Association between dairy product intake and abdominal obesity in Azorean adolescents

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BACKGROUND: Some studies have reported an inverse association between dairy product (DP) consumption and weight or fat mass loss.
OBJECTIVES: The objective of our study was to assess the association between DP intake and abdominal obesity (AO) among Azorean adolescents.
SUBJECTS/METHODS: This study was a cross-sectional analysis. A total of 903 adolescents (370 boys) aged 15--16 years was evaluated. Anthropometric measurements were collected (weight, height and waist circumference (WC)) and McCarthy's cut-points were used to categorize WC. AO was defined when WC was X90th percentile. Adolescent food intake was assessed using a self-administered semiquantitative food frequency questionnaire and DP intake was categorized in o2 and X2 servings/day. Data were analyzed separately for girls and boys, and logistical regression was used to estimate the association between DPs and AO adjusting for potential confounders.
RESULTS: The prevalence of AO was 54.9% (boys: 32.1% and girls: 70.7%, Po0.001). For boys and girls, DP consumption was 2.3±1.9 and 2.1±1.6 servings/day (P¼0.185), respectively. In both genders, the proportion of adolescents with WC o90th percentile was higher among individuals who reported a dairy intake of X2 servings/day compared with those with an intake o2 servings/day (boys: 71% vs 65% and girls: 36% vs 24%, Po0.05). After adjustments for confounders, two or more DP servings per day were a negative predictor of AO (odds ratio, 0.217; 95% confidence interval, 0.075 -- 0.633) only in boys.
CONCLUSION: We found a protective association between DP intake and AO only in boys.

Keywords: dairy products; waist circumference; adolescents

INTRODUCTION

The prevalence of abdominal obesity (AO) among adolescents in developed countries has been increasing, as have associated complications.[1--4]
Primary preventions of obesity, as well as AO, should focus on energy balance, but intake of some foods has been shown to affect the development of AO among adolescents.[5--7] Recently, several[5,8--11] but not all[12,13] epidemiological studies about this topic have shown that dairy product (DP) intake is inversely related to AO and body fat in children and adolescents. DPs are an important source of nutrient and/or bioactive constituents such as calcium. It appears that a high-calcium diet may have a role in preventing fat accumulation by affecting adipocyte lipid metabolism, lipogenesis and lypolysis, fat oxidation and fat absorption, through genetic and non-genetic mechanisms.[14] Furthermore, according to some studies, calcium from a dairy source may be more effective than other dietary sources in reducing and regulating body fat.[15,16] Although, the mechanism of this DP 'anti-obesity' effect is not yet clear, it was suggested that it may be mediated by dairy components (e.g., whey protein) other than calcium.[17]
At the present time, consumption of milk and milk products is not considered by dietary recommendations to have a special role in weight control,[18] despite some evidence from epidemiological observational and experimental studies linking dairy food consumption to obesity.[7,11,13,15,19--23] Furthermore, studies examining the association between markers of AO---such as waist circumference (WC)---and DP intake among adolescents are scarce.
Hence, the aim of the present study was to assess the association between DP intake and AO among Azorean adolescents.

MATERIALS AND METHODS

Sampling

Data for the present study were derived from a longitudinal school-based study---The Azorean Physical Activity and Health Study II, which aimed to evaluate physical activity, physical fitness, overweight/obesity prevalence, dietary intake, quality of life and other health-related factors. The 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 live.[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 and the Portuguese Foundation for Science and Technology Ethics Committees; 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 1422, but to

prevent information loss, data were collected for 1515 adolescents. For the purpose of the study and taking into account that cutoffs used to categorize WC are available only for age under 17, we only included adolescents aged 15--16 (n¼960), from which 57 were not included due to missing information on dietary intake (n¼41) and WC (n¼16). Therefore, this led a total of 903 participants (370 boys). Power analysis of the final sample was calculated post hoc being higher than 0.8 for P-value o0.05. Finally, the sample was weighted in accordance with the distribution of the Azorean population in schools and to guarantee the real representativeness of each group (by age and gender).

Anthropometric measures

Body height and body weight. Body height and body weight were determined using standard anthropometric methods. Height was measured to the nearest millimeter 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). Body mass index (BMI) was calculated using the ratio of weight/height^2 (kg/m^2). Subjects were classified as normal weight, overweight or obese, according to age- and sex-specific cutoff points specified by the International Obesity Task Force.[25]

Waist circumference. WC measurements were taken midway between the tenth rib and the iliac crest and recorded to 0.1 cm. A non-elastic flexible tape measure was used, with subjects standing erect with arms by sides, feet together and abdomen relaxed, as well as without clothing covering the waist area. Subjects were divided into two categories (o90th and X90th percentiles) according to age- and sex-specific cutoff points specified by McCarthy.[26] Subjects who were in the 90th percentile or above were considered to have AO.[27]

Pubertal stage. To determine pubertal stage (ranging from stage 1 to 5), each subject was asked to self-assess his/her stage of secondary sex characteristics. Stage of breast development in girls and genital development in boys was evaluated according to criteria outlined by Tanner and Whitehouse.[28] For the purposes of the present analyses, the original 5-stage Tanner scale was collapsed into four categories: (i) stage 1 or 2; (ii) stage 3; (iii) stage 4; and (iv) stage 5.

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

Smoking. Participants were classified as non-smokers, 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).[29] Occasional smokers were recoded and combined with current smokers, due to their small sample size.

Parental education. For the present study, the highest level of parental education (measured by number of school years completed) was used as a proxy measure of socio-economic status. Participants were divided into three categories, reflecting divisions within the Portuguese educational system: mandatory or less (p9 school years), secondary (10 --12 school years) and college/university (412 school years).

Dietary intake

Dietary intake was measured via a self-administered semiquantitative food frequency questionnaire that covered the previous 12 months and included 86 food item and beverage categories, validated for Portuguese adolescents.[30] This semiquantitative food frequency questionnaire was designed in accordance with criteria laid out by Willett[31] 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 software uses nutritional information from the United States that has been adapted for use with typical Portuguese foods and beverages.

This study considered two DPs: milk and yogurt. We used the following amounts per servings: 250 ml for milk (whole, reduced fat and fat free) and 200 g for yogurt. Participants were categorized according to the new Portuguese Food Wheel guide as eating two or more servings of milk and yogurt per day or less (X2 and o2 servings/day).[32] Portions of cheese per day were considered separately---that is, one serving comprised 40 g of cheese (cottage and cream cheese). In view of the fact that there are no recommendations for portions of cheese, the median servings of cheese (median¼0.3 serving/day) were used to categorize participants.

Calcium intake was expressed as the calcium-to-protein ratio, to offset the effects that these two nutrients have on each another and because ratio eliminates most of the portion size estimation error.[33,34]

Physical activity

Physical activity was assessed via a self-report questionnaire[35] that had been shown to have good test -- retest reliability among Portuguese adolescents (intraclass correlation coefficient 0.92 -- 0.96).[36] From this questionnaire, a summative index (range 5-- 20) was derived. Participants who reported 412.5 points were classified as active, and those who reported 12.5 points or less comprised the low-activity group.

Statistical analysis

Data was analyzed separately for girls and boys, because it was believed that sex might influence the accumulation of abdominal fat.[37] Descriptive analysis showed lifestyle, socio-demographic, anthropometric and dietary characteristics of the sample by gender. All variables were tested for normality. Independent sample t-tests were performed to compare continuous variables, and the w^2-test was used with categorical variables.

The Mann-- Whitney test was performed for quantitative variables when appropriate.

The association between DP intake and WC (the dependent variable) was investigated using logistical regression (multivariate models). The multivariate-adjusted models were controlled for the following potential confounders: age (in years), BMI (in kg/m^2), pubertal stage (reference--- stage 1 or 2), physical activity level (reference---low activity), energy

intake (in kcal), calcium-to-protein ratio and dietary fiber (in g/1000 kcal). Age, BMI, energy intake, calcium-to-protein ratio and dietary fiber were entered as continuous variables. To control for possible confounding by cheese intake, we also adjusted the multivariate models for this variable (reference---o0.3 serving/day). An odds ratio (OR) and a 95% interval (CI) were computed for the X2 servings/day DPs intake category.
A P-value of o0.05 was regarded as significant. All analyses were performed using the PASW Statistic v.18 (SPSS, Chicago, IL, USA).

RESULTS

The mean age was 15.5±0.5 years for both genders (P¼0.695).
The prevalence of overweight/obesity was 32.2% (boys: 29.3% and girls: 34.2%, P¼0.129) and of AO was 54.9% (boys: 32.1 and girls:
70.7%, Po0.001). Descriptive data on WC and other covariates are presented in Table 1. Average BMI for both genders was higher in those who had AO (boys: 26.4±4.0 kg/m2 vs 20.7±2.2 kg/m2, Po0.001; girls: 23.7±3.6 kg/m2 vs 20.4±2.9 kg/m2, Po0.001), while no significant association was found between boys and girls.
However, the percentage of adolescents who had AO was higher in girls (70.7% vs 32.2%, Po0.001). Boys were more active than girls
(83.7% vs 52.3%, Po0.001). Boys who had AO were less active than those with WC o90th percentile (77.3% vs 86.5%, P¼0.027).

Table 1. Characteristics of the subjects by gender

	Boys			*Girls*			*Boys*	*Girls*	P
	WC		$P^{a,b}$	*WC*		$P^{a,b}$	*Total (n = 370)*	*Total (n = 533)*	
	$<$ P90 (n = 251)	$\geq$ P90 (n = 119)		$<$ P90 (n = 156)	$\geq$ P90 (n = 377)				
BMI[c] (kg/m^2)	20.7 ± 2.2	26.4 ± 4.0	$<$0.001	20.4 ± 2.9	23.7 ± 3.6	$<$0.001	22.5 ± 3.9	22.7 ± 3.7	0.119
Parental education (%)									
Mandatory or less	52.2	53.4		51.9	59.6		52.6	57.3	
Secondary	29.3	33.1	0.465	29.2	23.5	0.252	30.5	25.1	0.213
College/university	18.5	13.6		18.8	17.0		16.9	17.5	
Smoking status (%)									
Non-smoker	82.1	86.4		81.1	81.5		83.5	83.7	
Former smoker	5.2	3.4	0.552	2.6	5.6	0.086	4.6	4.7	0.944
Current smoker	12.7	10.2		8.3	13.0		11.9	11.6	
Pubertal stage (%)									
Stage 1 or 2	1.2	2.5		1.9	0.5		1.6	0.9	
Stage 3	9.6	16.0	0.017	24.5	20.4	0.009	21.6	21.6	$<$0.001
Stage 4	64.1	47.1		63.2	57.3		59.4	59.0	
Stage 5	25.1	34.5		10.3	21.8		28.1	18.4	
Physical activity (%)									
Low active	13.5	22.7	0.027	48.1	47.7	0.944	16.5	47.8	$<$0.001
Active	86.5	77.3		51.9	52.3		83.5	52.2	

Abbreviations: BMI, body mass index; WC, waist circumference; P90, 90th percentile. [a]Analysis by Student's *t*-test for continuous variables. [b]Analysis by χ^2 for categorical variables. [c]Mean ± s.d.

Energy intake and dietary characteristics for each gender are presented in Table 2. Boys' diets were higher in energy and total and saturated fats, and lower in dietary fiber and carbohydrates, compared with girls (Po0.05 for all). There was no significant difference between boys and girls with regard to dairy, calcium and protein intake.
Distribution of adolescents by DP intake category was based on WC, as indicated in Figure 1. In both genders, the proportion of adolescents with WC o90th percentile was higher among individuals who had an intake of X2 dairy servings/day, compared with those who had an intake o2 servings/day (boys:
71% vs 65% and girls: 36% vs 24%, Po0.05, respectively).
Multivariate-adjusted ORs for AO for DP intake are shown in Table 3. In both genders, after adjusting for demographic variables and physical activity level, intake of X2 dairy servings per day was a negative predictor of AO (boys: OR, 0.474, 95% CI, 0.238 --0.945 and girls: OR, 0.545, 95% CI, 0.355 -- 0.839). After adjusting also for dietary factors (model 2), only boys who had X2 servings of DPs per day had lower risk of AO (boys: OR, 0.217, 95% CI, 0.075 --0.633 and girls: OR, 0.560, 95% CI, 0.307-- 1.022). A similar result was observed after adjustment for cheese intake (model 3).

DISCUSSION

In this study, we observed a protective association between eating two or more servings of milk and yogurt, and AO in boys. This association was not confounded by other lifestyle factors or nutritional variables, particularly calcium intake.
Evidence from observational studies on the relationship between consumption of DPs and AO in adolescents are limited, and most of them[8,11,12,38,39] have focused on weight and body fat loss. In children and

adolescents, few studies have reported a protective association between dairy consumption and overweight/ obesity. For instance, Moore et al.[11] in a cross-sectional study, found that adolescents in the lowest category of total dairy intake had higher BMIs and more subcutaneous fat. However, longitudinal studies have yielded conflicting results. Of 10 prospective cohort studies with children and adolescents reviewed by Louie,[40] 6 reported no significant association and 1 reported an increased risk, while 3 found a protective association between dairy consumption and the risk of being overweight/ obese.

Regarding the association between dairy consumption and AO, one study with adolescent found that central body fat measures (i.e., WC and the sum of suprailiac and scapular skinfold thicknesses) were inversely associated with total dairy intake.[5]

In adults, this relationship was examined in two cross-sectional studies.[41,42] However, in only one study[41] an inverse association was shown between dairy intake (milk and yogurt) and AO. In two longitudinal studies,[22,37] DPs were found to be negatively associated with WC. Vergnaud et al.[22] reported that milk and yogurt intake were protective against 6-year changes in WC only in men who were initially overweight, and Halkjaer et al.[37] found a protective association only in women, with a 5-year difference in WC for high-fat dairy intake.

The literature suggested that when DPs were separated into subgroups (i.e., milk, yogurt and cheese), a significant association with AO was only seen for some.[14,40] To the best of our knowledge, only one study investigated the cross-sectional relationship between 'type' of dairy and AO in adolescents. Bradlee et al.,[5] in data from the Third National Health and Nutrition Examination Surveys (NHANES III and NHANES 1998-- 2000), showed that adolescents who met the criteria for AO reported consuming significantly fewer milk servings per day. However,

Table 2. Dietary characteristics of the subjects by gender

	Boys			*Girls*			*Boys*	*Girls*	P
	WC		P	*WC*		P	*Total* (n = *370*)	*Total* (n = *533*)	
	<P90 (n = *251*)	⩾P90 (n = *119*)		<P90 (n = *156*)	⩾P90 (n = *377*)				
Energy intake[a,b] (kcal)	2720 ± 416.5	2631.0 ± 404.9	0.454	2544.9 ± 454.3	2362.2 ± 278.4	0.087	2691.9 ± 411.5	2415.6 ± 333.4	<0.001
Carbohydrates[a,b] (% of energy)	49.7 ± 8.3	50.2 ± 9.2	0.618	51.6 ± 8.6	50.7 ± 7.8	0.246	49.9 ± 8.6	51.0 ± 8.0	0.045
Total fat[a,b] (% of energy)	33.5 ± 5.2	33.2 ± 6.1	0.647	32.4 ± 6.0	32.6 ± 5.3	0.755	33.4 ± 5.5	32.5 ± 5.5	0.025
Saturated fat[a,b] (% of energy)	12.1 ± 2.6	11.6 ± 2.5	0.157	11.4 ± 2.6	11.2 ± 2.3	0.528	11.9 ± 2.6	11.3 ± 2.4	<0.001
Protein[a,b] (% of energy)	17.9 ± 3.6	17.9 ± 4.1	0.869	17.5 ± 3.2	18.1 ± 3.8	0.131	17.9 ± 3.8	18.0 ± 3.6	0.576
Dietary fiber[a,b] (g/1000 kcal)	9.1 ± 3.0	9.5 ± 3.4	0.395	10.6 ± 4.2	10.5 ± 3.4	0.797	9.2 ± 3.1	10.5 ± 3.7	<0.001
Total calcium intake[a,c] (mg)	1303.6 ± 791.9	1328.2 ± 811.5	0.874	1317.7 ± 742.8	1169 ± 680.7	0.017	1311.5 ± 797.0	1215.2 ± 702.8	0.086
Calcium-to-protein ratio[a,b]	11.1 ± 3.7	11.2 ± 4.4	0.830	12.0 ± 3.6	11.5 ± 4.0	0.130	11.2 ± 3.9	11.6 ± 3.8	0.048
Dairy intake[a,c] (servings/day)	2.4 ± 1.8	2.3 ± 2.1	0.289	2.3 ± 1.6	2.0 ± 1.6	0.058	2.3 ± 1.9	2.1 ± 1.6	0.185
Cheese[a,c] *(servings/day) (%)*	0.5 ± 0.7	0.5 ± 0.7	0.793	0.5 ± 0.8	0.4 ± 0.6	0.996	0.52 ± 0.67	0.46 ± 0.66	0.048
<0.3 serving/day	57.9	59.7	0.753	71.0	65.8	0.247	58.5	67.3	0.007
⩾0.3 serving/day	42.1	40.3		29.0	34.2		41.1	32.7	

Abbreviations: WC, waist circumference; P90, 90th percentile. [a]Mean ± s.d. [b]Between-gender and WC percentiles analysis by Student's *t-test*. [c]Between-gender and WC percentiles analysis by Mann–Whitney test.

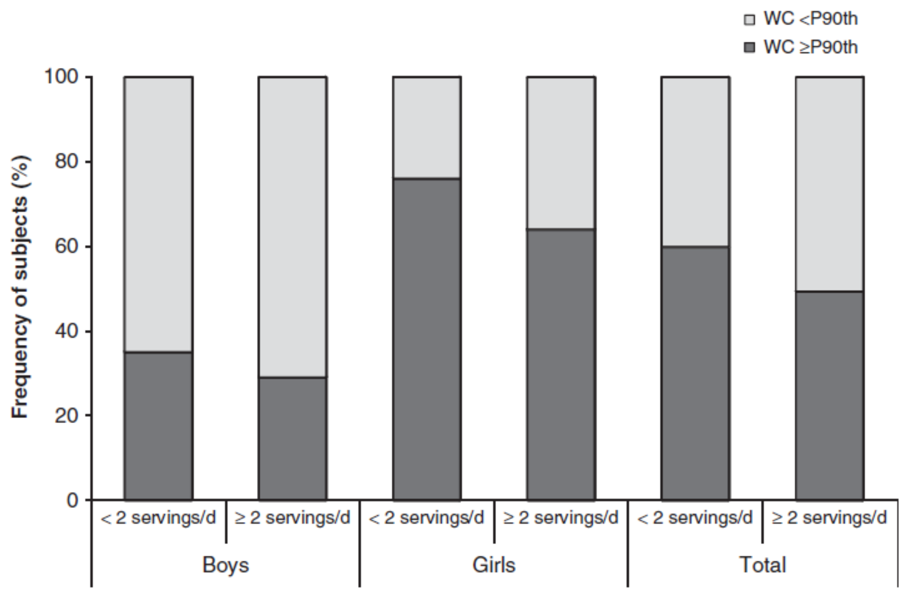

Figure 1. Distribution of subjects in dairy intake categories based on their WC.

it is noteworthy that the same finding for cheese consumption was only observed in NHANES III data. Regarding the beneficial role of different DPs on body fat, in children and adolescents, cross-sectional[11,43] and longitudinal[8,10,39] studies have shown an inverse association between milk and adiposity, but this association was not found in other studies.[12,38] On the other hand, cheese consumption was only addressed in adults,[21,41,42] and some of these studies[41,42] reported a positive association with prevalence of obesity and AO. Moreover, an inverse association between yogurt intake and adiposity was only shown in Beydoun's study.[41]

Therefore, overall, the evidence suggests that milk and yogurt are associated with lower adiposity, with cheese having the opposite effect.[14] In this study, we only analyzed the association between total milk and yogurt intake and AO (milk and yogurt when considered separately were not associated with AO; data not shown).

In agreement with our results, other studies have found a higher proportion of AO in girls.[1,2] Furthermore, the prevalence of

Table 3. Odds ratios (and 95% CIs) for the relationships between dairy servings intake (⩾2 servings/day) and abdominal obesity

	Boys (n = *370)*			*Girls* (n = *533)*		
	OR	*95% CI*	P	*OR*	*95% CI*	P
Model 1	0.474	0.238–0.945	0.034	0.545	0.355–0.839	0.006
Model 2[a]	0.217	0.075–0.633	0.005	0.560	0.307–1.022	0.059
Model 3[b]	0.208	0.070–0.617	0.005	0.563	0.307–1.032	0.063

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio; PA, physical activity. All models were adjusted for age (years), BMI (kg/m^2), pubertal stage and PA level. [a]Model 2 was also adjusted for energy intake (kcal), dietary fiber (g/100 kcal) and calcium-to-protein ratio. [b]Model 3 was also adjusted for energy intake (kcal), dietary fiber (g/100 kcal), calcium-to-protein ratio and cheese intake (reference–<0.3 serving/day).

AO has been increasing at a faster rate in girls than in boys.[1,2] On the other hand, even after adjusting for confounders, there was a non-significant association between dairy consumption and AO in girls. There are several possible explanations for these findings.

WC is unlikely to be due to visceral adipose tissue alone; it probably reflects both visceral and subcutaneous fat. It is known that adult women have a greater amount of subcutaneous fat than men and less visceral fat, a difference closely related to gender differences in cardiometabolic disease risk.[44--46] These differences begin early in life and become more apparent in puberty due to changes in sex hormone levels. However, studies on gender differences in visceral fat in adolescents have discrepant results. Some have suggested that boys have more visceral fat than girls,[47,48] while others have found no significant differences.[49] Nevertheless, it is important to note that this is one of few studies that addressed sexual maturation, controlling for the extent of biological growth and the individual nutritional needs of adolescents.[50]

Several studies have suggested a beneficial effect of some dairy components, especially calcium, on weight and body fat loss. The plausible mechanism most frequently cited relates to the effects of calcium on adipocyte metabolism and fatty acid absorption from the gastrointestinal tract.[14] Zemel[51,52] has demonstrated that the concentration of intracellular $Ca^{2þ}$ in human adipocyte is increased by the stimulation of parathyroid hormone and 1,25-dihydroxyvitamin D_3, which occurs in response to a lowcalcium diet. The resultant increase in intracellular $Ca^{2þ}$ exerts a coordinated effect on adipocyte lipid metabolism, serving to stimulate lipogenic gene expression and lipogenesis, thereby increasing lipid filling and adiposity. Calcium is also able to increase fecal excretion of fat via the formation of insoluble fatty acid soaps or by binding bile acids.[14] However, these mechanisms do not entirely explain the observed 'antiobesity' effects of DPs.[53]

Dairy is also an important source of proteins, and whey proteins have been positively associated with satiety.[14] Moreover, it has been shown that whey protein inhibits angiotensin-converting enzyme and consequently inhibits the production of angiotensin II hormone,[53] which has been reported to upregulate adipocyte lipogenesis, resulting in the inhibition of fat deposition.[54] Yet, there is lack of knowledge concerning the mechanisms that explain the effects of DPs on the loss of central adiposity. Visceral adipose tissue has greater amounts of 11-b-HSD-1 (11-b-hidroxysteroid dehydrogenase), which can generate active cortisol from cortisone, than does subcutaneous adipose tissue.[55] In-vitro data obtained from mice suggest that the selective overexpression of 11-b-HSD-1 in adipose tissue results in central obesity.[56] It has been suggested that a high-calcium and high-dairy diet may reduce cortisol production because visceral adipocytes stimulate lipolysis.[55] Nevertheless, no studies have specifically examined these mechanisms in children and adolescents, and the dynamic metabolic changes that occur during growth and puberty may further complicate these issues.[57] Furthermore, it is possible that the interaction between body fat and DPs depends not only on the threshold of percentage of body fat,[9] but also indeed on its distribution by gender, with boys having more visceral fat.

However, DP consumption may also be associated with dimensions of a healthier lifestyle that protect against adiposity, such as frequency of eating episodes.[58,59]

There are some limitations in our study that should be addressed. First, the cross-sectional design of this study prevents any conclusions related to cause and effect. Second, we did not include cheese in DPs, because the food frequency questionnaire was not specifically designed to account for different types of cheese, but we did control for the effects of cheese intake. Third, the measure of AO used in this study is an indirect estimate of abdominal fat. However, WC has been used as a simple anthropometric tool, to access and identify adolescents who are at risk of having AO. It has been suggested that WC is one of the most common proxy measures of AO[1] and is strongly associated with visceral adipose tissue.[60]

In conclusion, we found that DPs have a protective effect on AO only in boys. These results suggest that DP intake may be related to body fat distribution. Future research, with more accurate measures of visceral adiposity, is needed to address this relationship and to examine the effects of different types of DPs.

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