Association Between Femoral Neck Bone Mineral Density and Lower Limb Fat-Free Mass in Postmenopausal Women

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Abstract

Aging is associated with several physiological changes that lead to increased disability and mortality. Examples of these changes are deteriorations in bone and muscle tissues, referred, respectively, as osteopenia and sarcopenia. Both have been linked to multiple morbid outcomes in older adults. The main purpose of this study was to determine the association between femoral neck and trochanter bone mineral density (BMD) and lower limb non-bone fat-free mass (MM) in postmenopausal women. One hundred eighty nine postmenopausal women volunteered to participate in the study (mean age 66.92 ± 5.23 yr). Subjects were divided into different groups according to lower limb MM, femoral neck, and trochanter BMD measurements using the 2-step cluster analysis. Pearson chi-square was used to analyze the correlation between the BMD and MM distributions. The 2-step cluster analysis leads to the formation of 3 groups according to the levels of lower limb MM (LMM—low values of MM, IMM—intermediate values of MM, and HMM—high values of MM), 2 groups according to the values of femoral neck BMD (LFN—low values and HFN—high values), and 3 groups for trochanter BMD (LTR—low values, ITR—intermediate values, and HTR—high values). The results of Pearson chi-square revealed a significant association between femoral neck BMD and lower limb MM, and trochanter BMD and lower limb MM, suggesting that individuals with reduced lower limb MM are prone to have decreased femoral neck and trochanter BMD. The present study supports the hypothesis of a relation between the incidence of low BMD and MM. It is recommended that dual-energy X-ray absorptiometry screening should be used to identify both BMD and MM in postmenopausal women to assess more accurately the risk of fractures and disability.

Key Words: Aging; fracture risk; osteopenia; osteoporosis; sarcopenia.

Introduction

Aging is associated with several physiological changes that lead to increased disability and mortality. Examples of these changes are the deteriorations in bone and muscle tissues, which are, respectively, referred as osteopenia and sarcopenia (1,2). Sarcopenia and osteopenia have been linked to multiple morbid outcomes in older adults such as falls, fractures, functional capacity decline, impaired thermoregulation, and glucose intolerance (3–5).

The development of osteopenia depends on the maximum bone mass achieved in young adulthood and the rate of bone loss during the life span (2). Similar to bone mass, muscle strength tends to peak between the second and third decade of life and remains stable until about 45 to 50 yr of age, when losses then begin to occur at a rate of approximately 12–15% per decade (6). Menopause has been linked to
a reduction in both non-bone fat-free mass (MM) and bone mineral density (BMD) (2,7,8), which are directly related to a reduced output of ovarian hormones (8).

Several studies have suggested a positive correlation between MM and BMD (9–15); however, there are studies with contradictory results (16). Based on the theory that muscle mass is an indicator of BMD, it could be speculated that individuals with sarcopenia have an increased incidence of osteopenia. However, to date this hypothesis is controversial. Sowers et al. (13) reported that the mean femoral neck BMD values increased significantly for each tertile of whole body muscle mass in premenopausal women. On the other hand, the studies of Gillette-Guyonet et al. (17) and Walsh et al. (18) showed no association between sarcopenia and osteopenia or osteoporosis in postmenopausal women.

Although the use of fixed cutting points for defining sarcopenia and osteopenia is important for the classification of individuals, the use of fixed values may create heterogenous groups, with relatively large within-group variations. One alternative method is cluster analysis, which seeks to identify homogeneous subgroups of cases in a population, minimizing within-group and maximizing between-group variations. Additionally, according to Rhodes et al. (19) if muscular function is to be a determinant of BMD, the force of muscle contraction must impact on an anatomically related skeletal site or reflect actions of those muscles. However, no previous studies have compared BMD and MM at related sites (13,17,18). Therefore, the purpose of the present study were (1) to investigate the factors related to lower limb MM, femoral neck, and trochanter BMD, (2) to analyze the association between low femoral neck and trochanter BMD and the incidence of sarcopenia, and (3) to determine if the distribution of femoral neck and trochanter BMD into different clusters was associated with the distribution of lower limb MM in postmenopausal women.

Methods and Procedures

Subjects

The subjects were selected among a population of post-menopausal women who volunteered to participate in the study. Women impaired to perform the dual-energy X-ray absorptiometry (DXA) scanning; implanted with metallic prosthesis or affected by metabolic/endocrine dysfunctions that alter bone metabolism were not accepted in the study. One hundred and ninety two women complied with the criteria to participate. The subjects were informed about the experimental procedures and signed an informed consent form before participating in the study. The study was approved by an Institutional Review Board. The results of MM were not available for 1 subject and 2 subjects were classified as outliers regarding trochanter BMD. Therefore, the analyses were conducted on 189 subjects.

Anthropometry

Weight and height were recorded at morning, after an overnight fast. Measurements were made while the women were dressed in light indoor clothes and shoes removed. Body weight was measured at the nearest 0.01 kg using a calibrated balance-beam scale. Height was determined at the nearest 0.1 cm using a stadiometer.

Dual Energy X-Ray Absorptiometry

The body composition measurements were carried out by DXA (DPX-L, Lunar Radiation Corporation, Madison, WI). The software provided the nonbone fat-free mass (MM), fat mass (FM), and BMD for whole body and specific regions. It was previously reported that nonbone fat-free mass measured by DXA correlates strongly with muscle mass in humans across the age span (20,21).

Sarcopenia was defined as a relative skeletal muscle index (appendicular skeletal muscle mass divided by height squared) below 5.45 kg/m², as previously suggested by Baumgartner et al. (22). Osteopenia was not distinguished in the present study due to the lack of reference values for the Brazilian population.

Characterization of the Subjects

The hormonal reposition therapy (HRT), smoking and calcium supplementation status were assessed by a standard questionnaire. Physical activity level (PAL) was assessed by the International Physical Activity Questionnaire (IPAQ). IPAQ was chosen because its application is straightforward, there is a version validated in Brazilian subjects (23) and has been used in previous studies dealing with Brazilians (24). The official Portuguese short version of IPAQ (available at: www.celafiscs.com.br) was used in the present study. The questionnaires were applied face-to-face by a trained interviewer.

Statistical Analysis

Standard statistical procedures were used to calculate means and standard deviation (SD). Stepwise multivariate regression analyses were performed to identify predictors for femoral neck and trochanter BMD and lower limb MM. The variables included in the analysis were age, body weight, height, percent body fat, HRT, smoking, calcium supplementation status, and PAL.

The 2-step cluster analysis was used to create homogenous groups according to femoral neck and trochanter BMD and lower limb MM. Pearson chi-square was used to analyze association between the distribution of BMD and MM. Statistical significance was set at \( p < 0.05 \). All analyses were done using the Statistical Package for the Social Sciences, version 12 (SPSS, Chicago, IL).

Results

Subjects’ characteristics are presented in Table 1. The results of the questionnaire revealed that 2.1% of the subjects were smokers, 16.9% were in HRT, and 30.4% were using calcium supplementation. Regarding PAL, 4.2% were classified as sedentary, 35.5% as insufficiently actives, 58.7% as actives and 1.6% as very actives.
The regression analysis results revealed that the best model for femoral neck BMD prediction included body weight, age, smoking, and HRT status ($r^2 = 0.356$) and the model for trochanter BMD included only body weight and HRT ($r^2 = 0.311$). The model for lower limb MM included body weight, % body fat, and height ($r^2 = 0.687$).

Three clusters were formed for lower limb MM: (1) HMM—high values (14.47 ± 0.91 kg), (2) IMM—intermediate values (11.54 ± 1.03 kg), and (3) LMM—low values (8.85 ± 0.86 kg), which were composed of 28, 147, and 16 subjects, respectively. The analysis of femoral neck BMD data lead to the formation of 2 clusters: (1) HFN—high values (1.047 ± 0.088 g/cm²) and (2) LFN—low values (0.808 ± 0.097 g/cm²), composed of 48 and 144 subjects, respectively. The analysis of trochanter BMD included only body weight and HRT ($r^2 = 0.91$ kg), (2) IMM—intermediate values (0.786 ± 0.042 g/cm²) composed of 94 subjects; and (3) LTR—low values (0.630 ± 0.060 g/cm²) composed of 54 subjects.

According to the results, there was a significant association between the distribution of femoral neck BMD and lower limb MM ($\chi^2(2, 189) = 28.651, p < 0.001$). Similarly, there was a significant association between the distribution of trochanter BMD and lower limb MM ($\chi^2(4, 189) = 16.761, p < 0.01$). Therefore, individuals with lower MM have higher probability of having low BMD in both sites (Figs. 1 and 2).

Only 9 subjects were classified as sarcopenic. Among them, 8 were in the LFN group and 7 were in the LTR. The odds-ratio for LTR was 10.10 [95% CI: 2.03—50; $\chi^2(1, 189) = 11.481, p < 0.001$]. The odds ratio of sarcopenia in LFN was 2.75 (95% CI: 0.334—22.73); however, the result of the chi-square test was not significant [$\chi^2(1, 189) = 0.957; p = 0.328$].

### Discussion

The results of the present study indicated that body weight, age, smoking and HRT status may influence femoral neck BMD and only body weight and HRT influenced trochanter BMD.
influence in BMD through an increase in body weight, as previously suggested by Aloia et al. (7).

The prevalence of sarcopenia (4.8%) in the studied subjects was lower than the reported in previous studies (18,22,25). This could be caused by the characteristics of the sample, because most of the subjects were involved in a social project that provides medical and nutritional counseling. Seven of the 9 subjects classified as sarcopenic were in the LTR group, and this group showed and increased risk for developing sarcopenia. Although 8 of the 9 subjects classified as sarcopenic were in the LFN group, the odds ration was not significantly increased.

The main purpose of the present study was to test the association between the distribution of trochanteric and femoral neck BMD and lower limb MM. Pearson chi-squared analysis found significant associations between the distribution of femoral neck BMD and lower limb MM, and trochanter BMD and lower limb MM. Previously, Gillette-Guyonnet et al. (17) and Walsh et al. (18) did not report a significant correlation between sarcopenia and osteopenia or osteoporosis. The conflict between our results and the studies of Gillette-Guyonnet et al. (17) and Walsh et al. (18) could be caused by the differences in the method used to create the groups. Cluster analysis seeks to identify homogenous subgroups of cases in a population, minimizing within-group variation and maximizing between-group variation. Therefore, the groups analyzed in the present study are probably more homogenous than the groups formed by the fixed cutting points used for defining sarcopenia and osteopenia. Another source of difference between the present study and the studies of Gillette-Guyonnet et al. (17) and Walsh et al. (18) may be the site of analysis. Our study compared BMD and MM at related sites, while the referred authors have used the definition of osteoporosis and osteopenia, which involved the analysis of various sites. In agreement with this hypothesis, Capozza et al. (26) found a stronger relationship between bone mineral content and lean mass in the lower limbs, when compared with whole body correlations.

Therefore, our results confirm the hypothesis of a muscle-bone relationship. The source of this relationship is unclear, but one possibility is that both BMD and MM are influenced by related stimuli, as suggested by the results of previous studies (19,27,28). Another hypothesis is that the more intense muscle contraction generated by a greater muscle mass would influence BMD, given the importance of muscle-joint reaction forces to BMD (29). The association of low BMD and low MM is functionally important because low MM indirectly influences the risk of fractures because of impaired balance (1). Additionally, the amount of muscle that surrounds a bone may act as a form of protection or padding during a fall, as suggested by Walsh et al. (18). Therefore, the association of low BMD and low MM may lead to a higher risk of fractures.

The limitations of the current study are acknowledged. The subjects were not randomly selected. They were involved in a social project that included physical activity programs, medical, and nutritional counseling. Additionally, IPAQ may not be sensitive enough to detect differences in PAL among a homogenous group of subjects.

The main finding of the present study is the association of low lower limb MM with low femoral neck and low trochanter BMD. Therefore, it is recommended that DXA screening should be used to identify both BMD and MM in postmenopausal women to assess more accurately the risk fractures and disability. Resistance training seems to be an attractive intervention in a preventive and therapeutic context, because it has been shown to positively influence both BMD and MM and to be well tolerated in older subjects (5,27–34).

References


