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Original article

Association between bone mass as assessed by quantitative ultrasound and physical function in elderly women: The Fujiwara-kyo study

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ABSTRACT

Objectives: This study aimed to investigate differences in physical function by bone mass category as assessed by speed of sound, and the association between bone mass and physical function in Japanese elderly women.
Methods: Participants (≥65 years, n = 954) were divided into the osteoporosis, osteopenia, and normal groups based on speed of sound values, and physical function parameters were compared among groups. In addition, the predictive ability of physical function for low bone mass was determined by area under the curve analysis. Data were collected in four cities in Nara, Japan, in 2007 or 2008.
Results: All physical functions were significantly lower in the osteoporotic group than in the normal group. Lower bone mass was associated with poor muscle strength and physical function after adjusting for age, height and weight. In addition, one-leg standing time and 10-meter gait time were predictive of low bone mass (osteopenia and osteoporosis levels, respectively). Elderly women with low physical function, especially those with a short one-leg standing time, should be suspected of having decreased bone mass.
Conclusions: Measurements of physical function can effectively identify elderly women with low bone mass at an early stage without the need for bone mass measurements. In particular, one-leg standing time and 10-meter gait time were good predictors of low bone mass, and is easy to measure, low-cost, and can be self-measured. These findings will be helpful in the prevention and treatment of osteoporosis.

1. Introduction

Physical function becomes impaired and bone mass decreases with aging. Sex difference in gait speed and one-leg standing time increase after 64 years of age [1], and the rates of reduction in skeletal muscle mass, hand grip strength, and gait speed are higher in elderly women than in elderly men [2], although the rates of reduction in muscle mass and quality are greater in elderly men than in elderly women [3,4]. Onder et al. [5] reported a 16–27% decrease in lower-extremity function over the course of 3 years in elderly women. It is also well-known that bone loss occurs rapidly in post-menopausal women. A decline in physical function can lead to physical inactivity in the elderly, and this in turn can reduce total loading on bones. That is, a decrease of total loading on bones due to a decline in physical function can increase the risk of fracture. In fact, low physical activity has been reported as a factor that contributes to the risk of falls and fractures [6,7], with falls and fractures ranking fourth with respect to care need and support in the elderly [8]. Moreover, the risk of requiring care services in elderly women with the lowest tertile of speed of sound (SOS) at cancellous

Abbreviations: AUC, area under the curve; BMD, bone mineral density; CRT, chair rise time; HGS, hand grip strength; KES, knee extension strength; KFS, knee flexion strength; OLST, one-leg standing time with opened eyes; QUS, quantitative ultrasound; ROC, receiver operating characteristic; SOS, speed of sound; 10MGT, 10-m gait time.

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bone was 2.55-fold higher, compared to elderly women with the highest tertile of SOS [9]. Therefore, it is essential to prevent fractures as early as possible.

Despite the above, Japan has a low rate of osteoporosis screening, due to reasons such as financial burden and insufficient human resources [10]. In contrast, care prevention services are widespread, and physical function in the elderly is measured as part of these services, such as during classes for fall prevention, inactivity prevention, and/or improvement of physical function [11]. The Japan Osteoporosis Society introduced an Osteoporosis Liaison Service and an authorized Osteoporosis Manager System in order to make the service more widely available [12]. Identification of elderly women who are likely to have osteopenia or osteoporosis can contribute to fracture prevention. Consistent with this it has been reported that heel SOS is associated with hip bone mineral density (BMD) [13], and that heel quantitative ultrasound (QUS) parameters can predict fracture risk [14,15]. For example, elderly women at risk of osteopenia or osteoporosis can be identified promptly if the osteoporosis manager conducts physical function measurements and care prevention services. Since physical function measurements are considered a screening tool for low bone mass, investigating the association between bone mass and physical function can not only help prevent falls and fractures, but may also promote screening among elderly individuals with low bone mass.

The present study aimed to investigate differences in physical function by bone mass category, and between osteoporosis, osteopenia, and normal groups by SOS [16], and examine the association between SOS and physical function in elderly women.

2. Methods

2.1. Participants

Participants were elderly women aged ≥65 years (range, 65–96 years) who participated in a cohort study (the Fujiwara-kyo study) [17]. The Administrative Centre of the Fujiwara-kyo study recruited participants with the cooperation of local residents' associations and elderly people's clubs in four cities in Nara, Japan. Participants were able to walk either with or without walking sticks, and able to communicate. Applicants came to the place for a cohort study. A total of 2,253 elderly women provided written informed consent and underwent a baseline examination in 2007 or 2008. The numbers of women examined for anthropometric data, physical function data, and SOS measurements were 2,239 (99.4%), 2,081 (3 sites of muscle strength, 92.4%), 1,291 (3 kinds of physical performance, 57.3%), and 1,906 (85.1%), respectively. We enrolled 954 women for whom all data were available from the baseline examination.

This study was approved by the Ethics Committee for Human Subjects, Nara Medical University (No.111).

2.2. Anthropometric data collection

Height (cm) and weight (kg) were measured with an automatic scale. Participants stood upright for height measurements.

2.3. Physical function data collection

Hand grip strength (HGS), knee extension and flexion strength (KES and KFS), 10-m gait time (10MGT), one-leg standing time with opened eyes (OLST), and chair rise time (CRT) were measured. All physical function parameters were measured twice and mean values were used for analysis.

HGS of the dominant hand was measured in the sitting position and with an extended elbow joint using a digital hand grip dynamometer (TKK5401, Takei Scientific Instruments Co., Ltd. Niigata, Japan). Isometric muscle strength of knee extension and flexion were measured in the sitting position on a chair with the knees flexed at 90° using an isometric muscle strength dynamometer (μTasMF-01, ANIMA Corporation, Japan). Arm length was determined as the distance from the cleft between articulations at the knee to the center of the measuring dynamometer. KES and KFS were calculated as the isometric muscle strength of knee extension and flexion multiplied by arm length, respectively. 10MGT was measured using a 2-channel display timer (Takei Scientific Instruments Co., Ltd. Niigata, Japan), which records the time when participants pass the sensor system. Participants walked straight for 14 meter at maximum effort, and 10MGT was measured at the middle of 10 meter to reduce the effects of acceleration and deceleration. OLST was measured as the time participants stood on one leg with both hands on the waist, and with one leg raised forward using a stopwatch (SEIKO Watch Corporation, Tokyo, Japan). CRT was measured as the time it took to stand up and sit on the chair five times using a multi timer (TKK5801, Takei Scientific Instruments Co., Ltd. Niigata, Japan).

2.4. SOS measurements for bone mass

Calcaneal SOS was measured as an index for bone mass using an ultrasound bone densitometer (CM-100, Fruno Electric Co., Ltd. Hyogo, Japan). Measurements were generally made on the right foot, but the left heel was evaluated when the participant had a history of fractures or bone disease in the right foot. The precision of quantitative ultrasound (QUS) measurements *in vivo*, expressed as a coefficient of variation, was 0.51% based on five daily measurements in five different individuals. Participants were divided into osteoporosis (1,479 m/s ≥ SOS), osteopenia (1,501 m/s ≥ SOS ≥ 1,478 m/s), and normal (SOS ≥ 1,502 m/s) groups [16] to compare physical function by bone mass category. This grouping was based on SOS values rather than the diagnostic category of osteoporosis.

2.5. Statistical analysis

Measured values are expressed as mean and standard deviation. Differences among the three groups were examined by one-way ANOVA, and followed by pairwise comparisons using the Games–Howell test. Multilinear regression analyses were conducted to identify associations between SOS (dependent variable) and each physical function parameter (independent variable), adjusting for age in Model 1, and for height and weight, in addition to age, in Model 2. Receiver operating characteristic (ROC) curves were used to compare physical functions by SOS for osteopenia and osteoporosis groups, and areas under the curve (AUCs) were calculated for physical function parameters that were significant in Model 2. The point of the nearest coordinate (0,1), the upper left corner, was used to select cutoff values for the parameters. AUC values were also compared between each physical function parameter. $P < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS software (SPSS version 17.0 for Windows, SPSS Japan Inc., Tokyo, Japan) and the Excel Statistics software (BellCurve for Excel version 2.11 for Windows; Social Survey Research Information Co., Ltd., Tokyo, Japan).

3. Results

The prevalence of osteopenia and osteoporosis based on SOS were 38.4% (n = 366) and 37.0% (n = 353), respectively. Compared with normal women, osteoporotic women had a significantly