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Excess body fat negatively affects bone mass in adolescents

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ABSTRACT

Objective: The aim of this study was to investigate the effects of excess body fat on bone mass in overweight, obese, and extremely obese adolescents.
Methods: This study included 377 adolescents of both sexes, ages 10 to 19 y. Weight, height, body mass index (BMI), bone age, bone mineral content (BMC), and bone mineral density (BMD) were obtained by dual-energy x-ray absorptiometry. The results were adjusted for chronological age and bone age. Comparisons according to nutritional classification were performed by analysis of variance, followed by Tukey test. Linear regression models were used to explain the variation in BMD and BMC in the L1–L4 lumbar spinal region, proximal femur, and whole body in relation to BMI, lean mass, fat mass (FM), and body fat percentage (BF%), considering $P < 0.05$.
Results: For all nutritional groups, average bone age was higher than chronological age. In both sexes, weight and BMI values increased from eutrophic to extremely obese groups, except for BMD and BMC, which did not differ among male adolescents, and were smaller in extremely obese than in obese female adolescents ($P < 0.01$). Significant differences were observed for FM and BF% values among all nutritional groups ($P < 0.01$). Positive, moderate to strong correlations were detected between BMD and BMC for BMI, lean mass, and FM. A negative and moderate correlation was found between BMC and BF%, and between BMD and BF% at all bone sites analyzed in males and between BF% and spine and femur BMD, in females.
Conclusion: The results reveal a negative effect of BF% on bone mass in males and indicate that the higher the BF% among overweight adolescents, the lower the BMD and BMC values.

Introduction

Obesity is a pathologic epidemic of the group of non-transmissible chronic diseases. It is associated with a number of comorbidities and has been a subject of great interest for researchers as well as for health agencies worldwide. Obesity may be defined as a disorder of energy metabolism that results in excessive accumulation of body fat, with serious organic and psychosocial complications [1].

Overweight in adolescence is a major concern because of the association between obesity and metabolic abnormalities. These metabolic abnormalities, which were more evident in adults until recently, lately have been found with high frequency in adolescents [2–8]. The spurt period is of great importance for bone mineral acquisition, which rises exponentially in both genders. During this period, bone formation exceeds resorption, resulting in bone modeling and remodeling [9–13]. A few years after growth is completed, bone mass continues to increase until reaching a peak. The acquired skeletal mass remains for a few years, depending on the bone region, or declines after reaching the peak [14,15]. Several factors influence bone mass gain, such as sex, ethnicity, heredity, body weight, diet (calcium content,

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vitamin D intake or supplementation), frequent physical activity, and hormonal processes that influence bone mineralization. Among these factors, body weight, consisting primarily of fat mass (FM) and lean mass (LM), has been identified as a major determinant of bone mineral content (BMC). Body weight gain interferes with both the acquisition and loss of bone mass and is directly associated to the risk for overweight or obesity [16].

Because erroneous eating habits during childhood and adolescence may result in overweight, which in turn may lead to impaired peak bone mass acquisition and contribute to the increased risk for low bone mineral density (BMD) and fragility fractures in adulthood [17], understanding the effects of obesity on bone mass is extremely important. Studies have shown that the correlation between obesity and BMD may not protect against osteoporotic fractures, given the adiposity associated with the disease [18–23]. Studies of children and adolescents have yielded conflicting results regarding the relationships between FM and bone size and density [18]. It has been shown that obese children have insufficient bone mass relative to body weight and may be at increased risk for bone fractures [18]. Conversely, other studies have reported that bone mass, as assessed by BMC, is high when adjusted for height and LM of obese adolescents [24–26]. Given the lack of a consensus regarding the effect of fat on BMC and BMD, we sought to determine the effects of excess body fat on bone mass in overweight, obese, and extremely obese adolescents.

Materials and methods

Adolescents ages 10 to 19 y registered at the Adolescent Outpatient Clinic of Botucatu Medical School Clinical Hospital (SP, Brazil) were invited to participate in the study. The informed consent form was signed by the adolescent, or by their parents or guardians. The study was approved by the Research Ethics Committee of Botucatu Medical School (UNESP, OF.190/2009).

Anthropometric measures of weight (kg) and height (m) were obtained as previously recommended [27], and the body mass index (BMI, kg/m2) was subsequently calculated. BMI was used to classify nutritional status. Adolescents were classified into eutrophic (between the 5th and 85th percentiles), overweight (≥85th and <95th percentiles), obese (≥95th percentile), and extremely obese (>99th percentile), according to BMI curves, age, and sex [28,29]. Adolescents were non-smokers or non-drinkers, and did not practice regular physical activity.

Exclusion criteria were:

1. adolescents with history of prematurity;
2. weight > 100 kg (as it exceeded equipment manufacturer's recommendations for bone densitometry measures);
3. long-term therapy with corticosteroids;
4. use of supplemental calcium and/or iron in the 12 mo before data collection;
5. history of diabetes mellitus, congenital or acquired bone disease, gastrointestinal disease, history of renal disease, endocrine disorders, precocious or delayed puberty;
6. chronic use of medication;
7. use of hormone contraceptives;
8. current or past pregnancy.

Dietary exclusion criteria were:

1. an exclusively vegetarian diet;
2. high consumption of fiber [30,31];
3. failure to consume dairy products daily.

To evaluate skeletal maturation, bone age (BA) was obtained by the Greulich–Pyle method [32], in which the hand and wrist radiographs were compared with the atlas. Adolescents were then submitted to bone densitometry by dual-energy x-ray absorptiometry (DXA) (Hologic QDR 4500 Discovery A, Hologic Inc., Bedford, MA, USA). Bone mass results were analyzed with proper pediatric software and BMC results were expressed in g, and density in g/cm^2. Measurements were taken of the L1–L4 lumbar spinal region and the total proximal femur, including the femur neck, trochanteric, and intertrochanteric regions, of subtotal body (whole body less head), and of whole-body densitometry (to obtain total BMC, BMD, and whole-body composition) [33–35].

Statistical analysis

Data were analyzed using SAS (Cary, NC, US) for Windows v.9.2. Descriptive analysis was performed for quantitative variables, and values were expressed as mean, SD, median, and minimum and maximum values. For quantitative variables with normal distribution, comparison between groups was performed by analysis of variance with simple classification, followed by the Tukey test adjusted for chronological age (CA) and bone age (BA). To adjust according to CA, adolescents were divided into three groups as follows: 10 to 13 y; 14 to 16 y; ≥16 y. When adjusted for BA, the groups were 10 to 12 y; 13 to 15 y; >15 y. We considered the significance level of 5%. Linear regression models were used to explain the variation in BMD and BMC in the L1–L4 lumbar spinal region, proximal femur, and whole body with BMI, LM, FM, and body fat percentage BF%, assuming normal distribution after Shapiro-Wilk test.

Results

Among the 377 adolescents who participated in the study, 158 (41.91%) were eutrophic, 48 (12.73%) were overweight, 142 (37.67%) obese, and 29 (7.69%) extremely obese. Of these, 207 (54.91%) were female and 170 (45.09%) were male.

In each sex group, average BA was higher than CA in all nutritional groups (Table 1).

As for Tanner's criteria [36], 88% of all adolescents were in stages III to V. Interestingly, 78.5% of all female adolescents were in the final stage (IV and V) of puberty, whereas only 55% of male adolescents were in the same stage. A total of 5.2% of all females were at the initial stages (I and II) of development, whereas 20% of males were in these stages.

For female adolescents, significant differences were observed for weight and BMI among all nutritional groups, when CA and BA were considered. With respect to height, no significant difference was observed among groups, whether adjusted by CA or by BA (Table 2).

Analyzing the variables according to CA and BA, we observed that the average results increased progressively from eutrophic to extremely obese adolescents, with significant differences between groups ($P < 0.01$). No significant differences were observed between obese and extremely obese adolescents in relation to lean body mass, but differences were observed between all nutritional groups with respect to the amount of fat and the BF% ($P < 0.01$). Similar results were observed when variables related to BMD were analyzed. The average results obtained from eutrophic adolescents were significantly lower than those of overweight, obese, and extremely obese adolescents (Table 2). Conversely, average values of spine, whole-body, and subtotal body BMD, and spine, femur, and whole-body BMC were lower among extremely obese than obese female adolescents, although the differences were not statistically significant.

Table 1
Chronological and bone ages of adolescents evaluated according to BMI

	Eutrophic	Overweight	Obese	Extremely obese	*P*-value
Female					
n	72	28	92	15	
CA	13.64 ± 2.76	14.42 ± 2.41	13.66 ± 2.44	13.49 ± 1.65	0.05
BA	14.39 ± 2.61	14.94 ± 2.41	14.53 ± 2.26	14.40 ± 2.17	0.79
Male					
n	86	20	50	14	
CA	13.48 ± 2.53	14.05 ± 2.01	13.76 ± 1.92	13.73 ± 1.92	0.75
BA	13.98 ± 2.68	14.74 ± 2.51	14.41 ± 1.87	14.56 ± 1.26	0.54

ANOVA, analysis of variance; BA, bone age; BMI, body mass index; CA, chronological age; n, number
ANOVA followed by Tukey test