Milk intake is inversely related to body mass index and body fat in girls

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Abstract
Dairy foods comprise a range of products with varying nutritional content. The intake of dairy products (DPs) has been shown to have beneficial effects on body weight and body fat. This study aimed to examine the independent association between DP intake, body mass index (BMI), and percentage body fat (%BF) in adolescents. A cross-sectional, school-based study was conducted with 1,001 adolescents (418 boys), ages 15–18 years, from the Azorean Archipelago, Portugal. Anthropometric measurements were recorded (weight and height), and %BF was assessed using bioelectric impedance analysis. Adolescent food intake was measured using a self-administered, semiquantitative food frequency questionnaire. Data were analyzed separately for girls and boys, and separate multiple linear regression analysis was used to estimate the association between total DP, milk, yogurt, and cheese intake, BMI, and %BF, adjusting for potential confounders. For boys and girls, respectively, total DP consumption was 2.6 ± 1.9 and 2.9 ± 2.5 servings/day ($P = 0.004$), while milk consumption was 1.7 ± 1.4 and 2.0 ± 1.7 servings/day ($P = 0.001$), yogurt consumption was 0.5 ± 0.6 and 0.4 ± 0.7 servings/day ($P = 0.247$), and cheese consumption was 0.4 ± 0.6 and 0.5 ± 0.8 servings/day ($P = 0.081$). After adjusting for age, birth weight, energy intake, protein, total fat, sugar, dietary fiber, total calcium intake, low-energy reporters, parental education, pubertal stage, and physical activity, only milk intake was negatively associated with BMI and %BF in girls (respectively, girls: $\beta = -0.167$, $P = 0.013$; boys: $\beta = -0.019$, $P = 0.824$ and girls: $\beta = -0.143$, $P = 0.030$; boys: $\beta = -0.051$, $P = 0.548$). Conclusion: We found an inverse association between milk intake and both BMI and %BF only in girls.
Keywords
Dairy products; Milk Body; mass index; Body; fat; Adolescents

Introduction

The increasing prevalence of overweight and obesity among children and adolescents has been described in developed and developing countries alike [*60*]. In the European Union, the prevalence of childhood overweight and obesity is approximately 25 %, with Southern European countries showing the highest prevalence rates [*25*, *57*]. Indeed, in Portugal, 21.6 % of girls and 23.5 % of boys, ages 10 to 18 years, are overweight or obese [*44*]. Furthermore, according to some studies, more than 60 % of overweight/obese adolescents tend be obese as adults [*19*, *39*]. Obesity also has profound public health implications, being associated with increased risk of such chronic conditions as diabetes and cardiovascular disease and with high health care costs [*34*].

Obesity is a complex, multifactorial disease; however, the primary cause is related to the energy imbalance that results from low physical activity (PA) and inadequate nutrition [*14*, *29*]. In recent years, increasing attention has been focused on the preventive effects of dairy product (DP) intake. However, there is conflicting evidence regarding the relationship between DP intake and obesity. Some observational studies of children and adolescents have reported a significant inverse relationship between dairy consumption and measures of body composition [*1*, *17*, *31*, *37*, *38*], while others have found no association [*2*, *23*, *36*]. Several mechanisms have been proposed to explain how DP intake influences fatness and body composition. Although calcium was mentioned as a principal bioactive component of DPs, with effects on adipocyte lipid metabolism, other constituents such as proteins (in particular, whey proteins) and their peptide derivatives may affect body weight by regulating food intake and appetite [*16*].

The purpose of this study was to examine the independent association between DP intake, body mass index (BMI), and percentage body fat (%BF) after taking into account dietary factors, physical activity level (PAL), and other potentially confounding variables in a sample of Portuguese adolescents.

Materials and methods

Sampling

Data for the present cross-sectional study were derived from a longitudinal school-based study—The Azorean Physical Activity and Health Study II, which aimed to evaluate PA, physical fitness, overweight/obesity prevalence, dietary intake, health-related quality of life, and related factors in 15- to 18-year-old adolescents. This study was carried out in six of the nine Azorean Islands (S. Miguel, Terceira, Faial, Pico, S. Jorge, and Graciosa), where 95 % of the Azorean population lives [*24*].

All participants in this study were informed of its goals, and the parent or guardian of each participant provided written informed consent. The study was approved by the Faculty of Sport, University of Porto and the Portuguese Foundation for Science and Technology Ethics Committee; it was conducted in accordance with the World Medical Association's Helsinki Declaration for Human Studies.

The population was selected by means of proportionate stratified random sampling, taking into account location (island) and number of students, by age and sex, in each school. The estimated number of subjects needed was 1,422, but in order to prevent information loss, data were collected for 1,515 adolescents. Some adolescents were not included in our analysis (n = 514) because information was missing on their dietary intake (n = 286), BMI (n = 15), %BF (n = 15), and birth weight (n = 198). This resulted in a collection of data for a total of 1,001 participants (418 boys). The subjects who were excluded from this study did not significantly differ from those who were included, with regard to age (16.2 ± 1.0 vs. 16.1 ± 1.0 years, P = 0.118), parental education (8.8 ± 4.4 vs. 9.2 ± 4.4 years, P = 0.219), gender (girls, 60.3 vs. 58.2 % and boys, 39.7 vs. 41.8 %, P = 0.471), and BMI (22.9 ± 4.1 vs. 22.9 ± 3.9 kg/m^2, P = 0.888). Finally, the sample was weighted, so as to balance it in accordance with the distribution of the Azorean population in schools and to guarantee the real representativeness of each group (age and gender).

Anthropometric measures

Body height and body weight were determined using standard anthropometric methods. Height was measured to the nearest millimeters in bare or stocking feet, with adolescents standing upright against a Holtain portable stadiometer (Crymych, Pembrokeshire, UK). Weight was measured to the nearest 0.10 kg, with participants lightly dressed (underwear and T-shirt) and with the use of a portable digital beam scale (Tanita Inner Scan BC 532, Tokyo, Japan).

BMI was calculated using the ratio of weight/height^2 (in kilograms per square meter). Subjects were classified as normal weight, overweight, or obese, according to age- and sex-specific cutoff points specified by the International Obesity Task Force [*10*, *11*]. Underweight subjects (2.8 %) were combined with normal weight subjects due to the fact that they represented a small proportion of the sample. %BF was assessed using bioelectric impedance analysis–BIA (Tanita Inner Scan BC 532, Tokyo, Japan).

Pubertal stage

To determine pubertal stage (which ranged from 1 to 5), each subject was asked to self-assess his/her stage of development of secondary sex characteristics. Breast development in girls and genital development in boys was evaluated according to criteria outlined by Tanner and Whitehouse [*50*].

Sociodemographic and lifestyle variables

Participants answered a questionnaire that assessed several sociodemographic and lifestyle variables.

Smoking

Participants were classified as nonsmokers, former smokers (individuals who had stopped smoking for at least 6 months), occasional smokers (individuals who smoked, on average, less than one cigarette a day), and current smokers (individuals who smoked at least one cigarette a day) [*59*]. Occasional smokers were recoded and combined with current smokers due to the fact that they represented a small proportion of the sample.

Parental education

For the present study, the highest level of parental education (measured by the number of school years completed) was used as a proxy measure of socioeconomic status. Participants were divided into three categories, reflecting divisions within the Portuguese educational system: mandatory or less (≤9 school years), secondary (10 to 12 school years), and college/university.

Dietary intake

Dietary intake was measured via a self-administered semiquantitative food frequency questionnaire (FFQ) that covered the previous 12 months and included 86 food item and beverage categories, validated for Portuguese adolescents [*41*]. This semiquantitative FFQ was designed in accordance with criteria laid out by Willett et al. [*58*] and adapted to include a variety of typical Portuguese food items. For each item, the questionnaire offered nine frequency response options, ranging from “never” to “six or more times per day,” and measured portion size and seasonality. Any foods not listed in the questionnaire could be listed by participants in a free-response section. Energy and nutritional intake were estimated with regard to respondents’ ratings of the frequency, portion, and seasonality of each item, using the software Food Processor Plus (ESHA Research Inc., Salem, OR, USA). This program uses nutritional information from the USA that has been adapted for use with typical Portuguese foods and beverages.

DPs were defined according to the new Portuguese food wheel guide [*42*]. The amounts of milk (whole, reduced-fat, and fat-free), yogurt, and cheese (cottage and cream cheese) that counted as single servings were considered to be 250 ml, 200 g, and 40 g, respectively.

Physical activity

PA was assessed via a self-report questionnaire that evaluated leisure times physical activities [*52*]. This questionnaire has been shown to have good test–retest reliability among Portuguese adolescents (intraclass correlation coefficient, 0.92–0.96) [*33*]. From this questionnaire, a summative index (range, 5–20) was derived. Participants whose scores were greater than 12.5 points were classified as active, while those whose scores were 12.5 points or less comprised the low-activity group.

Statistical analysis

Data were analyzed separately for girls and boys. The Kolmogorov–Smirnov test was used to assess the assumption of normality. Independent sample t test or Mann–Whitney test were performed to compare continuous variables between gender, and the chi-square test was used with categorical variables. In this report, descriptive analysis is presented in terms of means and standard deviations.

To access associations between DP and BMI and %BF, we performed separate regression linear models for each DP: total dairy, milk, yogurt, and cheese. For each DP, we adjusted linear regression model for age (in years), birth weight (in kilograms), energy intake (in kilocalories), total calcium intake (in milligrams), protein intake (in grams per kilogram of weight), sugar intake (in percent of energy), total fat intake (in percent of energy), pubertal stage, PAL, and parental education. Age, birth weight, and dietary variables were entered as continuous variables. Pubertal stage, PAL, and parental education were entered as dummy variables. Furthermore, we adjusted linear models by misreporting of energy intake that was estimated using the ratio between reported energy intake and predicted basal metabolic rate (EI/BMR) [*4*, *5*, *18*]. In this study, a mean PAL of 1.73 was assumed for female adolescents ages 15 to 17 years old, 1.75 for boys ages 15 to 17 years old, and 1.70 and 1.85 for girls and boys age 18 years old, respectively [*6*, *7*]. The thresholds that defined low-energy reporters (under-reporters) were 1.70 and 1.71 for girls and boys between 15 and 17 years old and 1.67 and 1.81 for girls and boys age 18 years. "Low-energy reporter" (a categorical variable) was included in the model as a confounding factor.

A P value of <0.05 was regarded as significant. All analyses were performed using PASW Statistic v.18 (SPSS, Chicago, IL, USA).

Results

Descriptive characteristics of the adolescents in the sample are shown in Table 1. The prevalence of overweight/obesity was 29.2 % in boys and 32.6 % in girls (P = 0.252). In our study, boys were more active than girls (respectively, 83.7 vs. 50.4 %, P < 0.001). No significant difference was seen in the BMI and birth weight of boys compared to girls (P > 0.05, for all). In this study, for Tanner stages, 0.7 % of girls were reported to be in stage 2, 18.9 % in stage 3, 58.7 % in stage 4, and 21.7 % in stage 5. Similar figures for boys were as follows: 0.2 % in stage 1, 1.2 % in stage 2, 11.2 % in stage 3, 57.7 % in stage 4, and 30.2 % in stage 5.

Table 1 Characteristics of the study sample, by gender

	Girls (*n*=583)	Boys (*n*=418)	*P* value
Age[a,b] (years)	16.1±0.96	16.1±0.99	0.524
Weight[a,c] (kg)	58.9±10.9	67.8±12.9	<0.001
Height[a,c] (m)	1.60±0.06	1.72±0.07	<0.001
BMI[a,c] (kg/m^2)	22.9±3.8	22.9±4.0	0.983
BMI[d] (%)			0.252
Normal	67.4	70.8	
Overweight/obese	32.6	69.1	
Body fat[a] (%)	26.3±6.7	14.7±6.8	<0.001
Birth weight[a,c] (kg)	3.253±0.564	3.302±0.607	0.191
Parental education[d] (%)			0.518
Mandatory or less	50.2	46.5	
Secondary	34.8	37.6	
College/university	15.0	15.9	
Smoking status[d] (%)			0.564
Nonsmoker	88.3	86.1	
Former smoker	5.0	6.2	
Occasional/current smoker	6.7	7.7	
PA[d] (%)			<0.001
Low-active (≤12.5 points)	49.6	16.3	
Active (>12.5 points)	50.4	83.7	

BMI body mass index

[a] Mean±standard deviation

[b] Between-gender analysis by Mann–Whitney test

[c] Analysis by Student's *t* test for continuous variables

[d] Analysis by chi-square test for categorical variables

Energy intake and dietary characteristics for each gender are presented in Table 2. Boys' diets were higher in energy, total fat, total dairy, milk, and calcium intake and lower in carbohydrates and dietary fiber, compared to girls ($P < 0.05$, for all). There was no significant difference between boys and girls with regard to protein, sugar, yogurt, and cheese intake.

Table 2 Dietary characteristics of the study sample, by gender

	Girls (n=583)	Boys (n=418)	P value
Energy intake[a] (kcal)	2,273.9± 936.1	2,527.5± 1,078.6	<0.001
Protein[a] (% of energy)	18.0±3.7	18.2±4.0	0.578
Protein[b] (g/kg body weight)	2.0±1.6	2.0±1.7	0.824
Carbohydrates[b] (% of energy)	50.9±8.4	49.3±8.5	0.001
Sugar[b,c] (% of energy)	25.5±7.9	24.9±8.1	0.234
Total fat[b] (% of energy)	32.5±5.9	33.3±5.5	0.037
Dietary fiber[d] (g/1,000 kcal)	10.5±3.8	9.3±3.2	<0.001
Total calcium intake[d] (mg)	1166.0± 616.7	1260.6±707.9	<0.001
Total dairy[b] (servings/day)	2.6±1.9	2.9±2.5	0.004
Milk[b] (servings/day)	1.7±1.4	2.0±1.7	0.001
Yogurt[b] (servings/day)	0.5±0.6	0.4±0.7	0.247
Cheese[b] (servings/day)	0.5±0.6	0.5±0.8	0.081

Data are presented as the mean±standard deviation

[a] Between-gender analysis by Mann–Whitney test

[b] Between-gender analysis by Student's t test

[c] Sugars refer to all monosaccharides and disaccharides added to foods by the manufacturer, cook, or consumer, plus sugar naturally present in honey, syrups, and fruit juices

The results of the linear regression analyses used to estimate the association between DP intake and both BMI and %BF are presented in Table 3. After adjusting for age, birth weight, pubertal stage, dietary factors, parental education, and PAL (model 2), linear regression showed that milk intake was negatively and significantly associated with BMI and %BF only in girls (respectively, girls: β = −0.167, P = 0.013; boys: β = −0.019, P = 0.824 and girls: β = −0.143, P = 0.030; boys: β = −0.051, P = 0.548).

Table 3 Association between DP intake and both BMI and %BF, using separate linear regression models for total dairy, milk, yogurt, and cheese intakes (servings/day), by gender

	BMI (kg/m²)						BF (%)					
	Girls (n=583)			Boys (n=418)			Girls (n=583)			Boys (n=418)		
	β	95 % CI	P value	β	95 % CI	P value	β	95 % CI	P value	β	95 % CI	P value
Model 1												
Total dairy	−0.065	−0.245, 0.004	0.057	−0.008	−0.150, 0.124	0.854	−0.055	−0.409, 0.041	0.109	0.008	−0.213, 0.262	0.837
Milk	−0.092	−0.406, −0.065	0.007	−0.033	−0.272, 0.114	0.421	−0.074	−0.651, −0.033	0.030	−0.025	−0.436, 0.232	0.547
Yogurt	−0.002	−0.416. 0.395	0.960	−0.023	−0.659, 0.371	0.582	−0.014	−0.881, 0.581	0.687	0.018	−1.087, 0.695	0.666
Cheese	−0.004	−0.511, 0.465	0.926	0.010	−0.449, 0.553	0.858	0.010	−0.567, 0.776	0.760	0.090	0.083, 1.467	0.028
Model 2												
Total dairy	−0.213	−0.913, 0.100	0.113	−0.021	−0.512, 0.444	0.890	−0.171	−1.498, 0.302	0.192	0.082	−0.607, 1.063	0.591
Milk	−0.167	−0.770, −0.089	0.013	−0.019	−0.421, 0.335	0.824	−0.143	−1.245, −0.062	0.030	−0.051	−0.862, 0.458	0.548
Yogurt	0.056	−0.246, 0.976	0.241	0.042	−0.437, 0.952	0.467	0.035	−0.654, 1.470	0.451	0.026	−0.935, 1.493	0.652
Cheese	0.055	−0.206, 0.870	0.226	−0.029	−0.772, 0.476	0.641	0.062	−0.274, 1.594	0.166	0.080	−0.374, 1.803	0.198

Model 1 is the unadjusted model. Model 2 is adjusted for age (years), birth weight (kilograms), energy intake (kilocalories), protein intake (grams per kilogram body weight), total fat intake (percent of energy), sugar intake (percent of energy), total calcium intake (milligrams), parental education, low-energy reporters, pubertal stage, and PAL

BMI body mass index, *BF* body fat, *CI* confidence interval

Discussion

The present study explored the relationship between DP (total, milk, yogurt, and cheese) intake and BMI and %BF among adolescents. The results suggested that intake of milk was negatively associated with BMI and %BF only in girls. The associations identified were not confounded by other lifestyle factors or dietary variables, particularly calcium intake.

The literature related to DP intake, especially different types of dairy (such as milk, yogurt, and cheese) and overweight/obesity in adolescents is limited and conflicting. Data from cross-sectional epidemiological studies support the hypothesis that milk and/or dairy consumption is associated with lower body fat and BMI in children and adolescents [*1*, *17*, *31*, *36*, *37*]. Moore et al. [*31*] found that adolescents in the lowest category of total dairy intake had higher BMIs and more subcutaneous fat in their subscapular and triceps skinfolds. However, in their analysis, this association was not explored with different types of DP, as were the associations in our study. In addition, Barba et al. [*1*] found a significant inverse association between frequency of milk consumption and BMI in children. In adults, a cross-sectional survey carried out with a large sample of the Portuguese population showed that milk intake was inversely related to BMI in men and premenopausal women [*30*].

Nevertheless, prospective studies have yielded inconsistent results. Johnson et al. [*26*] found that each serving of milk at 5 and 7 years of age was associated with a decrease in %BF at 9 years of age. A recent study also found that higher intake of whole milk at 2 years of age was associated with a decrement in BMI z-score at 3 years of age; however, when analysis was restricted to children with normal BMI (5th to <85th percentile for age), this association disappeared [*23*]. One study found that children who reported higher total milk intake experienced larger BMI gains, although this appeared to be mediated by energy intake [*2*]. However, this association was stronger for skim and 1 % milk intake than for whole or 2 % milk. In our study, we did not separate high-fat milk from low-fat milk, but we did control for the effects of fat intake.

Controlled intervention studies have also examined the relationship between dairy and/or milk consumption and fatness or body weight. Chan et al. [*9*] reported that, when 50 children with low calcium intake (<800 mg daily) were allocated to either a dairy-supplemented group or a control group for 6 months, children in the control group gained body fat during the study, while children in the dairy group had no significant change in body fat. On the other hand, in a randomized controlled trial that evaluated whether high milk (4 servings/day) consumption leads to greater weight loss in overweight children than low milk (1 serving/day) consumption during the course of a 16-week healthy-eating diet, St-Onge et al. [*48*] observed no significant differences between the groups in weight loss. Numerous intervention trials have been conducted in adults, and their findings are also conflicting. Of 11 studies without energy restrictions that were reviewed by Dougkas et al. [*16*], 7 reported no significant difference in weight or body fat with milk supplementation or dairy treatment, 2 reported weight gain, and 2 found higher body fat loss in groups with dairy-rich diets.

Our results showed no significant association between yogurt and cheese intake and BMI and %BF. In the literature, the majority of studies have examined milk intake, while only a few have used other dairy foods as the exposure variable. The weight of evidence suggests that milk intake is more likely to be associated with beneficial weight and body fat outcome [*1*, *26*, *28*, *38*, *48*], while a very small number of studies, conducted only with adults, have shown the beneficial effects of such other DPs as yogurt and cheese [*3*, *46*, *56*].

Discrepancies in the findings of existing studies could be due to differences in study design, methods for assessing diet and body composition (dual-energy X-ray absorptiometry [DXA] vs. BIA), treatment of milk and dairy intake (servings/day, grams, consumers vs. nonconsumers), adjustment of potentially confounding factors during analysis and/or due to the complexity of interactions between nutrients in humans [*21*, *36*]. The inclusion of misreported dietary intakes may also lead to inconsistent findings; indeed, such misreporting is common in dietary studies [*8*, *20*, *22*]. Huang et al. [*20*] noted that underreporting is a major problem with adolescents, whereas overreporting is a significant problem with children under 12 years of age. In addition, Ventura et al. [*55*] found that under-reporters were selective in their underreporting, reporting fewer servings from the grain, dairy, sweets, and fats groups. In light of these findings, we did control for the effects of underreporting in our study.

In the present study, we found a significant and inverse association between milk intake and BMI and %BF only in girls. Another study has also found the same association [*38*]. Overall, the evidence suggests that gender may influence body composition, with girls having greater %BF [*12*, *51*]. We cannot exclude the hypothesis that the interaction between DPs (and its components) and weight and body fat may differ across different thresholds of %BF [*32*]. For instance, Vergnaud et al. [*56*] reported that milk and yogurt intake were protective against 6-year changes in body weight only in adults who were initially overweight. In line with this, dos Santos et al. [*15*] found a negative relationship between calcium intake and body trunk fat only in obese adolescents. However, in our study, DPs (total, milk, yogurt, and cheese) consumption was not associated with %BF when normal weight and overweight/obese adolescents were considered separately (data not shown). Furthermore, the dynamic metabolic changes that occur during growth and puberty may complicate the interaction between DPs and weight and body fat [*21*]. Nevertheless, this study addressed sexual maturation, controlling for the extent of biological growth and the individual nutritional needs of adolescents [*47*]. Although no inverse association was found in boys, consumption of DPs did not increase the probability of being obese, as other studies had reported [*2*, *23*, *36*]. It is noteworthy that DPs are widely recognized as good sources of nutrients in the adolescents' diet as they are important to in the promotion of bone and overall health [*54*].

Several mechanisms were proposed to explain how DP might influence energy balance and body composition. DPs are an important source of calcium, which appears to play a significant role in the regulation of energy metabolism by reduction of lipogenesis and enhancement of lipolysis on adipocyte, increasing both fecal fat excretion and fat oxidation [*16*]. In the present study, however, we found a significant association only for milk consumption, even after adjusting for calcium, and other plausible mechanisms should be taken into account. Recently, it has been suggested that milk is rich in bioactive peptides (whereas other DPs contain little or no such substances) that may also act independently of calcium to modulate body fat accumulation [*40*, *45*]. Milk bioactive peptides (casokinins and lactokinins) have been shown to inhibit angiotensin-converting enzyme and, consequently, to inhibit the production of angiotensin II hormone, which has been reported to upregulate adipocyte lipogenesis, resulting in the inhibition of fat deposition [*61*]. In addition, Strazzullo et al. [*49*] showed, in a prospective study with adult men, that carriers of the DD variant of the angiotensin-converting enzyme gene (associated with higher plasma levels of angiotensin-converting enzyme activity) reported a higher incidence of overweight. Milk, especially whey protein, also stimulates insulin secretion that may directly affect food intake regulation by suppressing appetite, independent of the effects of dietary Ca [*27*, *35*]. Yet, we could not exclude the possibility that milk consumption might be a marker of other healthier lifestyle traits that protect against overweight/obesity and that were not explored in the present study. A positive health relationship between milk intake and education may reflect a growing concern about health in the higher socioeconomic groups. However, the association between milk consumption and socioeconomic position is sometimes contradictory [*13*, *43*]; therefore, our results were adjusted for parental education.

Our study has some limitations. Its cross-sectional design prevents the drawing of any conclusions related to cause and effect. The measures of %BF used in this study are also less accurate than more sophisticated measurements (i.e., DXA, computerized tomography, magnetic resonance imaging). However, BIA has been used as a simple, reliable, valid, inexpensive, portable, and quick tool to assess %BF with large samples, and BIA has also been better correlated than anthropometric indices (BMI and weight-for-height index) in estimations of %BF [*53*].

In conclusion, we found an inverse association between milk intake and BMI and %BF in girls. Further studies are needed on the roles that diet and healthy lifestyles play in the interaction between DPs and body composition. Our findings may also encourage further research on the effects of a threshold BF and sex hormone effects explaining the difference between girls and boys as well as the influence of additional dairy components, such as whey proteins.

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