



# Chair rising time is longer in postmenopausal women with history of nonvertebral fracture

J. Iwamoto<sup>1</sup>, Y. Sato<sup>2</sup>, H. Matsumoto<sup>1</sup>

<sup>1</sup>Institute for Integrated Sports Medicine, Keio University School of Medicine, Tokyo, Japan;

<sup>2</sup>Department of Neurology, Mitate Hospital, Fukuoka, Japan

## Abstract

The objective of the present study was to clarify the relationships between physical function, bone mass, biochemical markers, renal function, and a history of nonvertebral fracture in postmenopausal women with osteoporosis. In total, 143 postmenopausal women with osteoporosis (mean age: 71.2 years) and an osteoporosis treatment-naïve status were recruited. Twenty-seven women had a history of nonvertebral fracture (nonvertebral fracture group) and 116 women did not (control group). The patients' bone mass, biochemical markers, estimated glomerular filtration rate (eGFR), unipedal standing time (index of body balance), and the five-repetition chair-rising time (index of muscle power) were compared between the two groups. Age, body mass index, bone mass, serum alkaline phosphatase, creatinine, albumin, urinary cross-linked N-terminal telopeptides of type I collagen, eGFR, and the unipedal standing time did not differ significantly between the two groups. However, the chair-rising time was significantly longer (12.3 sec vs. 9.6 sec) in the nonvertebral fracture group than in the control group. The odds ratio (95% confidence intervals) for nonvertebral fractures in subjects with a chair-rising time >10.1 sec (mean value) was 4.28 (1.78, 10.30). Thus, a significant association was found between the impairment of muscle power and a history of nonvertebral fracture in postmenopausal women with osteoporosis.

**Keywords:** Osteoporosis, Fall, Clinical Fracture, Muscle Power, Hypophosphatemia

## Introduction

Osteoporosis most commonly affects postmenopausal women, placing them at a significant risk for fractures. Osteoporotic fractures in women include vertebral fractures, hip fractures, wrist-forearm fractures, humeral fractures, rib fractures, pelvic fractures, clavicular, scapular, and sternum fractures, and tibial and fibular fractures<sup>1</sup>. Because most nonvertebral osteoporotic fractures occur as a result of falls, physicians should evaluate risk factors for falls, including physical function, in postmenopausal women with osteoporosis.

Clinically, the impairment of muscle strength and muscle power of the lower extremities, balance/postural control, and

walking ability have been recognized as important risk factors for falls<sup>2,3</sup>. However, muscle strength should be distinguished from muscle power; muscle strength is defined as the maximal force that a muscle can produce against a given resistance, while muscle power is defined as the product of force and speed<sup>2,3</sup>. The former is related to bone strength, whereas the latter is related to falling<sup>2-5</sup>. Thus, the evaluation of muscle power, rather than muscle strength, is likely to be important for the prediction of falls. Theoretically, flexibility, body balance, muscle power of the lower extremities, and walking ability should, at a minimum, be assessed in clinical practice<sup>6</sup>. Actually, an exercise program aimed at improving flexibility, body balance, muscle power, and walking ability reduced the incidence of falls in the elderly<sup>6</sup>. In particular, body balance can be evaluated by measuring the unipedal standing time, while muscle power can be evaluated by measuring the chair-rising time<sup>6,7</sup>.

Increased body sway is reported to be a risk factor for hip fractures in elderly women<sup>8</sup>. Sakai et al.<sup>9</sup> also reported that the unipedal standing time was shorter and the bone mineral density (BMD) was lower in women  $\geq 50$  years of age with a distal radius fracture, compared with age-matched women without a fracture. These reports suggest a relationship be-

The authors have no conflict of interest.

Corresponding author: Jun Iwamoto, Institute for Integrated Sports Medicine, Keio, University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan  
E-mail: jiwamoto@a8.keio.jp

Edited by: J. Rittweger  
Accepted 28 April 2013

tween poor body balance and the risk of distal radius and hip fractures in postmenopausal women with osteoporosis. Large asymmetrical leg extension power deficits, a slow stair-climbing speed, and a slow walking speed have been demonstrated in women recovering from a hip fracture<sup>10</sup>. To our knowledge, however, the relationship between muscle power and nonvertebral fractures other than hip fractures remains to be established in postmenopausal women with osteoporosis, despite the fact that poor muscle power is considered to be a risk factor for falls. The objective of the present cross-sectional study was to clarify the relationship between the chair-rising time (an index of muscle power) and a history of nonvertebral fracture other than hip fracture in postmenopausal women with osteoporosis. The unipedal standing time (an index of body balance), bone mass, biochemical markers, and renal function were also included in the analysis, since evaluations of these parameters are essential in patients with osteoporosis.

## Subjects and methods

### *Study subjects*

One hundred and sixty Japanese women were recruited in three outpatient clinics (Keiyu Orthopaedic Hospital, Gunma; Hiyoshi Medical Clinic, Kanagawa; Iбата Orthopaedic Clinic, Chiba, Japan) during the 4-month period between April 1 and July 31, 2012. The inclusion criteria were spontaneous menopause, a fully ambulatory status, a diagnosis of postmenopausal osteoporosis according to the Japanese diagnostic criteria<sup>11,12</sup>, an osteoporosis treatment-naïve status, and the feasibility of measuring the physical function parameters. The exclusion criteria for the physical function assessment were severe gait disturbance requiring some form of walking aid, current clinical fractures because of osteoporosis, sciatica because of lumbar spinal canal stenosis, rheumatoid arthritis, and severe cardiovascular disease. Because large asymmetrical leg extension power deficits observed in women recovering from hip fractures are reportedly associated with a slow stair-climbing speed<sup>10</sup>, a history of hip fracture was selected as an exclusion criterion. The exclusion criteria for the diagnosis of postmenopausal osteoporosis included glucocorticoid-use, gastrectomy, renal failure, or bone diseases including cancer-induced bone loss because of aromatase inhibitors, primary hyperparathyroidism, hyperthyroidism, Cushing syndrome, multiple myeloma, Paget's disease of the bone, osteogenesis imperfecta, or type 2 diabetes. None of the subjects had been laborers or had been engaged in any regular or leisure-time sporting activities.

Of 160 Japanese women screened, 17 women were excluded because of the past history of glucocorticoid-use (nephritis [n=1], asthma [n=1], rheumatoid arthritis [n=2], subacute thyroiditis [n=1], or otosclerosis [n=1]), stroke (n=4), gastrectomy (n=1), hyperthyroidism (n=1), breast cancer-induced bone loss because of aromatase inhibitors (n=3), type 2 diabetes (n=1), and liver metastasis of colon cancer (n=1). One hundred and forty-three Japanese women with postmenopausal osteoporosis who met the criteria were processed for analyses.

Age, height, body weight, body mass index, history of nonvertebral fracture after menopause, bone mass, and physical function (unipedal standing time and chair-rising time) were assessed. Nonvertebral fractures included fractures at the distal radius, proximal humerus, rib, pelvis, clavicle, femur, and lower leg (a history of hip fracture was selected as an exclusion criterion). Thoracic and lumbar spine radiographs were obtained to assess prevalent vertebral fractures. Blood and urine samples were obtained for biochemical analysis, and the estimated glomerular filtration rate (eGFR) was also calculated. Bone mass, biochemical markers, eGFR, unipedal standing time, and chair-rising time were compared between women with a history of nonvertebral fracture other than hip fracture (nonvertebral fracture group) and those without such history (control group). Informed consent was obtained from all the participants. The protocol was approved by the Ethical Committee of Keiyu Orthopaedic Hospital.

### *Japanese diagnostic criteria for primary osteoporosis*

All the patients had been diagnosed as having osteoporosis according to the Japanese diagnostic criteria<sup>11,12</sup>. Namely, patients with a BMD <70% of the young adult mean (YAM) or 70-80% of the YAM along with a history of osteoporotic fractures were diagnosed as having osteoporosis.

Measuring the BMD using dual-energy X-ray absorptiometry (DXA) is the currently most broadly established method for evaluating bone mass. A quantitative ultrasound (QUS) is a more recently developed non-invasive method of studying the bone density and structure *in vivo*. The QUS parameters can predict the risk of hip, wrist, and total non-vertebral fractures for up to 10 years<sup>13</sup>. QUS might enable a better accounting of structural changes in the bone than the traditional DXA method<sup>14</sup>. Although the reliability of the SOS of the calcaneus has not fully been established, we used the BMD and the SOS for the diagnosis of osteoporosis.

### *Assessment of morphometric vertebral fractures*

Plain lateral X-ray films of the thoracic and lumbar spine were obtained to detect evidence of prevalent morphometric vertebral fractures. According to the Japanese criteria, a vertebral fracture was defined according to the vertebral height on lateral X-ray films<sup>11,12</sup>. Briefly, the vertebral height was measured at the anterior (A), central (C), and posterior (P) parts of the vertebral body, and the presence of a vertebral fracture was confirmed when (1) a reduction in the vertebral height of more than 20% (A, C, and P) compared with the height of the adjacent vertebrae was observed, (2) the C/A or C/P was less than 0.8, or (3) the A/P was less than 0.75. The assessment for vertebral fractures was performed at the T4-L4 level.

### *Measurement of bone mass*

A DXA as the gold standard was available at the Keiyu Orthopaedic Hospital, but not either at the Iбата Orthopaedic Clinic or the Hiyoshi Medical Clinic. The lumbar spine BMD was measured in 77 subjects at the Keiyu Orthopaedic Hospital, the metacarpal BMD was measured in 31 subjects at the

Ibata Orthopaedic Clinic, and the calcaneus SOS was measured in 35 subjects at the Hiyoshi Medical Clinic.

At the Keiyu Orthopaedic Hospital, the BMD of the lumbar spine (L1-L4) in the anteroposterior view was measured using DXA with a Hologic QDR 1500W apparatus (Bedford, MA, USA). The coefficients of variation (CV,  $100 \times$  standard deviation (SD)/mean) of 5 measurements with repositioning within 72 hours each time was less than 1.2% among 3 persons.

At the Ibata Orthopaedic Clinic, the BMD of the metacarpus was measured using a computed X-ray densitometer (Teijin, Tokyo, Japan). An anteroposterior view radiograph of bilateral hands and an aluminum step wedge (20 steps, 1 mm per step) was obtained for each subject and was used as a standard. The BMD of the middle portion of the second metacarpus on the left hand was measured. The densitometer calculated the BMD based on the pattern expressed as graduations on the aluminum step wedge, and the BMD was expressed as the thickness of the aluminum equivalent (mmAl) with a corresponding X-ray absorption. For these measurements, the CV for the intraobserver error (based on 10 consecutive measurements by five persons), the daily change error (based on measurements performed on 10 consecutive days), and the X-ray picturing error (based on 10 exposures) were all within 1.3-3.8%.

At the Hiyoshi Medical Clinic, the speed of sound (SOS) of the left calcaneus was measured using a quantitative ultrasound (QUS) device (CM-200; Elk Corp., Osaka, Japan). The CV of 5 measurements with repositioning within 24 hours each time was 0.17-0.43% among 3 healthy adults and 0.25-0.35% among 3 osteoporotic patients.

#### *Blood and urinary biochemical tests and eGFR calculation*

Serum and urine samples were obtained from each patient and the following biochemical analyses were performed. The serum calcium, phosphorus, alkaline phosphatase (ALP), aspartate aminotransferase (AST), creatinine, hemoglobin, total protein, and albumin levels were measured using standard laboratory techniques. The urinary cross-linked N-terminal telopeptides of type I collagen (NTX) level was measured using an enzyme-linked immunosorbent assay (ELISA). eGFR was calculated using age and serum creatinine as follows:  $eGFR \text{ (mL/min/1.73 m}^2\text{)} = 194 \times \text{serum creatinine}^{-1.094} \times \text{age}^{-0.287} \times 0.739^{15,16}$ .

#### *Assessment of physical function*

The unipedal standing time for the left leg was assessed as an index of body balance. Subjects stood on one leg for as long as possible with their eyes open without using any assistive device and keeping both arms by their waist. This test was ended once 60 sec had elapsed<sup>17</sup>, when the stance of the foot shifted, when the lifted foot touched the floor, or when the hands detached from the waist. The patients were not allowed to press the lifted leg on to the standing leg.

The chair-rising time was assessed as an index of muscle power. The five-repetition chair-rising time was measured with the subject's arms crossed over her chest. The chair-rising time

was the time required for the subjects to stand up from a chair (45 cm in height) 5 times as quickly as possible without using their arms, as measured using a stopwatch.

#### *Statistical analysis*

Data were expressed as the means  $\pm$  standard deviation (SD). The unpaired t-test was used to compare anthropometry, bone mass, biochemical markers, eGFR, and physical function parameters between the nonvertebral fracture group and the control group. The Fisher's exact test was used to compare the percentages of subjects among categories between the nonvertebral fracture group and the control group. The logistic regression analysis was used to calculate the odds ratio and the 95% confidence interval (CI) of factors associated with nonvertebral fractures. All the statistical analyses were performed using the Stat View J-5.0 program (SAS Institute, Cary, NC, USA). The significance level was set at  $P < 0.05$  for all the comparisons.

## **Results**

#### *Anthropometry, bone mass, and prevalence of vertebral fractures*

The mean age of the participants was 71.2 years (range: 48-87 years). Twenty-seven (18.9%) women had a history of nonvertebral fracture (nonvertebral fracture group), and 116 (81.1%) women did not (control group). The fracture sites included the distal radius (n=14), proximal humerus (n=3), rib (n=5), and lower leg (tibia and fibula) (n=5), and all the fractures had completely healed, as assessed using plain radiographs. Table 1 shows that the patient's age, height, body weight, body mass index, lumbar spine BMD, metacarpal BMD, and calcaneus SOS did not differ significantly between the two groups. The prevalence of vertebral fractures was significantly higher in the control group than in the nonvertebral fracture group (41.4% vs. 7.4%,  $P < 0.001$ ).

#### *Biochemical markers and eGFR*

Table 2 shows that the hemoglobin, serum total protein, albumin, calcium, ALP, AST, creatinine, urinary NTX, and eGFR did not differ significantly between the two groups. However, the serum phosphorus level was significantly lower in the nonvertebral fracture group than in the control group (3.1 mg/dL vs. 3.4 mg/dL,  $P < 0.01$ ).

#### *Physical function parameters*

Figure 1 shows that the five-repetition chair-rising time was significantly longer in the nonvertebral fracture group than in the control group (12.3 sec vs. 9.6 sec,  $P < 0.001$ ). The mean value of the five-repetition chair-rising time in all the subjects was 10.1 sec. The odds ratio (95% CI) for nonvertebral fracture in subjects with a five-repetition chair-rising time  $> 10.1$  sec (mean value) was 4.28 (1.78, 10.30) ( $P < 0.01$ ). However, the percentages of subjects with a unipedal standing time of 0-29 sec, 30-50 sec, and 60 sec were not significantly different between the two groups (Table 3).

	Nonvertebral fracture Group (n=27)	Control Group (n=116)	P value
Age (years)	72.7±11.0	70.8±8.2	N S
Height (m)	1.50±0.06	1.51±0.06	N S
Body weight (kg)	51.4±7.7	51.1±6.8	N S
Body mass index (kg/m <sup>2</sup> )	22.8±3.4	22.4±2.5	N S
Lumbar spine BMD (g/cm <sup>2</sup> )	0.698±0.116 (n=13)	0.654±0.093 (n=64)	N S
%YAM in lumbar spine BMD	67.9±11.6	64.7±9.3	N S
Metacarpal BMD (mmAl)	1.85±0.22 (n=9)	1.82±0.25 (n=22)	N S
%YAM in metacarpal BMD	64.9±7.8	64.3±7.2	N S
Calcaneus SOS (m/sec)	1481±18 (n=5)	1473±13 (n=30)	N S
%YAM in calcaneus SOS	71.2±8.1	67.4±6.0	N S
Number (%) of subjects with prevalent vertebral fracture	2 (7.4%)	48 (41.4%)	<0.001

Data are expressed as the mean±SD. The unpaired t-test and the Fisher's exact test were used to compare data between the two groups. The lumbar spine BMD was measured in 77 subjects, the metacarpal BMD was measured in 31 subjects, and the calcaneus SOS was measured in 35 subjects. BMD: bone mineral density, YAM: young adult mean, SOS: speed of sound, NS: not significant.

**Table 1.** Characteristics of study subjects.

	Normal ranges	Nonvertebral fracture Group (n=27)	Control Group (n=116)	P value
Serum				
Hemoglobin (g/dL)	11.2-15.2	12.7±1.1	13.0±1.0	N S
Total protein (g/dL)	6.5-8.2	7.1±0.4	7.3±0.5	N S
Albumin (g/dL)	3.7-5.2	4.2±0.3	4.2±0.3	N S
Calcium (mg/dL)	8.4-10.2	9.2±0.5	9.2±0.4	N S
Phosphorus (mg/dL)	2.5-4.5	3.1±0.4	3.4±0.5	<0.01
ALP (IU/L)	100-340	237±88	257±89	N S
AST (U/L)	11-35	22.9±4.3	23.2±6.4	N S
Creatinine (mg/dL)	0.47-0.79	0.66±0.13	0.64±0.13	N S
Urine				
NTX (nmol BCE/mmol Cr)	9.3-54.3	51.6±18.5	55.8±23.3	N S
eGFR (mL/min/1.73 m <sup>2</sup> )	>60	69.6±15.6	72.6±16.2	N S

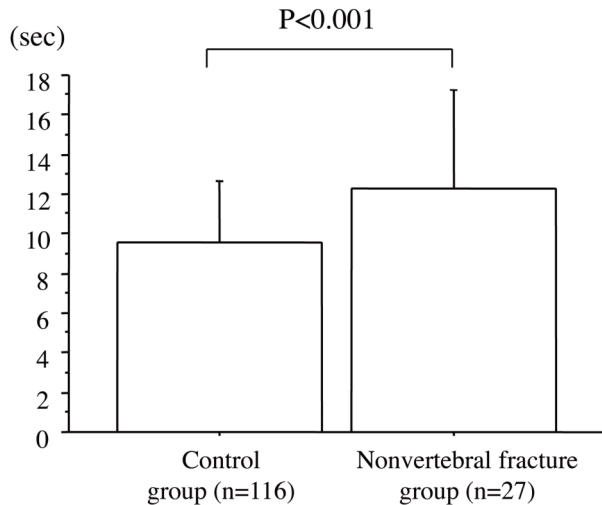
Data are expressed as the mean±SD. The unpaired t-test was used to compare data between the two groups. No significant differences were found in any parameters except for the serum phosphorus between the two groups. ALP: alkaline phosphatase, AST: aspartate aminotransferase, NTX: cross-linked N-terminal telopeptides of type I collagen, eGFR: estimated glomerular filtration rate, NS: not significant.

**Table 2.** Biochemical markers and eGFR.

Unipedal standing time	Nonvertebral fracture Group (n=27)	Control Group (n=116)	P value
0-29 sec	18	57	N S
30-59 sec	3	21	N S
60 sec	6	38	N S

The Fisher's exact test was used to compare data between the two groups. N S: not significant.

**Table 3.** Number of subjects by unipedal standing time.



**Figure 1.** Five-repetition chair-rising time. The five-repetition chair-rising time was significantly longer in the nonvertebral fracture group than in the control group (12.3 sec vs. 9.6 sec).

## Discussion

We conducted a cross-sectional study to clarify the relationships between physical function (muscle power index: chair-rising time, and body balance index: unipedal standing time), bone mass, biochemical markers, renal function and history of nonvertebral fracture in postmenopausal women with osteoporosis. A significant association was found between the impairment of muscle power (longer chair-rising time) and a history of nonvertebral fracture in postmenopausal women with osteoporosis.

We were not able to assess the chair-rising time (muscle power) and falling before suffering from nonvertebral fracture. A nonvertebral fracture is a deconditioning event which deteriorates physical function. Thus, it remains uncertain whether the impairment of muscle power was the causes or consequences of fractures in the present study, although nonvertebral fracture of the lower extremities (tibia or fibula) was experienced only in 18.5% of the study subjects. However, it is known that close to 75% of hip and non-hip fractures occur among seniors age 65 years and older<sup>18</sup>. The primary risk factor for a hip fracture is a fall, and over 90% of all fractures occur after a fall<sup>18</sup>. Furthermore, odds ratios (95% CI) predicting nonvertebral fractures are reported to be previous fracture, 2.67 (2.10-3.40); a fall in the last 12 months, 2.06 (1.63-2.59); and age (per year increase), 1.03 (1.01-1.05)<sup>19</sup>. These reports suggest that critical for the understanding and prevention of nonvertebral fractures at later age is their close relationship with muscle weakness and falling. Thus, a significant association between the impairment of muscle power and a history of nonvertebral fracture in the present study could possibly be attributable to physical function status before or after suffering from nonvertebral fracture, or a mixture of both. Individuals

who sustain a low-energy fracture of the hip, wrist, proximal part of the humerus, or ankle between the ages of forty-five and eighty-four years are reported to have an increased relative risk of sustaining another low-energy fracture<sup>20</sup>. Physician must pay attention to an increased risk of nonvertebral fracture in postmenopausal osteoporotic women with the impairment of muscle power and a history of nonvertebral fracture.

The unipedal standing time did not differ significantly between the two groups. We measured physical function parameters only one time. The reproducibility of unipedal standing time measurement in terms of the reliability of this parameter may be an issue than those of five-repetition chair-rising time in the present study. The average value of two or three times measurements should have been evaluated. Sihvonen et al.<sup>21</sup> reported that community-dwelling older adults with a history of hip fracture had a poor balance control as evaluated with the semi-tandem standing with their eye closed. Schacht et al.<sup>22</sup> reported that successful performance in the muscle tests (timed up and go, chair-rising test, and tandem gait test) was associated with a lower risk of falls and nonvertebral fractures in elderly patients with low bone mass. Dukas et al.<sup>23</sup> showed that treatment with alfacalcidol for 6 months improved parameters of timed up and go, chair-rising test, and tandem stand test, leading to a decrease in the absolute numbers of fallers and falls among elderly adults with a creatinine clearance of  $\leq 65$  ml/min. These reports suggest that chair-rising time (muscle power) and time up and go (dynamic body balance) are key parameters in the elderly with an increased risk of falls and that lateral balance as evaluated with tandem maneuver is correlated with falls and fractures. Further studies are needed to clarify the relationships between body balance as evaluated with tandem maneuver and a history of nonvertebral fracture in postmenopausal women with osteoporosis.

The Osteo-cise: Strong Bones for Life study evaluated the feasibility and effectiveness of a multifaceted community-based exercise, osteoporosis education/awareness and behavioral change program for improving musculoskeletal health and function in older adults at increased risk of osteoporosis, falls and fractures<sup>24</sup>. This study provided new information on the efficacy of a targeted multi-modal community-based exercise program incorporating high-velocity resistance training, together with osteoporosis education and a behavioral change program for improving multiple risk factors for falls and fractures. High-velocity resistance training aims to improve both muscle strength and muscle power. A randomized controlled trial also showed that power training improved balance, particularly using a low-load, high-velocity regimen, in older adults<sup>25</sup>. Thus, muscle power should be one of the key factors in strategies for preventing falls in the elderly.

Yamashita et al.<sup>26</sup> conducted a randomized controlled trial in patients with locomotive disorders to compare the effect of a one-leg standing exercise (static balance training) and a chair-rising exercise (muscle power training) on physical function. They showed that the chair-rising exercise was more effective than the one-leg standing exercise for improving dynamic body balance, probably because the chair-rising exercise improved

the function of the quadriceps and gluteus medius muscles and the joint movement of the lower extremities more effectively than a one-leg standing exercise. In the present study, the chair-rising time was significantly associated with a history of nonvertebral fracture and the odds ratio for nonvertebral fracture in subjects with a chair-rising time >10.1 sec was 4.28. So, a five-repetition chair-rising time of 10 sec could be a candidate cut-off value for the initiation of intervention to prevent falls in postmenopausal Japanese women with osteoporosis.

Bone mass, biochemical markers, and renal function were also included in the analysis, since the evaluation of these parameters is essential in patients with osteoporosis. The clinical risk factors for nonvertebral fractures other than hip fracture remain to be established, although the risk factors for hip fracture have already been established. BMD and a bone resorption marker (serum cross-linked C-terminal telopeptides of type I collagen [CTX]) have been reported as clinical risk factors for hip fracture<sup>8</sup>. Renal function is also reportedly related to the risk of hip fracture<sup>27,28</sup>. In the present study, however, the bone mass, urinary NTX, serum creatinine, and eGFR were not significantly different between the nonvertebral fracture and control groups. One possible explanation for these results may be that the study subjects in the present study were not frail enough to develop hip fractures, based on the mean serum albumin and creatinine levels and the eGFR (which were all within the normal ranges) and the mean bone mass (%YAM >60). Furthermore, we did not measure the serum CTX, but rather measured the urinary NTX. Therefore, these parameters were not correlated with a history of nonvertebral fractures other than hip fracture.

Not only the muscle function, but also the muscle mass should be evaluated in the elderly because sarcopenia is an increasing problem in Japan's aging society<sup>29,30</sup>. Sarcopenia is an age-related condition defined by the combined presence of reduced muscle mass, defined as 2SDs or less compared with the young adult mean, and reduced muscle function, measured as a gait speed of less than 0.8 or 1 m/sec<sup>31</sup>. The European Working Group on Sarcopenia in Older People (EWGSOP) suggests an algorithm for sarcopenia case finding in older individuals based on measurements of gait speed, grip strength, and muscle mass<sup>32</sup>. So, gait speed and grip strength must have been included in the neuromuscular test battery. Further studies are required to assess not only muscle power and body balance, but also grip strength and habitual/maximum gait speed in elderly women with or without a history of nonvertebral fracture.

An epidemiological study in Japan showed that the use of age, BMD, prior clinical fracture and vertebral fracture predicted future fracture risk<sup>33</sup>. Thus, the prevalence of vertebral fracture is considered to be a significant risk factor for fractures. However, the prevalence of vertebral fracture was significantly higher in the control group without a history of nonvertebral fracture than in the nonvertebral fracture group. The age-specific incidence rates of vertebral fracture per 1000 person-years in Japanese women are reported to be 5.2 for 50-59 years, 12.4 for 60-69 years, 24.5 for 70-79 years, and 56.1 for ≥80 years<sup>34</sup>, and those of distal radius fracture are reported to be 1.79 for 50-54 years, 3.18 for 55-59 years, 3.32 for 60-

64 years, 3.40 for 65-69 years, 3.64 for 70-74 years, 3.34 for 75-79 years, 3.80 for 80-84 years, and 4.21 for ≥85 years<sup>35</sup>. The incidence of vertebral fracture among elderly women aged ≥60 years is considered to be higher than that of distal radius fracture (12.4-56.1 vs. 3.34-4.21). The mean age of the present study subjects was 71.2 years. Hip fracture was not included in the nonvertebral fracture group and the main nonvertebral fracture in the nonvertebral fracture group was distal radius fracture (51.9%). Because of the greater incidence of vertebral fracture than that of distal radius fracture, the number of elderly women with prevalent vertebral fracture but without a history of nonvertebral fracture was greater than that with nonvertebral fracture (mainly distal radius fracture).

The limitations of the present study should be discussed. First, the present study was based on a conventional cross-sectional sample of elderly women. The objective of the present study was to clarify the relationship between the chair-rising time (an index of muscle power) and a history of nonvertebral fracture in postmenopausal women with osteoporosis, and the chair-rising time was a key parameter. However, the standard value of this parameter was not established so that no power analysis was done. A lack of a power analysis could make the study underpowered for the statistical analyses of physical function as well as laboratory parameters. Second, the prevalence of vertebral fracture was significantly higher in the control group than in the nonvertebral fracture group. Existing vertebral fracture and subsequent changes in the posture could affect physical function. Third, the method of bone mass measurement in the diagnosis of osteoporosis was different among three outpatient clinics. A DXA as the gold standard was available only at one outpatient clinic, and other methods were utilized in other two outpatient clinics. Therefore, there might have been a bias of including and excluding patients who were eligible for participating in the present study. Fourth, we did not evaluate vitamin D insufficiency/deficiency by measuring the serum 25(OH)D level. In Japan, vitamin D supplementation is uncommon, and the measurement of serum 25(OH)D levels is not covered by health insurance. Because low serum levels of 25(OH)D are correlated with an increased risk of falls and vitamin D supplementation reduces the incidence of falls in the elderly<sup>36-38</sup>, evaluating the vitamin D status is important. Further studies are needed to resolve these limitations.

In conclusion, the present study showed that the chair-rising time was significantly longer in the nonvertebral fracture group than in the control (no nonvertebral fracture) group. The odds ratio (95% CIs) for nonvertebral fracture in subjects with a chair-rising time greater than the mean value was 4.28 (1.78, 10.30). These results suggest a significant association between the impairment of muscle power and a history of nonvertebral fracture in postmenopausal women with osteoporosis.

## References

1. Giangregorio LM, Leslie WD; Manitoba Bone Density Program. Time since prior fracture is a risk modifier for

- 10-year osteoporotic fractures. *J Bone Miner Res* 2010; 25:1400-5.
2. Runge M, Rehfeld G, Resnicek E. Balance training and exercise in geriatric patients. *J Musculoskel Neuronal Interact* 2001;1:61-5.
  3. Runge M, Hunter G. Determinants of musculoskeletal frailty and the risk of falls in old age. *J Musculoskel Neuronal Interact* 2009;6:167-173.
  4. Frost HM. Defining osteopenias and osteoporosis: another view (with insights from a new paradigm). *Bone* 1997;20:385-391.
  5. Schiessl H, Frost HM, Jee WSS. Estrogen and bone-muscle strength and mass relationship. *Bone* 1998;22:1-6.
  6. Iwamoto J, Suzuki H, Tanaka K, Kumakubo T, Hirabayashi H, Miyazaki Y, Sato Y, Takeda T, Matsumoto H. Preventative effect of exercise against falls in the elderly: a randomized controlled trial. *Osteoporos Int* 2009; 20:1233-40.
  7. Iwamoto J, Sato Y, Takeda T, Matsumoto H. Whole body vibration exercise improves body balance and walking velocity in postmenopausal osteoporotic women treated with alendronate: Galileo and Alendronate Intervention Trail (GAIT). *J Musculoskel Neuronal Interact* 2012; 12:136-43.
  8. Kanis JA, Johnell O, Oden A, Jonsson B, Dawson A, Dere W. Risk of hip fracture derived from relative risks: an analysis applied to the population of Sweden. *Osteoporos Int* 2000;11(2):120-7.
  9. Sakai A, Oshige T, Zenke Y, Yamanaka Y, Otsuka H, Nakamura T. Shorter unipedal standing time and lower bone mineral density in women with distal radius fractures. *Osteoporos Int* 2010;21:733-9.
  10. Portegijs E, Sipilä S, Rantanen T, Lamb SE. Leg extension power deficit and mobility limitation in women recovering from hip fracture. *Am J Phys Med Rehabil* 2008; 87(5):363-70.
  11. Orimo H, Sugioka Y, Fukunaga M, Muto Y, Hotokebuchi T, Gorai I, Nakamura T, Kushida K, Tanaka H, Ikai T, Ohhashi Y. Diagnostic criteria of primary osteoporosis. *J Bone Miner Metab* 1998;16:139-150.
  12. Orimo H, Hayashi Y, Fukunaga M, Sone T, Fujiwara S, Shiraki M, Kushida K, Miyamoto S, Soen S, Nishimura J, Oh-Hashi Y, Hosoi T, Gorai I, Tanaka H, Igai T, Kishimoto H. Diagnostic criteria for primary osteoporosis: year 2000 revision. *J Bone Miner Metab* 2001;19:331-337.
  13. Fujiwara S, Sone T, Yamazaki K, et al. Heel bone ultrasound predicts non-spine fracture in Japanese men and women. *Osteoporos Int* 2005;16:2107-2112.
  14. Wüster C, Heilmann P, Pereira-Lima J, et al. Quantitative ultrasonometry (QUS) for the evaluation of osteoporosis risk: reference data for various measurement sites, limitations and application possibilities. *Exp Clin Endocrinol Diabetes* 1998;106:277-288.
  15. Matsuo S, Imai E, Horio M, et al. Revised equations for estimated GFR from serum creatinine in Japan. *Am J Kid Dis* 2009;53:982-992.
  16. Coresh J, Astor BC, Greene T, et al. Prevalence of chronic kidney disease and decreased kidney function in the adult US population. *Am J Kid Dis* 2003;41:1-12.
  17. Yoshimura N, Oka H, Muraki S, Akune T, Hirabayashi N, Matsuda S, Nojiri T, Hatanaka K, Ishimoto Y, Nagata K, Yoshida M, Tokimura F, Kawaguchi H, Nakamura K. Reference values for hand grip strength, muscle mass, walking time, and one-leg standing time as indices for locomotive syndrome and associated disability: the second survey of the ROAD study. *J Orthop Sci* 2011;16:768-777.
  18. Bischoff-Ferrari HA. The role of falls in fracture prediction. *Curr Osteoporos Rep* 2011;9:116-121.
  19. Porthouse J, Birks YF, Torgerson DJ, Cockayne S, Puffer S, Watt I. Risk factors for fracture in a UK population: a prospective cohort study. *Q J Med* 2004;97:569-574.
  20. Robinson CM, Royds M, Abraham A, McQueen MM, Court-Brown CM, Christie J. Refractures in patients at least forty-five years old. a prospective analysis of twenty-two thousand and sixty patients. *J Bone Joint Surg Am* 2002;84-A:1528-1533.
  21. Sihvonen S, Kulmala J, Kallinen M, Alén M, Kiviranta I, Sipilä S. Postural balance and self-reported balance confidence in older adults with a hip fracture history. *Gerontology* 2009;55:630-636.
  22. Schacht E, Ringe JD. Alfacalcidol improves muscle power, muscle function and balance in elderly patients with reduced bone mass. *Rheumatol Int* 2012;32:207-215.
  23. Dukas L, Schacht E, Runge M, Ringe JD. Effect of a six-month therapy with alfacalcidol on muscle power and balance and the number of fallers and falls. *Arzneimittelforschung* 2010;60:519-525.
  24. Gianoudis J, Bailey CA, Sanders KM, Nowson CA, Hill K, Ebeling PR, Daly RM. Osteo-cise: Strong Bones for Life: Protocol for a community-based randomised controlled trial of a multi-modal exercise and osteoporosis education program for older adults at risk of falls and fractures. *BMC Musculoskel Disord* 2012;13:78.
  25. Orr R, de Vos NJ, Singh NA, Ross DA, Stavrinou TM, Fiatarone-Singh MA. Power training improves balance in healthy older adults. *J Gerontol A Biol Sci Med Sci* 2006; 61:78-85.
  26. Yamashita F, Iwamoto J, Osugi T, Yamazaki M, Takakuwa M. Chair rising exercise is more effective than one-leg standing exercise in improving dynamic body balance: A randomized controlled trial. *Musculoskel Neuronal Interact* 2012;12(2):74-9.
  27. Fried LF, Biggs ML, Shlipak MG, et al. Association of kidney function with incident hip fracture in older adults. *J Am Soc Nephrol* 2007;18:282-286.
  28. Nickolas TL, McMahon DJ, Shane E. Relationship between moderate to severe kidney disease and hip fracture in the United States. *J Am Soc Nephrol* 2006;17:3223-3232.
  29. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, Abellan van Kan G, Andrieu S, Bauer J, Breuille D, Cederholm T, Chandler J, De Meynard C,

- Donini L, Harris T, Kannt A, Keime Guibert F, Onder G, Papanicolaou D, Rolland Y, Rooks D, Sieber C, Souhami E, Verlaan S, Zamboni M. Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. *J Am Med Dir Assoc* 2011; 12:249-256.
30. Wang C, Bai L. Sarcopenia in the elderly: Basic and clinical issues. *Geriatr Gerontol Int* 2012;12(3):388-96.
  31. Cederholm TE, Bauer JM, Boirie Y, Schneider SM, Sieber CC, Rolland Y. Toward a definition of sarcopenia. *Clin Geriatr Med* 2011;27:341-353.
  32. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, Topinková E, Vandewoude M, Zamboni M; European Working Group on Sarcopenia in Older People. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 2010;39:412-423.
  33. Fujiwara S, Hamaya E, Goto W, Masunari N, Furukawa K, Fukunaga M, Nakamura T, Miyauchi A, Chen P. Vertebral fracture status and the World Health Organization risk factors for predicting osteoporotic fracture risk in Japan. *Bone* 2011;49:520-525.
  34. Fujiwara S, Kasagi F, Masunari N, Naito K, Suzuki G, Fukunaga M. Fracture prediction from bone mineral density in Japanese men and women. *J Bone Miner Res* 2003; 18:1547-1553.
  35. Hagino H, Yamamoto K, Ohshiro H, Nakamura T, Kishimoto H, Nose T. Changing incidence of hip, distal radius, and proximal humerus fractures in Tottori Prefecture, Japan. *Bone* 1999;24:265-270.
  36. Suzuki T, Kwon J, Kim H, Shimada H, Yoshida Y, Iwasa H, Yoshida H. Low serum 25-hydroxyvitamin D levels associated with falls among Japanese community-dwelling elderly. *J Bone Miner Res* 2008;23:1309-1317.
  37. Sato Y, Iwamoto J, Kanoko T, Satoh K. Low-dose vitamin D prevents muscular atrophy and reduces falls and hip fractures in women after stroke: a randomized controlled trial. *Cerebrovasc Dis* 2005;20:187-192.
  38. Bischoff-Ferrari HA, Dawson-Hughes B, Staehelin HB, Orav JE, Stuck AE, Theiler R, Wong JB, Egli A, Kiel DP, Henschkowski J. Fall prevention with supplemental and active forms of vitamin D: a meta-analysis of randomised controlled trials. *BMJ* 2009;339:b3692.