Association Between Bone Mineralization, Body Composition, and Cardiorespiratory Fitness Level in Young Australian Men

Selma Coelho Liberato,*1 Louise Maple-Brown,1 and Josefina Bressan2

1Wellbeing and Chronic Division, Menzies School of Health Research, Charles Darwin University, Darwin, Northern Territory, Australia; and 2Departamento de Nutrição e Saúde, Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil

Abstract

The critical age for attainment of peak bone mineralization is however 20–30 yr, but few studies have investigated bone mineralization and its association with body composition and cardiorespiratory fitness level in young men. This study aimed to investigate relationships between age, bone mineral measurements, body composition measurements, and cardiorespiratory fitness level in a group of young healthy Australian men. Thirty-five healthy men aged 18–25 yr had anthropometric measures, body composition, and cardiorespiratory fitness level assessed. Bone mineral content was significantly associated with height, body mass, and lean mass, and bone mineral density positively correlated with lean mass and body mass. Bone mineral measurements did not correlate with fat mass, percentage of fat mass, or cardiorespiratory fitness level. Age was directly correlated with total body mass, body fat, and percentage of fat mass. Body mineral measurements correlated with lean mass but not with fat mass or with cardiorespiratory fitness in this group of young healthy men. Positive association between body fat and age in such young group suggests that more studies with young men are warranted and may help inform strategies to optimize increase in bone mineral measurements.

Key Words: Body fat; bone mineral content; bone mineral density; DXA.

Introduction

Osteoporosis is characterized by a reduction in bone mineral density (BMD), occurs in 4%–6% of men older than 50 yr, and is associated with increased mortality and morbidity in men (1). Although osteoporosis is more common in women, bone mass declines at a faster rate in men than in women with advancing age, such that mortality 1 yr after fracture is higher in men than women, even after controlling for age (1).

Available data report variable ages for peak bone mass. It has been shown that boys attain 86% of the reference adult bone mineral content (BMC) and BMD by 17 yr (2) and 95% by 18 yr (3), and peak BMC continues to increase in men after 18 yr (4). Different timings of peak bone mass for each skeletal region have been shown to occur in adolescents (5). Peak BMD values of the spine, femur, and total body were observed in Chinese men aged 20–29 yr (6). Most of the peak bone mass was attained by the mid-20s in a study conducted in United Kingdom with 116 healthy males and females aged 11–40 yr (7) and between 20 and 23 yr in American males (8). Most studies showed that the peak BMD occurs in adults aged 20 yr and older, whereas an Australian study reported that the increase in lumbar spine BMD reached a plateau at the age of 17.4 yr in males (9).

Positive associations between bone mineral measurements and lean mass have been found in children and adolescents (10–12), middle-aged and postmenopausal women (13–15), and in young (16), middle-aged, and older men (1). In contrast, however, the relationship between fat mass and bone mineral measurements has been shown to be inconsistent in both men and women (1,14).
Cardiorespiratory fitness level has been shown to be correlated with bone mineral measurements in women aged 20–76 yr (15), with femoral neck and lumbar BMD in postmenopausal women (17), with hip region BMD in women aged 60–79 yr (18), and negatively correlated with BMD reduction in the lumbar spine, femoral neck, and femur in women aged 49–73 yr (19).

Few studies have investigated the relationship between cardiorespiratory fitness level and bone mineral measurements in men. Cardiorespiratory fitness level was positively correlated with hip region BMD in males aged 60–79 yr (18). Another study (1) found that cardiorespiratory fitness level was positively correlated with bone mineral measurements in middle-aged men but not in older men (1). There are limited data on the relationship between bone mineral measurements and cardiorespiratory fitness level in young men.

This study aimed to investigate the relationship between age, bone mineral measurements, body composition measurements, and cardiorespiratory fitness level in a group of young men aged 18–25 yr.

**Methods**

**Sample**

Participants were recruited by flyers posted in shopping centers and education centers as well as by advertisements in local newspapers. Thirty-five healthy men aged 18–25 yr, recruited from the local community in the city of Brisbane, Australia, volunteered for the study. There was no restriction regarding ethnicity, sportive activity, physical workload, nutritional habits, alcohol consumption, and smoking consumption. The Queensland University of Technology Human Research Ethics Committee approved the participant recruitment and data collection procedures. Methods have been previously described in detail and are summarized here.

**Anthropometric Measurements**

Anthropometric measures including body weight, height, and waist and hip circumferences were undertaken. Body mass index was calculated as weight (kilogram) divided by height (square meter).

**Body Composition Measurements**

Body composition was measured by dual-energy X-ray absorptiometry (DXA) (DPX-Plus; Lunar Corp, Madison, WI). The participant removed shoes and any materials that could attenuate the x-ray beam, such as jewelry, watches, and clothes with zippers and laid on his back in the center of the table. Participants remained motionless in the supine position while the scanning arm of the DXA passed over their body from head to toe in parallel 1-cm strips. Quality assurance was assessed by analyzing a phantom spine provided by the company, and daily calibrations were performed before scans using a calibration block provided by the manufacturer.

**Cardiorespiratory Fitness Level Measurements**

Cardiorespiratory fitness level was measured by a continuous speed and incremental grade running test on a treadmill. Participants were fitted with a Polar Coded Transmitter and receiver (Polar Electro, Kempele, Finland), a Hans-Rudolf nose clip. After a 4-min warm up at 3.5 mph, 0% grade, speed was increased to a previously determined comfortable speed, which was the same until the end of the test. Thereafter, the treadmill slope was increased by 2% every minute, till the participants reached exhaustion. The rating of perceived exertion using the Borg scale was obtained during each stage, and participants were encouraged to achieve a rating of 18 or higher as an indicator of maximal effort. Maximal oxygen uptake (VO$_{2\text{max}}$) was assessed using a MOXUS Modular O$_2$ System (AEI Technologies, Pittsburgh, PA). VO$_{2\text{max}}$ was achieved when the difference between the last 2 completed stages determined by the average of the last 30-s period before the load increased was 1.6 mL/kg.min or when both heart rate ±10 bpm of 220 − age and respiratory exchange ratio >1.15 were achieved. VO$_{2\text{max}}$ was defined as the highest observed value averaged across 15 s in a completed stage. When the participant did not reach VO$_{2\text{max}}$, VO$_2$ peak oxygen uptake, the highest observed value of VO$_2$ was considered in analysis. VO$_2$ was expressed per kilogram body weight. Four men did not complete the test.

**Table 1**

<table>
<thead>
<tr>
<th>Participants</th>
<th>Average ± Standard deviation (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>21.8 ± 2.18 (18–25)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.76 ± 0.07 (1.60–1.89)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>77.4 ± 13.32 (54.5–103.8)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.9 ± 3.48 (18.76–33.15)</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>14.9 ± 7.83 (3.84–36.1)</td>
</tr>
<tr>
<td>Fat mass (%)</td>
<td>18.7 ± 7.81 (6.0–37.8)</td>
</tr>
<tr>
<td>Lean mass (kg)</td>
<td>62.42 ± 8.86 (46.61–79.22)</td>
</tr>
<tr>
<td>VO$_{2\text{max}}$ (mL of O$_2$/kg/min)</td>
<td>52.01 ± 7.42 (38.43–67.78)</td>
</tr>
<tr>
<td>BMC whole body</td>
<td>3408.8 ± 558.9 (2379.4–4519.5)</td>
</tr>
<tr>
<td>BMC arms</td>
<td>425.9 ± 90.1 (270.4–623.93)</td>
</tr>
<tr>
<td>BMC legs</td>
<td>1303.2 ± 240.4 (836.1–1684.2)</td>
</tr>
<tr>
<td>BMC trunk</td>
<td>1135.2 ± 228.2 (767.5–1622.2)</td>
</tr>
<tr>
<td>BMC L2–L4</td>
<td>65.2 ± 13.5 (43.3–103.7)</td>
</tr>
<tr>
<td>BMC L1–L4</td>
<td>99.7 ± 23.5 (57.6–156.7)</td>
</tr>
<tr>
<td>BMD whole body</td>
<td>1.29 ± 0.09 (1.06–1.44)</td>
</tr>
<tr>
<td>BMD arms</td>
<td>1.03 ± 0.09 (0.84–1.20)</td>
</tr>
<tr>
<td>BMD legs</td>
<td>1.46 ± 0.13 (1.23–1.71)</td>
</tr>
<tr>
<td>BMD trunk</td>
<td>1.06 ± 0.10 (0.84–1.26)</td>
</tr>
</tbody>
</table>

*Abbr:* BMC, bone mineral content; BMD, bone mineral density; BMI, body mass index; VO$_{2\text{max}}$, maximal oxygen uptake.

*Assessed in 31 participants.*
because of problems with equipment (2) or because they did not want to obtain medical permission to undertake the test (2).

**Statistical Procedures**

All measurements were undertaken by the same investigator. A technician helped with the body composition and cardiorespiratory fitness level assessment. Bivariate associations between variables were tested using Pearson correlation. The analyses were carried out using Statistic for Windows 9 software (Softonic International S.A., Barcelona, Spain).

**Results**

The participants were on average 21.8 yr old and had from 3.8 to 36 kg of fat. The highest bone mineral content and density were observed in the legs and the smallest in the arms (Table 1). Age correlated positively with body mass \( (0.37, p = 0.031) \), fat mass \( (0.39, p = 0.02) \), and percentage of body fat \( (0.36, p = 0.03) \) but not with height \( (0.26, p = 0.14) \) or fat-free mass \( (0.19, p = 0.27) \).

BMC was significantly correlated with height, body mass, and lean mass. BMD was positively correlated with lean mass and body mass. Age, fat mass, and percentage of fat mass did not correlate with BMC or BMD. Cardiorespiratory fitness level was not correlated with bone mineral measurements (Table 2).

**Discussion**

In this small group of healthy young men, we found that age was associated with body fat but not with any of the bone mineral measurements. Bone mineral measurements were strongly associated with lean mass but not with fat mass. Cardiorespiratory fitness level did not correlate with bone mineral measurements.

It is notable that at such a young age, body fat and age were positively associated. Overweight and obesity increased in prevalence among Australian children and adolescents from 1969 to 1997 (20). The prevalence of overweight increased by 35%, the prevalence of obesity trebled, and the prevalence of overweight and obesity combined increased by 60% among Australian boys aged 7–15 yr (20). From 1998 to 2008, there has been a plateau with almost no change in the percentage of Australian boys and girls classified as overweight or obese (21). A review of 41 Australian studies of childhood weight status conducted between 1985 and 2008 including data on 264,905 Australians aged 2–18 yr showed that prevalence rates have settled around 21%–25% for overweight and obesity together, and 5%–6% for obesity alone in boys and girls (21). The findings of the present study are limited by the small number of participants but suggest that more studies with young adult men are warranted and may inform strategies to prevent obesity.
Age was not correlated with any of the bone mineral measurements in the present study in these participants aged 18–25 yr. It has been shown that 95% of the bone mass is attained by 18 yr (3). The finding of the present study is consistent with this hypothesis that most of the bone mass had already been attained by 18 yr. It has also been shown that bone mass continues to increase by 5% in men between 18 and 30 yr (3,4,22).

Bone mineral measurements were strongly associated with height, body mass, and lean mass. Bone mineral mass has been shown to be related to body mass (1,12,23) and height (12,23). Weight and height predicted 85% of the variance in BMD for the lumbar spine in 4- to 20-yr-old males (12). BMC of the young male participants of the present study was more strongly related to body mass than to body height. Our findings are consistent with previous reports that BMC was more strongly associated with height in young children and more strongly associated with body mass in adolescents and young people (23).

Whole-body BMC positively correlated with fat mass, but this correlation was weaker than with lean mass and there were no significant correlations between any of the other bone mineral measurements and body fat. Similar to the finding of the present study, bone mineral mass in young men was related to lean mass (16) but not with body fat (16,24).

The finding of the present study that cardiorespiratory fitness level was not correlated with bone mineral measurements is consistent with findings of a study including women aged 20–76 yr (15) and among middle-aged (weak relationship) and older men (no relationship) (1). A suggested explanation for this finding is that training methods to achieve high cardiorespiratory fitness level do not include the same principles to attain peak bone mineralization (1).

Strengths of this study include use of lunar DXA to assess body composition of the participants. Lunar DXA provided excellent precision for total body composition measurements and good agreement between consecutive measurements for all measurements (25). Nonetheless, limitations of the study include the very small sample size of volunteers. The results of this study should be interpreted with the understanding that the data are cross-sectional, and thus causal inferences cannot be drawn. Nevertheless, the findings of this study contribute to a better understanding of the bone mineralization of young healthy Australian men.

In conclusion, bone mineral measurements of young men were strongly associated with lean mass but not with fat mass. Cardiorespiratory fitness level did not correlate with bone mineral measurements. Body fat and age were positively associated in this group of young men. The findings of the present study are limited by the small number of participants but suggest that more studies with young men are warranted and may inform strategies to optimize increase in bone mineral measurements.

**Acknowledgments**

The authors acknowledge Associate Professor Andrew P Hills for secured support for this study, the voluntary participants and the Queensland University of Technology for the use of its Laboratories and facilities. SCL acknowledges financial support from the Conselho Nacional de Desenvolvimento Científico e Tecnológico (processo 140931/2001-5 and processo 201075/003-2).

**Declaration of interest**

SCL defined the design of the study, undertook data collection, data collation, data analysis, and article preparation. LM-B and JB assisted with the writing of the article. All authors read and approved the article.

**References**


