PREDICTORS OF BONE MINERAL DENSITY IN ADOLESCENTS WITH EXCESS WEIGHT

PREDITORES DA DENSIDADE MINERAL ÓSSEA EM ADOLESCENTES COM EXCESSO DE PESO

PREDICTORES DE LA DENSIDAD MINERAL ÓSEA EN ADOLESCENTES CON EXCESO DE PESO

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ABSTRACT

Introduction: Adolescence is characterized as a phase of intense development of the skeletal system. Maximizing bone mass acquisition during adolescence may reduce the risk of bone fractures later in life. Objectives: To analyze bone mineral density (BMD) and its relation to nutritional status and serum vitamin D in adolescents with excess weight. Methods: This is a cross-sectional, exploratory study. Data from 102 adolescents with excess weight, of both sexes, were analyzed. The following indices were evaluated: body mass index (BMI), abdominal circumference (AC), intake of micronutrients (vitamin D, calcium, magnesium and phosphorus), serum 25-hydroxycholecalciferol (25(OH)D concentration, BMD of the proximal femur, lumbar spine (L1-L4) and total body, % body fat mass (% BFM), total BFM, total body lean mass (BLM), body fat mass (BFMI) and lean mass (BLMI). Results: The male adolescents (n=53) had higher values for weight, height, AC, BLM and BLMI, while the females (n=49) had higher % BFM. The majority were obese (53.9%) and had a BMD within the normal range for all evaluation sites. Of the 84 adolescents (n=84) with laboratory examination of 25OHD, 33.3% presented values considered insufficient or deficient. Multivariate linear regression analysis showed that the most important independent predictor of BMD for the girls was BLMI, regardless the evaluation site. For boys, in addition to BLMI, BMI-Z of the proximal femur (neck of the femur and total) was also was a determinant variable for BMD. Conclusion: In this sample of adolescents, BLMI was a positive predictor of BMD in both sexes; and BMI-Z was a positive predictor only in proximal femur in the boys. ***Level of evidence II; Prognostic studies.***

Keywords: Bone density; Obesity; Adolescent; Vitamin D; Body composition.

RESUMO

Introdução: A adolescência é caracterizada como uma fase de intenso desenvolvimento do sistema esquelético. A maximização do pico de massa óssea durante a adolescência contribui para a redução do risco de fraturas na vida adulta. Objetivos: Analisar a densidade mineral óssea (DMO) e sua relação com o estado nutricional e a concentração plasmática de vitamina D em adolescentes com excesso de peso. Métodos: Trata-se de uma pesquisa transversal, de caráter exploratório, onde foram analisados dados de 102 adolescentes com excesso de peso, de ambos os sexos. Avaliaram-se índice de massa corporal (IMC), circunferência abdominal (CA), consumo de micronutrientes (vitamina D, cálcio, magnésio e fósforo), concentração sérica de 25-hidroxicolecalciferol (25(OH)D), DMO do fêmur proximal, da coluna lombar (L1-L4) e do corpo total, % gordura total (%G), massa gorda (MG) e massa magra (MM) totais e índices de massa gorda (IMG) e massa magra (IMM). Resultados: Os adolescentes do sexo masculino (n=53) apresentaram maiores valores de peso, estatura, CA, MM e IMM e para o sexo feminino (n=49) encontrou-se maior %G. A maioria estava com obesidade (53,9%) e DMO dentro da normalidade para todos os sítios de avaliação. Dos 84 adolescentes que realizaram a dosagem de 25(OH)D, 33,3% apresentaram valores considerados insuficientes ou deficientes. A análise de regressão linear multivariada demonstrou que a variável mais importante como preditora independente da DMO para as meninas foi o IMM, independente do sítio de avaliação. Nos meninos, além do IMM, o IMC-Z também se comportou como variável determinante dos resultados da DMO na parte proximal do fêmur (colo e total). Conclusão: Nesta amostra de adolescentes, o IMM apresentou-se como preditor positivo para a DMO em ambos os sexos; e o IMC-Z como preditor positivo apenas para a parte proximal do fêmur no sexo masculino. ***Nível de evidência II; Estudos prognósticos.***

Descritores: *Densidade óssea; Obesidade; Adolescente; Vitamina D; Composição corporal.*

RESUMEN

Introducción: La adolescencia se caracteriza como una fase de intenso desarrollo del sistema esquelético. La maximización del pico de masa ósea durante la adolescencia contribuye para la reducción del riesgo de fracturas en la vida adulta. Objetivos: Analizar la densidad mineral ósea (DMO) y su relación con el estado nutricional y la concentración plasmática de vitamina D en adolescentes con exceso de peso. Métodos: Se trata de una investigación transversal, de carácter exploratoria, en donde se analizaron datos de 102 adolescentes con exceso de peso, de ambos sexos. Se evaluaron Índice de masa corporal (IMC), circunferencia abdominal (CA), consumo de micronutrientes (vitamina D, calcio, magnesio y fósforo), concentración sérica de 25-hidroxicolecalciferol (25(OH)D), DMO del fémur proximal, de la columna lumbar (L1-L4) y del cuerpo total, % grasa total (%G), masa grasa (MG) y masa magra (MM)

totales e índices de masa grasa (IMG) y masa magra (IMM). Resultados: Los adolescentes del sexo masculino (n = 53) presentaron mayores valores de peso, estatura, CA, MM e IMM; y para el sexo femenino (n = 49) se encontró mayor %G. La mayoría estaba con obesidad (53,9%) y DMO dentro de la normalidad para todos los sitios de evaluación. De los 84 adolescentes que realizaron el dosaje de 25(OH)D, 33,3% presentó valores considerados insuficientes o deficientes. El análisis de regresión lineal multivariada demostró que la variable más importante como predictora independiente de la DMO para las niñas era el IMM, independientemente del sitio de evaluación. En los niños, además del IMM, el IMC-Z también se comportó como variable determinante de los resultados de la DMO en la parte proximal del fémur (cuello y total). Conclusión: En esta muestra de adolescentes, el IMM se presentó como un predictor positivo para la DMO en ambos sexos; y el IMC-Z como predictor positivo sólo para la parte proximal del fémur en el sexo masculino. ***Nivel de evidencia II; Estudios pronósticos.***

Descriptores: *Densidad ósea; Obesidad; Adolescente; Vitamina D; Composición corporal.*

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INTRODUCTION

Adolescence is a stage of human development with specific needs and characteristics. Significant changes in the biopsychosocial order make adolescence a period of potentialities, vulnerability and risks.[1] The skeletal system is one of the organic systems with intense development at this stage of the life cycle, period in which the peak bone mass occurs and the magnitude of this process contributes to reduce the risk of fractures in adulthood.[2]

Body weight, age and sexual maturation can be considered as the main factors related to bone mass during adolescence.[3] The variation in peak bone mass is explained by numerous factors, such as gender, race, dietary habits and physical activity, hereditary factors, hormonal factors, presence of intercurrent diseases, chronic use of medications and body composition characteristics.4 Adiposity excess, although associated with increased bone size, can have an adverse effect on its quality.[2] Increased body weight interferes with both bone mass acquisition and loss and is directly linked to the risk of being overweight or obese.[4]

Adipose and bone tissues are metabolically active organs due to the constant production and release of molecules, cytokines and hormones. These molecules modulate via endocrine and paracrine signaling a number of metabolic activities.[2] The pathophysiological role of adipose tissue in bone tissue homeostasis is probably related to the action of these molecules in a homeostatic feedback system, in which adipokines and molecules secreted by osteoblasts and osteoclasts act on the bone-adipose-active axis. Deregulation of secreted factors in adipose tissue is not only linked to overweight and its complications, but also has important effects on bone metabolism.[5]

Obesity is a worrisome condition due to the increasing number of cases in children and adolescents, being a strong predictor of adult obesity [6] and related to the presence of comorbidities in all life cycle stages.[2] The prevalence of overweight and obesity among children and adolescents aged 5 to 19 increased dramatically from only 4% in 1975 to just over 18% in 2016. While just under 1% of children and adolescents aged 5 to 19 were obese in 1975, more than 124 million children and adolescents (6% of girls and 8% of boys) were obese in 2016, which requires immediate public health actions.[6]

When considering that: (a) obesity and osteoporosis are serious global public health issues,[2,6] (b) overweight and its comorbidities are increasingly present in early stages of the life cycle,[1,6] (c) the higher life expectancy led to an increased prevalence of osteoporosis and fractures[4] and (d) there is a correlation between body weight and bone mass development,[3,4] this research was conducted with the main objective of analyzing bone mass and its relationship with nutritional status and serum vitamin D concentration in overweight adolescents.

MATERIAL AND METHODS

This is a cross-sectional, descriptive, exploratory and quantitative study, based on data analysis from overweight adolescents selected from four Family Health Strategies Units (ESFs) of Blumenau/SC, linked to the Research Project "Life and health of adolescents in chronic condition," approved by the Research Ethics Committee (612.197/2014). This study included 249 adolescents registered in the research database with anthropometric information of 840 out of a total of 1,254 adolescents enrolled in the four ESF. Adolescents using continuous medication or vitamin D supplements, on a diet due to the presence of some disease, who performed scheduled physical activity in addition to curricular physical education and those who did not perform bone mass evaluation were excluded.

We measured body mass and height to determine body mass index (BMI), which was classified according to Z score (BMI-Z),[8] and waist circumference (WC). Food intake was collected through the Food Frequency Questionnaire for Adolescents (FFQA).[9] To estimate the intake of micronutrients (vitamin D, calcium, magnesium and phosphorus), we used the Food Composition Table as the main basis,[10] relating it to the frequency of intake. For foods not found, we used data from the United States Department of Agriculture (USDA) database.

Bone mass and body composition were evaluated by double X-ray densitometry (DXA) with Hollogic® Explorer device (Bedford, Massachusetts, USA). To evaluate bone mass, we used bone mineral density (BMD) in the whole body, femoral neck, total femur and lumbar spine (L1-L4) sites. In body composition, we used the parameters: body fat percentage (%F), fat mass (FM) and lean mass (LM) in Kg. BMD was measured in g/cm^2 and later transformed into a Z-score. For interpreting BMD, we followed the criteria by Zemel et al[11], who considers normal a BMD with Z-score $\geq$-1 SD; low bone mass (LM) a BMD with Z-score between 1 and -2 SD; and very low bone mass (VLM) a BMD with Z-score $\leq$-2 SD. From the %F data, we calculated the total fat mass (FM) and the total lean mass (LM), and then the fat mass index (FMI) (FM divided by height squared) and the lean mass index (LMI) (LM divided by height squared).

The serum concentration of 25-hydroxycholecalciferol (25(OH)D) was determined by high performance liquid chromatography, with ultraviolet reading by efficient protein precipitation and solid-phase extraction, where components are removed. Values lower than 15 ng/ml and between 15 and 20 ng/ml, were classified as deficiency and insufficiency, respectively.[12]

The data undertook statistical analysis. Normality of the distribution of the variables was verified by the Kolmogorov-Smirnov test. For bivariate analysis with gender, we used Student's t-test or Mann-Whitney's *U* test; for BMD, we used Pearson correlation or Spearman's rank correlation. We performed stepwise multiple regression analyses to determine the possible effects of each independent variable over dependent variables (Lumbar spine, femoral neck, total femur and total body BMD). Significance was considered when $p<0.05$.

RESULTS

Table 1 shows the adolescents' main characteristics, stratified by gender. The median age was 13 years and the median %F was 36.5%. Male adolescents had higher values of weight, height, AC, FM and LMI and female adolescents had a higher %F mean value. Most adolescents were obese (53.9%) or had normal BMD. Of the 84 adolescents who underwent the laboratory examination, 66.7% (n=58) had normal serum levels of 25(OH)D and 33.3% (n=28), levels considered insufficient or deficient. (Table 2)

In the bivariate analysis, the linear correlation coefficients showed that, for girls, the femoral neck BMD presented a positive correlation with the BMI (kg/m^2) and FMI values, and a negative correlation with the serum vitamin D. In males, there was a positive BMD correlation in all evaluation sites with height, BMI (kg/m^2), LM and FM. (Table 3)

Multivariate linear regression analysis showed that the most important variable as an independent BMD predictor for girls was the LMI, for total body, total femur and femoral neck sites. We found no significant predictor variables in the lumbar spine. Unlike girls, in boys, LMI was the most important independent predictor in all sites evaluated. In addition, BMI-Z also behaved as a decisive variable in the femur BMD results (neck and total). (Table 4)

DISCUSSION

In this study, we observed the prevalence of adolescents with obesity and excess abdominal fat, with boys showing higher values of lean mass and abdominal fat markers and girls of total fat. Aspects that can be justified by the presence of sexual dimorphism, which involves genetic, hormonal and environmental factors,[13] begining in adolescence, during the different pubertal stages.[5] During puberty, changes occur in the adolescents' growth spurt and body composition, with the most significant BMI increase occurring between seven and 15 years. However, boys develop FM more slowly, or they present a decrease in FMI with a rapid increase in LMI between 13 and 15 years. Girls, on the other hand, present a similar increase in LMI and FMI up to 13 years of age, with a

Table 2. Percentage of adolescents according to anthropometric, biochemical and densitometric classification.

Variable	Classification	Total % (n)	Female % (n)	Male % (n)
BMI-Z	Eutrophy	7.8 (8)	10.2 (5)	5.7 (3)
	Overweight	38.2 (39)	40.8 (20)	35.9 (19)
	Obesity	53.9 (55)	49.0 (24)	58.5 (31)
	Total	100.0 (102)	100.0 (49)	100.0 (53)
Lumbar spine BMD	Very low	3.0 (3)	2.0 (1)	3.8 (2)
	Low	10.9 (11)	8.2 (4)	13.5 (7)
	Normal	78.2 (79)	83.7 (41)	73.1 (38)
	High	7.9 (8)	6.1 (3)	9.6 (5)
	Total	100.0 (101)	100.0 (49)	100.0 (52)
Total body BMD	Very low	5.9 (6)	4.1 (2)	7.7 (4)
	Low	14.9 (15)	18.4 (9)	11.5 (6)
	Normal	76.2 (77)	77.5 (38)	75.0 (39)
	High	3.0 (3)	0.00 (0)	5.8 (3)
	Total	100.0 (101)	100.0 (49)	100.0 (52)
Femoral neck BMD	Very low	1.0 (1)	0.0 (0)	1.9 (1)
	Low	5.9 (6)	4.2 (2)	7.5 (4)
	Normal	76.2 (77)	77.1 (37)	75.5 (40)
	High	16.8 (17)	18.7 (9)	15.1 (8)
	Total	100.0 (101)	100.0 (48)	100.0 (53)
Total femur BMD	Very low	3.0 (3)	2.1 (1)	3.8 (2)
	Low	6.9 (7)	10.4 (5)	3.8 (2)
	Normal	85.1 (86)	87.5 (42)	83.0 (44)
	High	5.0 (5)	0.0 (0)	9.4 (5)
	Total	100.0 (101)	100.0 (48)	100.0 (53)
Vitamin D (25OHD)	Sufficient	66.7 (56)	63.4 (26)	69.8 (30)
	Insufficient	21.4 (18)	26.8 (11)	16.3 (7)
	Deficient	11.9 (10)	9.8 (4)	13.9 (6)
	Total	100.0 (84)	100.0 (41)	100.0 (43)

Body mass index (BMI); bone mineral density (MOD); female (fem); male .

Table 1. Descriptive measurements of anthropometric, densitometric, biochemical and micronutrient intake variables of overweight adolescents according to gender, Blumenau (SC), Brazil, 2014.

Variable	Total N=102	Female N=49	Male N=53
Age (years)	13 (10-19)	13 (10-17)	14 (10-19)
Age (months)	166.6±27.7	161.7±25.4	171.1±29.2
Weight (kg)*	72.5±17.0	66.3±14.1	78.3±17.5
Height (m)*	1.6±0.1	1.6±0.1	1.7±0.1
Body mass index (kg/m^2)	26.7 (20.3-40.6)	26.0 (20.3-35.6)	27.0 (20.3-40.6)
Body mass index (Z-score)	1.6±0.6	1.5±0.5	1.7±0.6
Waist circumference (cm)*	94.6±11.8	91.1±11.6	98.0±11.1
% total fat*	36.5 (13.3-49.3)	39.3 (26.2-45.5)	32.7 (13.3-49.3)
Lean mass (kg)	25.1±9.1	25.2±8.3	25.1±9.9
Fat mass (kg)*	47.4±12.3	41.1±9.2	53.2±12.1
Lean mass index (kg/m^2)*	17.7±2.9	16.5±2.8	18.8±2.6
Fat mass index (kg/m^2)	9.5±3.3	10.1±2.9	9.0±3.6
Lumbar spine (Z-score)**	0.254±1.169	0.296±1.049	0.215±1.281
Femoral neck (Z-score)**	0.717±1.233	0.769±1.164	0.670±1.301
Total body (Z-score)**	-0.130±1.154	-0.140±1.040	-0.120±1.261
Total femur (Z-score)**	0.338±1.120	0.312±1.111	0.360±1.138
25-Hydroxycholecalciferol (ng/mL)	25.3 (11.5-50.1)	22.8 (13.7-45.7)	25.5 (11.5-50.1)
Calcium (mg)	649.4 (76.8-1771.7)	642.3 (78.6-1771.7)	666.1 (76.8-1443.8)
Phosphorus (mg)	957.2 (115.0-2815.1)	985.4 (115.0-2438.6)	955.3 (212.0-2815.1)
Magnesium (mg)	245.2 (31.7-663.1)	271.1 (31.7-625.6)	231.7 (48.3-663.1)
Vitamin D (mcg)	219.0 (0.4-679.0)	219.1 (0.4-674.1)	221.5 (0.6-679.0)

(*) indicates significant difference between genders; (**) Bone Mineral Density.

Table 3. Coefficient of linear correlation of bone mineral density with anthropometric, nutritional, densitometric and body composition variables according to gender, Blumenau (SC), Brazil, 2014.

Variable	Lumbar spine BMD		Total body BMD		Femoral neck BMD		BMD total femur	
	fem	male	fem	male	fem	male	fem	male
Age (years)	-0.076	-0.105	-0.108	-0.064	-0.020	-0.190	-0.060	-0.196
Age (months)	0.051	0.379**	0.162	0.399**	0.204	0.389**	0.072	0.338*
Weight (kg)	-0.013	0.214	-0.008	0.229	-0.017	0.124	-0.061	0.101
Height (m)	0.118	0.355**	0.198	0.304**	0.352*	0.419**	0.181	0.362**
Body mass index (kg/m^2)#	0.166	0.365**	0.269	0.336*	0.321*	0.453**	0.198	0.435**
Body mass index (Z-score)	-0.072	0.219	0.045	0.164	0.173	0.222	0.046	0.178
Waist circumference (cm)*	-0.105	-0.042	-0.083	-0.128	0.169	0.048	-0.026	-0.008
% total fat#	-0.046	0.208	0.046	0.179	0.177	0.257	0.014	0.211
Lean mass (kg)	0.120	0.399**	0.207	0.452**	0.153	0.351**	0.124	0.315*
Fat mass (kg)	0.187	0.499**	0.277	0.551**	0.237	0.490**	0.275	0.456**
Lean mass index (kg/m^2)*	-0.025	0.172	0.051	0.128	0.232	0.242	0.067	0.206
Fat mass index (kg/m^2)	-0.188	-0.083	-0.150	0.055	-0.331*	-0.018	-0.217	-0.028
Lumbar spine (Z-score)**	-0.053	-0.010	0.107	0.090	-0.031	0.150	0.000	0.035
Femoral neck (Z-score)**	-0.062	-0.018	0.121	0.044	-0.029	0.151	-0.010	0.062
Total body (Z-score)**	0.059	-0.023	0.227	0.018	0.117	0.085	0.095	0.008
Total femur (Z-score)**	0.059	0.013	0.183	0.034	0.110	-0.164	0.080	-0.149
25(OH)D (ng/mL) #	-0.188	-0.083	-0.150	0.055	-0.331*	-0.018	-0.217	-0.028
Calcium (mg) #	-0.053	-0.010	0.107	0.090	-0.031	0.150	0.000	0.035
Phosphorus (mg) #	-0.062	-0.018	0.121	0.044	-0.029	0.151	-0.010	0.062
Magnesium (mg) #	0.059	-0.023	0.227	0.018	0.117	0.085	0.095	0.008
Vitamin D (mcg) #	0.059	0.013	0.183	0.034	0.110	-0.164	0.080	-0.149

Bone mineral density (BMD);25-hydroxycholecalciferol (25(OH)D); (#) Spermann's correlation; other variables: Pearson correlation; (*) p<0.05; (**) p<0.01.

Table 4. BMD multivariate linear regression analysis regarding gender, Blumenau (SC), Brazil, 2014.

Gender	BMD	Model	R^2	Adjusted R^2	p
Female	Lumbar spine	There were no significant variables			
	Total body	-1.853 + (0.104 x LMI)	0.077	0.057	0.050
	Femoral neck	-1.708 + (0.093 x LMI)	0.109	0.090	0.022
	Total femur	-2.314 + (0.162 x LMI)	0.076	0.055	0.050
Male	Lumbar spine	-4.621 + (0.259 x LMI)	0.249	0.234	<0.001
	Total body	-5.381 + (0.282 x LMI)	0.304	0.290	<0.001
	Femoral neck	-3.921 + (0.184 x LMI) + (0.677x BMI-Z)	0.317	0.289	0.022
	Total femur	-3.371 + (0.147 x LMI) + (0.584 x BMI-Z)	0.282	0.253	0.028

Bone mineral density (BMD); Lean Mass index (LMI); Body Mass Index (BMI).

subsequent significant and continuous increase in FM.[14] Although we did not evaluate the pubertal stage, it is worth highlighting that in our sample most adolescents were older than 13 years, age compatible with the pubertal development.

BMD evaluation showed normal bone mass in most adolescents studied, regardless of the anatomical site evaluated and similar in both genders. In addition, we found no correlation between BMD and the indicators of total adiposity. Similar results are described in obese adolescents of both genders.[3,15]

The data available in the literature regarding the relationship between fat mass markers and BMD are conflicting. Some studies describe both FMI[5] and FM[16] as bone mass predictors in female adolescents (regardless of nutritional status). While others have shown that the accumulation of body fat is unfavorable to bone structure in males,[17] females[18] or in both genders.[19]

Although the association between obesity and increased bone mass is explained by biomechanical,[20] hormonal[6] and cell differentiation[21] mechanisms, it seems that a higher BMD observed in individuals classified as obese would be disproportional to body weight increase. In this case, adiposity is the largest component derived from overweight.[21] There is also evidence that the BMD per BMI unit is lower in obesity,[22] and of the negative impact exerted by excess body fat on bone quality in adults and children.[23] An adequate amount of body fat is, then, needed for bone mass development, but its excess would be harmful.[24] Therefore, obesity could not be considered a protective factor against osteoporosis.[16]

Increased daily calcium and protein intake and prevention of vitamin D insufficiency have a potential impact on improving and maintaining bone health and protecting against fractures at all stages of life.[20,2] However, in the adolescents evaluated here, we found no BMD correlations with micronutrient intake; results that are in line with other studies,[3,25] and with the serum concentration of vitamin D. It should be noted that persistent vitamin D inadequacy during the entire adolescence stage can prevent the ideal peak of bone mass set for adulthood.[26] Vitamin D is an essential nutrient, which plays an important role in calcium homeostasis and bone health.[27] The cross-sectional design of our study may have hindered verifying the relationship of vitamin D and micronutrient intake with BMD.

In the multiple regression analysis, LMI was a positive mineralization predictor for both genders. Similar results have shown that LM is the body component that most influences acquiring or maintaining bone mass, both in adolescence[16,20] and in other stages of life.[28] It is justified by the mechanical stress stimulus originated from the greater amount of LM in obese individuals.[20] LM positively influences bone mass during osteogenesis, in addition to reducing or avoiding bone loss during a period of caloric restriction with weight loss, especially when associated with adequate calcium intake.[21] A static load proportional to the amount of adipose tissue seems to cause less bone expansion than the dynamic load, proportional to the amount of LM.[24] We also found that, particularly in males , the BMI-Z values influenced BMD positively and to a greater extent than the LMI, in the anatomical sites of the lower limbs. The femur is exposed to greater mechanical stress generated by body weight,[29] which favors the BMD increase, to benefit the body's support, because the bone adapts to the mechanical loads applied to it.[6] Moreover, this generated load stimulates bone formation, both by reducing apoptosis,

as well as by increasing proliferation and differentiation of osteoblasts and osteocytes, which favor osteoclastogenesis.[21]

The speed of growth in length and femoral strength is highly correlated with the speed of increased body weight, very little correlated with growth in stature, but significantly with the size of the thigh muscle.[30] This shows that the LM is a strong predictor of BMD of the proximal femur in all age groups.[16] These correlations are more significant in males due to the greater LM amount and, consequently, a higher body weight,[30] which could justify the high correlation found for femoral (neck and total) BMD with LMI and BMI-Z in boys and only the influence of LMI on the spine and total body, due to the lower static stimulus in these regions.

Thus, a very low body weight, especially with lower LM, would be harmful to the bones,[28] and normal levels of body fat would support bone health in the development of children and adolescents.[24] The higher the body weight, the higher the BMI and, consequently, the relationship of BMD with the lower limbs. However, body weight includes fat and LM, the latter being the positive influence on bone mass.

Studies have identified bone mass loss with weight loss programs for obese individuals. This loss may vary according to age (worse with advancing age), gender and the individual's adiposity (proportional to the amount of fat stored and weight loss).[25,21] When undergoing caloric restriction, obese individuals tend to have greater bone loss due to greater decline in estrogen levels and other sex steroids.[21] However, weight loss accompanied by physical activity (mainly impact exercises) is associated with lower bone loss when compared with weight loss followed solely by caloric restriction.[15,2] Corroborating these observations, studies cite that obesity does not provide mechanical advantage for the bone if not accompanied by greater lean mass, resulting from an physically active lifestyle and adequate nutrition.[21]

The results of this study show the influence of body composition on BMD in overweight adolescents, especially LM. In this sense, stimulating regular physical activity in this health condition assumes special importance, not only for promoting weight loss but also for acquiring a body composition that favors peak bone mass.

CONCLUSIONS

The results of this study show that body composition is a BMD predictor in overweight adolescents. LM was a positive BMD predictor in both genders at total body, femoral neck and total femur sites.

In males, in addition to body composition, age-adjusted BMI (BMI-Z) proved to be a positive BMD predictor in the proximal femur.

There was no association between BMD and adiposity parameters, micronutrient intake (calcium, phosphorus, magnesium and vitamin D) and serum vitamin D levels.

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