Relationship of milk intake and physical activity to abdominal obesity among adolescents

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ORIGINALRESEARCH

What is already known about this subject

- Diet and physical activity (PA) are recognized as important factors to prevent abdominal obesity (AO).
- Studies have found an inverse relationship between milk intake or milk products and body weight and/or body fat in children and adolescents.
- Evidence suggests that low levels of PA are associated with AO in youth.

What this study adds

- Our study explored the combined association of milk intake and PA on AO in adolescents, which are most often studied in isolation.
- Our findings suggested that adolescents with high milk intakes, regardless of whether they were active or low active, were less likely to have AO.
- Our findings could have a great epidemiological interest and bring important evidence in the field of AO management among adolescents.

Summary

Background: Diet and physical activity (PA) are recognized as important factors to prevent abdominal obesity (AO), which is strongly associated with chronic diseases. Some studies have reported an inverse association between milk consumption and AO.

Objective: This study examined the association between milk intake, PA and AO in adolescents.

Methods: A cross-sectional study was conducted with 1209 adolescents, aged 15–18 from the Azorean Archipelago, Portugal in 2008. AO was defined by a waist circumference at or above the 90th percentile. Adolescent food intake was measured using a semi-quantitative food frequency questionnaire, and milk intake was categorized as 'low milk intake' (<2 servings per day) or 'high milk intake' ($\geq$2 servings per day). PA was assessed via a self-report questionnaire, and participants were divided into active (>10 points) and low-active groups ($\leq$10 points) on the basis of their reported PA. They were then divided into four smaller groups, according to milk intake and PA: (i) low milk intake/low active; (ii) low milk intake/active; (iii) high milk intake/low active and (iv) high milk intake/active. The association between milk intake, PA and AO was evaluated using logistic regression analysis, and the results were adjusted for demographic, body mass index, pubertal stage and dietary confounders.

Results: In this study, the majority of adolescents consumed semi-skimmed or skimmed milk (92.3%). The group of adolescents with high level of milk intake and active had a lower proportion of AO than did other groups (low milk intake/low active: 34.2%; low milk intake/active: 26.9%; high milk intake/low active: 25.7%; high milk intake/active: 21.9%, $P = 0.008$). After adjusting for confounders, low-active and active adolescents with high levels of milk intake were less likely to have AO, compared with low-active adolescents with low milk intake (high milk intake/low active, odds ratio [OR] = 0.412, 95% confidence intervals [CI]: 0.201–0.845; high milk intake/active adolescents, OR = 0.445, 95% CI: 0.235–0.845).

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Conclusion: High milk intake seems to have a protective effect on AO, regardless of PA level.

Keywords: Abdominal obesity, adolescents, milk, physical activity.
Abbreviations: AO, abdominal obesity; PA, physical activity; WC, waist circumference; BMI, body mass index; % BF, percentage of body fat; FFQ, food frequency questionnaire; PAI, physical activity index; OR, odds ratio; CI, confidence intervals.

Introduction

In recent decades, the prevalence of obesity, including abdominal obesity (AO), has significantly increased among adolescents (1). These findings are alarming, in view of the fact that AO is an independent risk factor for insulin resistance, hyperinsulinaemia, dyslipidemia and hypertension in youth (2). Despite the upward trend in obesity, there is still a lack of knowledge of the factors associated with AO in adolescents. It has been reported that diet and physical activity (PA) play an important role in the prevention of AO (3,4). Several observational and prospective studies have suggested that milk or milk product intake is associated with lower risk of excessive adiposity in children, adolescents and adults (5–7). The weight of evidence suggests that milk intake is more likely to be associated with beneficial weight and body fat than other milk products such as yogurt or cheese (8). It has been suggested that milk is rich in bioactive peptides (whereas other milk products contain little or no such substances) that may modulate body fat accumulation (9,10). On the other hand, other studies have found a positive (11) or null association (12) of milk intake with adiposity.

The emergence of the prevalence of AO and related conditions parallels with the decreasing levels of PA, and increasing levels of time spent on sedentary activities (television watching, video game playing and computer use) has increased among adolescents (13,14). As recently noted, the practice of structured and vigorous PA is inversely associated with excess central adiposity (3). Despite the overwhelming evidence of the association between PA and body composition, PA levels are also linked to other health-related factors, lifestyle patterns and psychosocial well-being (15).

Although evidences suggest that milk intake and PA have an independent role in AO, gaps remain in the literature on the combined effects. Moreover, these two lifestyle habits are not mutually exclusive and often co-exist in the same individual (16). In a recent review, it is suggested that more research is needed in order to compare the combined effects of milk products consumption and PA on body composition (17). To the best of our knowledge, no study has examined this combined association in adolescents. In this context, the aim of this study was to identify the association of milk intake and PA on AO in a sample of Portuguese adolescents.

Materials and methods

Sampling

Data for the present cross-sectional study were derived from a 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 other factors in 15–18-year-old adolescents in 2008. 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.

All participants in this study were informed of its goals, and the parent or guardian of each participant provided written informed consent for his/her child to participate. 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 the location (island) and number of students, by age and sex, in each school. The estimated number of subjects for the representativeness of adolescent population was 1422, but in order to prevent incomplete information, data were collected from 1515 adolescents. Some adolescents were not included in our analysis ($n = 306$), because information was missing on their dietary intake ($n = 286$) and waist circumference (WC; $n = 20$). This resulted in the collection of data for a total of 1209 participants (503 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 years vs. 16.1 ± 1.0 years, $P = 0.158$), parental education (9.1 ± 4.5 years vs. 9.1 ± 4.4 years, $P = 0.890$) and gender (girls: 61.1% vs. 58.4% and boys: 38.9% vs. 41.6%, $P = 0.388$). Finally, the sample was weighted in accordance with the distribution of the Azorean

population in schools and so as 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 millimetre 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, Tanita, 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 cut-off points specified by the International Obesity Task Force (18,19). Underweight subjects (2.6%) were combined with subjects in the normal-weight category because of the fact that they represented a small proportion of the sample. Percentage of body fat (% BF) was assessed using bioelectric impedance analysis (Tanita Inner Scan BC 532).

Waist circumference

WC measurements were taken midway between the 10th rib and the iliac crest and recorded to 0.1 cm. A non-elastic flexible tape measure was used, with subjects standing erect – arms by sides, feet together and abdomen relaxed – as well as without clothing covering the waist area. Subjects were divided into two categories (<90th and ≥90th percentiles), according to age- and sex-specific cut-off points specified by Sardinha et al. (20). Subjects who were in the 90th percentile or above were considered to have AO (21).

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 (22). Adolescents in Tanner stage 1 (0.4%) were combined with subjects in the Tanner stage 2 because of the fact that they represented a small proportion of the sample.

Socio-demographic and lifestyle variables

Participants answered a questionnaire that assessed several socio-demographic 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 per day) and current smokers (individuals who smoked at least one cigarette per day) (23). Occasional smokers were recoded and combined with current smokers because of the fact that they represented a small proportion of the sample.

Parental education

For the present study, highest level of parental education (measured by 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 (10–12 school years) and college/university (>12 school years).

Dietary intake

Dietary intake was measured via a self-administered semi-quantitative food frequency questionnaire (FFQ), validated for the Portuguese adults (24). This semi-quantitative FFQ was designed in accordance with criteria laid out by Willett (25) and adapted to include a variety of typical Portuguese food items. The FFQ was adapted for adolescents by including foods more frequently eaten by this age group (26); the adolescent version covered the previous 12 months and comprised 91 food items or beverage categories. For each item, the questionnaire offered nine frequency response options, ranging from 'never' to 'six or more times per day', and standard 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 programme uses nutritional information from the United States that has been adapted for use with typical Portuguese foods and beverages. In order to verify the inter-item consistency, the Cronbach's alpha test was applied to the dimensions of

the FFQ and the score obtained ($\alpha = 0.892$) was high, which indicated a good internal consistency.

The amount of milk (whole, semi-skimmed and skimmed) that counted as a single serving was considered to be 250 mL. We included all types of milk in one variable because the majority of adolescents were consuming semi-skimmed (83.7%) or skimmed milk (8.6%). Participants were categorized according to the new Portuguese Food Wheel guide (27) and adolescents who consumed two or more servings of milk per day were included in the 'high milk intake group', while those who consumed less than two servings per day comprised the 'low milk intake group'.

Physical activity

PA was assessed via a self-report questionnaire that evaluated leisure-time PAs (28). This questionnaire has been shown to have good test–retest reliability among Portuguese adolescents (intraclass correlation coefficient: 0.92–0.96) (29). It consists of five questions with four answer choices (each rated on a 4-point scale): (i) outside school, do you take part in organized sports/PAs?; (ii) outside school, do you take part in non-organized sports/PAs?; (iii) outside school hours, how many times a week do you take part in sports or PAs for at least 20 min?; (iv) outside school hours, how many hours a week do you usually take part in PAs, so much that you get out of breath or sweat?; and (v) do you take part in competitive sports? The maximum number of points possible was 20. A PA index (PAI) was obtained for each respondent by totalling his/her points, which corresponded to activity level rankings that ranged from 'sedentary' to 'vigorous'. Participants whose PAIs were greater than 10 points were classified as 'active', while those whose PAIs were 10 points or less were classified as 'low active' (29); this procedure has been validated (30).

Statistical analysis

For the purposes of this study, participants were divided into four groups, according to their milk intake (high or low) and PA (active or low active): (i) low milk intake/low active; (ii) low milk intake/active; (iii) high milk intake/low active and (iv) high milk intake/active.

The Kolmogorov–Smirnov test was used to assess the assumption of normality. One-way analysis of variance, with the Bonferroni *post hoc* test, was performed to compare continuous variables, and the chi-square test was used to test for categorical variables across groups. When the continuous variables were found to not be normally distributed, the Kruskal–Wallis test was used to determine differences between groups, and the Mann–Whitney test was used to examine unique pairs. In this report, descriptive analysis is presented in terms of means and standard deviations, unless otherwise stated.

A multivariate logistic regression model was constructed to verify the relationship between AO and the combined associations of milk intake and PA, adjusting for age (in years), gender (reference – boys), parental education (reference – mandatory or less), BMI (reference – obese), pubertal stage, energy intake (in kcal), total calcium intake (in mg), protein intake (g kg^{-1}), total fat intake (% of energy) and dietary fiber (in g 1000 kcal^{-1}). Age and dietary variables were entered as continuous variables. Furthermore, we adjusted the logistical model by under-reporting energy intake, which was estimated using the ratio between reported energy intake and predicted basal metabolic rate (31,32). 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 aged 18. 'Low-energy reporter' (a categorical variable) was included in the model as a confounding factor.

Odds ratios (OR) and 95% confidence intervals (CI) were computed across groups, with the 'low milk intake/low-active' group as the reference group. A *P*-value of < 0.05 was regarded as significant. All analyses were performed using PASW Statistics v.18 (SPSS, Chicago, IL, USA).

Results

Descriptive characteristics of the adolescents in the sample are shown in Table 1. The higher proportion of girls was seen in the low-activity groups, regardless of milk intake (*P* < 0.001). Adolescents in the high milk intake/active group had higher body weight compared with adolescents in the high milk intake/low-active group (61.4 [14.4] vs. 58.6 [14.6], *P* = 0.001, respectively), and higher body height and lower % BF compared with adolescents in the high milk intake/low active and in the low milk intake/low-active groups (*P* < 0.001, for all). Active adolescents had lower % BF compared with low-active adolescents, regardless of milk intake (*P* < 0.001, for all). The higher proportion of parents with mandatory or less education was seen in the low milk intake/low-active group (*P* < 0.001). No significant differences were seen in age, BMI, pubertal stage and smoking across groups.

Table 1 Characteristics of the study sample, by milk intake and physical activity groups

	Total (n = 1209)	Milk intake/physical activity level				P
		Low milk intake/low active (n = 260)	Low milk intake/active (n = 417)	High milk intake/low active (n = 167)	High milk intake/active (n = 365)	
Age†¶ (years)	16.0 (2.0)	16.0 (2.0)	16.0 (2.0)	16.0 (2.0)	16.0 (2.0)	0.215
Weight†¶ (kg)	60.5 (15.0)	58.5 (13.6)	62.2 (15.2)*	58.6 (14.6)†	61.4 (14.4)*†§	<0.001
Height†¶ (m)	1.65 (0.12)	1.61 (0.12)	1.66 (0.14)*	1.63 (0.10)†	1.67 (0.14)*†§	<0.001
BMI†¶ (kg m⁻²)	22.1 (4.3)	22.3 (4.6)	22.1 (4.2)	21.6 (4.8)	21.9 (4.0)	0.160
Weight status (%)‡						
Normal	69.1	66.2	68.8	68.9	71.8	0.881
Overweight	23.2	25.8	23.3	23.4	21.4	
Obese	7.6	8.1	7.9	7.8	6.8	
Body fat**†† (%)	21.6 (8.8)	25.0 (8.0)	20.3 (9.1)*	23.9 (8.9)†	19.6 (8.3)*§	<0.001
Waist circumference†¶ (cm)	78.0 (13.0)	80.0 (14.0)	78.0 (13.0)	77.0 (14.0)*	76.0 (12.0)*†	0.017
Gender‡ (%)						
Girls	58.4	83.1	47.0	80.2	43.8	<0.001
Boys	41.6	16.9	53.0	19.8	56.2	
Pubertal stage‡ (%)						
Tanner stage 1 or 2	1.0	1.5	0.5	1.2	1.1	0.191
Tanner stage 3	15.7	16.2	13.2	23.4	14.8	
Tanner stage 4	59.1	58.1	61.9	51.5	60.0	
Tanner stage 5	24.2	24.2	24.5	23.9	24.1	
Parental education‡ (%)						
Mandatory or less	48.6	61.6	47.1	47.6	41.2	<0.001
Secondary	36.5	32.3	37.1	39.2	37.6	
College/university	14.9	6.0	15.8	13.2	21.2	
Smoking status‡ (%)						
Non-smoker	87.0	89.6	86.6	86.2	86.0	0.384
Former smoker	5.7	3.5	6.5	4.2	7.1	
Occasional/current smoker	7.3	6.9	7.0	9.6	6.8	
PAI†¶	13 (8)	8 (3)	15 (5)*	8 (3)†	16 (5)*§	<0.001

*P < 0.05, compared with the low milk intake/low-active group; †P < 0.05, compared with the low milk intake/active group; ‡P < 0.05, compared with the high milk intake/active group; §P < 0.05, compared with the high milk intake/low-active group.
‡Data are median (interquartile range).
¶Analysis by Kruskal–Wallis for continuous variables.
**Data are mean (standard deviation).
††Analysis by analysis of variance for continuous variables.
‡‡Analysis by chi-square for categorical variables.
BMI, body mass index; PAI, physical activity index.

Adolescents with high milk intakes had lower proportions of AO, compared with those who had low milk intakes (23.1% vs. 29.7%, $P = 0.006$, respectively). Active adolescents also had lower proportions of AO than low-active adolescents (24.6% vs. 30.9%, $P = 0.011$, respectively).

The energy intakes and dietary characteristics of each group are presented in Table 2. Regardless of whether they were active or low active, adolescents whose milk intakes were high had higher levels of energy and total calcium and protein intake, compared with those who had low milk intake ($P < 0.05$). There was no significant difference across groups with regard to carbohydrate and total fat intake.

The proportion of AO across milk intake and PA groups, as indicated in Fig. 1, showed that adolescents with high levels of milk intake and activity had lower proportions of AO, compared with other groups (low milk intake/low active: 34.2%, vs. low milk intake/active: 26.9%, vs. high milk intake/low active: 25.7%, vs. high milk intake/active: 21.9%, $P = 0.008$).

The results of the multivariate logistic regression analysis, predicting AO from a combination of milk intake and PA, are shown in Table 3. After adjusting for demographic and dietary variables, low-active and active adolescents with high milk intakes were less likely to have AO than were low-active adolescents with low milk intakes (low milk intake/low active, OR = 0.928, 95% CI: 0.562–1.531; high milk intake/low active, OR = 0.412, 95% CI: 0.201–0.845; high milk intake/active, OR = 0.445, 95% CI: 0.235–0.845). To demonstrate whether it is really milk intake making the difference, we made an additional multivariate logistic regression analysis with low milk intake/active group as the reference group. Low-active and active adolescents with high levels of milk intake remain to be less likely to have AO even after compared with active adolescents with low milk intake (low milk intake/low active, OR = 1.078, 95% CI: 0.653–1.779; high milk intake/low active, OR = 0.444, 95% CI: 0.217–0.909; high milk intake/active adolescents, OR = 0.480, 95% CI: 0.263–0.876).

Discussion

The present study explored the combined association of milk intake and PA on AO in adolescents. The results suggested that adolescents with high milk intakes, regardless of whether they were active or low active, were less likely to have AO, compared with those who had low milk intakes. This association was not confounded by other lifestyle factors or

Table 2 Dietary characteristics of the study sample, by milk intake and physical activity groups

	Total (n = 1209)	Milk intake/physical activity level				P
		Low milk intake/low active (n = 260)	Low milk intake/active (n = 417)	High milk intake/low active (n = 167)	High milk intake/active (n = 365)	
Energy intake[‡§] (kcal d[−1])	2301.2 (1431.1)	2070.9 (1343.3)	2044.3 (1458.3)	2544.3 (1358.4)[*†]	2621.9 (1513.4)[*†]	<0.001
Protein[¶∥**] (% of energy)	17.8 (3.8)	16.7 (3.5)	17.7 (4.2)*	18.3 (3.6)*	18.4 (3.8)*	<0.001
Protein[‡§] (g kg^{−1} body weight)	1.6 (1.0)	1.4 (1.0)	1.4 (1.0)	2.0 (1.0)[*†]	1.9 (1.2)[*†]	<0.001
Carbohydrate[¶∥**] (% of energy)	49.3 (7.9)	50.4 (8.3)	48.8 (8.4)	49.2 (7.4)	49.1 (7.1)	0.082
Total fat[¶∥**] (% of energy)	32.3 (5.7)	32.4 (5.7)	32.7 (5.7)	32.1 (5.4)	31.9 (5.3)	0.329
Dietary fibre[‡§] (g 1000 kcal[−1])	9.4 (4.2)	9.9 (4.2)	9.6 (4.6)	9.1 (3.8)[†]	9.1 (3.8)[*†]	0.004
Total calcium intake[‡§] (mg d^{−1})	1120.6 (419.0)	767.7 (230.3)	818.5 (251.6)	1579.9 (434.0)[*†]	1560.1 (456.8)[*†]	<0.001
Milk intake[‡§] (servings per day)	1.0 (0.8)	0.9 (0.3)	1.0 (0.3)	2.4 (0.1)[*†]	2.4 (0.1)[*†]	<0.001

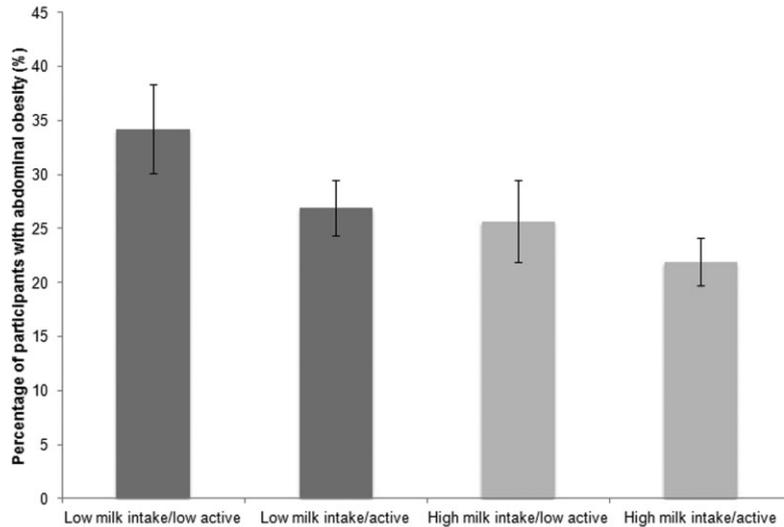*$P < 0.05$, compared with the low milk intake/low-active group; [†]$P < 0.05$, compared with the low milk intake/active group.
[‡]Data are median (interquartile range).
[§]Analysis by Kruskal–Wallis.
[¶]Data are mean (standard deviation).
[**]Analysis by analysis of variance.

Figure 1 Proportion of subjects with abdominal obesity across milk intake and physical activity groups.

Table 3 Odds ratio for abdominal obesity by milk intake and physical activity groups

		Model 1			Model 2		
		OR	95% CI	P*	OR	95% CI	P*
Low milk intake	Low active	1	Reference	0.008	1	Reference	0.027
	Active	0.706	0.501–0.987		0.928	0.562–1.531	
High milk intake	Low active	0.666	0.433–1.025		0.412	0.201–0.845	
	Active	0.539	0.378–0.770		0.445	0.235–0.845	

*P-value for heterogeneity;
Model 1 – unadjusted model. Model 2 – adjusted for age (years), gender (reference – boys), parental education (reference – mandatory or less), body mass index (reference – obese), pubertal stage, low-energy reporter, energy intake (kcal), total fat intake (% of energy), total calcium intake (mg), protein intake (g kg^{-1} body weight) and density fibre (g 1000 kcal^{-1}). 1, reference category; CI, confidence interval, OR, odds ratio.

nutritional variables, as it remained significant after adjustments.

Most cross-sectional and prospective studies have found an inverse relationship between milk intake or milk products and BMI, body weight and/or body fat in children and adolescents (5,7,33). Furthermore, evidence shows that the consumption of milk and milk products does not negatively affect weight and body composition (34). However, studies examining the association between milk intake or milk products and AO are limited. In one study with children, increased milk consumption was associated with lower WC (35). Bradlee et al. (36) analyzed data from the Third National Health and Nutrition Examination Survey and also found that mean dairy intake was inversely associated with central obesity in adolescents. Previous results, derived from the same sample, had shown that dairy product intake had a protective association with AO in boys (37). A randomized controlled trial on the effects of a dairy-rich diet on AO with obese children showed that those with isocaloric dairy-rich diets (>800 mg calcium d^{-1}) had lower WC than other groups (i.e. controls with and without energy restrictions) at the end of the study (38). It is noteworthy that, in addition to its possible 'anti-obesity' effect, milk is an excellent source of nutrients (such as calcium) for adolescents, who experience a period characterized by dynamic changes that occur in response to growth and puberty. Hence, consumption of recommended amounts of milk may help adolescents meet their nutrient requirements and improve their diets' quality (34,39). Moreover, moderate evidence shows that intake of milk and milks products is linked to improved bone health in children and adolescents and is also associated with reduced risk of cardiovascular disease, type 2 diabetes and blood pressure in adults (40).

In this study, we also found that active adolescents had a lower proportion of AO. PA also protects against central adiposity by increasing immediate energy requirements, which causes important changes in fuel utilization and mobilization (41). Evidence suggests that low levels of leisure-time PA are associated with AO in youth (3). Klein-Platat et al. (42) reported that, in an adoles-

cent sample, AO was negatively associated with structured PA (outside school, >140 min week^{-1}) and positively associated with sedentary activities (e.g. television, watching). By the same token, Ortega *et al.* (43) found that children and adolescents in the lowest tertile of vigorous PA had higher odds of having high WC, when compared with those in the highest tertile.

Concerning dietary habits and PA levels, some studies have found that the consumption of food by more active and less active adolescents differs (16,44). In a study by Ottevaere *et al.* (16), the most active adolescents consumed more milk products than did their less active counterparts. However, previous research indicates that spending more time on PA does not exclusively result in healthier eating habits (16,44). Although, in our study, the majority of active adolescents showed low milk intake, active adolescents with high milk intake, when compared with other groups, had lower proportions of AO, which shows the relevance of exploring both dietary patterns and PA simultaneously when assessing AO in adolescents.

When interpreting the results of the combined association between milk intake and PA, we observed that adolescents with high milk intake showed lower odds of expressing AO, regardless of their PA levels. These results are further enhanced by the lack of significance between groups with low milk intake where there was no significant differences between be active or low active. Thus, this finding suggests that the consumption of milk may overcome the potentially negative effects of low PA levels on the likelihood of having AO. Furthermore, milk compounds may also be involved in body fat distribution. Visceral adipose tissue has greater amounts of 11-β-hidroxysteroid dehydrogenase type 1 (45), which is over-expressed *in vitro* in those with central adiposity (46). It has been suggested that a high-calcium and high-dairy diet down-regulates 11-β-hidroxysteroid dehydrogenase type 1 expression and decreases the concentration of glucocorticoid, which consequently decreases the size of adipose fat deposits (45). However, we cannot exclude the hypothesis that milk consumption may also be associated with other healthy eating habits and healthier lifestyles, which may protect against AO.

In addition, we found that adolescents with higher milk intake and activity levels were taller and heavier but had lower % BF than adolescents who were less active and had higher high milk intake. It is well established that increased PA is associated with lower fatness (47) and thus the combined effect of PA and milk intake may enhance beneficial total body fat outcomes. Moreover, milk consumption and PA, along with other factors (i.e. genetics, age, gender, endocrine balance and overall diet) may influence growth. It has been described that children who do not drink milk have a shorter stature than those who do consume milk regularly (48,49). On the other hand, PA (i.e. sport participation) has been associated with bone accretion showing an important osteogenic effect, mainly when high-impact and weight-bearing PA occurs (50,51).

We also found that although energy intake is higher in adolescents with high milk consumption, the additional energy intake does not result in higher odds of AO. In a study to determine the effects of a calcium-rich diet on weight gain during 2 years, 9-year-old girls were randomly assigned to supplying at least 1500 mg (primarily from dairy food) of calcium d^{-1} or their usual diet (52). Although girls in the calcium-rich diet group consumed approximately 150 more calories d^{-1}, they did not have greater increases in body weight, BMI or fat or lean mass compared with the usual diet group. Furthermore, girls who consumed calcium-rich diet also significantly increased their intake of essential nutrients including calcium, protein, vitamins A and D, phosphorus and magnesium compared with girls on their usual diets. In adults, Zemel *et al.* (53) conducted 9-month randomized trials to compare the effects of low- (<1 serving per day) and high-dairy diet (>3 servings per day) on weight maintenance. Although the results showed that the high-dairy diet group had a higher energy intake than the low-dairy group, there were no differences in weight and body composition between the two groups after the intervention. Thus, the author suggested that the high-dairy diet group exhibited evidence of greater fat oxidation and was able to consume greater energy without greater weight gain compared with the low-dairy group.

Some limitations to our study should be addressed. First, it should be noted that, as in other cross-sectional studies, conclusions related to cause and effect cannot be drawn. Second, the measure of AO used in this study is an indirect estimate of abdominal fat and there are some sophisticated methods to accurately measure abdominal fat, such as magnetic resonance imagining or dual-energy X-ray absorptiometry. However, such techniques are not feasible to apply in large epidemiological studies because they are complex, time consuming and expensive. Furthermore, 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 (54). Third, because in our sample the majority of adolescents (92.7%) consumed

semi-skimmed and skimmed milk, we cannot state that any kind of milk is protective against AO. Moreover, we did not include in our analysis all milk products. However, the analysis with total milk product intake (i.e. milk, cheese and yogurt) was done but no significant association was found with AO. The lack of association between total dairy product and AO may be due to the nutritional differences between yogurt, cheese and milk. Cheese is characterized by its fat content and yogurt has frequently more sugar (added in industrial process) than other milk product. Finally, with the use of self-reported PA and dietary intake data, one cannot rule out some reporting bias. Yet, both questionnaires have been previously tested (24,29), and analysis was controlled to prevent the misreporting of energy intake.

In conclusion, we found that high milk intake seems to have a protective effect on AO, regardless of PA levels in adolescents. Future prospective and randomized clinical investigations, with more accurate measures, are needed on the combined effects of milk intake and/or milk products and PA on AO.

Conflict of Interest Statement

The authors declare no conflict of interest.

Acknowledgements

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ORIGINAL RESEARCH

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