Original Article

Soft tissues and bone health in sedentary women: A cross-sectional study

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ABSTRACT

Lean mass is a strong determinant of bone mass, however, there is controversial surrounding the role of fat mass. The aim of this study was to examine the association between lean mass and fat mass with bone mass in middle-aged sedentary women, including relevant covariates. A cross-sectional study was performed on a total of 55 healthy and sedentary women. Dual energy x-ray absorptiometry was used to measure bone mineral content and areal bone mineral density at the whole body, lumbar spine and hip. The relationships between lean and fat mass with bone outcomes were analysed using three regression models: model 0 using unadjusted data, model 1 was adjusted by age and stature and model 2 added lean mass or fat mass (depending on the predictor). Lean mass was positively associated with most bone mineral content and areal bone mineral density outcomes in models 0 and 1, and the majority of these associations remained significant in model 2 (after adjusted by fat mass). Fat mass was positively associated with some of the bone mineral content and areal bone mineral density outcomes in models 0 and 1, and interestingly all associations disappeared in model 2 (after adjusted by lean mass). The main finding of this study was that lean mass was positively related to bone outcomes, independent of age, stature and fat mass in middle-aged sedentary women. In addition, the association between fat mass and bone outcomes seems to be explained by lean mass. **Keywords:** Bone mass; DXA; Menopause; Osteoporosis.

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INTRODUCTION

Osteoporosis has become a public health problem in both developed and developing countries (R. Zhao et al., 2014). It is an age-related skeletal disorder, characterized by a low bone density and predisposes those who suffer it to have a high fracture risk, which have a great impact on quality of life and on mortality (Center et al., 1999). It is estimated that by 2050, more than 6 million hip fractures will occur related to osteoporosis (Gullberg et al., 1997). Thus, the medical attention caused by this illness produces a high socio-economic cost due to treatment and rehabilitation (Cruz et al., 2009). It is well known that bone mass is determined by non-modifiable genetic factors (Reppe et al., 2010) and there are other factors that can influence the risk of developing osteoporosis, as well as the risk of fracture, for example age, history of fractures, years since menopause, parental hip fracture, nutrition or physical inactivity, among others (Robbins et al., 2007).

There is scientific evidence that regular physical exercise, especially aerobic exercise and body-weight-bearing exercises positively affect the bone metabolism and significantly improve bone health in premenopausal women (Wallace and Cumming, 2000; Wolff et al., 1999). The favourable effect of regular exercise on the body derives from the physical tension and weight load that promote the acquisition of bone mass (Forwood and Larsen, 2000). Also, exercise modifies our body composition by increasing lean mass and decreasing fat mass, among others (Douchi et al., 2003). Therefore, regular exercise is widely accepted as an optimal way of stimulating bone formation and reducing bone loss in premenopausal women.

On the other hand, body weight has been identified as a determinant of bone mass development (Gerdhem et al., 2003), influenced by the independent effect of lean mass and fat mass on the bone (Ho-Pham et al., 2014). Some research in women has proven that lean mass is closely related with bone mineral density (aBMD) (Douchi et al., 2003; Hsu et al., 2006; Li et al., 2004; Wang et al., 2005). This relation between lean mass and bone mass can be explained through the mechanostat theory that establishes that bone resistance is regulated by modelling and remodelling processes depending on the mechanical load applied to the body (Rauch et al., 2004; Schoenau and Frost, 2002).

Regarding the relation between fat mass and bone mass, there is certain controversy as some studies in men and women have suggested that fat mass is positively associated with bone mass (Chen et al., 1997; Gjesdal et al., 2008), whilst others have shown that the increment of fat mass may not be beneficial to the bone (Benetos et al., 2009; L. J. Zhao et al., 2007). Also, other authors have suggested an indirect relation between fat mass and bone development in upper limbs in women and men due to the elevated contribution of the fat mass on the total body mass (Capozza et al., 2004). On the other hand, there are also studies in women that have found that both fat mass and lean mass are significant predictors of aBMD (Gnudi et al., 2007; Ijuin et al., 2002; Khosla et al., 1996). These discrepancies can be due to the differences in the study design, variability of the sample and covariates used (L. J. Zhao et al., 2008).

Therefore, to better understand the relationship between body composition and bone health, this research aims to examine the association of lean mass and fat mass with bone outcomes in middle-aged sedentary women, including relevant covariates. We hypothesize that lean mass is stronger predictor of bone outcomes than fat mass in this population.

MATERIALS AND METHODS

Participants

This study is a cross-sectional analysis of a total of fifty-five 30 to 50 year old healthy and sedentary women (43.1 ± 5.9 years old). The participants could not accumulate more than 150 minutes of moderate physical activity or more than 75 minutes of vigorous physical activity per week, according to the minimal recommendations of the World Health Organization (World Health Organization, 2010). Data were collected between winter and spring of 2016.

The selection criteria were: to be sedentary according to the minimal recommendations of the World Health Organization; not having reached menopause, not having or not having suffered any illnesses that affect bone health and not taking any type of supplement that helps the acquisition or deposit of calcium. They completed the Global Physical Activity Questionnaire (GPAQ) on physical activity habits, to ensure that the participants did not meet the physical activity guidelines of at least 150 minutes of moderate physical activity or 75 minutes of vigorous physical activity per week.

Leaflets were used to recruit participants so they could get in touch to partake in the study. The participants were informed verbally and in a written manner about the experimental procedures and the risks associated. All participants gave their written consent to participate in the study. The study was approved by the ethical committee of the CEIC of the Madrid Community (P2016/UEM33) and carried out in accordance with the Helsinki Declaration.

Anthropometry and dual energy x-ray absorptiometry

The weight (kg) and height (cm) were measured using the SECA scale (model 711; SECA GmbH & Co, KG, Hamburg, Germany; precision 0.1 kg and 0.1 cm; range 2-220 kg and 60–220 cm, respectively). Body mass index (BMI) was calculated using the formula: BMI ($kg \cdot m^{-2}$) = body weight (kg)/body height $(m)^2$.

A dual energy x-ray absorptiometry (DXA) (Hologic Series Discovery QDR, Software Physician's Viewer, APEX System Software Version 3.1.2. Bedford, MA, USA) was used to measure bone mineral content (BMC, g) and aBMD (g/cm^2). Three scans were performed to obtain data at whole body (including legs, arms and total body minus the head), lumbar spine (L1-L4) and right hip (including trochanter, intertrochanter, femoral neck, Wards and total hip). The DXA equipment was calibrated prior to each testing day by using a lumbar spine phantom following the manufacturer's recommendations. The positioning of the participants and the analyses of the results were undertaken according to the International Society of Clinical Densitometry. BMC was calculated using the formula BMC = aBMD · area. Laboratory precision errors for regional analysis of the complete body scan, defined by the coefficient of variation (CV) for repeated measures estimated in adult volunteers with repositioning, were as follows: BMC < 3.5%, aBMD < 4%.

Analysis

The distribution of the variables was checked and verified using Shapiro–Wilk's test, skewness and kurtosis values, visual check of histograms, Q-Q and box plots. Variables were also checked for collinearity using variance inflation factor values. Data were analysed by means of the statistic software SPSS V19.0 for Windows (SPSS Inc, Chicago, IL, USA) and data presented as mean and standard deviation. The relationships between lean and fat mass with bone outcomes were analysed using three regression models: model 0 using unadjusted data; model 1 was adjusted by age and stature; and model 2 added lean mass or fat mass (depending on the predictor). Bonferroni correction was applied to control for multiple testing, which is considered to be the most conservative method of controlling for familywise error rates. Based on a desired alpha level of 0.05 and nine different hypotheses (outcomes), values of p<0.006 were considered statistically significant (0.05/9).

RESULTS

Table 1 shows the descriptive characteristics (mean and standard deviation) of the participants (age: 43.8 ± 6.0; stature: 161.6 ± 6.0; body mass: 64.9 ± 12.4). Table 2 shows the association between lean mass and bone mass. In model 0 (unadjusted data), lean mass was positively associated with most BMC and aBMD outcomes (semip. corr: 0.377–0.728; all $p<0.006$). In model 1, these associations disappeared in lumbar spine BMC (semip. corr: 0.199; p=0.090) and total body less head aBMD (semip. corr: 0.359; p=0.006) after age and stature were added into the model. Finally, once fat mass was added into the model (model 2), few previous significant associations disappeared, such as arms BMC (semip. corr: 0.201; p=0.072), femoral neck BMC (semip. corr: 0.266; p=0.034), intertrochanter aBMD (semip. corr: 0.264; p=0.041) and hip total aBMD (semip. corr: 0.290; p=0.023); the rest remained significant ($p<0.006$).

Table 1. Descriptive characteristics of the participants (n=55)

Variables	Mean	SD
Age (years)	43.8	6.0
Stature (cm)	161.6	6.0
Body mass (kg)	64.9	12.4
BMI (kg/m^2)	24.9	4.5
BMC (g)		
Lumbar spine	55.45	9.85
Trochanter	6.74	1.25
Intertrochanter	24.64	7.31
Femoral neck	3.96	0.87
Wards	0.77	0.18
Hip total	35.35	7.92
Legs	363.24	63.23
Arms	141.10	27.42
TBLH	1555.21	263.38
aBMD (g/cm^2)		
Lumbar spine	0.96	0.12
Trochanter	0.66	0.09
Intertrochanter	1.08	0.14
Femoral neck	0.77	0.11
Wards	0.65	0.12
Hip total	0.92	0.12
Legs	1.14	0.12
Arms	0.74	0.09
TBLH	0.94	0.09
Lean mass (g)		
Arms	1751.81	301.40
Trunk	20378.62	3531.63
Legs	5900.47	930.71
TBLH	35349.40	5022.39

Fat mass (g)		
Arms	1435.95	542.42
Trunk	11268.07	5180.52
Legs	4844.67	1119.97
TBLH	23305.92	7935.11

BMI: body mass index; BMC: bone mineral content; aBMD: areal bone mineral density; TBLH: total body less head.

Table 2. Multiple linear regression analysis of bone mineral content and density as regards to lean mass

Dependent variables	Model 0			Model 1			Model 2		
BMC (g)	*B*	Semip corr	*p*	*B*	Semip corr	*p*	*B*	Semip corr	*p*
Lumbar spine	0.377	0.377	**0.005**	0.229	0.199	0.090	0.120	0.088	0.446
Trochanter	0.639	0.639	**<0.001**	0.790	0.585	**<0.001**	0.587	0.379	**<0.001**
Intertrochanter	0.093	0.093	0.501	0.052	0.039	0.776	-0.120	-0.077	0.561
Femoral neck	0.453	0.453	**0.001**	0.484	0.358	**0.005**	0.411	0.266	0.034
Wards	0.466	0.466	**<0.001**	0.770	0.570	**<0.001**	0.658	0.425	**0.000**
Hip total	0.236	0.236	0.083	0.226	0.167	0.212	0.027	0.018	0.891
Legs	0.728	0.728	**<0.001**	0.646	0.478	**<0.001**	0.495	0.320	**0.001**
Arms	0.518	0.518	**<0.001**	0.415	0.334	**0.005**	0.278	0.201	0.072
TBLH	0.705	0.705	**<0.001**	0.642	0.513	**<0.001**	0.447	0.284	**0.004**
aBMD (g/cm²)	*B*	Semip corr	*p*	*B*	Semip corr	*p*	*B*	Semip corr	*p*
Lumbar spine	0.057	0.057	0.679	-0.028	-0.024	0.854	-0.206	-0.027	0.838
Trochanter	0.459	0.459	**<0.001**	0.793	0.586	**<0.001**	0.753	0.487	**<0.001**
Intertrochanter	0.432	0.432	**0.003**	0.545	0.403	**0.003**	0.408	0.264	0.041
Femoral neck	0.560	0.560	**<0.001**	0.756	0.559	**<0.001**	0.564	0.364	**0.001**
Wards	0.458	0.458	**<0.001**	0.733	0.542	**<0.001**	0.611	0.395	**0.001**
Hip total	0.452	0.452	**0.001**	0.579	0.428	**0.001**	0.449	0.290	0.023
Legs	0.568	0.568	**<0.001**	0.744	0.551	**<0.001**	0.699	0.452	**<0.001**
Arms	0.293	0.293	0.030	0.276	0.222	0.084	0.231	0.166	0.195
TBLH	0.442	0.442	**0.001**	0.450	0.359	0.006	0.265	0.169	0.179

Significant results in bold letters p<0.006
Model 0: unadjusted data; Model 1: adjusted for age and stature; Model 2: model 1 + fat mass.
B is the estimated standardized regression coefficient; Semip corr is semi-partial correlation.
BMC: bone mineral content; aBMD: areal bone mineral density; TBLH: total body less head.

Table 3 shows the association between fat mass and bone mass. In model 0 (unadjusted data), fat mass was positively associated with some of the aBMD and BMC outcomes (semip. corr: 0.375-0.611; all $p<0.006$). Significant associations remained unchanged after age and stature were added into the model (model 1), except the hip total BMC (semip. corr: 0.312; p=0.018) and legs aBMD (semip. corr: 0.321; p=0.015). Finally, after adjusting for lean mass (model 2), all previous significant associations disappeared.

Table 3. Multiple linear regression analysis of bone mineral content and density as regards to fat mass

Dependent variables	Model 0			Model 1			Model 2		
BMC (g)	*B*	Semip corr	*p*	*B*	Semip corr	*p*	*B*	Semip corr	*p*
Lumbar spine	0.295	0.295	0.029	0.250	0.232	0.046	0.190	0.149	0.198
Trochanter	0.609	0.609	**<0.001**	0.594	0.520	**<0.001**	0.353	0.270	0.008
Intertrochanter	0.280	0.280	0.039	0.249	0.218	0.103	0.298	0.228	0.090
Femoral neck	0.315	0.315	0.019	0.296	0.259	0.045	0.127	0.097	0.427
Wards	0.454	0.454	**0.002**	0.465	0.407	**0.002**	0.194	0.149	0.187
Hip total	0.389	0.389	**0.003**	0.356	0.312	0.018	0.345	0.264	0.045
Legs	0.611	0.611	**<0.001**	0.465	0.408	**<0.001**	0.262	0.201	0.034
Arms	0.494	0.494	**<0.001**	0.380	0.347	**0.003**	0.271	0.222	0.047
TBLH	0.581	0.581	**<0.001**	0.517	0.474	**<0.001**	0.282	0.207	0.035
aBMD (g/cm²)	*B*	Semip corr	*P*	*B*	Semip corr	*P*	*B*	Semip corr	*p*
Lumbar spine	0.001	0.001	0.994	-0.003	-0.002	0.986	0.016	0.013	0.924
Trochanter	0.311	0.311	0.021	0.377	0.331	0.015	0.068	0.052	0.651
Intertrochanter	0.354	0.354	0.008	0.404	0.354	0.009	0.237	0.181	0.155
Femoral neck	0.518	0.518	**<0.001**	0.565	0.495	**<0.001**	0.333	0.255	0.021
Wards	0.460	0.460	**0.002**	0.463	0.406	**0.002**	0.212	0.163	0.156
Hip total	0.360	0.360	0.007	0.409	0.359	0.008	0.225	0.172	0.171
Legs	0.375	0.375	**0.005**	0.366	0.321	0.015	0.079	0.060	0.593
Arms	0.302	0.302	0.025	0.180	0.164	0.203	0.090	0.074	0.564
TBLH	0.425	0.425	**0.001**	0.406	0.373	**0.004**	0.267	0.196	0.120

Significant results in bold letters p<0.006
Model 0: unadjusted data; Model 1: adjusted for age and stature; Model 2: model 1 + lean mass.
B is the estimated standardized regression coefficient; Semip corr is semi-partial correlation.
BMC: bone mineral content; aBMD: areal bone mineral density; TBLH: total body less head.

DISCUSSION

The main findings of this study in middle-aged sedentary women support our hypothesis since (1) lean mass is positively related to BMC and aBMD, independent of age, stature and fat mass; and (2) the association between fat mass and BMC and aBMD disappears once lean mass is controlled.

The influence of lean mass on bone outcomes

The relationship between lean mass and bone mass has been described in previous studies, with most of them finding a high positive correlation between these factors. However, there are fewer studies about the association between lean mass and bone mass taking into account fat mass. The results of our study coincide with the revision by Ho-Pham et al. (2014), in which lean mass had a greater effect on bone mass compared to fat mass in men and women. Similarly, Travison et al. (2008) described a positive correlation between lean mass and bone mass, which does not occur with fat mass, in young children and teenagers of both sex. In other similar researches, only in teenagers is this relationship between lean mass and bone corroborated (Rauch et al., 2004; Vicente-Rodríguez et al., 2008).

In perimenopause women, Li et al. (2004) found correlations in bone mass and lean mass, specifically in the femoral neck and, as in the studies cited, no correlation between aBMD and fat mass was found. Similarly, another study supported that the aBMD was strongly related to lean mass in elder men and women (Taaffe et al., 2001; Wang et al., 2005). In conclusion, although there are studies that did not find any relation between lean mass and bone mass (Reid et al., 1992; Reid et al., 1995), there is strong evidence regarding a positive correlation between both factors (Douchi et al., 2003; Hsu et al., 2006; Li et al., 2004; Wang et al., 2005), which could be due to the mechanostat theory (Rauch et al., 2004; Schoenau and Frost, 2002). Thus, our study corroborated previous findings in which lean mass was important in relation to bone mass, and in addition, this relationship was maintained independent of age, stature and fat mass.

The influence of fat mass on bone outcomes

It is widely known that fat mass is one of the main indicators for obesity and it plays an important role in body weight in sedentary women (Ahmad et al., 2010). For this reason, it has also been a well-studied factor in relation to its association with bone mass. The relation between fat mass and bone mass has been described previously in other populations, finding very different results. On the one hand, some studies disregard the existence of a relationship between both factors (Benetos et al., 2009; L. J. Zhao et al., 2007), whilst on the other, contrary results are shown (Chen et al., 1997; Gjesdal et al., 2008). Thus, we found studies in which, after adjusting the results of correlations by lean mass, the relationship between fat mass and bone mass statistically disappeared (Yoo et al., 2012) or even became negative, suggesting that fat mass has a negative effect on bone mass (Travison et al., 2008).

Focusing on women, discrepant findings have been shown depending on whether they were menopausal or not. On the one hand, there are studies that support the idea that the association between fat mass and aBMD is higher before the menopause (Lindsay et al., 1992; Makovey et al., 2005) and on the other, there are researches that show a higher association in postmenopausal women (Khosla et al., 1996; MacInnis et al., 2003). It is possible that these discrepancies are due to the difference in the study design, variability of the sample and covariates used (L. J. Zhao et al., 2008). In relation to our results, there were positive correlations between fat mass and bone mass but these decreased significantly in model 2 when adjusted for lean mass. Therefore, our results suggest that the relation between fat and bone mass can be explained through the relation between lean mass and bone (Chen et al., 1997; Gómez-Cabello et al., 2013).

Thus, the practice of regular physical activity is important as it helps to improve lean mass and, therefore, bone health. It has been proven in numerous studies that exercise improves bone mass, especially in clinically relevant regions like the lumbar spine and femoral neck (Wallace and Cumming, 2000; Wolff et al., 1999; R. Zhao et al., 2014). Also, we must take into account the long-term effects that exercise produces in middle-aged women to cope with healthier ageing. In a longitudinal study in premenopausal women in which a high-impact exercise intervention was performed for 18 months, the benefits obtained on aBMD remained for three and a half years after the intervention (Kontulainen et al., 2004). These effects of exercise are important because during the ageing process, there is a decrease in lean mass and bone mass, which leads to the onset of osteoporosis contributing to a worsening of health and a lower quality of life (Gómez-Cabello et al., 2012).

Limitations

The main limitations of the study were that biochemical blood markers were not measured, which could have offered additional and useful information on the bone mineralization process. Also, it would have been interesting to perform the intervention over a longer period with the aim of discovering the effects of exercise long-term. In addition, the residual effect of exercise is an interesting aspect to be studied in the future, including more randomized trials that compare the effects of different exercise programmes on women’s bone health.

CONCLUSIONS

In conclusion, the results of our study indicated a positive and strong relation between lean mass and bone mass in premenopausal women. On the one hand, in terms of fat mass and bone mass, our results indicated that there is not a relationship between them once adjusted for age, stature and lean mass. Thus, we can confirm that maintaining a good level of physical exercise that develops the muscular component helps to prevent the loss of bone mass and osteoporosis in this population. These findings underline the concept that physical activity is an important factor in the prevention of bone loss and osteoporosis in women.

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CONFLICT OF INTEREST

The authors declare that they have no competing interest.

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