Three strategies for preventing bone fractures in the elderly are: 1) increasing bone mineral density (BMD) in fragile osseous tissue to prevent a fracture; 2) preventing falls that can cause fractures; and, 3) using hip protectors to cushion the body in the case of falls. The present randomized controlled trial (RCT) was conducted to ascertain whether 1-min unipedal standing exercise with eyes open 3 times/day could improve the BMD of the proximal femur.

Methods

The ethics review board at Showa University School of Medicine approved our study, an
RCT as part of research on health and labor sciences at the Department of Orthopedic Surgery and at six nearby clinics with no overnight facilities. The Department of Public Health at Showa University School of Medicine randomly divided subjects into an exercise group (stood on one leg for 1 min 3 times/day) and a control group (did not stand on one leg for 1 min 3 times/day).

Before exercise and at 3 and 6 months after starting exercise, dual-energy X-ray absorptiometry (DXA) was performed using the Hologic Explore to measure BMD (g/cm²) of the proximal femur and lumbar spine (anteroposterior scans). BMD was evaluated at six skeletal sites [total proximal femur (Total), femoral neck (Neck), trochanter (Troch), intertrochanter (Inter), Ward’s triangle (Ward), and lumbar spine (L2-4)] in all subjects. Percent change in BMI was calculated as:

\[
\text{Percent change in BMI} = \left( \frac{\text{after BMD} - \text{before BMD}}{\text{before BMD}} \right) \times 100.
\]

The Mann-Whitney U test was used for statistical analysis. A χ² test was used to compare the number of subjects with increased BMD (Total, Neck, Troch, Inter, Ward, and L2-4) between exercise and control groups.

**Subjects**

The study subjects comprised patients of ≥ 60 years old receiving treatment on an outpatient basis for spondylosis deformans, osteoarthritis of the knee, or shoulder joint inflammation, who had not received bone metabolism-related drugs for 6 months and were not performing active exercise therapy. Individuals prone to falls, such as patients with Parkinson’s disease, were excluded from the present study.

Common physical therapies such as thermotherapy and traction therapy were allowed, but bone metabolism-related pharmacotherapies and active exercise therapy were banned during the study.

**Results**

A total of 47 patients (3 men, 44 women) were enrolled and randomly grouped as follows: 26 patients in the exercise group (2 men, 24 women; age (mean±standard deviation), 72.3 ± 7.3 years) and 21 patients in the control group (1 man, 20 women; age, 69.4±7.8 years). A total of 16 subjects were excluded, comprising all 3 men, 6 of the 24 women in the exercise group, and 7 of the 20 women in the control group, due to consent withdrawal and various rule violations (bone metabolism-related drug administration, non-compliance with unipedal standing exercise, non-compliance with BMD measurement, and attendance failures). The final data were analyzed for 18 women in the exercise group and 13 women in the control group (Fig. 1). Table 1 lists the mean ages, heights, and body weights for all subjects. No significant differences were identified between groups. At the start of the study, no significant differences existed in Total, Troch, Inter, Ward, or L2-4 BMD between the two groups, but the mean Neck BMD was significantly smaller for the exercise group.
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Enrolled: n=47 (3 men, 44 women)

Randomly grouped

Exercise group: n=26 (2 men, 24 women)
Average age: 72.3±7.3 years

Control group: n=21 (1 man, 20 women)
Average age: 69.4±7.8 years

Excluded
2 men
(Withdraw consent, n=1; drug non-compliance, n=1; missed appointments, n=4)

Statistics target
18 women
Average age: 70.7±5.1 years

Statistics target
13 women
Average age: 72.6±5.5 years

Unipedal standing with eyes open
Month 3
DXA: n=10

No unipedal standing
Month 3
DXA: n=9

Unipedal standing with eyes open
Month 6
DXA: n=11

No unipedal standing
Month 6
DXA: n=10

Fig. 1. Flow chart for subjects who performed 1-min unipedal standing with eyes open 3 times/day and controls.

Table 1. Two-group comparison (mean±SD)
(Baseline characteristics of the participants)

<table>
<thead>
<tr>
<th></th>
<th>Exercise group (n = 18)</th>
<th>Control group (n = 13)</th>
<th>Statistical analysis*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>70.7 ± 5.1</td>
<td>72.6 ± 6.5</td>
<td>P = 0.4221</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>150 ± 4.2</td>
<td>148.2 ± 5.3</td>
<td>P = 0.2887</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>50.9 ± 7.9</td>
<td>49.8 ± 7.7</td>
<td>P = 0.6889</td>
</tr>
</tbody>
</table>

BMD (g/cm²) (Hologic Explorer)

<table>
<thead>
<tr>
<th></th>
<th>Exercise group</th>
<th>Control group</th>
<th>Statistical analysis*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>0.651 ± 0.124</td>
<td>0.690 ± 0.05</td>
<td>P = 0.1385</td>
</tr>
<tr>
<td>Neck</td>
<td>0.550 ± 0.09</td>
<td>0.625 ± 0.07</td>
<td>P = 0.0110</td>
</tr>
<tr>
<td>Troch</td>
<td>0.48 ± 0.108</td>
<td>0.517 ± 0.06</td>
<td>P = 0.1612</td>
</tr>
<tr>
<td>Inter</td>
<td>0.774 ± 0.152</td>
<td>0.804 ± 0.06</td>
<td>P = 0.3785</td>
</tr>
<tr>
<td>Ward’s</td>
<td>0.366 ± 0.08</td>
<td>0.420 ± 0.07</td>
<td>P = 0.1282</td>
</tr>
<tr>
<td>L2-4</td>
<td>0.763 ± 0.127</td>
<td>0.750 ± 0.12</td>
<td>P = 0.5751</td>
</tr>
</tbody>
</table>

* Mann-Whitney U test

(0.550 ± 0.09) than for the control group (0.625±0.07, P = 0.0110).

At month 3±1 (Table 2), the percent change in L2-4 BMD was −0.488±1.67 (increased in 6 of 10 subjects) for the exercise group and −0.383±1.79 (increased in 4 of 9 subjects) for the control group, but no significant difference was apparent. The percent change in Total BMD was −0.575 ± 5.71 (increased in 6 of 10 subjects) for the exercise group and
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—1.075 ± 1.32 (increased in 2 of 9 subjects) for the control group. The percent change in Neck BMD was −0.257 ± 5.34 (increased in 6 of 10 subjects) for the exercise group and −2.177 ± 4.99 (increased in 2 of 9 subjects) for the control group. Although no significant differences existed between groups for Total or Neck BMD, the exercise group tended to show increased numbers of patients with higher BMD at these sites. No significant differences existed in Troch, Inter, or Ward BMD between the exercise and control groups.

At month 6 ± 1 (Table 3), the percent change in L2-4 BMD was −1.160±2.72 (increased in 3 of 11 subjects) for the exercise group and −0.141±4.3 (increased in 7 of 10 subjects) for the control group. The percent change in Total BMD was −0.105±4.25 (increased in 5 of 11 subjects) for the exercise group and 1.534±5.42 (increased in 6 of 10 subjects) for the control group. The percent change in Neck BMD was −0.032±4.17 (increased in 7 of 11 subjects) for the exercise group and −3.042±5.49 (increased in 2 of 10 subjects) for the control group. From L2-4 to Ward BMD, the only significant difference was more subjects with higher Neck BMD in the exercise group (P = 0.0436).

**Discussion**

Three factors that determine peak bone mass in adult bone are genetics, endocrine / nutrition, and mechanical stress. According to a study on continuous recumbency where terrestrial gravitation, or natural mechanical stress, is eliminated, calcium loss occurs from the first day of recumbency, and negative calcium balance cannot be solved by drug or...
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physical therapy. In addition, this negative change of events reverses only when recumbency
is discontinued and the body is again subjected to terrestrial gravitation. For instance, when
astronauts spend 4–6 months in space, approximately 900 days is required for the proximal
femur BMD to reach predeparture levels. Mechanical stress is thus an extremely impor-
tant factor for bone strength.

While many investigations have used mechanical stress in exercise therapy, few RCTs
have examined whether exercise increases the proximal femur BMD, which would depend
on the exercise type and duration. One-minute unipedal standing with eyes open 3 times /
day has been called dynamic flamingo therapy, and is an exercise therapy utilizing body
weight as a mechanical stress. In terms of the amount of stress applied to the femoral
head, 3 min of unipedal standing is equivalent to 160 min of walking.

According to our 10-year case study, 1-min unipedal standing with eyes open 3 times /
day increased Neck BMD in 15 of 24 subjects at month 3 ± 1 (62.5%) and 15 of 37
subjects at month 6 ± 1 (40.5%). The present results show that exercise therapy tended to
increase BMD in many subjects, and the percent change in BMD varied greatly, although
few significant differences were seen. Our impression was that the number of subjects for
whom exercise increased BMD represents a better parameter for assessing the efficacy of
exercise therapy.

Sakai et al previously investigated BMD and unipedal standing time in 90 community-
dwelling Japanese women with a mean age of 54.7 years, showing that BMD correlated

Table 3. Rate of change in BMD (month 6±1)

<table>
<thead>
<tr>
<th>Exercise group (n = 11) (rate of change : mean ± SD)</th>
<th>Subjects with increased BMD</th>
<th>Control group (n = 10) (rate of change : mean ± SD)</th>
<th>Subjects with increased BMD</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total −0.105 ± 4.25</td>
<td>5 / 11</td>
<td>1.534 ± 5.42</td>
<td>6 / 10</td>
<td>* p = 0.8327</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>** p = 0.6698</td>
</tr>
<tr>
<td>Neck −0.032 ± 4.17</td>
<td>7 / 11</td>
<td>−3.042 ± 5.49</td>
<td>2 / 10</td>
<td>* p = 0.0783</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>** p = 0.0436</td>
</tr>
<tr>
<td>Troch −0.832 ± 4.99</td>
<td>4 / 11</td>
<td>−1.199 ± 1.72</td>
<td>2 / 10</td>
<td>* p = 0.6727</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>** p = 0.4071</td>
</tr>
<tr>
<td>Inter 2.055 ± 3.81</td>
<td>8 / 11</td>
<td>3.486 ± 6.67</td>
<td>7 / 10</td>
<td>* p = 0.8880</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>** p = 0.8901</td>
</tr>
<tr>
<td>Ward’s −0.818 ± 7.05</td>
<td>4 / 11</td>
<td>0.032 ± 5.38</td>
<td>5 / 10</td>
<td>* p = 0.6727</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>** p = 0.5283</td>
</tr>
<tr>
<td>L2-4 −1.160 ± 2.72</td>
<td>3 / 11</td>
<td>−0.141 ± 4.3</td>
<td>7 / 10</td>
<td>* p = 0.3600</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>** p = 0.0502</td>
</tr>
</tbody>
</table>

Rate of change (%) = (Month 6 BMD – Month 0 BMD) / Month 0 BMD×100, where BMD is bone mineral
density.

* Mann-Whitney U test (BMD comparison) ; ** χ² test (subjects with increased BMD comparison)
with unipedal standing time, the 10-meter timed up-and-go (TUG) test, and age. Among subjects ≥ 70 years old in the study of Sakai et al\textsuperscript{20}, BMD correlated with unipedal standing time. Sakai et al subsequently reported\textsuperscript{21} that 6 months of unipedal standing increased proximal femur BMD among subjects ≥ 70 years old. No such conclusion could be drawn in the present study because few subjects were of that age. Nevertheless, 1-min unipedal standing with eyes open increased the trochanter BMD in all subjects, suggesting that standing on one leg causes the gluteus medius muscle to apply tensile stress to the greater trochanter in elderly individuals with low BMD.

Studies have shown that exercise therapy is effective for increasing femoral neck BMD\textsuperscript{22,23}. Unipedal standing with eyes open is an exercise program that is conveniently performed without any special equipment which could help to prevent falls\textsuperscript{6}, and might increase proximal femur BMD. This exercise should thus prove effective in preventing proximal femur fracture, particularly in the elderly.

Appendix

In addition to the authors, the following investigators were members of the Randomized Controlled Trial Study Group of unipedal standing balance exercise: S. Sakurai, Sakurai Orthopaedic Clinic (Orth. Clin.); Y. Shimizu, Shimizu Orth. Clin.; K. Ishikawa, Ishikawa Orth. Clin.; H. Nakabayashi, Nakagami Clinic; M. Hosokawa, West-Kamata Orth. Clin.; and, F. Yamazaki, Umeyski Orth. Clin.

The present study was partially funded by the Ministry of Health, Labor and Welfare Grants-in-Aid for Comprehensive Longevity Sciences H19-Chojuu-General-031.

References


[Received July 8, 2009: Accepted August 3, 2009]