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Relationship between calcium intake and body mass index in adolescents

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SUMMARY. Epidemiologic and experimental data support the possibility that dietary calcium intake plays a role in human body weight regulation. The aim of the present study was to evaluate calcium intake and its relationship with body mass index (BMI) in adolescents. Weight, height, 3-day food record and a food frequency questionnaire were collected among all adolescents participants at the Outpatient Clinic for Adolescents at the Federal University of Sao Paulo between 2001 and 2003. The statistical analysis comprised Chi-square, Student's T-test, Pearson correlation and linear regression. One-hundred and twenty-one adolescents were studied (62.8% female), with a mean age of 14.9 ±2.2 years old. Mean energy and calcium intakes were 1729.9±557.8 kcal/day and 598.2±287.9 mg/day respectively, with no significant statistical differences between sex or age. Almost ninety-eight percent of adolescents presented a mean calcium intake lower than proposed values. Calcium intake adjusted for energy presented a significant negative correlation with body weight (r=-0.194, p=0.03) and BMI (r=-0.185, p=0.04). Furthermore, adolescents in the lowest quartile of calcium intake presented higher BMI (29.7±7.4 kg/m^2) than adolescents in the highest calcium quartile. These results indicated a dietary calcium intake lower than recommendations for this life stage, and a contribution of this mineral in the body mass index.
Key-words: Adolescents, calcium, body weight, obesity.

RESUMO. Relação entre a ingestão de cálcio e o índice de massa corporal em adolescentes. Estudos epidemiológicos e experimentais evidenciam a possibilidade da participação do cálcio com a regulação do peso corporal. O objetivo do presente artigo foi avaliar a ingestão de cálcio e sua relação com o índice de massa corporal (IMC) em adolescentes. Foram coletados o peso, a estatura, um registro alimentar de três dias e um questionário de frequência alimentar dos adolescentes atendidos, entre 2001 e 2003, no Centro de Atendimento e Apoio ao Adolescente da Universidade Federal de São Paulo. A análise estatística incluiu teste Qui-Quadrado, t-Student, correlação de Pearson e regressão linear. 121 adolescentes (32,8% meninas), com uma média de idade de 14,9±2,2 anos. O consumo de energia e cálcio foi de 1729,9±557,8kcal/dia e 598,2±287,9mg/dia, respectivamente, sem diferenças estatísticas entre os sexos e idade. Aproximadamente 98% dos adolescentes apresentaram una média de ingestão de cálcio inferior aos valores propostos. A ingestão de cálcio ajustado pela energia proveniente da dieta apresentou correlação negativa significante com o peso corporal (r:-0,194, p=0,03) e com o IMC (r:-0,185, p=0,04). Além disso, adolescentes no menor quartil de ingestão de cálcio apresentaram IMC superior (29,7±7,4kg/m^2) quando comparados aos adolescentes no maior quartil de ingestão de cálcio. Os resultados demonstram uma ingestão de cálcio inferior as recomendações para essa fase da vida e uma possível contribuição deste mineral para o índice de massa corporal.
Palavras chave: Adolescentes, cálcio, peso corporal, obesidade.

INTRODUCTION

Calcium is generally considered a key element for maintaining bone mineral homeostasis. New evidence and review of earlier studies supports the view that calcium also plays a role in adipocyte lipid kinetics at the cellular level and in moderating fatness at the population level. Within adipocytes, intracellular calcium level alter the balance between lipid synthesis and breakdown, favoring lipogenesis when cytosolic calcium levels are high (1). National Health and Nutrition Examination Surveys I and III both provide cross-sectional evidence for an inverse associatiom between calcium intake and body mass index (BMI; kilograms per square meter) (2,3). These population observations are supported by retrospective analysis of a number of data sets that included calcium intake information and, in some cases, longitudinal administration of calcium as part of an osteoporosis trial (4).

Both the mechanism and magnitude of the calcium-body weight effect remain uncertain. One theory, proposed by Zemel et al., is that low calcium intake stimulates dihydroxy vitamin D and PTH and that, in turn, these calcitropic circulating substances stimulate adipocyte calcium uptake (3). As noted, high intracellular calcium levels promote lipogenis and inhibit lipolysis. The theory suggests that dietary calcium increases lipolysis and preserves thermogenesis, thereby accelerating weight loss. Intracellular Ca^{2+} has a key role in regulating adipocyte lipid metabolism and triglyceride storage, with increased intracellular Ca^{2+} resulting in stimulation of lipogenic expression and lipogenesis, suppression of lipolysis, and adiposity (1). It is also suggested that the increased calcitriol released in response to low-calcium dietsmay contribute to

the Ca2+ influx in human adipocytes and adiposity (5). A second potential mechanism involves stimulation of increased fecal energy losses due to formation of nonabsorded complexes of calcium and fat (6, 7).

Most studies that have reported the relation between dietary calcium or dairy products and indexes of adiposity were conducted in adults; few studies have been conducted in children and adolescents (4,8,9). To date, one study recently reported no relation between dietary calcium or dairy consumption in a longitudinal assessment of adolescent females (10).

Obesity is increasing at adolescence and it is a critical period for implementation of good eating habits. Considering the lack of data regarding the relationship between calcium and body weight during this period of life, the present study was performed to further investigate the relation between calcium and the body weight of adolescents.

METHODS

Sample

Retrospective study based on the evaluation of all adolescents participants in the Outpatient Clinics for Adolescents (CSCA) between 2001-2003. CSCA is a public service for disease prevention and health promotion for adolescents in Sao Paulo city, Brazil. Most of adolescents attending CSCA were looking for dietary counselling (underweight and specially obesity) or general medical evaluation. Adolescents with incomplete data (16), implausible daily energy intake (< 500 kcal or > 5000 kcal) (23), eating disorders (anorexia or bulimia) (4) or taking calcium supplement (1) were excluded. A total of 121 adolescents from 10 to 18 years old participated in the study. None of them had metabolic disorders that might affect calcium absorption or body weight. The research was conducted with the approval of ethical committee of the Federal University of Sao Paulo.

Anthropometric assessment

Weight and height were collected from the participant's medical records, which were carried out by trained health workers. Weight was measured to the nearest 0.1 kg using Filizolla® scale. Height was measured without shoes to the nearest 0.1 while the subjects stood in bare feet against a wall-mounted stadiometer. The equipments used was tested and calibrated at frequent intervals (11). Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Nutritional status classification was performed according to WHO (1995), based on the Must *et al* criteria (12): underweight = percentile < 5 for BMI/age; normal weight = percentile between 5 and 85; overweight = percentile > 85 and ≤ 95; and obesity = percentile >95.

Dietary assessment

Calcium and energy intake were assessed by a three-day food record, obtained in three non-consecutive days. Data was analyzed by Virtual Nutri 1.0 software (13). The nutrient adequacy was compared to proposed values by *Dietary Reference Intakes* (14,15).

Qualitative assessment of the calcium rich foods present in the diet of adolescents was performed by a food frequency questionnaire adapted from Slater *et al* (16) that assessed the food consumption during the preceding 6 month period.

Statistical analysis

Data analysis was performed with SPSS 10.0 (SPSS, Inc. Chicago, IL, USA) (17). Variables distribution was verified by Kolmogorov-Smirnov test. Chi-square test was made to verify associations between nutritional status and sex or age groups. To examine the relationships between calcium intake and energy, and calcium intake and BMI, the Pearson correlation test was performed. Additionally, a one way analysis of variance was used for multiple comparisons between the quartiles of calcium intake based on Tukey's test. Statistical significance was defined as $p<0.05$. Data are expressed as the mean and standard deviation.

Calcium intake was adjusted for energy intake by residual nutrient method as recommended by Willet & Stamper (18). This method relies on the residuals from the regression of nutrient intake on total energy intake.

RESULTS

Sample

The sample was composed by 76 female and 45 male. The mean age was 14.9±2.2 years old in the overall sample, with a statistically significant difference between sex (14.1±2.3 *vs* 15.4±2.1 p=0.001, male and female, respectively). No direct assessment of puberty (maturity sexual) was performed. However, since there are many physiological and metabolic differences during pubertal development which are stronger in the beginning of adolescence (19), the sample was divided in two categories according to age: 10-13 y and 14-18 y (14).

Anthropometric evaluation

The anthropometric characteristics of the study population are presented in Table 1. There were statistically significant differences in weight and height of boys between age groups ($p<0.01$). The weight of girls with 10-13y was significantly higher than boys in same age group. While height of boys with 14-18y was significantly higher than girls in same group. No BMI differences between age groups were observed in boys and girls.

Nutritional status classification demonstrated a higher prevalence of underweight in boys than in girls, especially in

the 14-18y age group. Obesity was more frequently observed in the adolescents with 10 to 13 years. However, differences regarding underweight and obesity weren't statistically significant (p>0,05).

TABLE 1
Anthropometric characteristics of the study population

	Boys (n=45)		Girls (n=76)	
	10 – 13 y (n=23)	*14-18y* (n=22)	*10 – 13 y* (n=21)	*14-18y* (n=55)
Weight (kg)*	59.3 ± 19.4)†	78.9 ± 32.7†	73.1 ± 21.1	73.5 ± 19.4
Height (cm)*	153.3 ± 12.4‡	171.4 ± 9.3‡	158.3 ± 11.2	159.9 ± 7.3
BMI (kg/m²)*	24.9 ± 6.6	26.5 ± 9.1	28.4 ± 7.9	28.9 ± 7.1
Underweight (%)	17.4	13.6	14.3	7.3
Overweight (%)	21.7	18.2	23.8	21.8
Obesity (%)	52.2	31.8	51.9	49.1

*mean ± std deviation
†p<0,05
‡p<0,01

Energy and calcium intake

There were no statistical difference between sex and age groups for energy and calcium intake. The mean energy intake was 1729,9±557,8 kcal/day (1824,5±590,6 kcal/day for boys, and 1673,9±533,6 kcal/day for girls). The mean energy intake was lower than general recommendations for this group: 2750 kcal/day for boys and 2200 kcal/day for girls (15).

The mean daily calcium intake was 598.2±287.9 mg/day (635.1±276.8 mg/day for boys and 576.3±293.9 mg/day for girls). Only 2.5% of the adolescents present a calcium intake higher than Adequate Intake (AI) for the study population (1300mg/d) (13). Most of them (around 80% in both sexes) had mean calcium intake lower than 800mg/day.

Considering the positive correlation between calcium and energy intake (r=0.505 p<0.01), the calcium intake was adjusted for energy. The adjustment was done by residual nutrient method, since with this strong correlation between calcium and energy intake, the real relationship between this nutrient and body weight or BMI may not be identified (18). The mean of calcium intake was not altered with the adjustment although it was verified a decrease of 14% in standard deviation.

Calcium *vs* body weight and BMI

Adjusted calcium intake presented a negative correlation with body weight (r=-0.194, p=0.03) and BMI (r=–0.185, p=0.04). There were no differences between age groups. Furthermore, when the correlation of body weight and BMI with calcium intake was analyzed by nutritional status, the significant correlation was only observed in overweight and obese adolescents (r=-0.276, p=0.01 with body weight and r=-0.260, p=0.01 with BMI).

To evaluate the influence of calcium in body weight this nutrient intake was divided in quartiles and it was observed that adolescents in the lowest quartile presented higher BMI (Table 2). However, no statistical difference was observed between quartiles of calcium intake and BMI for either sex or age groups. The distribution of male and female in the different quartiles as well as age groups was similar the distribution in total sample.

TABLE 2
Distribution of Body Mass Index (BMI) of adolescents participants of CSCA[1] (2001-2003) according to quartile of calcium intake

Quartile	Calcium intake (mg/day)	BMI (kg/m²)
1 (n=31)	283.9 ± 91.6	29.7 ± 7.4
2 (n=31)	479.5 ± 40.2	27.3 ± 7.3)
3 (n=29)	642.1 ± 65.4	26.9 (8.6)
4 (n=30)	1003.0 ± 191.3	26.8 (7.3)

mean (std deviation)
[1]CSCA = Outpatient Clinics for Adolescents

Calcium sources

The qualitative food frequency questionnaire was used in order to identify the frequency of milk intake and dairy products, since they represent the major source of calcium in the diet.

Whole milk was the main source of calcium consumed by adolescents; 56.36% of the sample consumed milk at least once a day. The other foods mostly consumed on a daily basis were: butter, skimmed milk, and whole yogurt; 27.6%, 19.5% and 11.4% of the sample respectively. Low-fat yogurt was consumed by 31.2% of the adolescents. There wasn't significant difference in calcium sources between sex and age groups. However, overweight adolescents presented lower intake of food sources of calcium: 36.5% and 48.1% related never drink whole milk and low fat milk, respectively, compared to lower than 5% and 37% of normal weight adolescents.

DISCUSSION

Since calcium intake presented a negative correlation with body weight and BMI, the present study confirmed the hypothesis that dietary calcium could play a role in body weight regulation.

The small correlation between calcium intake adjusted by energy and the BMI of adolescents (r –0.185 p=0.04) can be explained in part by the low intake of this mineral. Zemel (20) emphasizes that the effects of calcium in weight reduction

are observed when calcium intake is at least, 1000 mg/d. Furthermore the relatively small sample size and large variability may have provided little power to identify small associations.

The contribution of calcium intake in body weight or BMI differs from 3% a 13% according to different studies (4,8,9,21). Certainly, this is significative because body weight regulation is a manifestly multifactorial matter and calcium intake as one of the several factors involved.

The low calcium intake observed in this study is also similar to others studies with adolescents (16,22). Since calcium is a nutrient with no established Estimated Average Requirement (EAR) and Recommended Dietary Allowance (RDA), it was not possible to estimate the prevalence of inadequacy of the nutrient (14). It is important to emphasize that calcium intake observed in the present study can be considered lower than the proposed Adequate Intake values (AI) according to Dietary Reference Intakes (DRIs). Furthermore, only 2,5 of the adolescents present a calcium intake higher than proposed values for AI, this can be an important factor for future risk of bone disorders, like osteoporosis. Skeletal maturity is achieved during the late stage of pubertal development with 90 to 95% of peak bone mass is attained by the second decade of life and bone growth during adolescence accounting for 45% of this attainment (17).

Energy intake was lower than estimated values for this age group, but it is similar to what has been observed in similar studies. Slater *et al.* demonstrated a mean energy intake of 2000 kcal in Brazilian adolescents (16). Matthys *et al.* (23) observed an intake of approximately 2000 kcal for boys, and 1800 kcal for girls with ages ranging from 13 to 18 years. It's necessary to consider the probability of underreporting of food intake, that are more pronounced among overweight and obese than among normal weight individuals. However this error could be minimized if the participants are well motivated (24).

The qualitative evaluation of the diet demonstrated that the main sources of calcium consumed by adolescents (like whole milk and butter) were also high energy food, explaining part of the significant correlation between calcium and energy intakes. This probably is one of several characteristics of a "typical" dietary habit of our adolescent population. It is recognized that a higher consumption of foods rich in this mineral but with low energy is required to increase calcium intake without increase energy intake. Vegetables, light and diet foods (low fat milk and dairy) are good options, although they are generally more expensive than regular foods (as such as whole milk and whole yogurt) in Brazil.

The present study also demonstrated a higher prevalence of overweight and obesity in adolescents. Considering the total number of participants, 70.3% were classified as overweight and obese. In part this is due to the fact that the study was undertaken from data of the Adolescents Outpatient Clinic, which comprises medical and nutritional evaluation for adolescents with nutritional disorders. This was confirmed by homogeneity of BMI between sex and age groups. The prevalence of overweight and obesity in the Brazilian adolescents its not well established, however Veiga *et al* 2004 (25), demonstrated that BMI increased dramatically in this population, mainly among boys. The prevalence of overweight was 17.9 (1.82)% and 17.8 (1.79)% between boys and girls, respectively, from urban region of Brazilian Southeast. In this study, the higher prevalence of overweight in the first age group (10 to 13 years) may be explained by significant weight gain in that happens at beginning of puberty, when the individual acquires 50% of adult body weight (19).

Considering the low calcium intake, its correlation with adiposity and the prevalence of obesity depicted in the present study, the need for an effort between health care professional should be stressed. The calcium rich foods with low fat content should be encouraged, not only to better regulate body weight, but also to prevent osteoporosis and the non-transmissible chronic diseases such as hypertension, negatively affected by the deficiency of this mineral.

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