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Original Article

Muscle Mass Is More Strongly Related to Hip Bone Mineral Density Than Is Quadriceps Strength or Lower Activity Level in Adults Over Age 50 Year

Neil A. Segal,[*,1] *James C. Torner,*[1] *Mei Yang,*[2] *Jeffrey R. Curtis,*[3] *David T. Felson,*[2] *and Michael C. Nevitt*[4] *for the Multicenter Osteoarthritis (MOST) Study Group*

[1]*University of Iowa and VA Medical Center, Iowa City, IA, USA;* [2]*Boston University, Boston, MA, USA;* [3]*Division of Clinical Immunology and Rheumatology, University of Alabama at Birmingham, Birmingham, AL, USA; and* [4]*University of California San Francisco, San Francisco, CA, USA*

Abstract

This cross-sectional study examined whether reduced hip bone mineral density (BMD) is better explained by isokinetic knee extensor strength (KES), lower limb lean body mass (L-LBM), or Physical Activity Scale for the Elderly (PASE). Through population-based recruitment, 1543 adults without knee osteoarthritis were recruited. For men and women respectively, means $\pm$ SD were age 60.8 ± 8.0 and 61.1 ± 7.9 yr; body mass index 29.6 ± 4.6 and 29.1 ± 5.4 kg/m^2; hip BMD 1.025 ± 0.138 and 0.895 ± 0.128 g/cm^2; KES 124.9 ± 41 and 72.7 ± 22.9 N$\cdot$m; L-LBM 10.3 ± 1.5 and 7.0 ± 1.2 kg; and PASE 206.4 ± 99.7 and 163.8 ± 77.0. The relationship between BMD and KES in men ($r^2 = 0.21$, $p \geq 0.002$) and women ($r = 0.23$, $p < 0.001$) was significant before adjustment. However, this association was no longer significant after controlling for L-LBM. Even after controlling for age, race, and sex, the association between BMD and KES was better explained by L-LBM (partial $R^2 = 0.14$, $p < 0.001$) than by PASE (partial $R^2 = 0.00$). Allometric scaling of KES to body size attenuated the association of BMD with KES (Std Beta = 0.03). The significant association between BMD and L-LBM (Std Beta = 0.36) remained stronger than that between BMD and weight (Std Beta = 0.21). Therefore, muscle mass accounted for a greater proportion of the variance in hip BMD than KES or activity level and explained a significant proportion of the association between weight and BMD.

Key Words: Allometric scaling; bone mineral density; muscle mass; physical activity level; quadriceps strength; rehabilitation.

Introduction

Studies have demonstrated that spine extensor muscle weakness is associated with low spine bone mineral density (BMD) *(1,2)* and spine deformity *(3)*. However, there are differing results regarding whether knee extensor strength (KES) is an independent predictor of BMD *(4)*. The relationship between BMD and KES is of clinical interest because weakness is a possible contributor to increased risk and impact severity of falls *(5)*, and individuals with low BMD are at greatest risk for fractures with falls. Therefore, an association between these would support a need for knee extensor strengthening in a group with dual risk factors.

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*Address correspondence to: Neil A Segal, MD, Department of Orthopaedics & Rehabilitation, University of Iowa and VA Medical Center, 200 Hawkins Drive, 0728 JPP, Iowa City, IA 52242-1088. E-mail: neil-segal@uiowa.edu

To date, populations studied have been mainly normal weight (body mass index [BMI] ≥25 kg/m^2), and this may significantly influence results, considering that increased obesity can be associated with both increased lean body mass (LBM) and lower activity level *(6,7)*. However, given the fact that 39% of older adults (age ≥54 yr) in the United States are obese and over 65% meet criteria for being either overweight or obese *(8)*, there is a need to examine the relationship between BMD and KES in a population that includes obese adults.

Study of KES must also consider the potential effects of lower limb lean body mass (L-LBM), weight, and age, as these have been shown to be inter-related and also related to hip BMD *(7,9)*. Activity level, weight, and age may also be related to hip BMD. Using multiple regression models to consider these relationships has revealed that in nonobese women, KES is strongly related to femoral neck BMD, but not to spinal BMD, suggesting a local effect. Due to the effects of body mass on both strength and BMD, it is appropriate to use allometric scaling to control for the effect of body mass when examining the relation between strength and BMD *(4,10–12)*. Additionally, to guide therapy to maintain or increase hip BMD, it would be useful first to examine whether there is a relationship between KES and BMD and then clarify whether this relationship is better explained by muscle bulk (L-LBM) or physical activity.

The aim of this study was to determine whether there is an association between BMD and several factors that could be targets of rehabilitative interventions: strength, LBM, and activity; testing the following hypotheses: *(1)* KES is significantly associated with total hip BMD *(2)*, LBM in the lower limbs explains the association between KES and BMD *(3)*, and activity level does not account for the relationship between KES and BMD *(4)*, The association between BMD and KES is better explained by L-LBM than by activity level. Finally, these results are not modified by either *(5)* stratifying by BMI or *(6)* adjusting strength for body size. The present report used cross-sectional data from the initial examination of the Multicenter Knee Osteoarthritis (MOST) Study.

Materials and Methods

Subjects

Subjects were excluded if they had radiographic knee osteoarthritis (Kellgren-Lawrence grade ≥2) or knee arthroplasty, possible confounders for the relationship between BMD and both KES and L-LBM. Subjects were selected from a population-based cohort of adults, aged 50–79 yr, enrolled in the MOST Study, in which eligible participants were targeted to have a BMI over 25 kg/m^2 or prior knee injury or surgery. The MOST Study excluded adults with rheumatoid arthritis or cancer.

Radiograph protocol for assessment of knee osteoarthritis in the MOST study has been described previously *(13)*. Knee osteoarthritis was defined as Kellgren-Lawrence grade 2 or greater at standard image size on posteroanterior weight-bearing semiflexed knee radiographs *(14)*. All subjects underwent an informed consent process approved by the Institutional Review Boards at each of the investigators' institutions before participating in research protocols.

BMD and Body Composition Measurements

L-LBM (g) and total hip BMD (g/cm^2) were measured using a Hologic QDR 4500W dual energy X-ray absorptiometry (DXA) (Hologic Inc., Bedford, MA: Software Version 12.0). Scans of the hip were conducted using Fast Array mode unless a subject weighed 170 lb or greater in which case Array mode was used. Whole body scans for body composition were conducted in default mode (Array) and L-LBM was obtained using the body composition analysis software provided by the manufacturer.

Operators were trained and certified and performed daily quality control scans as well as cross-calibration scans of phantoms used on both machines. Quality control data were collected using standard quality-assurance protocols and reviewed monthly by the University of California San Francisco Coordinating Center DXA Quality Assurance Center.

Height and Weight Measurements

Height was measured with a wall-mounted Harpenden stadiometer (Holtain Ltd., Crosswell, Crymych, Pembs., UK) and followed a written protocol. Height was assessed during full inspiration to the nearest 1 mm. The measurement was repeated twice and if these differed by >3 mm, 2 additional measurements were taken.

Weight was measured with a standard medical beam balance with the certified examiner standing behind the subject. Weight was recorded to the nearest 0.1 kg. The scale was calibrated monthly with a 50 kg weight for accuracy as well as with 5, 10, 15, and 20 kg weights for linearity calibration. BMI was calculated as weight divided by height squared, and obesity was defined as BMI ≥30 kg/m^2 *(15,16)*.

Knee Extensor Strength

Concentric KES was assessed with a Cybex 350 computerized isokinetic dynamometer (Avocent, Huntsville, AL) at 60°/s and a chair back angle of 85°. HUMAC software version 4.3.2/Cybex 300 for Windows98 Software Package was used for data acquisition. Subjects' KES was considered the peak torque in N·m obtained over 4 trials. Trained examiners, certified in the standardized MOST strength testing protocol, underwent annual recertification to assure uniformity in following the strength testing protocol and standardized script for subject testing. Examiners calibrated the isokinetic dynamometer position, angular velocity, and torque (at 25 and 245 N·m) monthly. Subject-specific KES was defined as the mean of the peak KES for both lower limbs.

Participants were excluded from strength testing for a systolic blood pressure greater than 199 mm Hg, diastolic blood pressure greater than 109 mm Hg, history of cerebral aneurysm, cerebral bleeding within the past 6 mo, back surgery within the previous 3 mo, myocardial infarction or cataract surgery within the previous 6-wk period, untreated inguinal