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Bone mineral mass in overweight and obese children: diminished or enhanced?

Abstract Childhood obesity has become a worldwide health problem. Recent studies have suggested that obese and overweight children have lower bone mass. We used dual-energy X-ray absorptiometry to examine the relation between bone mineral content (BMC) and body fatness (%Fat) in healthy children. Obese children (%Fat>30%) had higher BMC compared with age-, gender-, and ethnic-matched children with normal adiposity (%Fat<25%). When adjusted for height, these differences were less significant. We conclude obese children do not have lower whole-body BMC when compared with leaner children, even when adjusted for height, age, gender, and ethnicity.

Key words Children • Obesity • Bone mineral • Dual-energy X-ray absorptiometry

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Introduction

The incidence of early childhood obesity has increased dramatically worldwide during the last two decades. It is also known that obese children tend to be less active than leaner children [1]. Physical activity, however, is a cofactor that contributes to maximal peak bone mass during adolescence [2]. Thus, there has been a renewed interest on the bone status of overweight and obese children [3–8]. In particular, it has been suggested that low bone mineral mass may be a contributing factor for a higher incidence of fractures during childhood for these children. The primary aim of this study was to examine the effect of adiposity on whole-body bone mineral mass in children and adolescents. In particular, we wanted to test the hypothesis, recently proposed by others [4, 5], that children with excess adiposity have low bone mineral mass.

Methods

The protocol was approved by Baylor College of Medicine's Institutional Review Board for Human Studies, informed consent was obtained from a parent or guardian, and anthropometric measurements (weight, height, age, and Tanner stage) were obtained by trained pediatric research nurses. There were 865 children (444 girls and 421 boys) in the study; 359 European–American, 249 African–American, and 257 Mexican–American.

Body composition measurements were obtained by certified technologists using a Hologic QDR-2000W instrument (Hologic Corp., Bedford, MA, USA) (dual-energy X-ray absorptiometry, DXA) operated in the pencil-beam mode. A whole-body scan provides data for three body composition compartments: bone mineral mass (BMC), lean tissue mass (LTM), and fat mass (Fat). For children and adolescents, the precision for the bone values has been shown to be 1–2%, while the errors for the soft tissue compartments (LTM and Fat) are slightly higher [9, 10]. Body fatness, denoted as %Fat, was defined as 100xFat/(BMC+LTM+Fat). Three

adiposity classifications were used: normal range (%Fat<25%), overweight (25%≤%Fat<30%), and obese (%Fat≥30%).

Statistical analyses were performed using the software package MINITAB (version 12, Minitab Inc., State College, PA, USA). Linear regression analysis was used to establish correlations among variables. The analysis of variance (ANOVA), using the general linear model, was used to test for differences related to adiposity classification, with gender, ethnicity, age, and lean tissue mass as covariates. For all statistical tests, a p value less than 0.05 was considered significant.

Results

The anthropometric data for the three adiposity groups and each gender are given in Table 1. The mean ages among the three adiposity groups for each gender were not statistically different. The children with higher adiposity tended to be heavier (as would be expected), but they were also taller than their gender-matched cohorts with normal body fatness. The mean body composition values are also given in Table 1. Since %Fat was used as the classification parameter, it is to be expected that the mean %Fat values were significantly higher for the overweight' and 'obese' groups, compared with the 'normal' group. It was also expected that fat mass was higher for these groups. There were no statistical differences for BMC or LTM for the boys among the three %Fat groups, whereas the BMC and LTM values were higher in the two female groups with excess adiposity.

The relation between whole-body BMC and body weight is shown in Figure 1 for the female population. A similar relation, not shown, was observed also for males. Using body weight (Wt) as the common reference among the three groups, it might appear that BMC values for the overweight and obese groups are lower than those observed for children of the same weight with normal fatness. However, when the BMC vs. Wt relationship is viewed from the perspective of a common bone mineral mass (y-axis), then the overweight and obese groups are displaced to the right of the curve for the children with normal adiposity. In this case, the displacement of the data points for the overweight and obese groups are mainly an indication of higher body weight and not necessarily any alteration in BMC. Furthermore, the mean values presented in Table 1 for whole-body BMC do not support the hypothesis that obese children have lower bone mass.

The relation between BMC and height (Ht) is shown in Figure 2 for the female population; a similar relation was observed for the males (not shown). When one compares girls with the same height, those with excess body fatness tend to have higher BMC values than girls with normal body fatness. In this case, the BMC values for the children with excess adiposity are shifted upward from the normal curve. Alternately, when viewed from a common BMC value, the height of obese girls would appear to be lower than that of girls with normal adiposity. This, however, would contradict the differences in height reported in Table 1.

Table 1 Anthropometric and body composition values for males and females*

	Adiposity classification (%Fat)		
	Normal (<25%) n=318	Overweight (25%–30%) n=37	Obese (> 30%) n=66
Males,			
Age, years	11.2±4.1	11.0±3.8	11.6±2.4
Weight, kg	41.5±19.8	49.6±22.7[a]**	60.4±20.3[d]
Height, cm	145.1±24.2	146.1±21.9[d]	151.5±15.3[b]
%Fat	14.9±4.8	27.0±1.4[d]	36.1±4.2[d]
Fat, kg	6.1±3.6	13.3±6.0[d]	22.1±8.7[d]
LTM, kg	33.8±16.3	34.6±16.0	36.9±11.8
BMC, g	1,480±855	1,556±862	1,607±606
	Normal (<25%) n=188	Overweight (25%–30%) n=96	Obese (> 30%) n=160
Females			
Age, years	11.4±3.3	12.2±3.3	12.1±3.4
Weight, kg	36.2±11.7	45.6±12.0[d]	54.8±18.3[d]
Height, cm	143.8±16.6	150.5±16.3[c]	149.7±16.4[c]
% Fat	19.9±3.6	27.4±1.6[d]	36.5±5.0[d]
Fat, kg	7.3±3.0	12.4±3.4[d]	20.5±9.3[d]
LTM, kg	27.4±8.4	31.4±8.1[d]	32.6±9.2[d]
BMC, g	1,242±533	1,504±536[d]	1,616±596[d]

*Mean±SD; **Student's t test for elevated or obese vs. normal: [a]p<0.05; [b]p<0.01; [c]p<0.001; [d]p<0.0005
LTM, lean tissue mass; *BMC*, bone mineral content

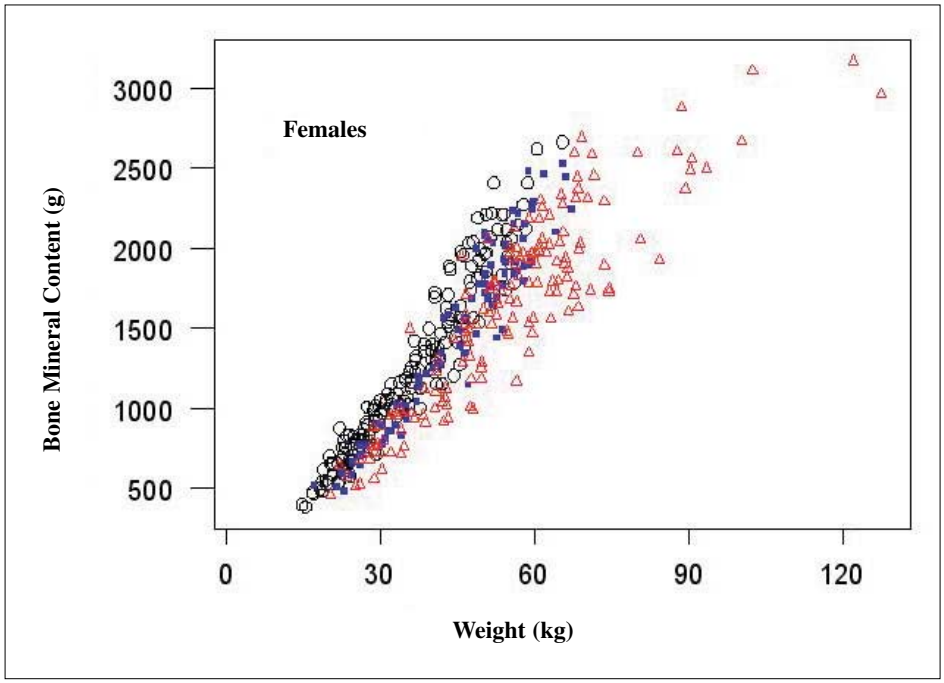

Fig. 1 Whole-body bone mineral content vs. body weight. Adiposity groups: ○, normal (%Fat<25%); ■, overweight (25%≤%Fat<30%); △ obese (%Fat>30%)

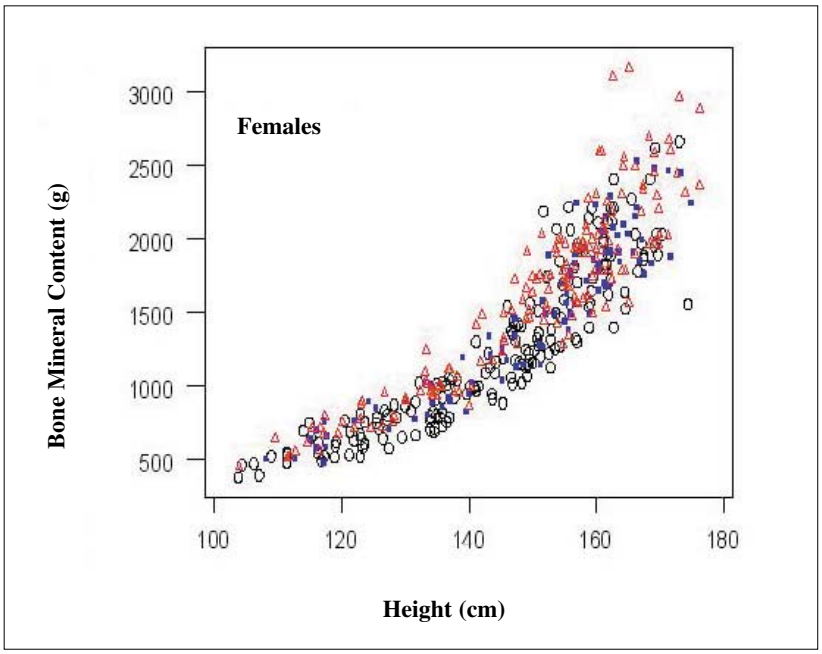

Fig. 2 Whole-body bone mineral content vs. height. Adiposity groups: ○, normal (%Fat<25%); ■, overweight (25%≤%Fat<30%); △ obese (%Fat>30%)

Discussion

We have examined the effects of body fatness on whole-body BMC of children and adolescents. We found that, in general, overweight and obese children have higher bone mass than children with normal fat mass. Even after adjusting for lean tissue mass or height, the BMC values for overweight or obese children continued to remain higher than those observed for children with normal adiposity levels. We also examined the effects of age, gender, and ethnicity on the relationship between BMC and %Fat, and found that BMC values were not lower in children with elevated body fatness. Our data strongly support the conclusion that whole-body BMC is higher in children with above normal adiposity.

In contrast, Goulding et al. [3, 4] have reported that overweight and obese children have low BMC. Their comparison between adiposity groups, however, was based only on body weight. We have basically duplicated this approach (as seen in Fig. 1), and have shown that the displacement from the normal relationship is dominated by the increase in body weight and not by a decrease in BMC. Furthermore, we have

shown that if height is chosen as the anthropometric reference index, there is still no indication of lower BMC for the children with elevated body fatness. In fact, our analyses indicate that these children had high whole-body BMC.

The results of our study show that when an anthropometric parameter is used to normalize body composition, it needs to be selected carefully [11]. In essence, when BMC is compared among the three adiposity groups on the basis of weight, basically the ratio BMC/Wt is being used. To illustrate this point, assume that three children have the same BMC values, but are drastically different in body weights, thus there would also be substantial differences in the BMC/Wt ratio. If one relied only on the BMC/Wt ratio to assess bone status, the obese child's ratio would indicate low bone mineral mass, whereas a malnourished child with a low body weight would have a high BMC/Wt ratio. It would be difficult to believe that a malnourished child has better than normal bone mineral mass.

At first it may appear that our conclusion contradicts the observations of Goulding et al. [3, 4]. Our approach, however, has shifted the risks away from a focus on the possibility of low bone mass to that of a known increased body weight. It may be more likely that obese children may have an increased frequency of falls and/or the added body weight simply increases the mechanical stress on bones during a fall. Another possibility is that the added body weight during growth may influence the normal bone architecture such that it is more susceptible to fracture from a fall [12].

Height or stature is probably a more appropriate anthropometric index than body weight for the normalization of body composition within a pediatric population. In support of this position, we have previously shown that height, adjusted for age, gender, and ethnicity, provides the best prediction model for whole-body BMC of children [13]. In conclusion, we did not find any evidence for lower bone mineral mass in overweight or obese children when compared with children having normal levels of body fatness.

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