Impact of calcium intake on body mass index in Venezuelan adolescents

CRISTINA PALACIOS, MSc, Ph D*; PAOLA BENEDETTI†; SILVIA FONSECA‡

The prevalence of overweight and obesity is increasing worldwide, affecting approximately 15% of adolescents in Venezuela, 17% in United States, and more than 30% in Mexico and Puerto Rico. Recent studies have shown that dietary calcium and dairy intake are associated with body fat. These studies show that a high calcium intake results in low body mass index (BMI). Therefore, the objective of the present study is to relate calcium intake from foods rich in calcium-rich foods to body weight and BMI in a random sample of 100 adolescents, aged 13-18 years. Anthropometric measurements (weight and height) were obtained for each participant, who also completed a food frequency questionnaire (FFQ), modified with calcium-rich foods. Dietary calcium consumption was 1076±534 mg/d among the adolescents, which represented an adequacy of 90%. A negative and significant association was found between calcium intake and BMI in the boys aged 13-15 years (r= -0.39, p<0.05). This population subgroup exhibited the widest range of BMI values among all groups evaluated. This correlation was not found among the older boys (aged 16-18 years) or girls, in which BMI was in the normal range and with relatively high calcium intake. In conclusion, we found that high calcium intake in younger boys was related to a lower BMI. A high calcium intake, not only helps to maintain a healthy body weight, but also is essential for acquiring peak bone mass in this crucial stage of life.

Key words: Calcium, Body weight, Body mass index, Adolescents.

Overweight and obesity in children and adolescents are major public health problems worldwide. It has been estimated at a prevalence of 15% in Venezuelan adolescents (1), 17% in children and adolescents from United States (2), up to 29% in European adolescents (3), 27.7% in Mexican adolescents (4), and about 27-35% in Puerto Rican adolescents (5, 6). Despite extensive efforts to reduce overweight and obesity rates, the worldwide prevalence has been steadily increasing over the years.

It is of great interest to identify dietetic factors involved in the increasing prevalence of overweight and obesity in children and adolescents. One such factor is calcium consumption. Several studies have shown an association between calcium intake, mainly from dairy products, and body weight and body fat content. The first study to show this association was based on an analysis of the National Health and Nutrition Examination Survey (NHANES III), conducted from 1988-1994 (7). The study showed that the odds ratio of being in the highest quartile of body fat was markedly reduced from 1.00 for the first quartile of calcium intake (255 mg/d) to 0.75 for the second quartile of calcium intake (484 mg/d), to 0.40 for the third quartile of calcium intake (773 mg/d), and finally to 0.16, for the fourth quartile of calcium intake (1346 mg/d) in adult women, after controlling for energy intake and physical activity. Therefore, this indicates that, for any given level of energy intake and expenditure, a high calcium diet favors a decrease in adipose tissue energy storage. The CARDIA study, conducted for 10 years in 3157 black and white US adults, aged 18 to 30 years, showed that the incidence of obesity was greater in those consuming the least dairy products (8). Other epidemiological studies confirmed this association in different populations (9-11).

There are a few studies relating calcium intake and body weight in children and adolescents. A longitudinal study in preschool children aged 5 to 6 years showed a significant reduction of 2 kg of body fat with the consumption of 1200 mg/d of calcium compared to those consuming only 500 mg/d (12). In a case-control study of Puerto Rican children aged 7 to 10 years, multiple regression analysis indicated that low calcium intakes were a strong predictor of obesity in girls (Odds Ratio 0.41) (13). This study showed that obese girls had a mean consumption of 647 mg/d of calcium while their non-obese counterpart had a mean calcium intake of 985 mg ($p<0.02$). Others have found similar results in North American, Italian, Chilean and Portuguese

*Program of Nutrition, School of Public Health, University of Puerto Rico, Medical Sciences Campus, San Juan, Puerto Rico, †Universidad Simón Bolivar, Caracas Venezuela, ‡Universidad Católica Andrés Bello, Caracas Venezuela

Address correspondence to: Cristina Palacios, Ph.D, Assistant Professor, Program of Nutrition, School of Public Health, University of Puerto Rico, Medical Sciences Campus, PO Box 365067, San Juan, Puerto Rico 00936-5067, Phone (787)758-2525, Ext. 1460, Fax (787) 759-6719, E-mail cpalacios @rcm.upr.edu

children (14-18) as well in North American, Greek and Hungarian adolescents (19-21). In Asian adolescents, the intake of 1 milk portion was found to decrease subcutaneous fat in the ilic skinfold by 0.78 mm (22). However, such association was not found in Danish adolescents if the source of calcium was from supplements (23).

These studies indicate a role for dietary calcium in the prevention and treatment of overweight and obesity. This relationship has not been studied in Venezuelan adolescents. Therefore, the goal of the present study is to determine in a sample of adolescents the association between dietary calcium and body weight.

Methods

Subjects: Subjects were adolescent students from a private school in Caracas, Venezuela. A convenient sample of 100 adolescents, aged 13-18 years, was randomly chosen. The participants and their parents received verbal and written information about the objectives of the study and written consent was obtained. Participation in the study was voluntary.

Measurements: Anthropometric measurements, such as weight and height, were taken by a trained researcher The measurements were taken while subjects were wearing underwear, shorts, shirts and socks, at the same time, during the morning recess period. For weight, a calibrated digital balance was used and for height, a wall stadiometer was used. Body mass index (BMI) was calculated for each subject by the following equation: weight (kg) / height $(m)^2$. BMI-for age was plotted on the sex specific growth charts from the Center of Disease Control (CDC). These charts indicate specific percentiles to determine weight status as either underweight (BMI-age < 5^{th} percentile), at risk for overweight (BMI-age 85^{th}-95^{th} percentile), or overweight (BMI-age >95^{th} percentile). The technical error of measurement for weight was 0,33 kg (tolerance level: 0,5 kg) and for height was 0,003 m (tolerance level: 3 mm) (24).

Dietary intake: Usual dietary calcium intake was assessed by a semi-quantitative food frequency questionnaire (FFQ), previously used and validated in Venezuelan adolescents (25). This FFQ was modified to include 49 foods rich in calcium. Subjects responded the questionnaire at school, with the help of the teacher and the researchers.

From the FFQ, an estimate of daily calcium intake was obtained for each subject by multiplying the amount reported for each food, by the response frequency (for example, 2 to 3 times a week = [((2+3)/2)/7] x amount of calcium (mg) for that food). To calculate the calcium content of each of the foods included in the FFQ, the Food Composition Table for Venezuela was used (26). The US Department of Agriculture food composition table was used for foods that were not included in the Venezuelan table (USDA Nutrient Data Laboratory and HealthTec Inc). Calcium adequacy was determined based on the daily recommended intakes of calcium for Venezuela (27).

Statistics: Means and standard deviations (DS) were computed for all the continuous variables. The data was checked for normality by normal probability plots and residual plots. Interactions between age and gender were assessed by analysis of variance. Since no interactions were found, a Student t-test was used to assess age differences within gender in general characteristics and calcium intake. Pearson correlation coefficients were obtained to describe the relationships between anthropometric measurements (weight and height) and BMI to calcium intake. When Pearson correlations were significant, the regression equations were used to predict this relationship. All means are reported with ± SD. Statistical significance was set at $p<0.05$. The Statistical Analysis System (SAS Institute, Cary, NC) program and Microsoft Excel for Windows 2000 was used for all the statistical analyses.

Results

Table 1 shows the subject's characteristics. A random sample of 50 adolescent girls and 50 adolescent boys was chosen. Boys were statistically significant heavier and taller than girls, but no significant differences were found in BMI. Most of the subjects had normal weight (Figure 1). Only 12% of the girls were at risk of overweight and none were overweight, while 6% of the boys were at risk and 8% were overweight.

Table 1. Subject's Characteristics (mean ± SD)

Subjects	N	Weight (kg)			Height (m)			BMI (kg/m		
		Mean		SD	Mean		SD	Mean		SD
Adolescent girls										
13-15 years	28	51.3	±	8.1	1.61	±	0.07	19.7	±	2.6
16-18 years	22	54.5	±	8.3	1.63	±	0.07	20.5	±	2.1
Total	**50**	**52.7**	**±**	**8.3**	**1.62**	**±**	**0.07**	**20.0**	**±**	**2.4**
Adolescent boys										
13-15 years	28	54.9	±	13.6*	1.67	±	0.10*	19.5	±	3.1
16-18 years	22	67.4	±	11.9*	1.74	±	0.05*	22.3	±	3.8
Total	**50**	**60.4**	**±**	**14.2**	**1.70**	**±**	**0.09**	**20.7**	**±**	**3.6**

SD: Standard Deviation
*Statistically significant compared to girls from same age at $p<0.05$

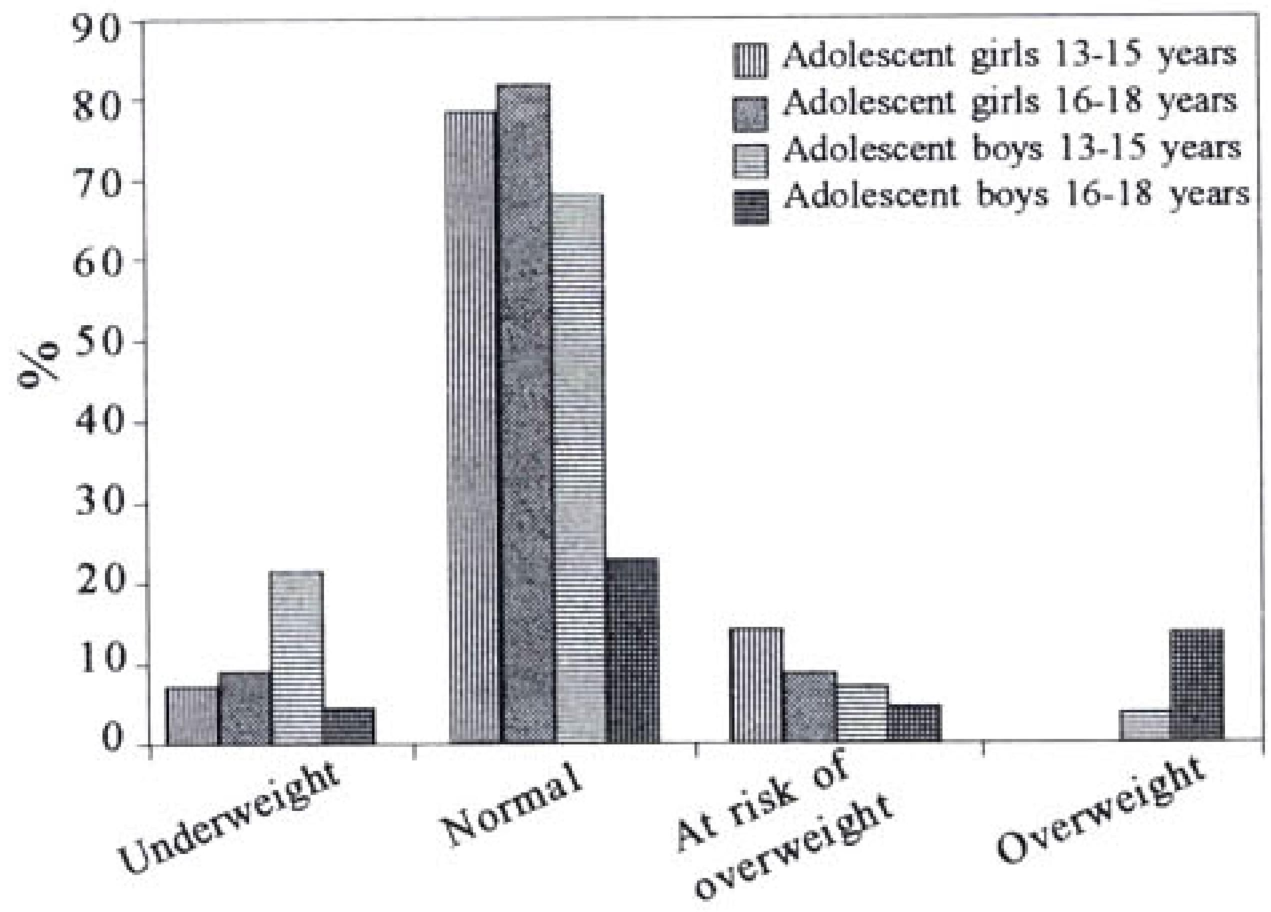

Figure 1. Body mass index (BMI) classification using sex specific growth charts from the Center for Disease Control (CDC).

Table 2 indicates that calcium intake was statistically significant higher in the younger adolescents, aged 13-15 years, compared with the older adolescents, aged 16-18 years (1176±582 mg/d vs 948±440 mg/d, respectively; $p<0.05$). Consequently, dietary calcium adequacy, as establish by the National Institute of Nutrition in Venezuela, 1200 mg/d of calcium, was adequate in the younger adolescents, but more than 20% were under the recommended levels in the older adolescents. No interactions were found in calcium intake and adequacy by age and gender.

Dairy products represented 76% of total calcium intake, followed by prepared foods with dairy products (Table 3). The 5 food items with the greatest contribution to calcium intake were: low fat milk, whole milk, white cheese (paisa/mozzarella), soft white cheese and liquid yogurt. About 28% of the sample consumed less than 3 servings of dairy products daily, 38% consumed between 3 and 4 servings, and only 34% consumed 5 o more servings daily.

Table 2. Dietary Calcium Intake and Adequacy (mean ± SD)

Subjects	N	Dietary calcium (mg) Mean		SD	Calcium intake adequacy (%)*
Adolescent girls					
13-15 years	28	1225.9	±	625.3	102.2
16-18 years	22	963.6	±	456.1	80.3
Total	**50**	**1110.5**	**±**	**567.3**	**92.5**
Adolescent boys					
13-15 years	28	1126.2	±	542.6	93.8
16-18 years	22	932.5	±	433.1	77.7
Total	**50**	**1041.0**	**±**	**502.0**	**86.7**

*Calcium requirement by the National Institute of Nutrition in Venezuela: 1200 mg/d
SD: Standard deviation

Table 3. Calcium intake by food item (mean ± SD)

Food item	Calcium intake (mg/d) Mean		SD	%
Dairy products	814.0	±	459.1	75.6
Processed foods*	114.6	±	113.4	10.6
Vegetables	61.3	±	57.6	5.7
Leguminosas	34.7	±	81.8	3.2
Fruits	30.5	±	29.6	2.8
Meats	12.9	±	20.9	1.2
Cereals	7.8	±	19.5	0.7

*Includes: pizza, ice creams, cheese finger, cheese empanada and chocolate
SD: Standard Deviation

Table 4 shows the Pearson correlation results between calcium intake and body weight and BMI. There was a significant correlation between calcium intake and BMI in the younger boys ($r=-0.39$, $p<0.05$) (Figure 2). No associations were found between dairy products or low fat milk intakes and body weight or BMI. A non-significant and positive trend was found between calcium intake and BMI in the older girls.

Table 4. Pearson Correlation Between Dietary Calcium Intake and Body Weight and BMI.

Subjects	N	Pearson correlation coefficient (r): Association between calcium intake and body weight	Association between calcium intake and BM
Adolescent girls			
13-15 years	28	-0.12	-0.14
16-18 years	22	0.27	0.30
Total	50	-0.02	-0.04
Adolescent boys			
13-15 years	28	-0.27	-0.39*
16-18 years	22	-0.03	-0.11
Total	50	-0.25	-0.31

* p< 0.05

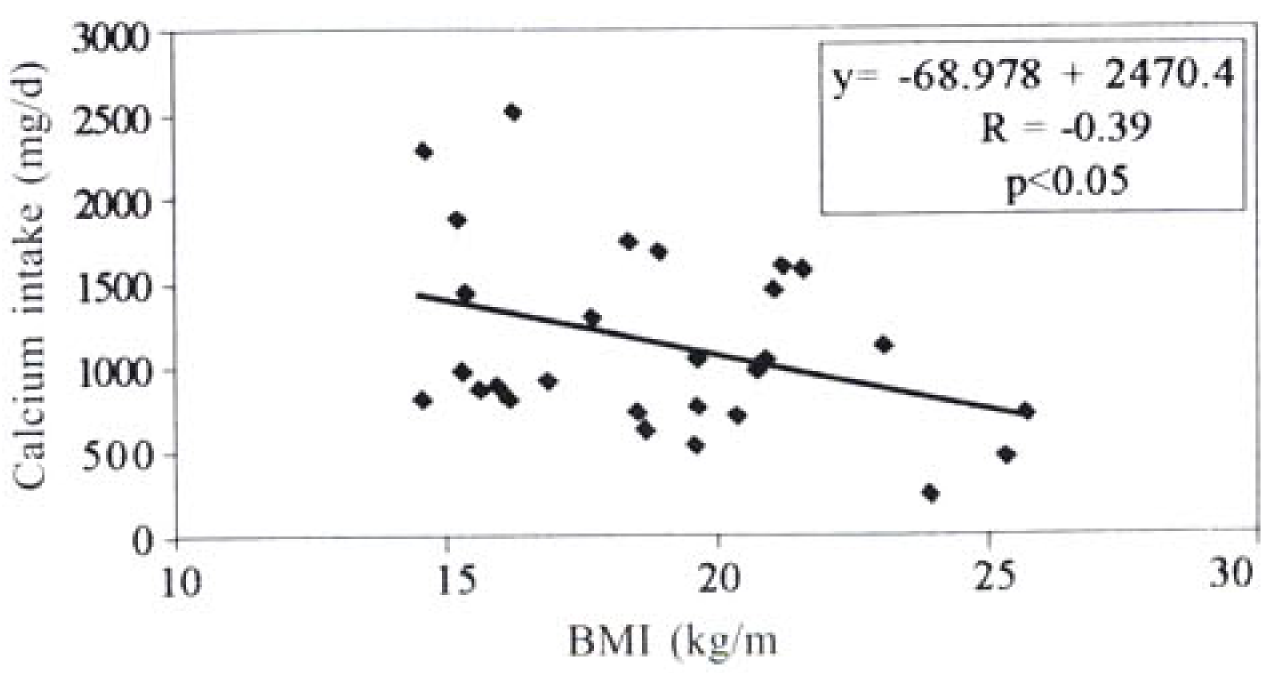

Figure 2. Pearson correlation between BMI (weight/kg²) and calcium intake (mg/d) in boys aged 13-15 years.

Discussion

The present study found a significant association between dietary calcium intake and BMI in a sample of adolescent boys aged 13-15 years. No associations were found among the older boys or among the girls.

Average calcium consumption was 1076 mg/d, with about 90% adequacy. The younger girls were the only group achieving 100% of calcium intake adequacy. Compared to other studies, calcium intake in our sample was very high. A study in 625 adolescents from 3 private schools and 3 public schools in Caracas found a lower calcium adequacy (83%) and only 14% achieved the recommendation of 5 daily servings of dairy products (25). In the present study, 34% of the subjects reached this recommendation. Another study in 607 children and adolescents between 4 and 14 years, in an urban community in Venezuela, found a 43% adequacy in the older children, but 70% of the sample did not reach 2/3 of the calcium intake recommendation (800 mg/d) (28). In US adolescents, calcium intake is very low; about 62% consume less than 900 mg/d of calcium (29). In European adolescents, calcium intake is about 700-1000 mg/d (30).

In the younger boys, a high dietary calcium intake was significantly associated with a lower BMI. Similarly, a study in 315 adolescent Asian girls, aged 9-14 years, with a mean calcium intake of 737±371 mg/d, found a significant and negative association between calcium intake and fat mass, measured by the iliac skin-fold (22). In Dutch adolescents, a weak association was also found between calcium intake and BMI and skinfold thickness (31). Another study in 80 Hungary adolescents (40 overweight and 40 controls) found that those overweight had a significantly lower calcium intake compared to controls, with intakes as low as 300-400 mg/d of calcium (20). However, others have found the opposite effect. A study in 12,829 North American children and adolescents, aged 9-14 years, reported a relationship between higher calcium intake and higher BMI (32).

Cellular, animal, and human studies indicate several possible mechanisms to explain how calcium and dairy products lead to changes in body composition. In vitro and mice studies show that high calcium intakes inhibit the influx of calcium into fat cells, a process stimulated by 1α, 25-dihydroxyvitamin D3 (the active form of vitamin D), therefore, inhibiting storage of fat and promoting the breakdown of fat (33). They also found that 1α, 25-dihydroxyvitamin D3 has an inhibitory effect on uncoupling protein 2, a protein found in fat cells that helps the body "burn energy", which is suppressed by a high calcium diet (34). In addition, studies in mice found that a calcium rich diet upregulates this fat burning mechanism (35). Alternatively, a diet high in calcium and dairy protein results in an increase in fecal fat excretion (36), presumably due to formation of insoluble calcium fatty acid soaps or to the binding of bile acids, which impairs the formation of micelles (37). A low calcium intake decreases fatty acid saponification with calcium in the gut, which increases fat absorption (38). Furthermore, a high dairy calcium intake attenuates postprandial lipidemia (39).

A limitation of the study was that the majority of the adolescent girls had a normal weight, resulting in a small range of BMI to detect such relationship. For further research, a more diverse and larger sample should be included, as well as to confirm these results in other population groups. Another limitation was that calcium intake from supplements was not included in the FFQ. However, several studies have reported a greater effect of calcium intake from dairy products on body composition compared to calcium from supplements (40).

In conclusion, a high dietary calcium intake in younger boys benefits body weight control. A high calcium intake would potentially benefit the acquisition of peak bone mass, a vital process in this stage of life.

Resumen

Influencia de la ingesta de calcio en el índice de masa corporal en adolescentes

La prevalencia del sobrepeso y la obesidad está en aumento a nivel mundial, afectando aproximadamente al 15% de los adolescentes en Venezuela, 17% en Estados Unidos, y más del 30% en México y Puerto Rico. Recientemente se han reportado varios estudios relacionando la ingesta de calcio con el peso corporal. Éstos parecen sugerir que a mayor consumo de calcio, menor es el peso corporal del individuo. El objetivo del presente estudio fue relacionar la ingesta de calcio con el peso corporal y el índice de masa corporal (IMC) en una muestra de 100 adolescentes femeninos y masculinos de 13 a 18 años de edad. Se tomaron medidas antropométricas (peso y talla) y se aplicó un cuestionario de frecuencia de consumo de alimentos altos en calcio. El consumo de calcio fue 1076±534 mg/d, lo cual representa un 90% de adecuación en el consumo diario de calcio. Se encontró una relación negativa y significativa entre el consumo de calcio y el IMC en los varones de 13 a 15 años ($r = -0.39$, $p<0.05$). Este subgrupo tuvo el rango mas amplio en IMC entre todos los grupos evaluados. Esta correlación no se observó en los varones mayores (16-18 años) o en las hembras, en donde el IMC se encontró dentro de los rangos normales, con una ingesta relativamente alta en calcio. En conclusión, se encontró en los adolescentes varones más jóvenes que el consumo de calcio favorece el control del

peso corporal. Un alto consumo de calcio no sólo favorecería el control de peso en los adolescentes, sino que además es de vital importancia para el desarrollo óseo óptimo en esta etapa del individuo.

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