Height Reduction in Middle-aged and Elderly Women. Estimating Body Height Using Spinomalleolar Distance

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ABSTRACT.

Height reduction in middle-aged and elderly female patients was calculated with a formula based on actual height and spinomalleolar distance in young female volunteers.

A formula was obtained from the linear regression of actual height and spinomalleolar distance in 151 young female volunteers, (age range, 20-39 years old). In 131 middle-aged and elderly female patients (age range, 50-83 years old), measurement of bone mineral density (BMD) in three sites and thoracic and lumbar vertebral X-rays were performed. Height reduction was determined from the measured height and the estimated height calculated by the regression equation.

We investigated the correlation between height reduction and vertebral fracture, age, BMD, and clinical diagnosis.

The formula for spinomalleolar distance (x) and measured body height (y) in young women was $y = 1.41x + 47.28$ ($r = 0.862$, $p<0.0001$). A significant correlation was found between height reduction and age (non-vertebral fracture group: $r = -0.617$, $p<0.0001$; vertebral fracture group: $r = -0.699$, $p<0.0001$). Height reduction in the group diagnosed with osteoporosis was larger than that in the normal or osteopenic groups. The cut-off value of height reduction for the diagnosis of the osteoporosis was -5.6 cm.

The initial body height of middle-aged and elderly female patients can be estimated using spinomalleolar distance. In addition, height reduction may be helpful in the diagnosis of osteoporosis.

Key words ① **height reduction** ② **spinomalleolar distance** ③ **osteoporosis** ④ **vertebral fracture** ⑤ **bone mineral density (BMD)**

In the last few decades, the elderly population in Japan has markedly increased. As a result, there has been an increase in the incidence of degenerative diseases such as osteoporosis. Osteoporosis is defined as a systemic bone disease in which a fracture may be caused by low bone mass and a deterioration of bone

quality[1]. Vertebral fractures caused by osteoporosis are one of the most common causes of height reduction in the elderly. Therefore, determining the degree of height reduction may be useful in diagnosing osteoporosis.

Many articles have reported estimating height using the length of a long bone[2-7]. In this study, we estimated body height using spinomalleolar distance in middle-aged and elderly women. We calculated height reduction using estimated the initial body height, and evaluated height reduction and relations with a vertebral fracture, age, bone mineral density (BMD), and clinical diagnosis.

SUBJECTS

We studied 282 subjects, including 151 female volunteers younger than 40 years old (mean, 25.9 ± 6.3 years old; range, 18-39 years old) and 131 women older than 50 years old (mean, 63.4 ± 7.0 years old; range, 50-83 years old). The women in latter group were considered middle-aged or elderly patients. Patients with a metabolic bone disease (other than osteoporosis), deformity of the hip joint and knee joint or scoliosis were excluded.

Written informed consent was obtained from each subject.

METHODS

Measurement of Spinomalleolar Distance and BMD

The spinomalleolar distance from the anterosuperior iliac spine to the medial malleolus was measured using a metal tape measure (Fig. 1). In the 131 middle-aged and elderly female patients, BMD of the lumbar spine, proximal femur and distal radius were determined using dual-energy X-ray absorptiometry (QDR-2000; Hologic; Waltham, MA, USA) for the lumbar spine and proximal femur, and DCS-600EX (Aloka; Mitaka, Tokyo, Japan) for the distal radius. In addition, radiographs of the thoracic and lumbar spines were obtained to determine if a vertebral fracture was present. BMD was not determined in the younger

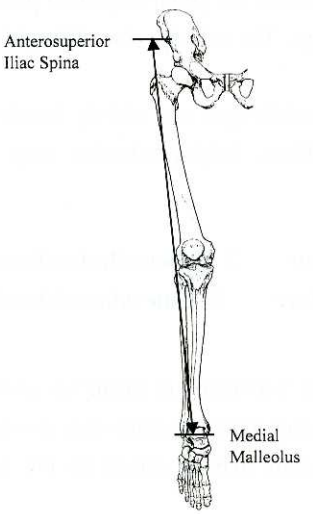

Fig. 1. Schematic diagram of spinomalleolar distance.

group.

Estimation of Body Height

We assumed that the 151 young female volunteers did not have height reduction and calculated a regression equation between measured height and spinomalleolar distance.

The difference in physique between generations in Japan is known to be remarkable. The relative leg length of each generation was investigated to examine whether the regression equation could be applied to all generations. Body height and sitting height during the youth (18 to 20 years old) of the females whose age in 2006 was 21 to 91 years old were taken from the Japan Statistical Yearbook[8]. The relative leg length (body height - sitting height) of each generation was calculated using these data. The mean relative leg length was calculated from the statistical data for women under 40 years old in 2006. The percent relative leg length of women older than 40 years old was calculated based on the mean relative leg length.

The reason we used 40 years old as the cut-off age for calculation of the mean relative leg length was based on the data of age distribution of percent relative leg length. A formula for women older than 40 years old was calculated using age (x) and the percent relative leg length (y). A correction factor for spinomalleolar distance was given for an inverse number of y values provided by the formula. The corrected spinomalleolar distance was substituted in the regression equation using measured height and spinomalleolar distance for young women, and the estimated initial body height was calculated for middle-aged and elderly women.

Evaluations of Height Reduction

We evaluated the relation between height reduction with vertebral fracture, age, and BMD. Height reduction in middle-aged and elderly women was defined as the difference between measured body height and estimated initial body height. Vertebral fractures in thoracic and lumbar vertebrae were diagnosed by a radiologist. Middle-aged and elderly women were divided into three age groups: 50s, 60s and older than 70 years old, and the relationship between height reduction and vertebral fracture was evaluated within these groups.

In addition, patients were divided into non-vertebral and vertebral fracture groups, and we evaluated correlation coefficients between height reduction and age, lumbar BMD, hip BMD, and radial BMD.

For diagnostic purposes, patients were classified into three groups (normal, osteopenia, and osteoporosis) and the degree of height reduction among these groups was compared. The classification into groups was based on the diagnostic criteria of primary osteoporosis proposed by the Japanese Society for Bone and Mineral Research[9].

In addition, patients were also divided into two other groups: a normal and osteopenic group and an osteoporosis group, and the feasibility of using height reduction to diagnose osteoporosis was evaluated using receiver operating characteristic (ROC) analysis.

Statistical Analysis

Regression equations for height estimation and percent relative leg length distance were calculated using the least squares method. For relations between height reduction and vertebral fractures, an unpaired t-test was used. A post-hoc test (Fisher) was used to examine the relation between height reduction and clinical diagnosis. A p value of <0.05 was considered significant. For the relation between height reduction and age or BMD, correlations were assessed using Pearson's correlation coefficients. Statistical analysis was performed using Stat View software (Abacus; Baltimore, MD, USA).

RESULTS

The equation for spinomalleolar distance (x) and measured body height (y) in the 151 young female volunteers is shown in Figure 2. The regression equation was $y = 1.41x + 47.28$ ($r = 0.862$, $p<0.0001$). The percent error of estimated body height to measured body height was $0.17 \pm 1.93\%$.

For women aged 20 to 91 years old in 2006, data for body height and sitting height during youth (age 18 to 21 years old) were taken from the Japan Statistical Yearbook. The mean relative leg length in women younger than 40 years old, calculated from statistical data, was 74.2 ± 0.61cm. A regression equation of $y = 0.0023x^2-0.4021x+112.93$ was determined from age (x) and the percent relative leg length (y) (Fig. 3). The spinomalleolar distance of the women older than 40 years old was corrected based on the equation obtained by percent relative leg length. Height reduction was also calculated by the following formula.

Height reduction = Actual height - Estimated height where estimated height = $1.41x \cdot CF + 47.28$, x = Spinomalleolar distance, and CF (correction factor) = $100/(0.0023x2 - 0.4021x + 112.93)$.

Vertebral fractures were diagnosed in 7 of 44 patients in their 50s, 16 of 59 patients in their 60s, and 12 of 28 older than 70 years old. The number of vertebral fractures was 1.6 ± 1.5 in women in their 50s, 1.6 ± 0.7 in women in their 60s, and 1.9 ± 0.8 in women older than 70 years old. The comparison of height reduction between the non-vertebral fracture and vertebral fracture groups showed a significant difference in height reduction in patients older than 70 years old ($p= 0.0157$, Fig. 4).

Correlations between height reduction and age or BMD are shown in Table 1. A significant correlation was found in height reduction and age between the non-vertebral fracture group ($r = -0.617$, $p<0.0001$) and the vertebral fracture group ($r = -0.699$, $p<0.0001$). In terms of BMD, a significant correlation was shown between the non-vertebral fracture group and radial BMD ($r=0.333$, $p = 0.0010$) and between the vertebral

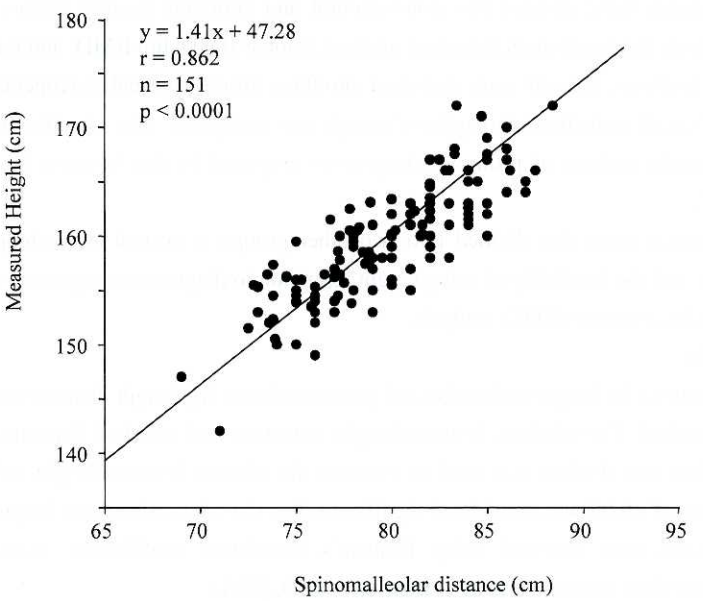

Fig. 2. Correlation between measured height and spinomalleolar distance in 151 young women.

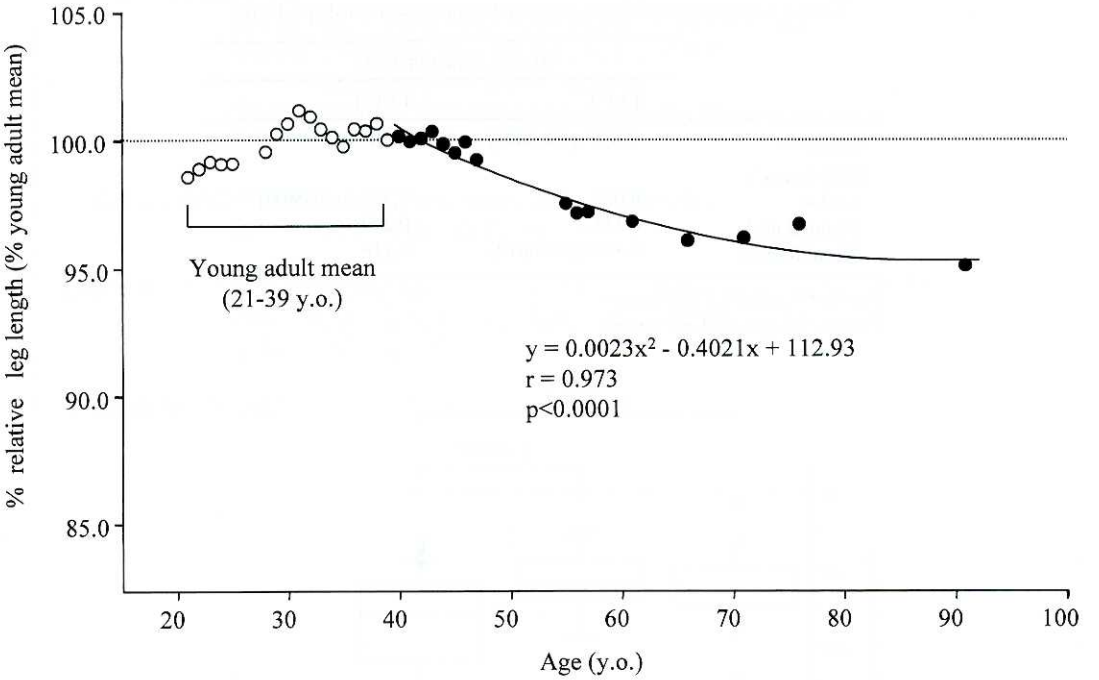

Fig. 3. Correlation between age and percent relative leg length.

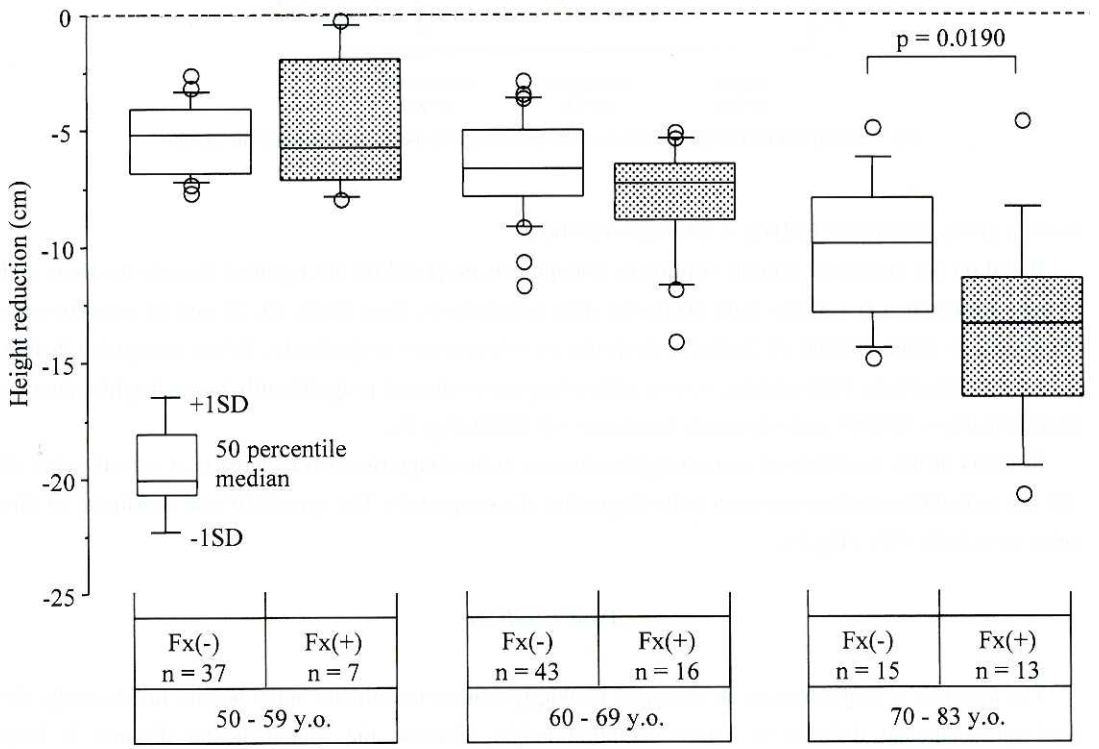

Fig. 4. Comparison of height reduction between patients with and without vertebral fracture in three age groups.

Table 1. Correlation coefficients between height reduction and age, BMD.

	Height reduction (cm)	
	Fx (-)	Fx (+)
Age (yrs.)	-0.617 (p<0.0001)	-0.699 (p<0.0001)
BMD (g/cm^2)		
L2-L4	0.065	0.349 (p=0.0400)
Femoral neck	0.181	0.279
Distal Radius	0.333 (p=0.0010)	0.318

Fx(-):n=95, age; 62.5 ± 6.6 years
Fx(+):n=36, age; 65.9 ± 7.7 years

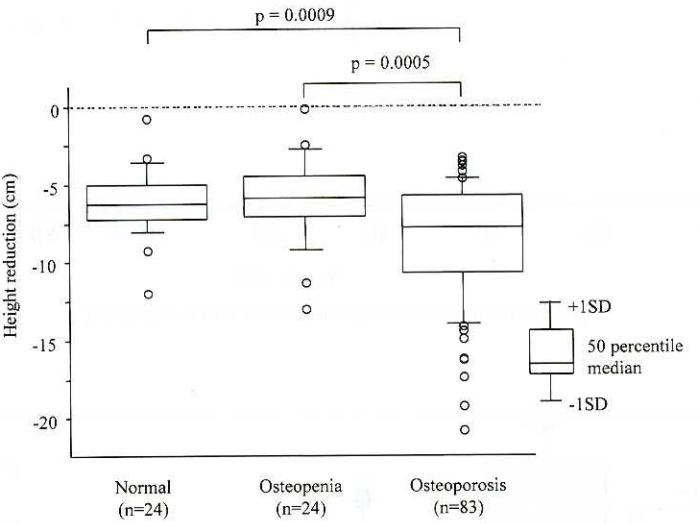

Fig. 5. Comparison of height reduction among normal, osteopenic, and osteoporotic groups.

fracture group and lumbar BMD (r = 0.349, p = 0.0400).

Based on the diagnostic criteria of primary osteoporosis proposed by the Japanese Society for Bone and Mineral Research, 131 patients were diagnosed with osteoporosis. As a result, 24, 24 and 83 patients were diagnosed as being normal or having osteopenia or osteoporosis respectively. When comparing height reduction among these three groups, women with osteoporosis showed a significantly larger height reduction than normal (p = 0.0009) and osteopenic females (p = 0.0005) (Fig. 5).

In terms of the feasibility of using height reduction in the diagnosis of osteoporosis, a cut-off value of -5.6 cm in height reduction was seen to be diagnostic of osteoporosis. The specificity and sensitivity of this value were both ~60% (Fig. 6).

DISCUSSION

The length of a long bone can be measured in elderly women to estimate initial height. In this study, we used spinomalleolar distance to determine initial height. Because the spinomalleolar distance is long compared with knee height and arm-span, the measurement error is relatively low.

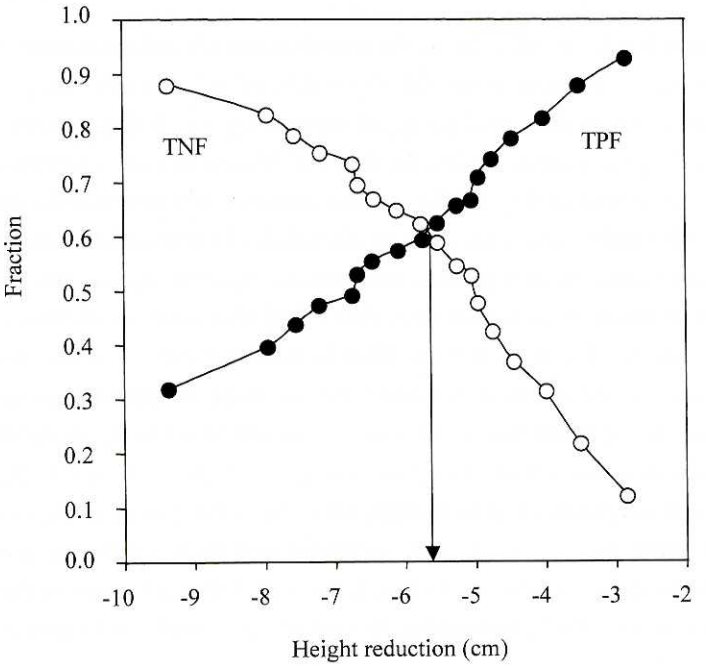

Fig. 6. Receiver operating characteristic (ROC) analysis of height reduction. TPF; true positive fraction, TNF; true negative fraction.

Hikson et al.[7] presented a height estimation method using the demi-span (the distance from the middle of the sternal notch to the tip of the middle finger), arm-span, and knee height. Results showed high correlations (r = 0.86-0.89) between measured height and the length of the long bone. Other researchers have reported similar correlations[4,6]. In this study, we obtained a correlation coefficient of 0.862. The percent error of estimated body height to measured body height was 0.17 ± 1.93%. Therefore, estimating height using spinomalleolar distance, as was done in this study, provided highly precise estimates of initial height.

However, it is difficult to apply a formula of height estimation obtained in young Japanese women to elderly Japanese women, because of the difference in percent relative leg length between these two groups (Fig. 1). Therefore, the spinomalleolar distance of middle-aged and elderly women was corrected.

When comparing height reduction in the non-vertebral fracture and vertebral fracture groups, a significant difference in height reduction was seen in women older than 70 years old. One reason for this result is that the number of vertebral fractures among the women in their 70s (1.9 ± 0.8) was larger than that of among the women in their 50s (1.6 ± 1.5) and 60s (1.6 ± 0.7).

A significant correlation was seen between height reduction and age, but was not seen between height reduction and BMD in four of six combinations. In the coefficient of correlation between height reduction and BMD, there was a tendency for the correlation coefficient in the vertebral fracture group to be higher than that in the non-vertebral fracture group. Height reduction is considered to occur with vertebral fractures, which may be caused by low BMD. However, the results in this study suggested that factors other than vertebral fractures influence height reduction, such as compression of the intervertebral disk, abrasion of the cartilage of each joint, and loss of good posture that occurs with the age-related decrease in muscular

strength.

The comparison of height reduction among the normal, osteopenic and osteoporotic groups showed that height reduction in the osteoporosis group was larger than in the other two groups, but there were no significant differences between the normal group and osteopenic group. In the diagnostic criteria of primary osteoporosis proposed by the Japanese Society for Bone and Mineral Research, patients with a BMD of less than 70% of the young adult mean (i.e., 20-44 years old) or cases with a nontraumatic vertebral fracture with a BMD of less than 80% of the young adult mean are diagnosed as having osteoporosis. Cases with a BMD of 70-80% of the young adult mean without a nontraumatic vertebral fracture are diagnosed as having osteopenia. Cases with a BMD of more than 80% of the young adult mean are diagnosed as normal. In other words, patients are diagnosed as normal if the BMD is more than 80% of young adult mean, even if a nontraumatic vertebral fracture is present. It is likely that the diagnostic criteria used influenced the lack of significant differences in height reduction between the normal and osteopenic groups in this study.

Our results also showed that a height reduction of at least -5.6 cm can be used to diagnose osteoporosis with a specificity and sensitivity of approximately 60%. To detect groups at high-risk for osteoporosis without measuring BMD, Koh[10] used an index calculated with body weight and age. This index could classify a high-risk group for osteoporosis with high precision. Our results showed that the assessment of height reduction is a simple method for identifying women who are at high risk for developing osteoporosis.

CONCLUSION

The initial body height of middle-aged and elderly female patients can be estimated using spinomalleolar distance. In addition, height reduction may be helpful in the diagnosis of osteoporosis.

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