Age-Related Changes in Vertebral Height Ratios and Vertebral Fracture

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Abstract. Because no gold standard for the definition of vertebral fracture exists, there has been controversy about whether mild vertebral deformities are truly fractures or simply normal variation in vertebral size and shape. The aim of this study was to assess the associations of mild variations of vertebral height ratios to definite vertebral fractures. In 479 Japanese women (age 53.9 ± 9.1 years) who visited our institute for a medical checkup, we performed lateral lumbar radiographs and morphometric parameters were derived by measuring the anterior (Ha), middle (Hm) and posterior (Hp) height of each vertebral body from T12 to L4. Vertebral height ratios, Ha/Hp, Hm/Hp or Hp/Hp' of adjacent vertebrae that were more than 3 SD different from vertebra-specific means of normative data were considered to indicate fractures. Forty-five women were diagnosed with at least one fracture. After excluding the subjects with vertebral fracture, we examined the associations of the variations in vertebral height ratios with age, anthropometric parameters and lumbar bone mineral density (BMD) measured by dual-energy X-ray absorptiometry. Vertebral height ratios, especially Hm/Hp in postmenopausal women, tended to decrease with age and were positively associated with BMD. No significant correlation was observed between anthropometric parameters and vertebral height ratios. Age-related decrease in vertebral height ratios (Ha/Hp and Hm/Hp) each averaged from T12 to L4 was significant even after the correction for BMD. Mean values of height ratios of non-fractured vertebrae adjusted for age and BMD were significantly lower in postmenopausal women with vertebral fracture than in those without vertebral fracture. Logistic regression analysis showed that BMD and height ratios of non-fractured vertebrae were independent predictors of vertebral fracture risk. The results suggest that older women, and women with at least one obvious (3 SD) fracture, tend to have mild deformities which do not qualify using the 3 SD definition. These mild deformities may represent real consequences of osteoporosis, because they are more pronounced among women with obvious fracture.

Keywords: Aging; Morphometry; Osteoporosis; Vertebral deformity; Vertebral fracture

Introduction

Osteoporosis is a major health concern among postmenopausal women and vertebral fractures form an integral component of this syndrome [1]. Indeed, their presence has sometimes been included in its definition. Osteoporotic compression fractures of the spine differ from other age-related fractures in that they are most often associated with minimal trauma and with loads no greater than those encountered during normal activities of daily living. This indicates that, in most cases, vertebral fracture may be the result of a gradual loss of vertebral height rather than sudden vertebral collapse. The signs and symptoms of vertebral fractures are non-specific and the diagnosis largely depends upon a radiological assessment or quantitative vertebral morphometry to characterize vertebral deformities [2–6]. However, there has been controversy about whether
The aim of this study was to investigate the associations vertebral fractures and to assess the relations of these of mild variations in vertebral height ratios with definite deformities with osteoporosis.

**Materials and Methods**

**Subjects**

The total study population constituted 479 pre- and postmenopausal Japanese women, 32–84 years of age. They were recruited from those who underwent a medical checkup in Kawasaki Medical School Hospital between 1989 and 1994. Exclusion criteria were severe scoliosis, vertebral deformities developed by mechanisms other than non-traumatic fractures [9], history of surgical intervention in lumbar vertebrae, and history of disease or treatment known to affect bone metabolism. Subjects with apparent aortic calcifications were also excluded when these were suspected to affect dual-energy X-ray absorptiometry (DXA) measurement. Height and weight were measured with clothes and the body mass index (BMI) was calculated as body weight/height\(^2\).

**Morphometric Vertebral Assessment**

Conventional lateral radiographs of the lumbar vertebrae were obtained in all subjects. Tube–film distance was 105 cm and the X-ray beam was centred over the second or third lumbar vertebra. The radiographs were digitized using a laser scanner (LD-4500, Konica, Tokyo, Japan) with a 200 μm pixel size and 8-bit grayscale quantization. The digitized images were then displayed on a CRT monitor. Six points were marked for each vertebral body and coordinates of these points were stored in a personal computer. The points were marked by an independent trained assistant in a standardized fashion [10]. From these coordinates the anterior (Ha), middle (Hm) and posterior (Hp) heights were calculated for each vertebral body from T12 to L4. Using Ha, Hm and Hp, the following ratios were calculated to define vertebral fracture: anterior–posterior ratio (Ha/Hp), middle–posterior ratio (Hm/Hp) and posterior–posterior adjacent ratio (Hp'/Hp). Intraobserver reproducibilities were assessed by measuring 15 randomly selected radiographs on five consecutive days and five times on the same day; the coefficients of variation were 1.5% and 0.9%, respectively. A prevalent fracture was defined, according to the published reports [3], as a 3 standard deviation (SD) difference in height ratios from normative data. Means and SD of ratios of normal vertebral heights were estimated from data of all subjects according to the method described by Black et al. [11]. Due to the limited portion of the spine visible on the lumbar radiographs and to the varying radiographic density, 113 vertebrae at T12 could not be measured. Any films classified as fracture by morphometry had their point placement reviewed and were re-pointed if necessary.

**Bone Mineral Assessment**

Bone mineral density (BMD, in g/cm\(^2\)) was measured at the lumbar spine (L2–4) by DXA (Hologic QDR-1000 or QDR-2000, Waltham, MA). Fractured vertebrae were excluded from measurements by DXA. The coefficient of variation in our institution in normal subjects for BMD is 1.8% for the lumbar spine.

**Statistical Methods**

Statistical analyses were carried out with the SPSS software packages (SPSS, Inc., Chicago, IL). Analyses included standard descriptive statistics, correlation analysis, analysis of covariance and logistic regression analyses. In order to standardize measurements among vertebrae, values of vertebral height ratios (VHR) were converted to Z-scores, defined as observed value minus the normal mean for that vertebra, divided by the normal SD for that vertebra. The use of Z-scores provides a common scale that allows dimensions from different vertebrae to be averaged, and the following indices were calculated: \(\text{VHR}_{\text{ap}} = \text{mean } Z\)-scores of Ha/Hp for non-fractured vertebrae from T12 to L4, \(\text{VHR}_{\text{mp}} = \text{mean } Z\)-scores of Hm/Hp for non-fractured vertebrae from T12 to L4.

Comparisons of the height ratios of non-fractured vertebrae between postmenopausal women with and without fracture were made by analysis of covariance. The analysis was performed with \(\text{VHR}_{\text{ap}}\) or \(\text{VHR}_{\text{mp}}\) as dependent variables, and age and BMD as covariates. Analysis of residuals was done using a normal probability plot to evaluate the distribution and was found to be within limits of acceptance for the covariance analysis. In a multivariate test we evaluated the difference between these two groups by specifying both \(\text{VHR}_{\text{ap}}\) and \(\text{VHR}_{\text{mp}}\) as dependent variables. Logistic regression analyses were performed to evaluate the relationship of fracture risk to vertebral height ratios, BMD and age. All variables in the regression model were entered in a single step. Odds ratios were calculated by taking the exponent of the coefficient from the logistic regression model, after first multiplying by the corresponding difference in the predictor variable (e.g.