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Original Article

Anthropometric Predictors of Geometric Indices of Hip Bone Strength in a Group of Lebanese Postmenopausal Women

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Abstract

The effects of anthropometric characteristics on hip bone strength in postmenopausal women are not completely elucidated. The aim of this study was to investigate the influence of anthropometric characteristics on geometric indices of hip bone strength using the hip structure analysis (HSA) program in a group of Lebanese postmenopausal women. This study included 109 postmenopausal women (aged 64−84 yr). Age and years since menopause were recorded. Body composition and bone mineral density were assessed by dual-energy X-ray absorptiometry (DXA). To evaluate hip bone strength, DXA scans were analyzed at the femoral neck (FN), the intertrochanteric (IT), and the femoral shaft (FS) by the HSA program. Cross-sectional area (CSA), an index of axial compression strength, section modulus (Z), an index of bending strength, and buckling ratio (BR), an estimate of cortical stability in buckling, were measured from bone mass profiles. Using univariate analysis, weight, height, body mass index (BMI), lean mass, and fat mass were positively correlated to CSA and Z of the FN, IT, and FS. Weight, BMI, fat mass, and fat mass percentage were negatively correlated to BR of the FN, IT, and FS. Multiple linear regression analysis showed that lean mass was a stronger determinant of FN CSA, FN Z, IT Z, and FS Z than fat mass, whereas fat mass was a stronger determinant of IT CSA, FS CSA, IT BR, and FS BR than lean mass. This study suggests that, in postmenopausal women, fat mass is a strong predictor of hip axial compression strength and cortical stability in buckling, and lean mass is a strong predictor of hip bending strength.

Key Words: Body mass index; body weight; elderly women; hip geometry; osteoporosis.

Introduction

Osteoporosis is a worldwide major public health concern *(1−9)*. It is known to mainly affect postmenopausal women *(1−9)*. In fact, bone loss in postmenopausal women appears to be largely the result of estrogen deficiency *(2)*. The loss of estrogen action on estrogen receptors in bone increases bone resorption and decreases bone mineral density (BMD) *(2)*. The World Health Organization has defined osteoporosis as a BMD value more than 2.5 standard deviations (SDs) below the mean for normal young white women. However, BMD is not a measure of bone strength; it is a surrogate of bone strength *(10−12)*. In reality, bone strength is composed of many components that include BMD, cortical porosity, microarchitecture, and geometry *(10−12)*. Interestingly, Beck et al *(11)* developed a computer program to derive hip geometry from bone mineral data for an estimate of hip strength. The program, called hip structure analysis (HSA), was developed originally to improve the predictive value of hip bone mineral data for osteoporosis fracture risk assessment *(11)*. Later on, many researchers used this program to detect the effects of aging *(13−15)*, gender *(14,16)*, body mass index (BMI) *(17−19)*, and physical activity *(20−24)* on hip bone strength indices.

Bone strength may be better represented by HSA variables, such as cross-sectional area (CSA), an index of axial compression, and section modulus (Z), an index of bending

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strength, than BMD or bone mineral content (BMC) (10,11). Lean mass has been shown to be the strongest predictor of CSA and Z in adolescents (17), young adults (18,19,22), and elderly men (25). However, little is known concerning the best predictors of all HSA variables in postmenopausal women. Large epidemiologic studies have shown that cortical thickness (CT) and buckling ratio (BR) predict hip fracture incidence in elderly men and women (26–28).

The aim of this study was to determine the influence of anthropometric characteristics (weight, height, BMI, lean mass, lean mass percentage, fat mass, and fat mass percentage) on femoral neck (FN), intertrochanteric (IT), and femoral shaft (FS) HSA variables (CSA, Z, and BR) in a population-based random sample of Lebanese postmenopausal women.

Materials and Methods

Subjects and Study Design

One hundred nine Lebanese postmenopausal women (aged 64–84 yr) participated in this study. The women were randomly selected from the greater Beirut area. The estimated resident population of Beirut is around 1 million (a mixture of the various Lebanese communities) (7). Age and years since menopause (YSM) were recorded.

Exclusion Criteria

Subjects with any medical condition likely to affect bone metabolism, including history of chronic disease with vital organ involvement or intake of medications that may affect bone metabolism (i.e., steroid intake for more than 6 mo, treatment with bisphosphonates, or other bone antiresorptive drug), were excluded. Similarly, subjects with a history of radiotherapy or chemotherapy or those in bed rest for more than 1 mo within 6 mo before the study were excluded. Subjects with conditions technically interfering with dual-energy X-ray absorptiometry (DXA) assessment were also excluded (i.e., previous spine or hip surgery). The study was approved by the Institutional Review Board of Hotel-Dieu Hospital, Saint Joseph University, and informed consent was obtained from all study participants (7).

Anthropometric Measurements

Height (in centimeter) was measured in the upright position to the nearest 1 mm with a Seca standard stadiometer (Seca GmbH, Hamburg, Germany). Body weight (in kilogram) was measured on a Taurus mechanic scale with a precision of 100 g. The women were weighed wearing only underclothes. BMI was calculated as body weight divided by height squared (kilogram per square meter). Body composition (lean mass, fat mass, and body fat percentage) was assessed by DXA (Hologic QDR-4500W; Hologic Inc., Waltham, MA). In our center, the in vivo coefficients of variation were $<1\%$ for fat and lean mass (29,30).

Bone Mass Measurements

BMC (in grams), bone mineral area (in centimeter square), and BMD (in grams per square centimeter) were determined for each individual by DXA at whole body and proximal femur (total hip [TH] and FN). In our laboratory, the coefficients of variation were $<1\%$ for BMC and BMD (29,30). The same certified technician performed all analyses using the same technique for all measurements.

Table 1
Clinical Characteristics of the Study Population

Characteristics	Mean ± SD	Range
Age (yr)	72.4 ± 5.1	64–84
YSM	23.3 ± 4.8	19–34
Weight (kg)	68.6 ± 13.1	41–102
Height (cm)	151.8 ± 6.4	132–172
BMI (kg/m^2)	29.7 ± 5.2	19.1–48.9
Lean mass (kg)	39.4 ± 6.1	26.5–53.0
Lean mass (%)	57.7 ± 6.3	45.0–76.9
Fat mass (kg)	26.8 ± 8.2	8.7–46.3
Fat mass (%)	38.8 ± 6.0	19.7–50.3
TH BMD (g/cm^2)	0.716 ± 0.129	0.358–1.058
FN BMD (g/cm^2)	0.624 ± 0.107	0.399–1.005

Abbr: SD, standard deviation; YSM, years since menopause; BMI, body mass index; TH, total hip; BMD, bone mineral density; FN, femoral neck.

Hip Structure Analysis

In brief, the HSA program measures BMD and geometry of cross sections using distributions of mineral mass traversing the bone axis, averaged for precision over 5 parallel lines (5 mm) across the bone axis (11,12). The FN at its narrowest region, the IT region, and the FS were analyzed and used in this study. Bone CSA (in square centimeter) and Z (in cubic centimeter) were directly determined from the bone profile at the 3 regions using algorithms described previously (11,12). CSA is equivalent to the amount of bone surface area in the cross section after excluding soft tissue space and is proportional to conventional BMC in the corresponding cross section (31–34). In mechanical terms, CSA is an indicator of resistance to loads directed along the bone axis. Z is an indicator of strength of the bone to resist bending and torsion (31–34). BR was also calculated in this study. BR is an index of susceptibility to local cortical buckling under compressive loads (31–34). All HSA analyses were completed by a single technician at Balamand University. In our laboratory, the coefficients of variation for CSA and Z of the 3 regions (FN, IT, and FS) evaluated by duplicate measurements in 10 women were $<3\%$.

Statistical Analysis

The means and SDs were calculated for all clinical data and the bone measurements. Associations between clinical and HSA variables were given as Pearson correlation coefficients. Multiple linear regression analysis models were used to test the relationships between HSA variables (CSA, Z, and BR) of the 3 regions (FN, IT, and FS) and the number

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