milk), and 96 children without a 2 year BMI z-score, leaving 852 children for this analysis.

Compared with the 727 eligible children excluded from our analyses, children included in our analyses were more likely to be of White race/ethnicity (73.9% vs. 55.1%), and less likely to report a yearly household income of less than \$40,000 (9.7% vs. 20.3%). Mean BMI (16.5 vs. 16.6), BMI z-score (0.43 vs. 0.50), and % overweight (26.1% vs. 27.6%) at age 3 years were similar among included and excluded children, as was the reported milk type (data not shown). Mean birth weight (3498g vs. 3453g) and child daily energy intake at age 2 (1547 kcal vs. 1501 kcal) were similar among included and excluded children. Mean maternal BMI was slightly lower among mothers of included children (24.3 kg/m² vs. 25.4 kg/m²), and paternal BMI was similar (26.5 kg/m² vs. 26.4 kg/m²).

Exposures: Dietary Data

We assessed dietary intakes using a semiquantitative child food frequency questionnaire previously validated among preschool-age children,(25) and completed by each mother when the child was 2 years old. Mothers reported their children's usual type of milk consumed: whole, 2%, 1%, skim milk, breast milk, formula, soy, other. The average number of daily milk servings over the preceding month was reported using seven response options, ranging from "Never" to "5 or more times per day". Six additional questions specifically addressed servings per day of other dairy foods (cheese, cream cheese, cottage cheese, yogurt, ice cream, and pudding), each with six response options ranging from "Never" to "2 or more times per day". For non-dairy beverage intake, we combined responses from four questions querying intakes of 100% orange juice, other 100% juice, fruit drinks, soda-not sugar free, and hot chocolate. We calculated daily energy and fiber intake using the Harvard nutrition database, which is used for the Nurses' Health Studies and other large cohort studies (26). Our primary exposures were daily servings of whole, 2% or 1%/skim milk consumed, examined as both categorical and continuous variables. Continuous variables were generated by computing a count of daily servings as the average within each category; for example, we coded "1 to 3 servings per day" as two servings per day. Our secondary

exposures were total daily servings of all types of milk combined and total daily servings of dairy foods.

Outcome Measures

For each child at the age 3-year visit, a trained research assistant measured height using a research-standard stadiometer (Shorr Productions, Olney, MD), and weight using a digital scale (Seca model 881, Seca corporation, Hanover, MD), from which we calculated BMI (weight in kg/height in m²). BMI is an accepted method to assess adiposity in children and is highly correlated with other adiposity measures.(27, 28) We calculated age- and sex-specific BMI percentiles and z-scores using US national reference data (29). We defined our primary outcomes as 1) BMI z-score at the 3-year visit, and 2) overweight at the 3 year visit, defined as BMI (kg/m²) for age and sex $\geq$ 85th %ile (v. 5th to <85th %ile).(18, 28)

Covariates

We collected sociodemographic and medical data through in-person interviews at enrollment and at age 3, yearly self-administered questionnaires, and hospital and ambulatory medical records. We obtained child race/ethnicity data from maternal questionnaires administered when the child was 3 years old. To describe their child's race or ethnicity, mothers were asked to choose one or more of the following categories: Hispanic or Latina, white or Caucasian, black or African American, Asian or Pacific Islander, American Indian or Alaskan Native, and other (specify). For the participants who chose the "other" race/ethnicity, we compared the specified responses to US census definitions for the other 5 race and ethnicities and reclassified them where appropriate. If maternal report of child race/ethnicity was missing, we used maternal race/ethnicity reported during the first trimester of pregnancy. For this analysis, we grouped race/ethnicity into three categories: white or Caucasian, black or African American, and other. We used data reported by mothers at study enrollment for household income and to calculate maternal pre-pregnancy BMI and paternal BMI. We used data collected at age 2 regarding child physical activity level, weekly hours spent watching TV, weekly hours spent with another caregiver, and daily hours of sleep. To calculate BMI at age 2 years, we obtained clinical measurements performed at well-child visits between the ages of 23 to 29 months. We calculated age- and sex-specific BMI z-scores using US national reference data (29). For 157 participants without clinical height measurements at age 2, we used heights reported by mothers on the 2-year questionnaire, in response to the question: "At your child's 2-year pediatric visit (2 year-old check-up), about how long was your child in inches?" When we excluded from our analyses the 157 participants with parentally-reported height measurements at age 2, our results did not materially change; therefore, we included these 157 participants in our final analyses.

Statistical Methods

To assess associations between milk intake and adiposity, we used separate regression models for each of 3 milk types, defined by fat content: whole milk, 2%, and 1% / skim milk. For each milk type, we used linear and logistic regression models to examine unadjusted and multivariable associations of milk intake at age 2 with BMI z-score and overweight at age 3. Multivariable Model 1 included child age, sex, race/ethnicity, energy intake, non-dairy beverage intake, and TV viewing; maternal BMI and education; and paternal BMI. We examined possible reverse causality in two ways: by adjustment for 2-year BMI z-score in multivariable Model 2, and by repeating our analyses among participants with a normal 2-year BMI, defined as a BMI from the 5th to < 85th percentiles. We excluded from our final models potential confounders that did not change our effect estimates, including child fiber intake, hours spent with another caregiver, daily hours of sleep, height, and physical activity level.

In separate models, we examined associations of total daily milk and dairy intakes at age 2 with outcomes at age 3. We conducted all data analyses using SAS version 9.1 (SAS Institute Inc., Cary, NC, USA).

Results

At age 2 years, the mean total milk intake was 2.6 (SD 1.2) servings per day, and mean total dairy intake was 4.3 (SD 1.5) servings per day. Of the 852 children, 452 (53.1%) predominantly drank whole milk, 226 (26.5%) drank 2% milk, and 174 (20.4%) drank 1%/skim milk. At age 3, 222 (26.1%) had a BMI $\geq$ 85th percentile and 76 children (8.9%) had a BMI $\geq$ 95th percentile. Among 113 children at age 2 with BMI $\geq$ 85th percentile, 81 (72%) had a BMI $\geq$ the 85th percentile at age 3. At age 3, weight-for-age z-score was 0.49 units (64th percentile, weight-for-age), a change from a mean weight-for-age z-score of 0.21 units (56th percentile, weight-for-age) at age 2. Mean height-for-age z-score at age 3 was 0.27 units (58th percentile, height-for-age), a change from a mean height-for-age z-score of 0.68 units (68th percentile, height-for-age) at age 2.

Participant characteristics by type of milk intake are shown in Table 1. Among whole milk drinkers, 34% were of non-white race/ethnicity, compared with 20% and 13% of 2% and 1%/skim milk drinkers respectively. Mean birth weight was lowest among whole milk drinkers (3435 g, compared with 3552 g and 3590 g for 2% and skim/1% drinkers respectively). Mean BMI, BMI z-score, and % overweight at both ages 2 and 3 were lowest in the whole milk group, and highest in the 1%/skim milk group. Mean child 3-year height was slightly higher in the 1%/skim milk group (97.9 cm) compared with the 2% (97.3 cm) and whole milk (96.8 cm) groups. Mean energy intake was higher for whole milk drinkers than for the other milk groups. Mean calcium intake was 1069 g in the whole milk group, compared with 1171 g/day in the 1%/skim group. Mean fiber intake was slightly higher in the 1%/skim milk group (13.3 g per day) than in the 2% (12.6 g per day) and whole milk (12.2 g per day) groups. Other demographic characteristics were similar among the three groups.

Table 2 shows adiposity outcomes at age 3 years by type and quantity of milk intake at age 2 years, unadjusted for covariates. In unadjusted analyses among whole milk drinkers, mean BMI z-score and the proportion of overweight children appeared to be lower for children who drank 2 or more servings per day, compared with those who drank fewer servings. Among 2% milk drinkers, there was no clear pattern of mean BMI z-score across categories of milk intake, but the proportion of overweight children was higher among children with greater milk intake, ranging from 21.7% for those drinking less than 1 serving per day, to 37.5% among children drinking 5 or more servings. Among 1%/skim milk drinkers, mean BMI z-score was higher across increasing categories of milk intake (0.42 vs. 0.74 units for <1 vs. >5 milk servings per day).

Unadjusted and multivariable regression models using milk intake as a continuous variable are presented in Tables 3 and 4. In unadjusted analyses among whole and 2% milk drinkers, we did not detect an association between 2-year milk intake and 3-year BMI z-score (Table 3). After adjustment for covariates including BMI z-score at age 2, whole milk intake at age 2 was associated with a modest decrease in 3-year BMI z-score among whole milk drinkers (−0.09 units per serving, 95%CI −0.16, −0.01), with a similar trend among 2% milk drinkers (−0.08 units, 95%CI −0.17, 0.01). Among 1%/skim milk drinkers, the unadjusted effect estimate for each milk serving at age 2 was a 0.13 unit (95%CI −0.01, 0.26, $p=0.06$) increment in BMI z-score at age 3; adjustment for covariates including 2-year BMI z-score rendered this association nearly null (0.05 units, 95%CI −0.06, 0.16).

To further examine possible reverse causality, we performed analyses restricting the study sample to 656 children who were not overweight at age 2 (BMI 5th to < 85th percentile for age and sex). In these analyses, we found no association between milk intake at age 2 and BMI z-score at age 3 (Table 3, Model 3). After adjustment for covariates, the increment in BMI z-score at age 3 years for each daily milk serving at age 2 was −0.05 units (95% CI −0.13, 0.02) for whole milk, −0.08 units (95% CI −0.17, 0.02) for 2% milk, and 0.00 units (95% CI −0.14, 0.14) for 1%/skim milk.

We found no association between milk intake at age 2 and incident overweight at age 3 (Table 4), regardless of type of milk intake. After adjustment for covariates (Model 3), the odds of incident overweight at age 3 for each daily milk serving at age 2 were 1.04 (95% CI 0.74, 1.44) for whole milk, 0.91 (95% CI 0.62, 1.34) for 2% milk, and 0.95 (95% CI 0.58, 1.55) for 1%/skim milk.

Neither total milk nor total dairy intake at age 2 was associated with BMI z-score or incident overweight at age 3. After adjustment for covariates (Model 3), the increment in BMI z-score at age 3 years for each daily milk serving at age 2 was −0.05 units (95% CI −0.10, 0.00). The odds of incident overweight at age 3 (Model 3) per daily total milk serving at age 2 was 1.01 (95% CI 0.76, 1.15). After adjustment for covariates (Model 3), the increment in BMI z-score at age 3 per daily serving of all dairy products at age 2 was −0.04 units (95% CI −0.08, 0.01). The odds of incident overweight at age 3 (Model 3) per daily total dairy serving at age 2 was 1.01 (95% CI 0.83, 1.23).

Discussion

In this prospective cohort analysis, we found that cow's milk intake at age 2, whether full- or low-fat, was not associated with incident overweight at age 3 years. Intake of total dairy products at age 2 was not associated with incident overweight or BMI z-score at age 3. We did find that higher intake of whole milk at age 2 was associated with a modest −0.09 unit decrement in BMI z-score at age 3, after controlling for energy intake, 2-year BMI z-score, and other covariates. However, when we restricted this analysis to children with a normal BMI (5th to < 85th percentile for age) at age 2, this association became null. Thus, among children with a normal BMI at age 2, higher intake of whole milk was not associated with lower adiposity at age 3. We did not have enough overweight subjects at age 2 to examine the effects of milk intake within that group alone.

Few studies of dairy intake and adiposity have focused on the preschool age group (11, 13, 14). Although adiposity in early childhood does not predict adult adiposity as well as does adiposity in adolescence (32), early childhood obesity is itself associated with serious psychosocial and medical consequences (3, 33), and thus is an important target for prevention. A recent cross-sectional analysis of 2- to 5-year-old children in NHANES reported that neither quantity nor type of milk consumed was associated with BMI, but results by type of milk were not shown (14). Our prospective study design enabled assessment of the relationships of both quantity and type of milk consumed with risk of incident overweight. The few previous longitudinal studies have found conflicting results. Our findings are consistent with a longitudinal study of 1,345 low-income 2- to 5-year-old children that reported no association between milk or other beverage intakes and annual change in child BMI (13). Our findings differed from results of two smaller longitudinal studies. A longitudinal study of 54 children found that higher intakes of calcium and dairy products were associated with lower body fat at age 70 months (11). The analyses in that study adjusted only for child BMI at age 60 months, whereas our study adjusted for energy intake, parental BMI, child attained BMI, and several other potential confounders. Energy intake has been shown to be directly associated with milk intake (14, 30), and to attenuate

associations between milk intake and adiposity (16). Another study of 99 children examined the relationship between dairy intake at 3–6 years of age with repeated BMI measures at age 10 to 13 years (12). Children in the lowest tertile of dairy intake during preschool had a mean adolescent BMI of 21.1 kg/m², compared with values of 18.8 kg/m² and 19.3 kg/m² in the middle and highest tertile of dairy intake (12). However, the analyses of BMI in that study did not adjust for milk or dairy intake during adolescence, which is inversely associated with adiposity in some (31) but not all (16) studies. Follow-up of our study participants at older ages could address whether dairy intake during the preschool years is inversely associated with adiposity in adolescence.

Our findings support data from both observational studies and intervention trials in older children that have not found an association between dairy intake and adiposity (15, 16, 30, 34–38). For example, four randomized trials of adolescent girls that compared ≥ 1 year of milk or dairy supplementation with usual diet found no difference between groups in mean height, weight, lean body mass, or fat mass (35–37, 39). One of these studies, a 2-year milk supplementation trial of 757 Chinese girls, reported that milk supplementation was associated with a greater percentage increase in height and weight at the end of the trial, but there was no difference in attained height and weight or BMI at either the trial end (38) or at 3 years after withdrawal of milk supplementation (39). One exception to the null results is a cross-sectional observational study of 884 Italian children aged 3–11 years that reported an inverse association between frequency of milk consumption and BMI in children (10); however, this study was limited by the lack of adjustment for energy intake and pubertal status.

The potential mechanism underlying any relationship between milk or dairy consumption and adiposity is unclear. Some data suggest that the replacement of milk intake with sugar sweetened beverages has contributed to the rise in the prevalence of childhood obesity (40, 41). In our models, adjustment for intake of non-dairy beverages, which included sugar-sweetened beverages, made no difference to the risk of overweight. In our final multivariable model, which contained both non-dairy beverage and energy intake, non-dairy beverage intake was not independently associated with adiposity (data not shown).

Zemel (42) has hypothesized that components of dairy, such as calcium, vitamin D or protein may promote lower adiposity. We did not find an association between calcium, vitamin D or protein intake at age 2 and adiposity at age 3 (data not shown). Milk also contains many bovine hormones and growth factors identical to those found in humans (43). While many hormones are destroyed by digestion or first-pass metabolism, those that are absorbed intact may have potential effects on growth and metabolism (43). Cow's milk consumption has been associated with increased circulating levels of both insulin-like growth factor-1 (37, 43) and growth hormone (43) in children. Additional research is required to determine whether the hormone content in milk affects child adiposity.

The strengths of our study include prospective dietary data collection; research-standard anthropometric outcome measures; and detailed information regarding potential biological, social and environmental confounders. Our study has some limitations. Some misclassification of the exposure may also have occurred from using a single estimate of intake over a one-month period at age 2 as a proxy for habitual intake. In addition, the reliance on maternal report to estimate dietary intake likely resulted in some misclassification of the exposure. For example, mothers of children frequently cared for by an alternate caregiver may have more difficulty assessing diet; adjustment for hours spent with an alternate caregiver made no difference to our estimates. Systematic underreporting of energy intake by mothers of overweight children would likely have biased the association between dairy and adiposity away from the null, as shown previously in a study of 11 year-

old girls (44). Selection bias could have occurred if overweight children were preferentially lost to follow-up; however, mean BMI and dairy intakes were similar among analyzed children and those lost to follow-up. Finally, the generalizability of our study may be limited because of relatively high levels of maternal education and household income in our cohort; however, the 26.1% prevalence of child overweight at age 3 was similar to nationally representative data for 2003–2004 (45).

The AAP Committee on Nutrition has recommended that children aged 1 to 3 years drink the equivalent of 2 to 3 cups of milk daily, to meet calcium requirements for optimal bone health (46). Similar quantities are recommended by the U.S. Department of Agriculture (21), and the AHA (3). The AAP and AHA have suggested that children age 2 and older drinking whole milk should be transitioned to 1% or skim milk, as part of a population-based approach to prevent children with a normal BMI from becoming overweight (3, 17). Our study suggests that a change to low-fat milk at age 2 may not be effective in preventing the development of overweight at age 3 years. However, given the beneficial effects of milk intake on bone health, and the potential for dyslipidemia associated with saturated fat intake, we see no reason to alter the AAP or AHA guidelines. In addition, transitioning children to 1% or skim milk at age 2 may help to establish a dietary preference for low-fat milk intake that persists into adulthood, when reduced saturated fat consumption is recommended to help prevent cardiovascular disease (47).

Conclusions

Our findings suggest that a higher intake of milk, whether full- or low-fat, is unlikely to prevent the development of obesity among preschool-age children. Milk intake, however, may offer other health benefits, including provision of calcium, vitamin D and other nutrients.

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Abbreviations

BMI	body mass index
AAP	American Academy of Pediatrics
AHA	American Heart Association

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Table 1

Characteristics of 852 children in Project Viva, by predominant type of milk intake at age 2 years

	Milk type			p-value
	Whole n=452	2% n=226	1%/skim n=174	
Demographic Characteristics	Mean or %			
Child race/ethnicity, %				<0.001
White	65.7	80.5	86.8	
Black	11.5	7.5	5.2	
Other	22.8	12.0	8.1	
Birth weight, g	3435	3552	3590	0.002
Maternal BMI, kg/m ²	24.2	24.3	24.4	0.95
Paternal BMI, kg/m ²	26.2	26.6	27.0	0.05
% mothers with college degree	73.3	79.7	77.0	0.18
Yearly household income, %				0.11
< \$40,000	10.4	10.0	7.6	
\$40,000 to \$70,000	24.1	15.6	20.9	
>\$70,000	65.5	74.4	71.5	
Child Characteristics at age 2				
BMI, kg/m ²	16.2	16.5	16.7	0.0004
BMI z-score, units	−0.33	−0.09	0.05	0.0002
% overweight (BMI ≥ 85 th percentile)	9.7	13.2	22.4	0.0002
Height, cm	88.2	88.7	88.8	0.07
TV viewing, hours per week	1.4	1.4	1.3	0.26
Time spent with other caregivers, hours per week	3.5	3.5	2.7	0.002
Non-dairy beverage intake, servings per day	2.1	2.1	2.1	0.97
Fiber intake, g per day	12.2	12.6	13.3	0.002
Energy intake, kcal	1604	1496	1465	<0.0001
Milk intake, servings per day	2.7	2.6	2.6	0.67
Total dairy intake, servings per day	4.3	4.2	4.4	0.55
Low fat dairy intake, servings per day	0.6	0.5	3.2	<0.0001
Calcium intake from foods, mg per day	1069	1115	1171	<0.0001
Vitamin D intake from foods, IU per day	255	262	270	0.22
Child Characteristics at age 3				
BMI, kg/m ²	16.3	16.6	16.7	0.002
BMI z-score, units	0.31	0.54	0.62	0.001
% overweight (BMI ≥ 85 th percentile)	21.5	30.1	32.8	0.004
Height, cm	96.8	97.3	97.9	0.01

All nutrients reported are energy-adjusted, using the nutrient residual method. BMI, Body mass Index. P-values for categorical characteristics are from Chi-square and ANOVA for continuous characteristics.

Table 2

Adiposity outcomes at age 3 years by category of milk intake at age 2 years among 852 participants from Project Viva

	Milk category at age 2 years, servings per day				P for trend
	>0 to <1	1 to <2	2 to <5	>5	
Mean BMI z-score at age 3 years					
Whole milk (n=452)	0.49	0.46	0.25	0.34	0.15
2% milk (n=226)	0.45	0.50	0.57	0.47	0.66
1% / Skim (n=174)	0.42	0.27	0.71	0.74	0.09
% overweight (BMI ≥ 85 th percentile) at age 3 years					
Whole milk (n=452)	23.3	26.2	20.1	20.0	0.35
2% milk (n=226)	21.7	27.3	31.2	37.5	0.24
1% / Skim (n=174)	23.5	26.9	35.3	33.3	0.30

Table 3

Increment in BMI z-score at age 3 years associated with each additional serving per day of milk intake at age 2 years, using separate linear regression models for each milk type, among 852 participants from Project Viva

	Increment in child BMI z-score (95% CI) at age 3 years							
	Model 0		Model 1		Model 2		Model 3	
Milk intake, servings per day	Beta (95% CI)	p-value	Beta (95% CI)	p-value	Beta (95% CI)	p-value	Beta (95% CI)	p-value
Whole milk	−0.05 (−0.13, 0.02)	0.16	−0.09 (−0.17, 0.00)	0.05	−0.09 (−0.16, −0.01)	0.02	−0.05 (−0.13, 0.02)	0.18
2% milk	0.02 (−0.08, 0.11)	0.75	−0.00 (−0.11, 0.11)	0.98	−0.08 (−0.17, 0.01)	0.07	−0.08 (−0.17, 0.02)	0.13
1% / Skim milk	0.13 (−0.01, 0.26)	0.06	0.10 (−0.03, 0.24)	0.14	0.05 (−0.06, 0.16)	0.39	0.00 (−0.14, 0.14)	0.96

Model 0 unadjusted for covariates. Model 1 adjusted for child age, sex, race/ethnicity, energy intake, non-dairy beverage intake (including juice), and TV viewing; maternal education and BMI, and paternal BMI. Model 2 adjusted for Model 1 covariates and BMI z-score at age 2 years. Model 3 adjusted for Model 2 covariates, but analyses restricted to subjects (n=656) with a BMI in the 5th to <85th percentile at age 2 years.

Table 4

Odds of incident overweight (BMI $\geq$ 85th percentile) at age 3 years associated with each additional serving of milk intake at age 2 years, using separate logistic regression models for each milk type, among 645 participants from Project Viva

	OR for overweight (95% CI) at age 3 years					
	Model 0		Model 1		Model 2	
Milk intake, servings per day	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Whole milk	0.98 (0.78, 1.23)	0.83	1.13 (0.84, 1.51)	0.42	1.04 (0.74, 1.44)	0.84
2% milk	1.12 (0.84, 1.51)	0.44	1.03 (0.73, 1.44)	0.89	0.91 (0.62, 1.34)	0.63
1% / Skim milk	1.03 (0.70, 1.50)	0.89	0.94 (0.59, 1.49)	0.78	0.95 (0.58, 1.55)	0.83

Analyses restricted to 645 participants with a BMI in the 5th to < 85th percentile at age 2 years and $\geq$ 5th percentile at age 3 years. Model 0 unadjusted for covariates. Model 1 adjusted for child age, sex, race/ethnicity, energy intake, non-dairy beverage intake (including juice), and TV viewing; maternal education and BMI, and paternal BMI. Model 2 adjusted for Model 1 covariates and BMI z-score at age 2 years.