Abstract  The aim of the present study was to investigate the effects of home-based exercise without home visits on physical function, falls, and bone mineral density in community-dwelling elderly women. Sixty community-dwelling, elderly (≥65 years of age) women were recruited from a Japanese community. Subjects were randomly assigned to a home-based exercise group or a control group. The subjects assigned to the home-based exercise group performed home-based exercise without home visits 3 times per week for 6 months in their homes. Assessments of physical function and bone mineral density were conducted before and after intervention in both groups. Muscle strength, gait velocity, the timed up and go test (TUGT), single leg stance time, the bend reach performance test, and reaction time were measured to assess physical function. The patients’ history of falls was also assessed before and after the 12-month follow-up. To determine bone mineral density, the speed of sound (SOS) at the right calcaneus was measured using a quantitative ultrasound device. There were no significant differences between the two groups in baseline characteristics. 82.6% of subjects completed the prescribed exercise program in the home-based exercise group. Compared to the control group, TUGT improved significantly \((p<0.05)\) in the home-based exercise group. Home-based exercise without home visits can be adopted for community-dwelling elderly women, particularly since no specific place or instructor is needed.

Introduction  Hip fractures affect elderly people’s independence in activities of daily living, since the rate of dependence is high following a hip fracture in the elderly (Chrischilles et al., 1991). A previous study reported that, since 1997, the incidence of hip fractures has tended to decrease in Canada and Finland (Jaglal et al., 2005; Kannus et al., 2006). In contrast, the incidence rate appears to have increased in urbanized Asian countries such as Hong Kong and Singapore (Lau et al., 2001). In particular, the incidence rate has been increasing in the last 15 years in Japan (Hagino et al., 2005). Therefore, the prevention of hip fractures is important to maintain community-dwelling elderly people’s independence in their activities of daily living and their quality of life in Japan, since the elderly population has been growing.

The known risk factors for hip fractures include older age, female sex, bone mineral density, falls, and physical function (NIH, 2001). In fact, it has been reported that each 1 standard deviation (SD) decrease in bone mineral density of the lower limbs increased the age-adjusted risk of a hip fracture by 2.0–2.8 times (Cummings et al., 1993); that 96% of hip fractures occurred following a fall (Norton et al., 1997); and that each 1 standard deviation (SD) decrease in gait speed increased the age-adjusted risk of a hip fracture by 1.4 times (Dargent-Molina et al., 1996). Therefore, maintenance of bone mineral density, fall prevention, and improvement of physical function in elderly women should be considered as a strategy to help prevent hip fractures. The evidence suggests that physical exercise maintains bone mineral density, prevents falls, and improves physical function (Gillespie et al., 2003; Wolff et al., 1999; Wallance and Cumming, 2000; Buchner et al., 1997; Hauer et al., 2001; Barnett et al., 2003). However, the cost-effectiveness and feasibility of exercise using machines, such as weight machines or cycle ergometers (Buchner et al., 1997; Hauer et al., 2001), or group-based exercise (Barnett et al., 2003) have not been clearly shown in community-dwelling elderly women. From the standpoint of cost-effectiveness and feasibility, a simple, home-based exercise program is considered to be better for improving physical function, preventing falls, and maintaining bone
mineral density in community-dwelling elderly women. Furthermore, a home-based, exercise program is feasible within their daily activities. However, compliance with home-based exercise tends to be lower than with group-based exercise (Mayoux-Benhamou et al., 2005) and it has been suggested that home-based exercise is less effective than group-based exercise (van der Bij et al., 2002). However, there has been a lack of evidence of the effectiveness of home-based exercise, since there have been few randomized control trials (RCTs) evaluating home-based exercise. Therefore, we tried to develop a simple, home-based exercise program that would be feasible for community-dwelling elderly women. Home-based exercise is less expensive and is expected to be practical for long-term performance. The aim of the present study was to examine the feasibility and effectiveness of the home-based program we developed.

**Methods**

**Subjects**

Sixty community-dwelling elderly women were recruited from 271 women aged 60 years or older who were registered at an employment agency for older people (Silver Jinzai Center) in Kanagawa, Japan. The Silver Jinzai Center is an organization established to provide light work or volunteer activities for older people and to encourage older people to participate in social activities. Therefore, it is presumed that these older people registered at the Silver Jinzai Center have higher levels of competence, social activity, and self-rated health than average elderly persons living at home. The inclusion criteria included: age of 65 years or older; could walk independently without an assistive device; no history of cerebral vascular disease, neuromuscular disease, or fractures in the spine or lower limbs; no restrictions in physical activities; and could give written informed consent to participate in the present study. The exclusion criteria included: cardiopulmonary disease; liver disease; kidney disease; hyperthyroidism; unstable diabetes mellitus; unstable hypertension; medication using prednisolone; and performance of regular exercise. The subjects were randomly assigned to either the home-based exercise group or the control group so as to have an equal number in each pool after they were assessed for the inclusion and exclusion criteria. The random assignment procedure was performed using random numbers generated by a computer program (Microsoft Office Excel 2003, Microsoft Co., Tokyo, Japan). Written informed consent was obtained from all participants. The study was approved by the research ethics committee of the Society of Physical Therapy Science.

**Intervention**

A 1-hour educational session that was followed by instruction in the exercise program was given to introduce the subjects in the home-based exercise group to the exercise program. The educational session included general information about osteoporosis, osteoporotic fractures, prevention of fractures, and the meaning of exercise. Following this, the subjects were instructed about the exercise program for 1 hour by an exercise therapist (an experienced physiotherapist). The home-based exercise program consisted of stretching for the lower limb, strength training for the lower limb, balance training, and impact training, all of which could be performed at home. Stretching was used for warm-up and cool-down before and after exercise, and two lower limb exercises were performed. The subjects used a Thera-Band® for strength training and did four exercises for the hip and knee joints. The strength training in this program was presumed to be of moderate intensity (Sakanoue and Katayama, 2007); it was performed as one or two sets of 15 repetitions of each exercise according to the subject’s ability. Balance training consisted of a stepping exercise. When performing the stepping exercise, subjects stepped forward, backward, right, and left with one leg as quickly and safely as possible. The stepping exercise was performed ten times in each direction for both right and left legs. The heel drop exercise (Bassey and Ramsdale, 1995) was used for impact training. When performing the heel drop exercise, the barefoot subjects raised their body weight onto their toes and then let their heels drop to the floor while keeping their knees and hips extended. The heel drop exercise was performed from 60 to 100 times according to the subject’s ability. The subjects were instructed to complete the exercise program for at least 3 days each week for 6 months. The content and intensity of the program remained the same during the 6-month intervention period.

No exercise therapist visited the homes of the subjects in the home-based exercise group during the intervention period; however, the therapist contacted each subject by telephone or mail every month to maintain their motivation. In the first month of the intervention period, the therapist contacted all subjects in the home-based exercise group and instructed them again on the frequency and content of the exercise program. Furthermore, adherence to the exercise program was confirmed using log sheets, and the subjects were told to fill in their log sheets daily and to mail them to the therapist each month. In addition, a blank section was included in the log sheets for the subjects to ask any questions. The therapist contacted subjects by telephone to answer questions. Adherence was defined as subjects completing the program at least 3 days per week.

The subjects who were assigned to the control group were instructed to continue with their usual daily activities, with no restrictions on their exercise activities. A therapist contacted them every 3 months by telephone or mail.

**Measurements**

Functional capacity, physical function, and bone mineral density were assessed in all subjects in both groups before and after the 6-month intervention. The staff performing the assessments were blinded to each subject’s group assignment. Falls were also assessed before and after the 12-month follow-up.
Functional capacity

Functional capacity was assessed using the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) (Koyano et al., 1991). This index consists of 13 items, and it has been widely used to measure the extent of elderly people’s competence. A higher score indicates higher competence; the maximum score on this index is 13 points.

Muscle strength

The grip strength of the right hand was measured using a dynamometer (GRIP-D, T.K.K. 5401, Takei Scientific Instruments Co., Ltd., Niigata, Japan) in the standing position, and isometric quadriceps strength of the right side was measured using a Hand-Held Dynamometer (μTas F-1; ANIMA Co., Tokyo, Japan) with the subject in the sitting position with the knee and hip joints flexed to 90°.

Flexibility

The bend reach performance test was used to measure muscle flexibility. Subjects were instructed to reach ahead as much as possible by bending the trunk and hip joint while sitting on the floor with their knee joints extended; the distance that the subjects could reach was measured using a specific device (T.K.K.5112, Takei Scientific Instruments Co., Ltd., Niigata, Japan).

Balance

Single leg stance time and the timed up and go test (TUGT) (Podsiadlo and Richardson, 1991) were used to assess balance. For the single leg stance time, the length of time that the subject, keeping her eyes open, could stand on her right leg without hand support or falling was measured using a stopwatch. When performing the TUGT, the subjects were verbally instructed to stand up from a chair without hand support, walk 3 m as quickly and safely as possible, put a cone on the floor, turn around, walk back, and then sit down, as previously reported by Shumway-Cook et al. (2000). The time required to complete the entire sequence was measured using a stopwatch.

Gait time

For gait time, the time required to walk a 10-m course was measured using a stopwatch under two conditions: the first was done at the subjects’ preferred speed; the second was done at the subjects’ fastest speed possible. All subjects wore the same kind of shoes during the test.

Reaction time

General reaction time was used as a measure of reaction time. The subjects were shown a light and asked to jump up as soon as they recognized the light. The reaction time from the stimulus to the jump was measured using a specific device (Type II, Takei Scientific Instruments Co., Ltd., Niigata, Japan).

Falls

Fear of falling, the number of fallers, and the number of falls were assessed. Fear of falling was measured using the modified fall efficacy scale (MFES) (Hill et al., 1996) before and after the 6-month intervention. The number of fallers during the previous 6-month period was collected retrospectively during face-to-face interviews with the subjects before and after the 12-month follow-up. A fall was defined as “unintentionally coming to rest on the ground, the floor, or other lower level; excludes coming to rest against furniture, a wall, or other structure (Buchner et al., 1993).”

Bone mineral density

Bone mineral density was assessed by measuring the speed of sound (SOS) at the right calcaneus using a quantitative ultrasound device (CM-100; FURUNO ELECTRIC Co., Ltd., Hyogo, Japan). SOS is useful as a predictor of hip fractures without the risk of radiation exposure (Fujiwara et al., 2005). The quantitative ultrasound device has an accuracy of ±1% in the % coefficient of variation.

Statistical analysis

Unpaired t-tests were used to compare the baseline anthropometric data (such as height and body weight), functional capacity, SOS, physical function, and MFES between the groups. Paired t-tests were used to compare the before and after intervention results within each group. Differences between the two groups after intervention were compared using analysis of covariance (ANCOVA) adjusted for age, baseline functional capacity, SOS, physical function, and MFES values. Fisher’s exact probability test was used to compare the number of fallers before and after the 12-month follow-up between the two groups. All of the statistical analyses were performed using SPSS for Windows, version 11.0J (SPSS Japan Inc., Tokyo, Japan). The significance level was set at 5%.

Results

Of the 60 subjects initially recruited for the study, 3 were excluded at the time of assessment for eligibility due to: unstable hypertension (n=1); regular exercise (n=1); and inability to follow up due to moving house (n=1). Thus, the remaining 57 subjects were randomly assigned to the two groups: 28 subjects were assigned to the home-based exercise group, and 29 subjects were assigned to the control group.

The subjects’ baseline characteristics are shown in Table 1. There were no significant differences between the two groups in the baseline anthropometric data, functional capacity, SOS, physical function, and MFES (Table 1). Seven subjects dropped out before the 6-month follow-up, and their data were not included in the final data analysis. Reasons for drop-out included moving house (n=2), illness (n=1), loss of interest (n=1), and refusal to allow final assessments (n=3) (Fig. 1). Thus, 23 subjects in the home-based exercise group and 27 subjects in the control group completed the 6-month follow-up. Drop-out rates did not differ significantly between the two groups (Fisher’s exact probability test, p=0.253). Furthermore, there were no significant differences in baseline characteristics between the subjects who completed the follow-up and those who dropped out.

In the home-based exercise group, 19 of 23 (82.6%) subjects...
completed the exercise program at least 3 days per week, and 21 of 23 (91.3%) subjects performed the program at least 2 days per week. No injuries occurred as a result of this home-based exercise program during the intervention period. The subjects in the home-based exercise group were contacted a total of 45 times by telephone and 135 times by mail during the intervention period. The single leg stance time and the TUGT improved significantly after the intervention in the

<table>
<thead>
<tr>
<th>Measure</th>
<th>Home-based exercise group (n=28)</th>
<th>Control group (n=29)</th>
<th>Baseline difference p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>71.0±3.8</td>
<td>70.9±3.4</td>
<td>0.943</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>151.0±5.2</td>
<td>150.3±5.3</td>
<td>0.656</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>53.0±8.0</td>
<td>54.3±8.2</td>
<td>0.550</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.2±2.8</td>
<td>24.1±3.7</td>
<td>0.324</td>
</tr>
<tr>
<td>Speed of sound (m/sec)</td>
<td>1501.8±22.6</td>
<td>1499.0±21.0</td>
<td>0.640</td>
</tr>
<tr>
<td>TMIG-IC† (points)</td>
<td>12.8±0.6</td>
<td>12.6±0.9</td>
<td>0.341</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>23.1±3.8</td>
<td>23.0±2.7</td>
<td>0.861</td>
</tr>
<tr>
<td>Quadriceps strength (N)</td>
<td>271.3±69.0</td>
<td>267.8±72.7</td>
<td>0.853</td>
</tr>
<tr>
<td>Bend reach performance test (cm)</td>
<td>32.7±6.2</td>
<td>32.9±10.5</td>
<td>0.933</td>
</tr>
<tr>
<td>Single leg stance time (sec)</td>
<td>27.3±18.0</td>
<td>22.5±18.8</td>
<td>0.331</td>
</tr>
<tr>
<td>Timed Up &amp; Go test (sec)</td>
<td>5.9±0.9</td>
<td>6.0±0.7</td>
<td>0.605</td>
</tr>
<tr>
<td>Gait time (preferred speed) (sec)</td>
<td>7.4±1.3</td>
<td>7.3±1.0</td>
<td>0.613</td>
</tr>
<tr>
<td>Gait time (fastest speed) (sec)</td>
<td>5.5±0.9</td>
<td>5.4±0.6</td>
<td>0.787</td>
</tr>
<tr>
<td>General reaction time (msec)</td>
<td>477.7±86.9</td>
<td>514.5±120.6</td>
<td>0.194</td>
</tr>
<tr>
<td>Modified Fall Efficacy Scale (points)</td>
<td>137.5±5.6</td>
<td>136.6±7.0</td>
<td>0.575</td>
</tr>
</tbody>
</table>

†: Tokyo Metropolitan Institute of Gerontology Index of Competence

Fig. 1 Flow of subjects through the study.
home-based exercise group (single leg stance time, \( p<0.05 \); TUGT, \( p<0.01 \)), and the MFES score was significantly higher than at baseline (\( p<0.05 \)). In the control group, the TUGT time was shorter after 6 months than at baseline (\( p<0.05 \)). Conversely, the SOS decreased significantly in both groups after the 6-month follow-up (\( p<0.01 \)). Compared to the control group, TUGT in the home-based exercise group improved significantly (\( p<0.05 \)). In contrast, there were no significant differences between the two groups in SOS, single leg stance time, and MFES (Table 2).

With respect to falls in the previous 6 months, the number of fallers was not significantly different between the home-based exercise group (2 of 28) and the control group (4 of 29) at baseline. At the 12-month follow-up, 20 subjects in the home-based exercise group and 23 subjects in the control group completed fall data collection. There had been no falls in the home-based exercise group and one fall in the control group. The falser in the control group had a history of a fall in the previous 6-month period, but had fallen only once. The difference in the follow-up rate between the two groups was not significant (Fisher’s exact probability test, \( p=0.55 \)). There was no significant difference between the two groups in the number of fallers at the 12-month follow-up.

**Discussion**

The results of this study showed that the home-based exercise program without home visits, the purpose of which was to improve physical function, prevented falls, maintained bone mineral density, and improved balance ability in community-dwelling elderly women. In particular, the Timed Up and Go Test (TUGT), as a measure of balance ability, was significantly improved by our exercise program. TUGT has been reported to be associated with falls in community-dwelling elderly persons (Shumway-Cook et al., 2000) and in elderly women with a previous vertebral fracture (Morris et al., 2007). Furthermore, TUGT has been found to comprehensively reflect other physical functions or functional capacity in elderly persons (Podsiadlo and Richardson, 1991). Therefore, the home-based exercise program without home visits performed in the present study may contribute to fall prevention, improvement of other physical functions, or improvement of functional capacity. However, the present study did not show a decrease in falls. Three main factors may be responsible for this result. First, subjects in both groups may have a tolerance to falls, because they already had high functional capacity at baseline (Table 1). Second, the period of the exercise intervention or follow-up could have been too short, because it has been shown in a previous study that long-continuing exercise has an effect on fall prevention in community-dwelling elderly persons (Fujisawa et al., 2007). Third, the small sample size may have affected this result. Therefore, further study involving a larger sample size is necessary to verify the effect of the home-based exercise program without home visits on fall prevention.

There have been some randomized controlled trials of physical exercise interventions for fall prevention or improvement in physical function (Buchner et al., 1997; Barnett et al., 2003; Suzuki et al., 2004). In these studies, strength training using weight machines or balance training was used as the intervention in the group-based exercise program. A place that is easily accessible by public transport and well-trained instructors are needed for the group-based exercise programs evaluated in those studies, and their cost-effectiveness and feasibility among community-dwelling elderly persons are not clear. In contrast, a home-based exercise program without home visits, as in the present study, can solve these problems of place and human resources, and it may solve the problems of cost and feasibility.

In previous studies, Campbell et al. (1997) reported that 1-
year, home-based exercise significantly decreased the fall rate in community-dwelling elderly persons. In addition, there have been some studies on home-based exercise that showed improved physical function in mobility-limited elderly persons or hip fracture patients (Sherrington et al., 2004; Rosie and Taylor, 2007). However, in these studies, physiotherapists or exercise instructors regularly visited the subjects’ homes for the implementation of the program. Even if home visiting were at the minimum frequency, these programs may not solve the problem of human resources, since physiotherapists or instructors are needed for the home visits. King et al. (1991) reported that 1-year, home-based exercise without home visits improved physical fitness. However, the feasibility for elderly persons could not be determined because this study did not include elderly subjects. In the present study, it was shown that home exercise without home visits has a favorable effect on physical function relating to falls in elderly women.

The adherence rate for a home-based exercise program with home visits has been reported to be 66% to 73% in a program lasting 1 year or less (Sherrington et al., 2004; Rosie and Taylor, 2007). On the other hand, the adherence rate in the home-based exercise program without home visits in the present study was 82.6%. Thus, even if home visits are not included in a home-based program, the adherence rate is thought to be maintained at a high level. King et al. (1991) suggested that telephone contact with subjects plays an important role in maintaining adherence. Therefore, in the present study, the subjects in the intervention group were contacted regularly by telephone or mail to maintain their motivation. Maintenance of the exercise program at a high level is considered feasible by regular contact, even if there are no home visits. Furthermore, the adherence rate may be enhanced by expert instruction regarding the significance of the program following the baseline survey. Indeed, an educational program has been shown to have an effect on physical activity in middle-aged and elderly persons (van der Bij et al., 2002), which suggests that an educational program at the time of starting of the program is also important to enhance the adherence rate.

The exercise program used in the present study had no significant effect on bone mineral density. Two main factors may be responsible. First, heel drop training, which was used for impact training in the present study, may not have a sufficient load to enhance bone mineral density. Mechanical stress on bone resulting from physical activity, especially weight bearing or resistance exercise, improves bone mineral density (Turner and Robling, 2005). However, to improve bone mineral density, it is necessary that the mechanical stress is above the threshold that promotes bone formation (Frost, 2001). Consequently, mechanical stress caused by heel drop training may be below the necessary threshold. Second, the findings of previous studies indicate that changes in bone mineral density are produced by long-term exercise interventions that last for at least 1 year (Asikainen et al., 2004). Thus, the 6-month intervention period of the present study may have been insufficient to change bone mineral density.

The present study had several limitations. The studied subjects had high functional capacity and good physical function at baseline; the TMIG-IC scores indicated that both groups had a high functional capacity. As a result, the difference in the TUGT between the intervention group and the control group was modest and may not be clinically significant. Besides, the acceptance of the exercise program in the present study by elderly women recruited from the general population must be interpreted carefully, because the subjects studied were recruited from older people registered at the Silver Jinzai Center and could have been more motivated compared to the general population. Furthermore, since the duration of the study was 6 months, a long-term effect of greater than 6 months could not be assessed. Moreover, adherence to the exercise program may change with long-term follow-up. In addition, due to the small sample size, no hip fractures occurred, so that the effect of the present home-based exercise program on the incidence of hip fracture could not be assessed. Also, the present results are only applicable to elderly women, since elderly men were not studied. However, the results of the present study show that the subjects had a high adherence, and TUGT, a measure that reflects falls or functional capacity, was improved in the home-based exercise program without home visits. Furthermore, the home-based exercise program without home visits evaluated in the present study appears to be useful in community-dwelling elderly women, since they can complete the program without needing a specific place and instructors.

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**References**


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