ORIGINAL ARTICLES

Impact of Obesity on Bone Mineral Content and Density in Group of Egyptian Adolescent Girls

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ABSTRACT

Recent studies suggest conflicting findings regarding association between obesity and adolescent bone mineral content (BMC) and bone mineral density (BMD). Aim: to explore the impact of being obese on whole-body (WB) BMC and BMD in a group of Egyptian adolescent girls. Methods: Study included 35 obese adolescent girls (13.5±1.8 years) with body mass index (BMI) ≥ 95th percentile and 35 maturation-matched (14.2±1.4 years) controls with BMI 15th - 85th percentile for age and gender. Bone mineral areas (BMA), BMC, BMD at the WB and body composition (lean mass, fat mass and fat %) were assessed by dual-energy X-ray absorptiometry (DXA). Calculations of the BMC/height ratio and bone mineral apparent density (BMAD) were computed for the WB. Results: BMD, BMC, BMAD and BMC/height ratio were highly significant higher in obese adolescent girls compared to controls. Body weight, height, BMI, lean mass, fat mass and fat% had highly significant positive correlations with BMD, BMC, BMAD and BMC/height ratio. BMA had highly significant positive correlations only with weight, height, lean and fat mass. After adjusting for either body weight or total fat mass, BMD, BMC, BMAD, BMC/height and even BMA became highly significant higher in control than obese girls. After adjusting for total lean mass, the same was observed but the differences were only highly significant between the two groups in BMC and BMA. Conclusion: This study suggests that there is positive effect of obesity on BMC, BMD, BMAD and BMC/height ratio due to body weight, while obesity has no effect on BMA.

Key words: Obesity; Body composition; Bone mass; adolescent girls; Egypt

Introduction

Studies of children and adolescents have yielded conflicting results with regard to the relationships between fat mass, bone size and density [Flodmark et al., 2004; Cobayashi et al., 2005]. The mechanisms at the origin of the storage of fatty mass remain unknown. More precisely, obesity can result from one (seldom), two or several factors. In general, it is about the interaction of environmental factors and hereditary factors. Physical inactivity and unhealthy dietary habits predispose to obesity; the same factors may compromise also bone growth and development [Sayers and Tobias, 2010].

Obesity is often associated with the following disorders: resistance to insulin and hypertension. It may be also linked to orthopedic disorders such as slipped capital epiphyses of femur, scoliosis, and genu valga [Deckelbaum and Williams, 2001; Goulding et al., 2001]. However, it is well established that adult obesity seems to have a protective effect on osteoporosis because of the observed decreased risk for fragility fractures and increased bone mineral density (BMD) [Bakker et al., 2003].

In adolescents, studies are contradictory. Some studies report that obesity has positive effects on bone mineral content (BMC) and density (BMD) [Goulding et al., 2005; Timpson et al., 2009], with others additionally demonstrating negative associations with bone mineral content and density [Weiler et al., 2000; Janicka et al., 2007], suggesting a failure of the skeleton to achieve adequate adaptation to the excess load resulting from obesity. Even they also, suggest that obesity is associated with decreased BMC and BMD after adjustment to body weight and to fat mass. The question of adjusting BMC and BMD values for weight in order to judge effects of obesity on these parameters remains open. Besides, it is well known that the bone mass acquisition is mainly limited to the first two decades of the life of the human [Compston, 2001]. Thus, it is recognized that maximizing peak bone mass may provide important protection against fracture risk occurring later in life [Deckelbaum and Williams, 2001]. In addition, it seems so important to detect the effects of obesity on bone mass at this age.

In Egypt, as in other parts of the world, the obesity epidemic affects a growing number of children and adolescents. A study among female adolescents showed that 35 percent of the girls were overweight and 13

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percent were obese. Overweight was more prevalent in urban than in rural girls (Jackson et al. 2003). In the final report of Diet, Nutrition and Prevention of Chronic non communicable diseases in Egyptian Adolescents (DNPCNCD 2008), it was found that about 20.5% of the adolescents were either overweight or obese with higher prevalence among urban than rural and females compared to males.

The aim of this study was to explore the impact of being obese on whole-body (WB) BMC and BMD in a group of Egyptian adolescent girls.

Subjects & Methods:

Subjects:

A total of 70 adolescent girls participated in this study. Inclusion criteria were being postmenarchal (at least six months of regular menstrual cycles), adolescent, sedentary (practicing less than 2 h of physical activity per week and not involved in impact sports) girls from 11 to 16 years of age with no diagnosis of co-morbidities and no history of fracture. The girls were divided into 2 groups depending on the Egyptian Growth Curves (Ghalli et al. 2008) as standard population: group of obese (BMI ≥ 95th percentile; n = 35) and a group of control girls (BMI < 85th percentile; n = 35). The study participants were recruited from a private school in Egypt. An informed written consent was obtained from the girls and their parents. The girls were nonsmokers and had no history of major orthopedic problems or other disorders known to affect bone metabolism. This study was approved by the Ethical Committee of “National Research Centre”.

Anthropometric measurements:

Height (cm) was measured in the upright position to the nearest 1mm via Holtain portable anthropometer. Body weight (kg) was measured on a Seca scale Balance with a precision of 100 g. Anthropometric measurements were attempted using standardized equipments, and following the recommendations of the International Biological Programme (Hiernaux and Tanner, 1969). Three consecutive measurements were taken, and when the differences between the readings were acceptable the mean was recorded. BMI was calculated as body weight divided by height squared (kg/m²).

DXA measurements:

Body composition (lean mass, fat mass, body fat percentage) was measured by dual-energy DXA (Dexa Norland XR-46 version 3.9.6, USA). Bone mineral content (BMC, in gm), density (BMD, in gm/cm²) and area (BMA, in cm²) were determined for each individual.

The DXA measurements were completed for the whole body (WB) using the instrument previously described. This technique (DXA) has been previously validated in obese and non-obese girls [Arabi et al, 2004; Thomas, 2005]. Bone mineral apparent density (BMAD) (g/cm³), an estimate of volumetric bone density, was calculated as previously described [Katzman et al, 1991]. For the WB, the formula BMAD= BMC/ [(BMA²)/body height] was used. Moreover, an adjustment was made by dividing BMC by height [Reid et al., 1992; Bachrach et al., 1999; Wang et al., 2005]. The same certified technician performed all analyses using the same technique for all measurements.

Statistical analysis:

Basic data are presented as mean ± standard deviation (SD) or as mean ± standard error (SE). Comparisons between the obese and the control group were made, using independent –samples t test; after checking for normal distribution using “One-Sample Kolmogorov-Smirnov Test”. Associations between anthropometric, body composition and bone data were given as Pearson’s correlation coefficients. DXA values were compared after adjustment for body weight, lean mass and fat mass using a one-way analysis of covariance (ANCOVA). The difference was considered statistically significant at P < 0.05. Data were analyzed using the Statistical Package for Social Sciences (SPSS/Windows Version 16, SPSS Inc., Chicago, IL, USA).

Results:

Characteristics of the subjects:

Age, anthropometrical and body composition characteristics are presented in Table 1. Insignificant differences between the obese and control girls in the age and height were observed. However, compared to
controls, obese girls had highly significant higher values of body weight, BMI, lean mass, fat mass and fat % ($P < 0.001$).

| Table 1: Clinical characteristics of the obese and control adolescent girls. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Obese (N=35)** | **Controls (N=35)** | **P**          |
| **Age (years)** | 13.51±1.80       | 14.22±1.43      | 0.071           |
| **Weight (Kg)**  | 85.82±11.88      | 54.88±10.26     | 0.000**         |
| **Height (cm)**  | 157.44±8.49      | 158.67±7.93     | 0.534           |
| **BMI (Kg/cm²)** | 34.50±3.13       | 21.57±2.57      | 0.000**         |
| **Lean mass (Kg)** | 44.76±8.13       | 34.24±5.41      | 0.000**         |
| **Fat mass (Kg)** | 38.64±6.53       | 18.92±5.39      | 0.000**         |
| **Fat %** | 45.00±4.03       | 33.87±5.75      | 0.000**         |

* $P < 0.05$; ** $P < 0.01$.

Bone parameters in the two groups:

BMD, BMC, BMAD and the ratio BMC/height were highly significant higher in obese girls compared to controls ($P < 0.01$) (Table 2). However, BMA was not statistically different between obese and control girls ($P > 0.05$). After adjusting for either body weight or total fat mass, BMD, BMC, BMAD and the ratio BMI/height and even BMA became highly significant higher in the control than obese girls (i.e. The results reversed). After adjusting for total lean mass, the same was observed but the differences were insignificant, except in BMC and BMA where the differences were highly significant between the two groups (Table 3).

| Table 2: Crude bone mineral values in obese and control adolescent girls. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Obese (N=35)** | **Controls (N=35)** | **P**          |
| **BMD (gm/cm³)** | 0.94±0.10       | 0.85±0.10       | 0.000**         |
| **BMC (gm)** | 2466.45±359.74  | 2190.74±359.74  | 0.004**         |
| **BMA (cm²)** | 2598.06±222.99  | 2561.74±186.76  | 0.463           |
| **BMAD (gm/cm³)** | 0.05±0.006      | 0.05±0.006      | 0.003**         |
| **BMC/height (gm/cm)** | 15.58±1.971     | 13.74±1.815     | 0.000**         |

BMD: bone mineral density; BMC: bone mineral content; BMA: bone mineral area; BMAD: bone mineral apparent density. * $P < 0.05$; ** $P < 0.01$.

Table 3: Bone mineral values adjusted for body weight, lean mass and fat mass in obese and control girls.

| **Obese (n=35)** | **Control (n=35)** | **P**          |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| **BMD (gm/cm³)** | 0.83±0.014| 0.95±0.014| 0.000**         |
| **BMC (gm)** | 2006.43±48.966| 2650.76±48.966| 0.000**         |
| **BMA (cm²)** | 2457.81±36.110| 2757.87±36.110| 0.000**         |
| **BMAD (gm/cm³)** | 0.05±0.001| 0.05±0.001| 0.000**         |
| **BMC/height (gm/cm)** | 13.48±0.274| 15.85±0.274| 0.000**         |

BMA: bone mineral area; BMC: bone mineral content; BMD: bone mineral density; BMAD: bone mineral apparent density. ** $P < 0.01$.

Table 4: Correlation matrix between clinical characteristics and bone parameters in girls.

<table>
<thead>
<tr>
<th><strong>BMD (gm/cm³)</strong></th>
<th><strong>BMC (gm)</strong></th>
<th><strong>BMA (cm²)</strong></th>
<th><strong>BMAD (gm/cm³)</strong></th>
<th><strong>BMC/height (gm/cm)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>.294**</td>
<td>.442**</td>
<td>.569**</td>
<td>1.66</td>
</tr>
<tr>
<td><strong>Weight (Kg)</strong></td>
<td>.768**</td>
<td>.740**</td>
<td>.466**</td>
<td>0.676**</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>.566**</td>
<td>.766**</td>
<td>.865**</td>
<td>0.461**</td>
</tr>
<tr>
<td><strong>BMI (Kg/cm²)</strong></td>
<td>.605**</td>
<td>.486**</td>
<td>.151</td>
<td>0.551**</td>
</tr>
<tr>
<td><strong>Lean mass (Kg)</strong></td>
<td>.833**</td>
<td>.872**</td>
<td>.655**</td>
<td>0.720**</td>
</tr>
<tr>
<td><strong>Fat mass (Kg)</strong></td>
<td>.686**</td>
<td>.599**</td>
<td>.285*</td>
<td>0.631**</td>
</tr>
<tr>
<td><strong>Fat %</strong></td>
<td>.472*</td>
<td>.341**</td>
<td>0.454**</td>
<td>0.441**</td>
</tr>
</tbody>
</table>

BMD: bone mineral density; BMC: bone mineral content; BMA: bone mineral area; BMAD: bone mineral apparent density. * $P < 0.05$; ** $P < 0.01$.

Correlations between clinical and bone data:

Age was significantly positive related to BMD, BMC, BMA and BMC/height ratio (Table 3). Body weight, height, BMI, lean mass, fat mass and fat % were revealed highly significant positive correlated with BMD, BMC, BMAD and BMC/height ratio. Weight, height, lean and fat mass were showed highly significant positive association with BMA, while BMI and fat% had insignificant correlations with BMA (Table 4).
Discussion:

This study, conducted on 70 Egyptian adolescent girls, revealed that obesity had an impact on bone mineral values, as after adjustment of either body weight or fat mass; the bone values became significantly higher in the control than obese girls. There was also no difference in BMA between the obese and control groups, however after adjustment of lean mass, BMA became significantly higher in the control than obese girls.

In the current study, obese girls had highly significant higher values of BMC than controls. In general, it is well established that the crude values of BMC is higher in obese adolescents compared to controls [Clark et al., 2008; Beck et al., 2009; Roa et al., 2009]. In fact, obesity during adolescence augment bone mass and bone dimensions [Beck et al., 2009]. In parallel, obesity is well known to increase BMD of weight-bearing bones (lumbar spine and hip). However, the effect of obesity on whole-body BMD is less evident. Thus, the influence of obesity on weight-bearing bones is the result of load, this effect being comparable to the influence of physical activity [Magnusson et al., 2001]. The present study showed that WB BMA was not significantly different between obese and control girls which came in adverse with the results of other study on Lebanon adolescent girls (El Hage et al., 2009). The WB is composed of 80% cortical bone [Martin and Nicholson, 1988]. In response to mechanical loading, cortical bone mainly increases its BMA and BMC and trabecular bone preferentially enhances its BMD [Ducher et al., 2004].

After adjusting for either body weight or total fat mass, BMD, BMC, BMAD and the ratio BMC/height and even BMA became highly significant higher in the control than obese girls. After adjusting for total lean mass, the same was observed but the differences were highly significant between the two groups in BMC and BMA only. Our results are in agree with Rocher et al., 2008 and Viljakainen et al., 2011, who showed that obese children displayed lower values of BMD and BMC in comparison to controls after adjustment for body weight and lean mass. While, the study of El Hage et al., 2009, showed that after adjusting for either weight, lean mass or fat mass for overweight and obese adolescents, there were no differences between the two groups regarding BMD, BMAD and the ratio BMC/height. However, BMC had a tendency to being lower (P = 0.1) in overweight girls compared to controls after adjusting for weight and for fat mass.

In our study, obese girls displayed lower values of BMA in comparison to controls after adjustment for body weight. This result is in accordance with those of two previous studies [Goulding et al., 2000; Rocher et al., 2008]. Indeed, in obese girls there is a mismatch between body weight and bone development during growth: their bone mass and bone area are low for their body weight. This can augment the risks of fractures in this population [Goulding et al., 2001, Goulding et al., 2000].

The morphological characteristics (Body weight, height, BMI, lean mass, fat mass and fat %) were highly significant positive correlated to BMD, BMC, BMAD and BMC/height ratio. Weight, height, lean and fat mass were highly significant positive associated to BMA, while BMI and fat% had insignificant correlations with BMA. These results are in line with those of many previous studies [Ellis et al., 2003; Leonard et al., 2004; Cobayashi et al., 2005]. Lean mass and fat mass were both positively associated to BMD. However, there is significant disagreement in the literature regarding the relative contributions of lean and fat components to BMD in adolescents. Thus, many studies showed a positive effect of fat mass on BMD [Ellis et al., 2003; Leonard et al., 2004; Cobayashi et al., 2005] whereas one study showed that the body fat percentage is a negative determinant of BMD in adolescent girls [Weiler et al., 2000]. The relation between the fatty mass, the lean mass on the one hand and the BMD on the other hand could be dependent on the weight status of the studied population. In fact, the study conducted by Nunez et al. (2007) showed that extreme obesity reduces BMD in women and also in rats. In this case, one can notify that extreme obesity which is accompanied by many hormonal disturbances could negatively influence the bone tissue [Nunez et al.2007]. It is important to note that the majority of the studies support a close relation between lean mass and the bone parameters (BMC and BMD) at this age.

In spite of the finding that body weight, lean mass and fat mass were all positively related to BMAD, obese girls had higher BMAD in comparison with controls. This result is in contrast with those reported by Rocher et al., 2008 who showed that obese children had lower BMAD in comparison with controls.

In conclusion, the positive effect of obesity on BMC disappears after adjustment for body weight and total fat mass. Moreover, obese girls displayed lower values of BMA in comparison to controls after adjustment for body weight and total fat mass. Thus, this study shows the importance of adjusting the values of BMD and BMC for weightin order to explore the impact of obesity on these parameters in adolescence. Up to our knowledge, this is the first study that aimed at exploring the impact of obesity on BMC and BMD in Egyptian adolescent girls.

Finally, DXA data provide only quantitative information and do not allow the assessment of qualitative factors (architecture) [Fulton, 1999] contributing to bone fragility. Therefore, further investigations on bone geometry and micro architecture are necessary to better understand the effects of obesity on bone parameters. In addition, it would be interesting to undertake a similar study among adolescent boys in order to explore the possible sex differences regarding the osteogenic response to obesity.
Funding sources:

Funding of this work was given by National Research Centre, Cairo, Egypt.

Acknowledgments

We thank the parents and adolescents who gave us their time; School managers, teachers and a team of dedicated research nurses and ancillary staff; of DEX Unit in National Research Centre; for their assistance. This work was supported by National Research Centre, Cairo, Egypt.

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