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Arm span increases predictive value of models for prevalent vertebral deformities: The Japanese Population-based Osteoporosis (JPOS) Study

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ABSTRACT

Objective: We examined anthropometric indicators to improve predictive ability of asymptomatic vertebral fracture screening models.

Study design and setting: Data were obtained from the 1996 Japanese Population-based Osteoporosis (JPOS) Study. McCloskey–Kanis criteria diagnosed vertebral deformities on X-ray absorptiometric images in 693 women aged ≥50.The multiple logistic regression model included age, height, weight, postmenopausal status, total hip BMD, and arm span (AS) or sitting height as explanatory variables. Akaike's information criterion (AIC) evaluated model goodness-of-fit.

Results: Age-adjusted AS and sitting height in subjects with and without vertebral deformities were 147.2 ± 0.6 cm and 148.5 ± 0.2 cm (P = 0.055), 78.5 ± 0.5 cm and 79.9 ± 0.2 cm (P = 0.007), respectively. Every 5-cm increase in AS indicated 1.5-fold increased risk of prevalent vertebral deformity in the model including age, height, weight, postmenopausal status, and BMD. Including the explanatory variable AS in models yielded better predictive accuracy than excluding AS (AIC, 441.7 vs 446.6, respectively). Sitting height did not significantly influence model predictive ability.

Conclusion: Predictive accuracy of model for vertebral fracture including age, height, weight, postmenopausal status, and BMD improved when AS was added as an explanatory variable. Models to screen for asymptomatic vertebral fractures should include AS.

1. Introduction

Vertebral fractures are the most common type of osteoporotic fracture, occurring in 10–26% in men and women aged 50 or older [1]. Vertebral fractures are associated with a variety of adverse health outcomes, including increased risk of mortality [2]. However, three-fourth of vertebral fractures do not come to immediate clinical attention, because they are often asymptomatic [3].

The standard methodology for diagnosing vertebral fracture is vertebral morphometry on conventional radiographs, supplemented with visual semi-quantitative methods, as recommended by the 2007 International Society for Clinical Densitometry (ISCD) Official Positions [1]. A simple tool to detect those with a high risk of prevalent vertebral fracture could benefit primary health care settings, as it could serve as a preliminary step before the diagnostic radiograph is ordered.

Although a bone mineral density (BMD) measurement is important to predict prevalent vertebral fractures, the use of BMD values alone is insufficient and less capable of detection, than if other factors were combined, such as menstrual history [4], historical height loss, history of non-vertebral fractures, and history of back pain [5–7]. Several reports have suggested historical height loss, obtained by subtracting the current measured height from the individual's tallest recalled height, to be associated with prevalent vertebral fracture [6–10]. However, the historical height loss is subject to the error inherent in the individual's recall.

It has been indicated that arm span (AS) as a surrogate measure for peak body height [11–15]. However, the predictive value of models that included AS without BMD values has been insufficient [16–20], except for reports by Nores et al. [16] and Abe et al. [21]. A model combining AS with BMD values may demonstrate improved predictive ability for prevalent vertebral fracture.

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As vertebral deformities often result in a certain degree of kyphosis, the use of sitting height along with body height in the model might better predict vertebral fractures. Wang et al. [19] reported that the combination of age and sitting height was the best fit model for prevalent vertebral fracture in 334 women. Thus, a model including sitting height with BMD values also may demonstrate improved the predictive ability.

We investigated whether combining the anthropometric indicators, arm span or sitting height, with BMD values could improve the fit of screening models for asymptomatic vertebral fractures to the data observed in a representative sample of Japanese women from the Japanese Population-based Osteoporosis (JPOS) Study.

2. Methods

2.1. Setting and follow-up study

The JPOS study conducted its baseline survey in 1996; details of this study have been described elsewhere [22]. Briefly, 4550 women aged 15–79 years old were selected randomly from 5-year age-stratified groups from seven municipalities throughout Japan. Among those women, 3985 (87.6%) completed the survey.

2.2. Study population

Of these initial participants, we examined 851 subjects (age ≥50) from whom we obtained thoracolumbar vertebral X-ray images that were morphometrically assessable. We excluded 128 subjects with a history of menstrual irregularities, premature menopause, or a history of illness or medication usage known to affect bone metabolism. We also excluded 30 cases which lacked information regarding total hip BMD, anthropometric indicators, or menopausal status. A total of 693 women were included in our cross-sectional analysis.

The study protocol was approved by the ethics committee of the Kinki University School of Medicine, Osaka-sayama, Osaka, Japan. Written informed consent regarding all study procedures was obtained from each subject prior to their participation.

2.3. Spinal vertebrae morphometry and diagnosis of vertebral deformities

The thoracolumbar vertebrae of each participant were imaged by dual energy X-ray absorptiometry (QDR4500A, Hologic Inc., Bedford, MA, USA). Bone morphometric software (QDR4500A Lateral Image Analyze, Hologic Inc., Bedford, MA, USA) was used to measure the anterior edge height, central height, and the posterior edge height of each vertebra from the fourth thoracic vertebra to the fourth lumbar vertebra. The McCloskey–Kanis criteria [23] were used to diagnose vertebral deformities, which were used as a proxy for vertebral fractures in the present study. The measurements of vertebral body height were conducted by two trained investigators (E.K. and Y.S.) under the supervision of an experienced physician (M.I.).

2.4. Bone mineral density measurement

BMD was measured using dual energy X-ray absorptiometry (QDR4500A (vehicle-mounted), Hologic Inc., Bedford, MA, USA) at the second, third, and fourth lumbar vertebrae and the right hip. The percent coefficient of variation (%CV) for the measurements was 1.2% for both the lumbar spine and total hip [22]. The BMD *T*-score was calculated with age-stratified mean and standard deviation values for the spine and total hip BMD derived from 1403 healthy women, 20–44 years old, from the JPOS baseline population [22].

2.5. Anthropometric measurements

Body height (cm) and weight (kg) were measured using an automatic scale (model TK-11868h, Takei Kagaku, Japan). To obtain sitting height, subjects sat on a stool with the back against a scale and sitting height was measured as the distance from the top of the stool to the crown of the head. To obtain AS measurements, subjects stood straight facing forward with arms at a 90° angle from the trunk and palms facing forward. The distance between the middle fingertips was measured. Trained public health nurses performed these measurements throughout the study. Measurements of body height, AS, and sitting height were recorded with unit increments of 0.1 cm and weight was recorded with unit increments of 0.1 kg.

2.6. Interviews

Participants completed a questionnaire about aspects of menstrual history, medical history, and medication history that may have affected bone metabolism. Each subject was interviewed by trained public health nurses based on questionnaire responses.

2.7. Statistical analysis

We performed a cross-sectional analysis of the association between existing vertebral deformities and the anthropometric indicators obtained in the baseline survey. We applied a trend-test to compare the demographic characteristics, anthropometric indicators, and bone status among age-stratified groups. We analyzed continuous variables with Student's *t*-test and binominal variables with the chi-squared test to determine differences between groups with or without existing vertebral deformities.

A logistic regression analysis for vertebral fractures was conducted using age, body weight, body height, postmenopausal status, BMD *T*-score at the total hip, and anthropometric indicators to estimate the expected probability for existing vertebral deformities. We used total hip BMD instead of BMD at the lumbar spine because these values were not available for 75 subjects with vertebral deformities at the second, third, or fourth lumbar vertebrae. To evaluate the goodness-of-fit for the estimated regression equations, Akaike information criterion (AIC) was calculated using the following equation:

$$\mathrm{AIC} = -2(\log M - k)$$

for which M was the maximum likelihood of the model and k was the number of independently adjusted parameters in the model [24]. The area under the receiver operating characteristic (ROC) curve was calculated for each logistic model to demonstrate how well the model differentiated between subjects groups (with or without vertebral deformities). Statistical analyses were performed with SPSS (version 14.0J; SPSS, Tokyo, Japan), or SAS system for personal computers (release 6.12; SAS Institute, Cary, NC, USA).

3. Results

3.1. Basic participant characteristics

Basic characteristics of the participants by 10-year age groups are shown in Table 1. Body height, AS, and sitting height were reduced with increasing age. A total of 123 vertebral deformities were observed in 85 subjects: 63 subjects had one vertebral deformity and 22 had 2 or more vertebral deformities. Of these, deformities were found in the thoracic spine ($n = 48$), in the lumbar