Nutrition 30 (2014) 847–852

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Excess body fat negatively affects bone mass in adolescents

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ARTICLE INFO

Article history:
Received 24 August 2013
Accepted 7 December 2013

Keywords:
Adolescents
Bone mineral content
Bone mineral density
Obesity
Osteoporosis
Overweight

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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0899-9007/$ - see front matter © 2014 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.nut.2013.12.003

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

Table 2
Characterization of female adolescents according to nutritional classification, chronological age, and bone age

Variables	Nutritional status (N = 176)				*P*-value	
	Eutrophic (n = 72)	Overweight (n = 28)	Obese (n = 92)	Extremely obese (n = 15)	CA	BA
Weight (kg)	47.40 ± 9.57*,†	59.59 ± 9.61‡,§	71.28 ± 13.19$^{\|,\P}$	88.89 ± 17.09$^{\#,**}$	0.01	0.01
Height (m)	1.56 ± 0.10*,†	1.58 ± 0.08*,†	1.58 ± 0.07*,†	1.57 ± 0.05*,†	0.49	0.52
BMI (kg/m^2)	19.35 ± 2.45*,†	23.72 ± 1.71‡,§	28.45 ± 3.79$^{\|,\P}$	36.00 ± 6.02$^{\#,**}$	0.01	0.01
Lean mass (g)	31820.48 ± 5715.62‡,§	37974.13 ± 5482.44*,†	43649.20 ± 7428.82$^{\#,\ddagger,\P}$	49140.79 ± 4824.06$^{\#,\ddagger,\P}$	0.01	0.01
Fat mass (g)	13732.60 ± 4864.02*,†	19962.32 ± 4824.5‡,§	26351.65 ± 6613.80$^{\|,\P}$	35386.46 ± 6811.09$^{\#,**}$	0.01	0.01
BF%	28.49 ± 5.07*,†	32.98 ± 4.31‡,§	36.65 ± 4.06$^{\|,\P}$	40.86 ± 4.11$^{\#,**}$	0.01	0.01
BMD-spine (g/cm^2)	0.81 ± 0.15‡,§	0.89 ± 0.16*,†	0.98 ± 0.19*,†	0.96 ± 0.14*,†	0.01	0.01
BMD-femur (g/cm^2)	0.85 ± 0.13‡,§	0.91 ± 0.13$^{*,\|,\dagger}$	0.98 ± 0.14*,†	1.02 ± 0.17$^{\|,\dagger}$	0.01	0.01
BMD-subtotal (g/cm^2)	———	0.84 ± 0.09‡,§	0.88 ± 0.09*,†	0.88 ± 0.07*,‡,†,§	0.01	0.04
BMD-whole body (g/cm^2)	0.93 ± 0.12‡,§	0.95 ± 0.11*,‡,†,§	0.99 ± 0.10*,†	0.97 ± 0.07*,‡,†,§	0.04	0.06
BMC-spine (g/cm^2)	41.14 ± 13.26*,§	46.09 ± 13.15*,‡,†,§	51.07 ± 14,29‡,†	49.54 ± 8,22*,‡,†,§	0.01	0.01
BMC-femur (g/cm^2)	29.46 ± 10.16*,§	30.45 ± 6.85*,‡,†,§	34.46 ± 7.98‡,†	34.13 ± 6.05*,‡,†,§	0.02	0.01
BMC-subtotal (g/cm^2)	————	1330.81 ± 304.59‡,§	1474.89 ± 310.49*,†	1495.38 ± 180.49*,‡,†,§	0.01	0.09
BMC-whole body (g/cm^2)	1584.99 ± 391.67$^{\S,\ddagger,\|}$	1702.38 ± 365.02*,‡,§	1857.45 ± 377.54*,†	1842.07 ± 189.81*,‡,†,§	0.01	0.01

ANOVA, analysis of variance; BA, bone age; BF%, body fat percentage; BMC, bone mineral content; BMD, bone mineral density; BMI, body mass index; CA, chronological age
ANOVA followed by Tukey test
$^{*,\ddagger,\|,\#}$ indicates no significant differences among groups (eutrophics, overweight, obese, and extremely obese) adjusted by CA.
†,§,¶,** indicate no significant differences among groups (eutrophics, overweight, obese, and extremely obese) adjusted by BA.

The anthropometric variables of male adolescents adjusted for CA and BA (Table 3) showed results similar to those of females. Statistical differences were found for weight and BMI among the nutritional groups, whereas height showed no significant difference among groups.

No significant differences were found among groups for BMD of spine, whole body, and subtotal body, as detected by DXA. In all groups, increased average values were observed for femur BMD, whole-body BMC, and the amount of LM. However, no statistical differences were found between overweight, obese, and extremely obese adolescents.

Average values of spine BMC were higher among overweight and extremely obese adolescents; average values of femur BMC increased progressively from eutrophic to extremely obese adolescents, but statistical differences were observed only between eutrophic and extremely obese adolescents. In contrast, subtotal body BMC was similar in all nutritional groups.

FM values, as expressed in g, were significantly different among groups. The BF% increased from eutrophic to extremely obese adolescents, however, when adjusted for BA, the values presented by obese and extremely obese groups were not statistically different (Table 3).

In overweight females, BMD significantly correlated with the variables BMI, LM, and FM (in g) whereas correlations between BMC and the same variables were positive and moderate to strong, in all three sites evaluated. Only spine BMD and femur BMD negatively correlated with BF% (Table 4).

For overweight males, both spine and femur BMD values significantly correlated with both BMI and LM. BMC values of each of the sites evaluated correlated with BMI and LM. Negative, moderate, and significant correlations were found between BMD and the BF% and between BMC and the BF% in the three sites analyzed (Table 4).

Discussion

In this study, we investigated the effects of excess body fat on BMC and BMD in adolescents. In both male and female adolescents, the anthropometric variables such as weight and BMI showed increasing values from eutrophic to extremely obese

Table 3
Characterization of male adolescents according to nutritional classification, chronological age, and bone age

Variables	Nutritional Status (N = 170)				*P*-value	
	Eutrophic (n = 86)	Overweight (n = 20)	Obese (n = 50)	Extremely Obese (n = 14)	CA	BA
Weight (kg)	50.62 ± 12.22^{aA}	62.91 ± 13.26^{bB}	75.53 ± 13.25^{cC}	87.04 ± 7.95^{dD}	0.01	0.01
Height (m)	1.63 ± 0.12^{aA}	1.64 ± 0.12^{aA}	1.64 ± 0.10^{aA}	1.63 ± 0.06^{aA}	0.97	0.07
BMI (kg/m^2)	18.73 ± 2.55^{aA}	23.11 ± 1.72^{bB}	27.76 ± 2.78^{cC}	33.48 ± 2.73^{dD}	0.01	0.01
Lean mass (g)	38161.72 ± 10413.12^{bB}	45614.87 ± 11804.59^{aA}	50284.30 ± 10102.04^{acA}	52679.58 ± 657.62^{cA}	0.01	0.01
Fat mass (g)	8535.58 ± 2668.21^{bB}	16211.66 ± 4590.15^{dD}	23778.60 ± 4915.22^{cC}	31822.86 ± 6459.29^{aA}	0.01	0.01
BF%	18.56 ± 4.77^{aB}	26.41 ± 6.61^{bC}	31.55 ± 5.18^{cA}	36.18 ± 6.05^{dA}	0.01	0.01
BMD-spine (g/cm^2)	0.76 ± 0.15^{bA}	0.82 ± 0.18^{ab}	0.82 ± 0.15^{abA}	0.86 ± 0.11^{aA}	0.01	0.01
BMD-femur (g/cm^2)	0.87 ± 0.10^{bB}	0.97 ± 0.19^{abA}	0.98 ± 0.14b^{abA}	1.04 ± 0.16^{aA}	0.01	0.01
BMD-subtotal (g/cm^2)	—————	0.87 ± 0,13^{aA}	0.86 ± 0.10^{aA}	0.87 ± 0,07^{aA}	0.53	0.64
BMD-total (g/cm^2)	0.92 ± 0.09^{aA}	0.96 ± 0.13^{aA}	0.94 ± 0.11^{aA}	0.95 ± 0.07^{aA}	0.23	0.12
BMC-spine (g/cm^2)	39.78 ± 12.55^{aB}	45.01 ± 18.21^{aA}	43.31 ± 14.37^{aAB}	46.70 ± 11.85^{aA}	0.11	0.09
BMC-femur (g/cm^2)	36.86 ± 10.34^{aB}	38.01 ± 14.45^{aaAB}	39.33 ± 11.75^{aAB}	43.87 ± 17.22^{aA}	0.12	0.03
BMC-subtotal (g/cm^2)	————	1502.17 ± 507.94^{aA}	1546.10 ± 368.77^{aA}	1608.97 ± 263.14^{bA}	0.40	0.64
BMC-total (g/cm^2)	1579.30 ± 432.72^{bB}	1869.06 ± 575.39^{abA}	1853.96 ± 478.36^{abA}	1964.57 ± 308.73^{aA}	0.05	0.01

ANOVA, analysis of variance; BA, bone age; BF%, body fat percentage; BMC, bone mineral content; BMD, bone mineral density; BMI, body mass index; CA, chronological age
ANOVA followed by Tukey test
Same lower letters indicate no significant differences among groups (eutrophics, overweight, obese, and extremely obese) adjusted by CA age
Same capital letters indicate no significant differences among groups (eutrophics, overweight, obese, and extremely obese) adjusted by BA age

Table 4
Pearson correlation between variables related to bone mass and BMI, lean mass, fat mass, and fat percentage for overweight adolescents, according to sex

	Spine BMD	Femur BMD	Whole-body BMD	Spine BMD	Femur BMD	Whole-body BMC
Female (n = 135)						
BMI (kg/m^2)	0.572 (<0.01)	0.591 (<0.01)	0.512 (<0.01)	0.524 (<0.01)	0.512 (<0.01)	0.546 (<0.01)
LM (g)	0.730 (<0.01)	0.691 (<0.01)	0.692 (<0.01)	0.782 (<0.01)	0.730 (<0.01)	0.813 (<0.01)
FM (g)	0.582 (<0.01)	0.535 (<0.01)	0.496 (<0.01)	0.545 (<0.01)	0.510 (<0.01)	0.593 (<0.01)
BF%	−0.400 (0.05)	−0.438 (0.03)	0.131 (0.13)	0.146 (0.10)	0.116 (0.19)	0.186 (0.03)
Male (n = 84)						
BMI (kg/m^2)	0.314 (0.03)	0.338 (0.01)	0.173 (0.11)	0.321 (0.03)	0.361 (0.08)	0.265 (0.01)
LM (g)	0.781 (<0.01)	0.758 (<0.01)	0.751 (<0.01)	0.840 (<0.01)	0.841 (<0.01)	0.768 (<0.01)
FM (g)	0.084 (0.45)	0.022 (0.84)	−0.128 (0.25)	−0.009 (0.93)	0.065 (0.55)	−0.011 (0.91)
BF%	−0.400 (0.01)	−0.438 (<0.01)	−0.580 (<0.01)	−0.513 (<0.01)	−0.405 (0.01)	−0.468 (<0.01)

BF%, body fat percentage; BMC, bone mineral content; BMD, bone mineral density; BMI, body mass index; FM, fat mass; LM, lean mass

groups, according to BA and CA. The average values of BMD and BMC of all bone sites analyzed were lower in extremely obese compared with obese female adolescents, whereas these variables did not differ among male adolescents. Values of fat content and BF%, obtained by densitometry of whole body, also increased from eutrophic to extremely obese adolescents, according to BA and CA. These results demonstrate that for both sexes, bone mass gain differed from the other anthropometric variables, as well as from the variables related to body composition, which progressively increased from eutrophic to extremely groups.

This study indicates that significant positive correlations exist between BMD, as well as BMC, and LM and FM in females. In males, the correlations of BMD and BMC are observed with LM only. For female and male adolescents, negative correlations were observed between BF% and femur and lumbar spine BMDs in females, and between BF% and BMD, as well as BMC, in all bone sites analyzed in males. These findings indicate that the higher the BF% in male adolescents with excess weight, the lower the BMD and BMC. Thus, we can infer that the bone mass of overweight, obese, and extremely obese adolescents is influenced by the BF%, highlighting the importance of evaluating BMC and BMD according to body composition. Similarly to our findings, it has been previously shown [37] that, although the bone mass of prepubertal obese children was higher than that of normal children, BMD and BMC tended to be lower in obese children, suggesting that obesity does not exert a protective effect on bone mass.

In a study that investigated the influence of body composition on bone mass, it was demonstrated that in boys, as age increases, weight, height, LM, waist circumference, and waist-to-hip ratio also increases, whereas in girls increasing values in LM, FM index, BF%, and hip circumference are observed [38]. These results agree with those of our study regarding the correlations of the variables related to both bone mass and anthropometric variables and DXA-derived body compartments.

Corroborating our results, a previous study showed a positive correlation between body weight, BMI, LM, and FM with BMC, bone mineral area, and BMD values in lumbar spine (L2–L4), hip, femur, and whole body. However, when the results were adjusted for body weight, LM, and FM, no significant differences were found between overweight and eutrophic female adolescents, except for the apparent BMD of the spine, which remained higher in overweight adolescents [39]. Results of another study [40] also demonstrated that the BMC and bone mineral area of whole body, BMD of the lumbar spine (L2–L4), hip, femur, and forearm were higher in overweight compared with eutrophic male adolescents, with the exception of BMD of whole body [40]. After adjustments, the researchers also found no statistical differences between the two groups for the variables related to bone mass.

Another study evaluated the BMC obtained by DXA, and also analyzed the bone mass of radio and tibia by peripheral computed tomography in women ages 18 to 22 y [41]. The authors concluded that fat had no mechanical effect on the bone that could lead to increased bone mass, unlike the force exerted by the muscle mass. The authors found that LM, FM, and weight have positive correlation with bone parameters obtained for the radio and tibia. Although the authors evaluated sites different than those evaluated in our study, their findings support our results.

A recent survey based on the results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study, a multicentric trial conducted in 10 European cities, demonstrated that overweight male adolescents had higher whole-body BMC than their non-obese counterparts, and that female adolescents had higher BMC and BMD in most regions analyzed compared with eutrophic girls. The authors suggested that excess FM could indirectly increase bone mass by increasing LM. However, once the LM values were adjusted, the associations between bone mass and FM became negative, indicating that FM itself had no beneficial effect on bone mass [42].

Various mechanisms have been proposed to explain the complex relationship between adipose tissue and bone. The physiopathological role of adipose tissue in bone homeostasis is probably related to the participation of adipokines in bone remodeling. These molecules are released from fat cells and some of them interfere with both bone formation and resorption. Because bone cells express specific hormone receptors, bone tissue has been suggested to be an endocrine organ [43,44].

Adipose tissues also secrete inflammatory cytokines such as interleukin (IL)-6 and tumor necrosis factor (TNF)-α [45]. Alterations in the production of these proinflammatory markers can have adverse metabolic effects and cardiovascular repercussions. IL-6 and TNF-α also promote bone resorption by stimulating the differentiation of osteoclasts. All of these molecules, including resistin, adiponectin, leptin, and IL-6, affect energy homeostasis in humans and might be involved differently in bone metabolism, thus contributing to the complex relationship between adipose tissue and bone tissue [16,46]. The relationship between adipose tissue and bone probably results in a homeostatic feedback system in which adipokines and molecules secreted by osteoblasts and osteoclasts are part of an active bone–adipose axis. However, the mechanisms involved in these events remain unclear [47].

Whole-body densitometry does not permit to differentiate the distribution or type of fat and its possible metabolic consequences. However, a literature review showed that practically 100% of extremely obese adolescents become obese adults with a large waist circumference, a consequence of the deposition of visceral fat, which is a risk factor for metabolic syndrome. It has

been demonstrated that 96% of extremely obese adolescents have an increased waist circumference [8]. In this group, 41.7% of extremely obese adolescent girls had metabolic syndrome (MetS) and presented three or more cardiovascular risk factors. For adolescent boys, the prevalence was 30.6%. These results suggest that extremely obese adolescents are at high risk for developing MetS, indicating different metabolic consequences including negative repercussions on bone mass. Using DXA to evaluate total bone mass and FM and magnetic resonance imaging to quantify visceral fat, one study suggested that numerous factors are involved in the reduction of bone mass in adolescents with MetS, including insulin resistance, increased excretion of calcium, alterations in the growth hormone/insulin-like growth factor-1 axis, hyperleptinemia, and especially factors related to inflammatory cytokines [41].

Conclusion

The results of this study support the hypothesis that FM or LM influence BMC and BMD, but the underlying mechanisms remain to be clarified. Prospective longitudinal studies, sophisticated methods that complement the assessment of body composition and distribution of fat, LM, and bone mass by body segments may contribute to unraveling such mechanisms.

Despite being a transversal study and having limitations for studying causal relationships, we found important results, such as the moderate to strong correlations between anthropometric variables (BMI), those obtained by DXA (LM), and the variables related to bone mass, as well as the negative relationship of BF% with BMD and BMC variables in males, and for femur BMD and spine BMD in females. Based on the observation that the higher the BF%, the lower the BMD and BMC, our results indicate that excess FM is detrimental to the development of bone mass in male adolescents, whereas in females the femur and spine BMDs are the most affected.

Acknowledgments

This work was supported by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo)–Process nos. 07/07731-0 and 2011/05991-0, Pro-Rector for Research of UNESP, and FUNDUNESP.

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