Cent. Eur. J. Med. • 9(1) • 2014 • 121-125
DOI: 10.2478/s11536-013-0259-1

VERSITA

Central European Journal of **Medicine**

Body fat, lean mass and bone density of the spine and forearm in women

Research Article

Mihail A. Boyanov*

Clinic of Endocrinology and Metabolism, University Hospital Alexandrovska, Department of Internal Medicine, Medical University Sofia, 1431 Sofia, Bulgaria

Received 19 April 2013; Accepted 3 September 2013

Abstract: The aim of this study was to determine the relative contributions of fat mass and lean mass to the variability of bone mineral density (BMD) of the lumbar spine and proximal 1/3 forearm in Bulgarian women. 180 women aged 21 through 76 years participated (mean age 50.8 ± 9.7 years). 130 of them were postmenopausal. Lumbar spine and forearm BMD were measured by dual-energy X-ray absorptiometry, followed by a whole-body scan for body composition examination (Hologic QDR 4500 A device, software version 1.26). The strongest linear correlation was found with body weight (r2=0.231, p<0.001). Using this model, 18.1 % of the variability of lumbar spine BMD was attributable to fat mass and 16.0 % to lean mass. The relative influence of fat mass on L1-L4 BMD was greater than that of lean mass (standardized regression coefficient 0.291 versus 0.199). There were weak correlations of body weight, fat and lean mass with the forearm BMD. Lean mass correlated slightly better (r=0.187, p=0.050) to forearm BMD than fat mass (r=0.162, p=0.055). In conclusion, the differentiation between fat and lean mass does not strengthen the BMD correlations beyond that with total body weight.

Keywords: *Bone mineral density • Body weight • Lean mass • Fat mass • Correlation*

1. Introduction

Obesity is regarded as a protective factor against osteoporosis and fractures. In a large meta-analysis low body mass index (BMI) emerged as a risk factor for fractures with the risk decreasing non-linearly with increasing BMI [1]. The identification of the body compartment (i.e. fat or lean mass), which is better correlated with bone mineral density (BMD) is, therefore, of interest. A number of previous studies favor the contribution of lean mass to the variability of BMD in adolescents and young women [2-4]. The dominant effect of lean mass on BMD compared to that of fat mass is also found in postmenopausal women, although less consistently [5-7].

The aim of this study was to test the relative contributions of body fat and lean mass to the variability of BMD of the lumbar spine and the proximal 1/3 forearm in Bulgarian women.

2. Materials and methods

2.1 Study population

This is a cross-sectional study. All participants had been referred by their general practitioner; endocrinologist or rheumatologist for bone density testing or whole body scans and gave their informed consent. The study was approved by the responsible authorities. During the 3-year study, 180 women aged 21 through 76 years participated (mean age 50.8 ± 9.7 years). 130 of them were postmenopausal (mean age at menopause 45.7 ± 7.1 years).

Subjects with any medical conditions or medications known to cause excessive obesity, dehydration, water retention or electrolyte disturbance affecting body composition measurements were excluded from this study. All participants had no history of secondary osteoporosis caused by diseases or medications. The exclusion criteria also included the presence of deformed or fractured lumbar vertebrae, severe scoliosis (>15°) and other conditions which interfere with proper analysis of BMD scans.

* *E-mail: mihailboyanov@yahoo.com*

2.2 Experimental procedures

All subjects underwent a structured interview followed by lumbar spine and non-dominant forearm bone mineral density (BMD) and body composition measurements obtained using dual-energy X-ray absorptiometry (DXA). Forearm dominance was self-reported by the participants in the study. A Hologic QDR 4500 A device with software version 1.26 was used (Hologic Inc., Bedford, MA, USA). BMD was expressed in g/cm^2, young adult T-scores and age-adjusted Z-scores according to the Hologic DXA lumbar spine L1-L4 and proximal 1/3 forearm Caucasian female reference data (versions from 04/11/1991 and 25/10/1991 respectively). The body composition data included percent body fat (% fat), lean mass and fat mass, both of which were measured in grams (g). Body weight was also assessed from the whole body scan using the software. BMI was calculated in kg/m^2 based on stadiometer height measurements (Tanita TBF-215 bio-electrical impedance analyzer; Tanita Corp., Japan) and DXA whole body scan weight measurements. The DXA site-specific precision errors, expressed as% coefficient of variation, were found to be 1.4% for whole body fat mass and lean mass, 1.26% for lumbar spine BMD and 1.1% for forearm BMD.

2.3 Statistical analysis

A sample size of greater than 150 participants was regarded as the minimum for statistical power. The statistical analysis was performed using SPSS statistical software for the WINDOWS 13.0 platform (SPSS corp., Chicago, IL, USA, 2004). The data were first tested for normal distribution and homogeneity of variance. ANOVA and non-paired Student's t-tests were performed. A number of regression analyses were conducted: linear, logarithmic, inverse, quadratic, cubic, compound, power, S, and exponential. Multiple linear regression analyses were performed to evaluate the effect of fat and lean mass on BMD of the lumbar spine and the non-dominant forearm (selected according to data provided by the patients). They were performed following the completion of co-linearity tests using the backward method. An alpha-level of 0.05 was considered statistically significant. In an effort to find correlations of BMD with fat and lean mass respectively in the general female population, subgroup analyses were not performed based on menopausal status.

3. Results

The study population consisted of slightly obese women (the mean body mass index was 32.7 ± 4.5 kg/m^2). The mean body weight of the participants was 84.3 ± 19.6 kg; the mean fat mass – 36.6 ± 13.0 kg; and mean lean mass – 46.0 ± 7.6 kg. Mean participant% body fat was 42.3 ± 6.2%. 118 of the women (65.6%) had a BMI ≤ 35.0 kg/m^2 and 62 (34.4%) had a BMI > 35.0 kg/m^2. The BMD data of the participants are presented as absolute values (expressed in g/cm^2) and T-, and Z-scores (expressed in standard deviations) in Table 1. 22.2% of the women were found to have a lumbar spine T-score ≤ -2.5 (consistent with osteoporosis), 25.6% had a T-score between -1.0 and -2.5 (low bone density) and 52.2% - a T-score above -1.0 (normal bone density). The corresponding T-score percentages for the proximal 1/3 forearm were found to be 13.9%, 24.4% and 61.7% respectively.

Table 1. Anthropometric and BMD values at the lumbar spine and 1/3 proximal forearm (in g/cm^2).

	Mean	Standard deviation	Range
Age, years	50.8	9.7	21.0 - 76.0
Age at menopause, years	45.7	7.13	31.0 - 56.0
Height, cm	160.5	5.4	148.0 - 172.0
Body weight, kg	84.3	19.6	45.8 -138.2
Fat mass, kg	36.6	13.0	15.3 - 69.8
Lean mass, kg	46.0	7.6	28.5 - 66.3
% body fat	42.3	6.2	23.5 - 55.7
Lumbar spine BMD, g/cm^2	0.954	0.174	0.581 - 1.539
Lumbar spine T-score	-1.0	1.5	-4.2 - +4.9
Lumbar spine Z-score	-0.1	1.4	-2.9 - +5.4
1/3 forearm BMD, g/cm^2	0.653	0.104	0.371 – 0.800
1/3 forearm T-score	-0.54	1.22	- 3.8 - +1.2
1/3 forearm Z-score	0.02	1.33	-2.8 - + 1.8

Compared to post-menopausal women, pre-menopausal women had lower body weight (by a mean of 5.1 kg), lower BMI (by a mean of 1.7 kg/m^2), lower body fat (by 3.5%) and higher BMD at both site. That is, only 8.0% of the women had lumbar spine T-scores ≤ -2.5 and 18.0% - a T-score between -1.0 and -2.5. The remaining 74.0% had normal BMD.

At the lumbar spine the strongest correlation was found between BMD and body weight, followed by that of BMD and fat mass. Table 2 summarizes the correlation coefficients between lumbar spine BMD (in g/cm^2), body weight and its components – fat and lean mass. The best models describing these correlations were the quadratic and cubic, as is often seen in biological variables. The linear model was, however, only slightly inferior.

According to the cubic model (the best fitting model), whole body weight was responsible for 28.0% of the variability in L1-L4 BMD, while fat mass and lean mass were responsible for 22.9% and 20.2% of the variability respectively. Using the simple linear equation, these variability contributions were found to be 23.1%, 18.1 %, and 16.0% respectively. The combined contribution of

Table 2. Correlation coefficients (R-square) from curve estimation analyses with lumbar spine BMD as the dependent variable and body weight,% body fat, fat and lean mass, as the independent variables.

Model	R Square			
Equation	Fat mass	Lean mass	Total body weight	% body fat
Linear	0.181	0.160	0.231	0.106
Logarithmic	0.207	0.177	0.258	0.095
Inverse	0.209	0.190	0.275	0.077
Quadratic	0.226	0.202	0.280	0.117
Cubic	0.229	0.202	0.280	0.112
Compound	0.181	0.154	0.232	0.109
Power	0.212	0.174	0.265	0.097
S	0.220	0.191	0.288	0.079
Exponential	0.181	0.154	0.232	0.109

The significance was $p<0.001$ for all equations including body weight, fat and lean mass, and $0.01 > p > 0.001$ - for the% body fat.

fat and lean mass to the variability of lumbar spine BMD in this linear model was 20.5%.

The multiple linear backward regression analyses produced the following equation ($p<0.001$):

BMD L1-L4 (g/cm^2) = 0.594 + 0.004 x fat mass (kg) + 0.004 x lean mass (kg)

The results in Table 3 show that fat mass had, however, a stronger impact on L1-L4 BMD. This resulted in higher standardized regression coefficients (0.291 for fat mass versus 0.199 for lean mass) and a higher statistical significance level (p=0.033 for fat mass and p=0.141 for lean mass).

Table 3. Standardized and non-standardized regression coefficients describing the correlations of lumbar spine BMD and fat and lean mass respectively in the linear model.

	Non-standardized coefficients		Standardized coefficients	Significance, p
	B	Standard error	Beta	
Constant	0.594	0.106		<0.001
Fat mass	0.004	0.002	0.291	0.033
Lean mass	0.004	0.003	0.199	0.141

The type of correlation between lumbar spine BMD and fat and lean mass respectively remained the same when examined separately in participants with different BMI (below and above 35.0 kg/m^2). The regression coefficients were, however, different and with a lower statistical significance.

In comparison to the lumbar spine, the correlations of body weight, fat and lean mass with forearm BMD were weaker, of borderline significance, and are therefore, not shown in detail. Similarly to the lumbar spine results, the strongest linear correlation of forearm BMD was found with body weight (r=0.277, p=0.001). However, in contrast to the lumbar spine, lean mass correlated slightly better (r=0.187, p=0.050) than did fat mass (r=0.162, p=0.055). A multiple linear backward regression analysis produced the following equation:

Proximal 1/3 forearm BMD (g/cm^2) = 0.564 + 0.002 x lean mass (kg) + 0.0014 x fat mass (kg)

The level of statistical significance was p=0.005.

4. Discussion

A body composition and BMD correlation study was conducted favoring the role of fat mass on lumbar spine BMD variability. In contrast, forearm BMD (composed of purely cortical bone) is much less influenced by body weight, with lean mass showing a somewhat stronger correlation.

In a similar study, body weight, lean and fat mass were all positively correlated with BMD at the lumbar spine, femoral neck and 1/3 forearm [7]. However, fat mass had generally a stronger correlation to BMD than lean mass at all sites. Lean mass was not significantly correlated to the femoral and forearm BMD after controlling for fat mass and years since menopause [7].

A recent study addressed the issue in reproductive-aged women of different races/ethnicities (white, black and Hispanic) and produced opposing results [8]. Fat-free mass correlated more strongly than fat mass with BMD at the lumbar spine (r=0.52 versus r=0.39) and the femoral neck. The association of fat-free mass with spinal BMD was greater in 16-24-yr-old than in 25-33-yr-old women [8]. The effect of fat mass on spinal BMD was less in blacks than Hispanics. The authors concluded that both fat mass and fat-free mass are contributors to bone density, although their relative importance might be slightly different in populations of different age, race, and ethnicity [8].

In the present study, pre- and post-menopausal women were not examined separately for two reasons: to preserve the integrity of the calculations as applied to the general female population and to preserve better statistical power.

Another recent study investigated the association of bone mineral density and body composition in patients with chronic obstructive pulmonary disease [9]. Lumbar spine BMD was best correlated with BMI (r=0.37, p=0.01), followed by fat-mass index (r=0.35, p=0.02) and fat-free mass index (r=0.32, p=0.03). The results of that study showed that the correlations are of similar magnitude, with all of them being rather weak (r<0.5), which is in concordance with the data from the current study [9].

The difference in the results of the present study when compared to other studies favoring the role of lean mass on lumbar spine BMD [2-6,8] can be explained in terms of a number of factors:

1. The contribution of fat and lean mass to BMD might differ substantially in cortical and trabecular portions of

bones. The different proportions of the two bone components might explain the discrepancies noted in the results of previously published studies focusing on the lumbar spine, femoral neck and distal forearm.

2. Age and obesity might alter the relative contributions of both lean and fat mass as sarcopenia is common in the elderly postmenopausal population. Aging and obesity might increase the proportion of fat mass and, therefore, its influence on BMD.

A study looked at the differential effects of body compartments on BMD in women with or without osteoporosis and higher fat mass [6]. Fat mass was strongly associated with BMD only in osteoporotic and obese postmenopausal women. In non-osteoporotic women, lean mass was significantly associated with BMD ($p < 0.001$), while fat mass was not. In osteoporotic women, both lean and fat mass were equally associated with BMD ($P < 0.05$). In women with a fat/lean mass ratio greater than 1 (as an indicator of overweight/obesity), fat mass affected BMD ($P < 0.05$), while lean mass did not [6].

Lean mass is believed to drive bone mass accrual and strength during adolescence, in addition to BMD maintenance during adulthood [10]. On the other hand, fat mass is metabolically more active and might have a greater influence on overweight and obese individuals (as in our study population). Furthermore, the role of gender cannot be excluded as there may be sex-specific differences in the impact of the fat and lean body compartments on BMD [11]. A DXA study examined muscle-bone relationships in the whole body and limbs of 2512 normal men and pre- and post-menopausal women [12]. Besides the obvious anthropometric associations, fat mass was suggested to exert a mechanical effect as a component of body weight, which was clearly evident in the lower limbs, while muscle contractions were found to induce a more significant, dynamic effect in both lower and upper limbs. In this study, muscle mass was found to have a greater influence than fat mass, body weight and age on BMD of the whole body and lower limbs, regardless of the gender and reproductive status of the individual [12].

A limitation of our study is the relatively limited number of participants, which did not allow for further subgroup analyses based on presence/absence of low BMD, menopause or overweight/obesity. Moreover there was a bias toward higher body weights than those expected in the general Bulgarian female population.

In conclusion, our data show that fat and lean mass have a rather similar effect on BMD, even though this may differ in different sample populations and measurement sites. They do not add any information to that provided by total body weight as the differentiation between fat and lean mass does not significantly strengthen their respective correlations with BMD.

Acknowledgments

The author would like to thank Dr. Plamen Popivanov (Head of the DXA Unit, where the study was performed) and Mrs. Darinka Antonova (DXA-technologist) for their help in conducting this study as well as Prof. Dr. Gencho Genchev for his expertise in statistics.

The author declares no conflicts of interest or sponsorship.

References

[1] De Laet C., Kanis J.A., Odén A., Johanson H., Johnell O., Delmas P., et al. Body mass index as a predictor of fracture risk: a meta-analysis, Osteoporos Int ., 2005, 16, 1330-1338

[2] Wang M.C., Bachrach L.K., Van Loan M., Hudes M., Flegal K.M., Crawford PB. The relative contributions of lean tissue mass and fat mass to bone density in young women, Bone, 2005, 37, 474-481

[3] El Hage R., Courteix D., Benhamou C.L., Jacob C., Jaffré C. Relative importance of lean and fat mass on bone mineral density in a group of adolescent girls and boys, Eur J Appl Physiol., 2009, 105, 759-764

[4] Sayers A., Tobias J.H. Fat mass exerts a greater effect on cortical bone mass in girls than boys. J Clin Endocrinol Metab., 2010, 95, 699-706

[5] Chen Z., Lohman T.G., Stini W.A., Ritenbaugh C., Aickin M. Fat or lean tissue mass: which one is the major determinant of bone mineral mass in healthy postmenopausal women? J Bone Miner Res., 1997, 12, 144-151

[6] Gnudi S., Sitta E., Fiumi N. Relationship between body composition and bone mineral density in women with and without osteoporosis: relative contribution of lean and fat mass, J Bone Miner Metab., 2007, 25, 326-332

[7] El Hage R., Jacob C., Moussa E., Baddoura R. Relative importance of lean mass and fat mass on bone mineral density in a group of Lebanese postmenopausal women, J Clin Densitom., 2011, 14, 326-331

[8] Berenson A.B., Breitkopf C.R., Newman J.L., Rahman M. Contribution of fat-free mass and fat mass to bone mineral density among reproductive-

aged women of white, black, and Hispanic race/ethnicity, J Clin Densitom., 2009 12(2):200-206

[9] Fountoulis G.A., Minas M., Georgoulias P., Fezoulidis I.V., Gourgoulianis K.I., Vlychou M. Association of bone mineral density, parameters of bone turnover, and body composition in patients with chronic obstructive pulmonary disease, J Clin Densitom., 2012, 15, 217-223

[10] Ilich-Ernst J., Brownbill R.A., Ludemann M.A., Fu R. Critical factors for bone health in women across the age span: how important is muscle mass? Medscape Womens Health, 2002, 7, 2

[11] Ferretti J.L., Capozza R.F., Cointry G.R., García S.L., Plotkin H., Alvarez Filgueira ML., Zanchetta JR. Gender-related differences in the relationship between densitometric values of whole-body bone mineral content and lean body mass in humans between 2 and 87 years of age, Bone, 1998, 22, 683-690

[12] Capozza R.F., Cointry G.R., Cure-Ramírez P., Ferretti J.L., Cure-Cure C. A DXA study of muscle-bone relationships in the whole body and limbs of 2512 normal men and pre- and post-menopausal women, Bone, 2004, 35, 283-295