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Anthropometric profile of female handball players is related to bone mineral density

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Abstract: The aim of this study was to evaluate the relationship of a wide range of anthropometric parameters with BMD in normal-weight women: handball players and healthy untrained students. Thirteen former female handball players, (age 21.2±0.9 years, body mass 64.2±6.1 kg, training experience 6.7±2.4 years) and 51 randomly selected untrained students (age 20.6±1.2 years, body mass 58.1±6.8 kg), were examined. The anthropometric measurements included 16 variables. BMD was measured on the radius of the non-dominant hand at distal and proximal points with dual-energy X-ray absorptiometry (DXA), using a Norland pDEXA densitometer. Relationships between BMD and anthropometric variables were assessed in 64 normal-weight women (BMI$\geq$18.5 and $\leq$ 24.99 kg/m^2), by calculating Pearson's linear correlation coefficient. We found a significant positive relationship between bone mass characteristics and biacromial breadth (0.30-0.53), calf (0.28-0.47) and arm (0.27-0.42) girth corrected, and lean body mass (LBM) (kg) (0.38-0.61) and (%) (0,27) in the group of normal-weight women. The student groups were significantly different (analysis of variance with Scheffé post hoc test, $p<0.001$) in BMD, bone mineral content (BMC) and Z-score at both measured points. The former handball players were also characterized by higher body mass and LBM (kg), as well as corrected body girths and biacromial breadth ($p<0.001$), compared to untrained students. The groups did not differ significantly in body height or total fat. The morphological profile of the female handball players is conducive to BMD. Skeletal characteristics and muscle tissue had a significant beneficial effect on bone mineral characteristics in young women with normal weight.

Key words: body component, densitometer, students

Introduction

Body weight and the body mass index (BMI) have been found to be inversely related to the risk of osteoporotic fractures (Lloyd et al. 2014). Studies in men as well as pre- and post-menopausal women have reported that lean body mass (LBM) is a key determinant of bone mineral density (BMD) (Zhu et al. 2015), because the LBM affects bone density through direct mechanical loading (muscle contraction and gravitational loading) (Kohrt et al. 2009), which is also dependent on body skeletal size. The positive relationship between body mass, LBM and BMD of most skeletal sites was also reported in normal-weight women (BMI $\geq$18.5 and $\leq$ 25.0 kg/m^2), (Liu et al. 2014). Many studies have reported improvement in hip and spine (BMD) with physical activity, but

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this effect may be site specific (Liu et al. 2003). The analysis of the bone structure showed that physical loading inherent in different sports is associated not only with increased bone mineral mass, but also with a strong bone structure. Greater cross-sectional bone area (Nikander et al. 2005) and cortical thickness (Nikander et al. 2009) at the hip and periosteal circumference (Weidauer et al. 2012) at the tibia have been reported in athletes as compared to non-athlete controls.

In handball, players are required to accelerate, decelerate and change direction throughout the game in response to a stimulus such as a player's movement against the movement of the ball.

The basic movement in handball training requires many diverse activities such as jogging, sprinting, and jumping, including in the female team sport (Süel 2015). These training elements are kinds of physical activities which have a positive effect on the bone health condition (Turner and Robling 2003). The literature review of the topic indicates the positive effects of handball training on the BMD in teenagers (Boshnjaku et al. 2015; Mrabet et al. 2013) and young women (Hornstrup et al. 2018). On the other hand, the anthropometric profile of female handball players demonstrates increased musculature and skeletal robustness (Granados et al. 2007), which is probably related to BMD.

The relationship between BMD and BMI or body composition, a plethora of publications (Liu et al. 2014). However, there are few studies analysing associations between BMD and anthropometric measurements (de Lima et al. 2016; Chowdhury and Bandyopadhyay 2014) with except BMI or body composition.

The aim of this study was to evaluate the relationship of a wide range of anthropometric parameters with BMD in normal-weight women: handball players and healthy untrained students.

Material and Methods

Participants

Thirteen former female handball players (age 21.2±0.9 years, body mass 64.2±6.1 kg, training experience 6.7±2.4 years) students of the University of Physical Education and 51 randomly selected untrained students (Pastuszak et al. 2016) of the University of Technology (age 20.6±1.2 years, body mass 58.1±6.8 kg) were examined. Women with normal-weight (BMI ≥ 18.5 and ≤ 24.99 kg/m^2) were selected, indicated by guidelines from the National Institutes of Health (National Institutes of Health 1998), and who had regular menstrual cycles currently and in the past. Women with any known comorbidities or family history of osteoporosis or bone disease were excluded from the analysis. The examinations were positively approved by the Senate's Research Bioethics Commission at the Józef Piłsudski University of Physical Education in Warsaw, Poland. The study participants were informed about the goal of the study, methodology and procedures and the possibility of stopping the experiment at any time. The subjects (or their legal guardians) gave written consent to participate in the experiment. The study was performed according to the Declaration of Helsinki.

Measures

The anthropometric measurements included the following 16 variables: body height, body mass, five skinfolds (over triceps and biceps, subscapular, suprailiac, medial-calf), biceps girth (flexed 90° and tensed), calf, waist and hip girths, bicondylar femur and humerus breadth, wrist breadth biacromial breadth. Body height was determined using a Siber Hegner anthropometer (Switzerland), body mass was evaluated on an electronic scale (Tanita TBF 300, Japan), skinfolds were measured using a Harpenden skinfold caliper, girth measurements were acquired using a steel measuring tape and bicondylar diameters of femur humerus and wrist breadth were measured using a small spreading caliper (Siber Hegner, Switzerland). Body composition was estimated by the anthropometric method using Durnin's method (Durnin and Womersley 1974). Total body fat (kg, %) and total LBM (kg, %) were then calculated. All measurements were taken in duplicate by the same investigator applying standard anthropometrical methods according to the procedure of the International Society for the Advancement of Kinanthropometry protocol (ISAK, 2001). Body height, mass and skinfold thickness was measured with the accuracy of 0.1 cm, 0.1 kg and 0.01 cm, respectively. Maximum relative repeatability error for measurements of skinfolds expressed by the variability index ranges from 1.6% to 3.0% depending on the skinfold site. The maximum values of the relative repeatability errors are consistent with the results discussed in a study by Kutáč and Gajda (2011). BMI and WHR (waist/hip ratio) indexes were calculated and girths corrected by skinfolds. The arm girth tensed was corrected by triceps and biceps skinfolds and calf girth was corrected by calf skinfold.

BMD was measured on the radius of the non-dominant hand at two measurement points, ultradistal and proximal, with dual-energy X-ray absorptiometry (DXA) using the Norland pDEXA densitometer. The DXA machine was calibrated each morning before the test. The coefficient of variation for these records was <1.01%. Relationships between BMD characteristics – BMD, bone mineral content (BMC), Z-score (the difference between individuals' BMD and the mean age – matched value of the reference population) – and anthropometric variables were assessed by calculating Pearson's linear correlation coefficient.

Statistical Analysis

The one-way analysis of variance (ANOVA) was used for a comparison of two groups. The significance of differences between the means was evaluated using the Scheffé post-hoc test. The level of significance for the statistical analyses was set at $p<0.05$. Relationships between BMD and components of somatotype were assessed by calculating Pearson's linear correlation coefficient. The level of statistical significance was set at $p<0.05$.

All the calculations were carried out by means of STATISTICA software (v. 13.0, StatSoft, USA).

Results

The subjects' anthropometric, body composition and BMD characteristics are summarized in Tables 1 and 2. When comparing handball and control groups, they were similar in age, body height, some measurements of skeletal breadth and total body fat (%, kg) and skinfold thickness with except medial calf skinfold (Table 1).

Significant differences between examined female students were found in body mass (kg), relative weight (BMI), LBM (kg), body girths corrected and only in the biacromial breadth ($p<0.001$), although all the skeleton width parameters were greater in handball players (Tables 1).

The handballers also exhibited significantly ($p<0.001$) higher BMD, BMC and Z-score at both measured points on the radius than students (Table 2).

Analysing relationships between BMD and anthropometric variables assessed in 64 women with correct relative weight (BMI ≥18.5 and ≤ 24.99), we found a significant positive relationship between bone mass characteristics and biacromial breadth (0.30-0.53), calf (0.28-0.47) and arm (0.27-0.42) girths corrected, body mass (kg) (0.28-0.43) and LBM (kg) (0.38-0.61). Only the percentage of total fat in the body, was negatively correlated (-0,27) with BMD and Z-scor at distal measured point (Table 3).

Table 1. Anthropometric characteristics (mean±SD) of female handball players and students

Variables	Handball	Students	*F*	*p*	η^2
Age (years)	21.2±0.9	20.8±1.2	1.58	0.24	0.02
Body height (cm)	168.4±6.2	166.2±6.6	1.22	0.27	0.02
Bicondylar humerus breadth (cm)	6.11±0.27	6.01±0.27	1.25	0.27	0.02
Wrist breadth (cm)	5.07±0.26	4.98±0.33	0.80	0.38	0.01
Bicondylar femur breadth (cm)	9.07±0.34	8.90±0.41	1.95	0.17	0.03
Biacromial breadth (cm)	37.66±1.55	36.15±1.81*	7.57	0.00	0.11
Bicristal breadth (cm)	28.12±1.07	28.55±1.93	0.59	0.44	0.01
Arm girth relaxed (cm)	26.53±1.51	26.49±2.65	0.00	0.96	0.00
Arm girth flexed and tensed (cm)	28.25±1.39	26.83±2.12*	5.24	0.03	0.08
Arm girth corrected (cm)	26.23±1.31	24.44±1.69*	12.64	0.00	0.17
Waist girth (cm)	71.52±3.81	69.48±5.30	1.70	0.20	0.03
Hip girth (cm)	97.24±3.09	94.71±5.02	2.97	0.09	0.05
WHR index	0.74±0.03	0.73±0.04	0.04	0.85	0.00
Calf girth (cm)	36.79±1.99	35.77±1.72	3.40	0.07	0.05
Calf girth corrected (cm)	35.64±1.97	34.12±1.66*	8.06	0.01	0.12
BMI index (kg/m2)	22.64±1.60	21.03±2.01*	7.14	0.01	0.10
Medial calf skinfold (cm)	1.15±0.44	1.65±0.51*	10.69	0.00	0.15
Triceps skinfold (cm)	1.38±0.38	1.64±0.53	2.62	0.11	0.04
Biceps skinfold (cm)	0.64±0.15	0.75±0.24	2.56	0.12	0.04
Subscapular skinfold (cm)	1.14±0.35	1.47±0.54*	4.37	0.04	0.07
Suprailiac skinfold (cm)	1.65±0.44	1.87±0.53	1.96	0.17	0.03
Fat (%)	22.63±2.81	24.56±4.04	3.17	0.08	0.05
Fat (kg)	14.57±2.51	14.43±3.44	0.02	0.89	0.00
LBM (%)	77.38±2.81	75.44±3.66	3.17	0.08	0.05
LBM (kg)	49.68±4.65	43.67±4.04*	21.54	0.00	0.26
Body mass (kg)	64.2±6.05	58.1±6.78*	8.87	0.00	0.13

* – indicates statistically significant difference from handball players, $p<0.05$.

Discussion

The peak bone mass is reached in middle of the third decade, and its potentiation or attenuation is empowered by nutrition, physical activity or illness (Weaver et al. 2016) Some skeletal characteristics, such as cortical density and structural strength, determined by bone dimensions and thickness, continue to increase after epiphyseal fusion and into the third decade of life, but 95% of adult bone mass is achieved during adolescence (Baxter-Jones et al. 2011). For this reason, it is important to analyse the factors that in the early life of women promote better accumulation of bone mineral content.

It appears that among other factors, the bone tissue condition is related to a specific type of body structure. In some studies, the relationship between BMD and anthropometric variables describing

Table 2. Bone mass characteristics (mean±SD) of female handball players and students, measured on the radius in distal and proximal measurement points

Variables	Handball	Students	*F*	*p*	η^2
BMD distal (g/cm^2)	0.406±0.041	0.337±0.041*	30.37	0.00	0.33
BMD prox (g/cm^2)	0.795±0.057	0.702±0.060*	29.76	0.00	0.32
BMC distal (g)	1.634±0.227	1.297±0.174*	34.01	0.00	0.35
BMC prox (g)	1.872±0.289	1.703±0.202*	6.25	0.02	0.09
Z-Score distal	1.105±0.828	-0.253±0.779*	30.80	0.00	0.33
Z-Score prox	-0.370±0.883	-1.832±0.859*	29.72	0.00	0.32

* – indicates statistically significant difference from handball players, $p<0.05$

Table 3. Relationships between bone mass characteristics and anthropometric variables in 64 women with BMI ≥18.5 and ≤ 24.99, measured on the radius in distal and proximal measurement points

Variable	BMD distal	BMD prox	BMC distal	BMC prox	Z-Score distal	Z-Score prox
Body height (cm)	0.090	0.188	0.359*	0.224	0.093	0.189
Bicondylar humerus breadth (cm)	0.137	0.198	0.338*	0.309*	0.136	0.201
Wrist breadth (cm)	0.176	0.241	0.476*	0.281*	0.175	0.244
Bicondylar femur breadth (cm)	0.064	0.212	0.285*	0.259*	0.061	0.214
Biacromial breadth (cm)	0.297*	0.421*	0.532*	0.394*	0.296*	0.422*
Arm girth flexed and tensed (cm)	0.228	0.243	0.275*	0.172	0.227	0.243
Arm girth corrected (cm)	0.353*	0.366*	0.414*	0.270*	0.352*	0.367*
Hip girth (cm)	0.114	0.178	0.292*	0.080	0.114	0.181
Calf girth (cm)	0.243	0.338*	0.324*	0.395*	0.239	0.341*
Calf girth corrected (cm)	0.288*	0.388*	0.371*	0.468*	0.283*	0.390*
Body mass (kg)	0.229	0.327*	0.431*	0.280*	0.229	0.329*
LBM (kg)	0.381*	0.448*	0.605*	0.380*	0.380*	0.449*
LBM (%)	0.265*	0.169	0.268*	0.169	0.265*	0.170
F (%)	-0.265*	-0.169	-0.268*	-0.169	-0.265*	-0.170
BMI (kg/m^2) index	0.195	0.235	0.222	0.149	0.192	0.236

* Statistically significant at $p<0.05$ level

skeletal size was confirmed (de Lima et al. 2016; Chowdhury and Bandyopadhyay 2014). For children and adolescents living with human immunodeficiency virus predictive equations have been developed for bone mineral content and BMD based on anthropometric variables such as height, arm circumference and femoral diameter (de Lima et al. 2016). In healthy Indian women age 40–75, skeletal mass assessed by humerus, wrist, femur and ankle breadth were variables for prediction of BMD in elderly women (Chowdhury and Bandyopadhyay 2014). Our study also confirmed the relationship of skeletal size expressed by bicondylar humerus and femur breadth, wrist and biacromial breadth and bone mass characteristics in normal-weight young women. Moreover, it confirmed the positive correlation between LBM as measured by arm and calf girths or the total in kilograms and the BMD of the radius. A similar study among postmenopausal women also found a positive relationship between the calf circumferences and lumbar spine BMD ($p \leq 0.05$), but in contrast to this study there was no significant relationship between the calf circumference and the hip BMD (Arazi et al. 2016). This study also indicated a negative relationship between BMD of the lumbar spine and hip and waist-to-hip ratio (WHR), which was confirmed by the Chinese population (Wang et al. 2013). It was confirmed that obesity, especially visceral adipose accumulation, may not only be a risk factor for many diseases but also be detrimental to BMD in Chinese women. On the other hand in elderly Indian female population, fat mass was positively correlated with BMD (T-score) measured by ultrasound bone densitometry (Chowdhury and Bandyopadhyay 2014). Due to the fact that our study was performed among students with no visceral fat, no relationship was found between BMD and WHR, however was found negative relationship radius BMD to total fat % in normal-weight women.

It seems that high BMD is related to the genetically determined type of body structure characterized by increased skeletal and bone features as presented by handball players in our research. Generally female athletes of this sport exhibit more developed musculature and skeletal robustness, as confirmed by studies in youth (Moss et al. 2015) and female adult handball players (Granados et al. 2007). The specific nature of this game and also the training in this discipline are based on many different movements such as running, side-cutting, jumping, shooting, and changing direction (Michalsik et al. 2014; Süel 2015). These kinds of physical activities that are dynamic, moderate to high in load magnitude, short in load duration, odd or nonrepetitive in load direction, and applied quickly have a positive effect on the bone health condition (Turner and Robling, 2003).

In summary, the body type of handball players, as a result of selection in this discipline and the kind of handball training, has resulted in high BMD as evidenced by the spectacular Z-scores of tested athletes, particularly in the distal part of the radius (1.105 ± 0.828). Our observations have been confirmed in former handball players compared to an average group of young women. The higher BMD of the athletes' skeleton at different measured sites, forearm (Boshnjaku et al. 2015) or spine and femur (Mrabet et al. 2013), was associated with the effect of regular practice of handball. Also recreational handball represents intermittent high-intensity exercise leading to beneficial effects on BMD, muscle mass, and performance in young women (Hornstrup et al. 2018).

Based on our results, analysing a wide range of anthropometric measurements, it seems that we can use some physiological and anthropometric indices that are important determinants of BMD and risk of osteoporosis in women.

Conclusions

Morphological profile of female handball players is conducive to BMD.

Skeletal characteristics and muscle tissue had a significant beneficial effect on bone mineral characteristic in young women with normal weight.

Authors' contributions:

AP worked out the idea, design the study, collected the data, prepared the data for statistical analyses, prepared the first draft and the final version; MG prepared the first draft and the final version; JG made statistical analyses, prepared the first draft and the final version; KB worked out the idea, design the study, made statistical analyses, prepared the first draft and the final version.

Conflict of interest

Authors declare that there is no conflict of interests regarding publication of this work.

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