ORIGINAL ARTICLE

Efficacy of training program for ambulatory competence in elderly women

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(Received for publication on December 15, 2003)

Abstract. The optimal prevention of osteoporotic fractures in the elderly consists of increasing the bone density and preventing falls. We report on the efficacy of training program to promote ambulatory competence in elderly women. Twenty-five elderly women were enrolled in our training program, which is a three-month program consisting of dynamic balance training with Galileo 900 (Novotec, Pforzheim, Germany) once a week, combined with daily static balance (standing on one leg like a flamingo) and resistance (half-squat) trainings. The mean age of the participants was 72.8 years (range, 61–86 years). After 3 months of training, the step length, knee extensor muscle strength, and maximum standing time on one leg were significantly increased, while the walking speed and hip flexor muscle strength were not significantly altered. During the study period, no serious adverse events such as new vertebral fractures or adverse cardiovascular symptoms were observed in any participant. The present preliminary study shows that our training program may have the potential to promote ambulatory competence in elderly women. (Keio J Med 53 (2): 85–89, June 2004)

Key words: elderly women, fall, balance training, strength training, walking ability

Introduction

Fall-related injuries, *e.g.*, hip fractures are serious problems in the elderly with osteoporosis. Osteoporosis is known to be especially common among elderly women. The incidence of spinal fractures increases with age after menopause in women, and the incidence of hip fractures increases exponentially after 80 years of age in elderly women. More than 90% of hip fractures result from a fall.[1] Falls are also becoming increasingly common among the elderly, so that up to 80% of all 80-year-olds sustain at least one fall per year.[2] While the life expectancy of women is higher than that of men, the proportion of those who are functionally independent is higher in elderly women than in men, which is known as the ''gerontologic paradox.'' Thus, prevention of trauma, i.e., injuries by falls would reduce disability, improve the quality of life, and reduce the cost of treatment for fall-related injuries, especially in elderly women with osteoporosis.

Exercise is generally thought to be effective for the prevention of falls in the elderly. However, randomized controlled trials have not consistently shown beneficial effects of exercise on fall prevention,[3–5] and the efficacy of exercise for promoting ambulatory competence and preventing falls in the elderly has not yet been unequivocally established. Strategies for the prevention of falls, as well as for the management of osteoporosis in the elderly still need to be established.

Recently, vibration training has been developed as a new modality in physiotherapy. It has been suggested that vibration training possibly increases muscle power in athletes,[6] and muscle blood volume in healthy adults,[7] and improves muscular performance and body balance in young healthy subjects.[8] Although high-intensity vibration training may increase both the muscle strength and volume in young subjects, we surmise that low-intensity vibration training may have a greater potential to promote ambulatory competence in elderly women with an increased risk of falls, by stimulating the neuromuscular system.[6]

Low-intensity vibration training once a week may be

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safe, easy to practice, and easy to continue in the elderly, and may promote ambulatory competence, including by improving balance and muscle strength, more effectively when combined with daily static balance and resistance training. We report on the efficacy of our three-month training program consisting of once-weekly dynamic balance training with the Galileo system (Novotec, Pfozheim, Germany), combined with daily static balance and resistance training, aimed to promote ambulatory competence in elderly women.

Subjects and Methods

Twenty-five elderly women, who visited our hospital during the 3 months between October and December in 2002, were recruited to our training program. The program consisted of dynamic balance training with the Galileo 900 (frequency, 20 Hz; duration, 4 minutes) once a week, combined with daily static balance training (standing on one leg like a flamingo for one minute: ''Flamingo exercise'') and resistance training (10 sets of half-squats) daily. Tables 1 and 2 show the characteristics and physical fitness of the participants, respectively. The training program was administered for 3 months, and all the participants completed the program. None of the participants experienced any fall during the study period.

All data are presented as means plus/minus standard deviation (SD). The correlation of age with ambulatory competence and grip strength was examined by single regression analysis. The longitudinal changes in the parameters were evaluated by one-way analysis of variance (ANOVA) with repeated measurements. All statistical analyses were performed using the Stat View J-5.0 program (SAS Institute, Cary, NC, USA) on a Macintosh computer. The significance level of $P < 0.05$ was used for all comparisons.

Table 1 Characteristics of Participants

Age (years)	72.8 ± 7.0	(61–86)
Height (cm)	144.7 ± 6.8	(132.2–162.6)
Body weight (kg)	48.3 ± 8.0	(35.9–61.6)
BMI (kg/m^2)	23.0 ± 3.2	(16.7–29.9)
Lumbar BMD (g/cm^2)	0.616 ± 0.118	(0.314–0.785)
T score of Lumbar BMD (%)	61.7 ± 11.9	(31–77)
Number of prevalent vertebral fractures	3.2 ± 3.1	(0–9)
Number of falls during one year prior to the study	0.52 ± 1.26	(0–6)

Data are expressed as means ± SD. Numbers in parenthesis are rangers. BMI: body mass index, BMD: bone mineral density. BMD was measured by dual energy X-ray absorptiometry using a Hologic QDR 1500 W (Bedford, MA, USA). Vertebral fractures were evaluated at the T4–L5 level using the Japanese criteria for vertebral fractures.[9,10]

Table 2 Physical Fitness of Participants

Ten-meter walking time (sec)	11.6 ± 5.2	(5.9–15.2)
Step length (cm)	53.5 ± 9.7	(37.0–76.9)
Maximum torque		
Knee extensor muscle (N)	133.3 ± 28.7	(73–91)
Hip flexor muscle (N)	105.8 ± 30.5	(48–189)
Maximum standing time on one leg (sec)	10.2 ± 13.0	(0–60)
Grip strength (kg)	17.0 ± 4.7	(5.0–29.0)

Data are expressed as means ± SD. Numbers in parenthesis are ranges. The maximum torques of the muscles were measured by Power Track II Commander (Japan Medix, Tokyo, Japan) and grip strength was measured by Smedley's Hand Dynamometer. All parameters were measured three times and the mean values were obtained. All parameters for the extremities were obtained from the non-dominant side.

Results

Figure 1 shows the correlation of age with the ambulatory competence and grip strength. Age was significantly positively correlated with the 10-meter walking time ($r = 0.622$, $p < 0.001$) and significantly negatively correlated with the step length ($r = -0.661$, $p < 0.001$). However, no significant correlation was found between age and the maximum torque of the knee extensor and hip flexor muscles, maximum standing time on one leg, or grip strength.

Figure 2 shows the changes in the ambulatory competence and the grip strength. The step length, maximum torque of the knee extensor muscle, and maximum standing time on one leg were found to have significantly increased by 4.5%, 6.8%, and 72.5%, respectively, while the 10-meter walking time and maximum torque of the hip flexor muscle were not significantly altered. During the study period, no serious adverse events such as new vertebral fractures or adverse cardiovascular symptoms were observed in any participant.

Discussion

The results of the present study showed that the walking speed and the step length were correlated with the age of the subject, and that our training program increased the step length, knee extensor muscle power, and maximum standing time on one leg in the subjects. Age-related decrease in the muscle strength is known to be much more marked in the lower extremities than in the upper extremities,[11] and gait in the elderly is

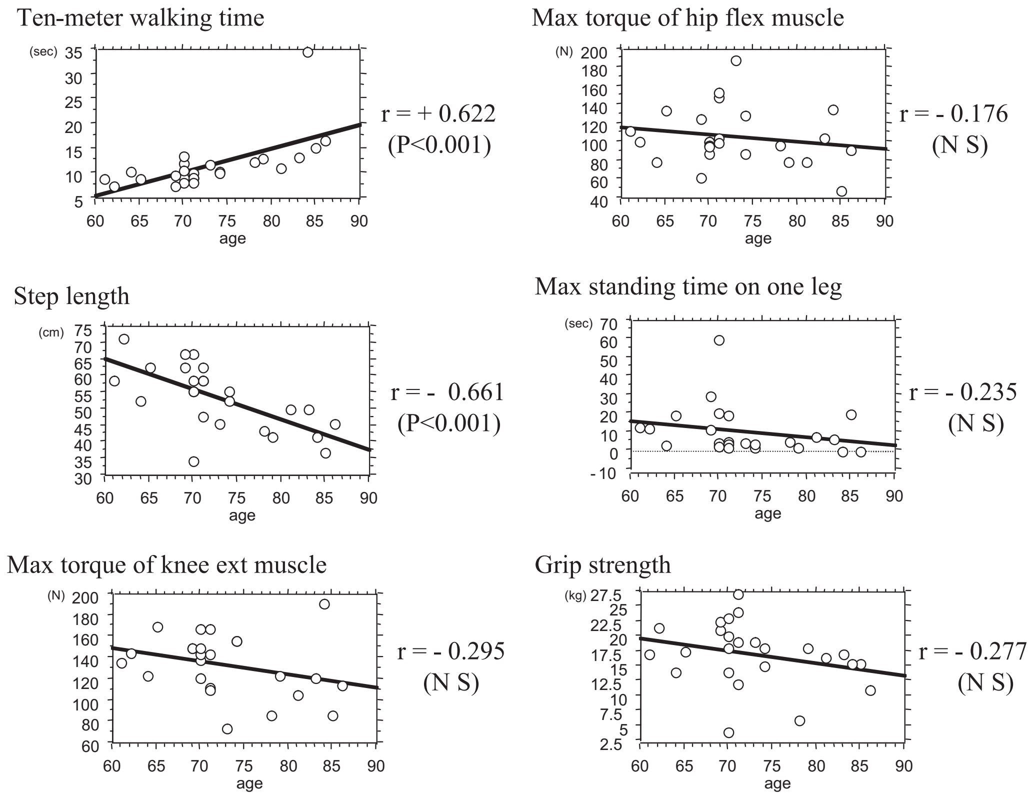

Fig. 1 Correlation of age and physical fitness. The correlation of age with the ambulatory competence and grip strength was examined by single regression analysis. Age was significantly positively correlated with the ten-meter walking time and significantly negatively correlated with the step length. However, no significant correlation was found between age and the maximum torque of the knee extensor and hip flexor muscles, maximum standing time on one leg, or grip strength.

characterized by a decreased step length and step width.[12] Impairment of muscle strength of the lower extremities, balance/postural control, and gait has been found to be important risk factors for falls.[1] While we found age-related impairment of gait in elderly women with osteoporosis, we could not detect any age-related changes in the strength of the knee extensor and hip flexor muscles in these subjects, probably because the sample size in the study was small and younger women without disability were not included.

The optimal prevention of osteoporotic fractures in the elderly consists of increasing bone density and preventing falls. With regard to fall prevention, objective measures of balance and muscle strength that meet the criteria of reliability and validity are required as the bases for exercise regimens. However, randomized controlled trials have not consistently shown beneficial effects of exercise on fall prevention.[3–5] The reason for this may be that the type, duration, frequency, and intensity of the exercise components varied across the studies. In particular, one or more of endurance, resistance, and static and dynamic balance training was administered. Of the balance exercises, Tai Chi has proved to be the most successful for decreasing the likelihood of falls.[13,14]

Whole-body vibration training with Galileo was developed as a new modality in physiotherapy. Galileo is a unique device for applying whole body vibration/oscillatory muscle stimulation. The subject stands with bent knees and hips on a rocking platform with a sagittal axle, which alternately thrusts the right and left leg 0.7–4.2 mm upwards and downwards at a frequency of 20 Hz, thereby stretching of the extensor muscles of the lower extremities. The reaction of the neuromuscular system is a chain of rapid muscle contractions. This type of training provides reflex muscle stimulation to improve balance and possibly the muscle strength, with no serious side effects.

The type of exercise that is considered to be safe, well-tolerated, and sustainable in the elderly, is mild static and dynamic balance, and mild resistance trainings. Based on this view, our training program consisted of once-weekly dynamic balance training using Galileo, combined with daily static balance training (standing on one leg) and resistance training (half-squat training). These training sessions were administered to produce a stable gait, and during the study period, no serious adverse events such as new vertebral fractures or adverse

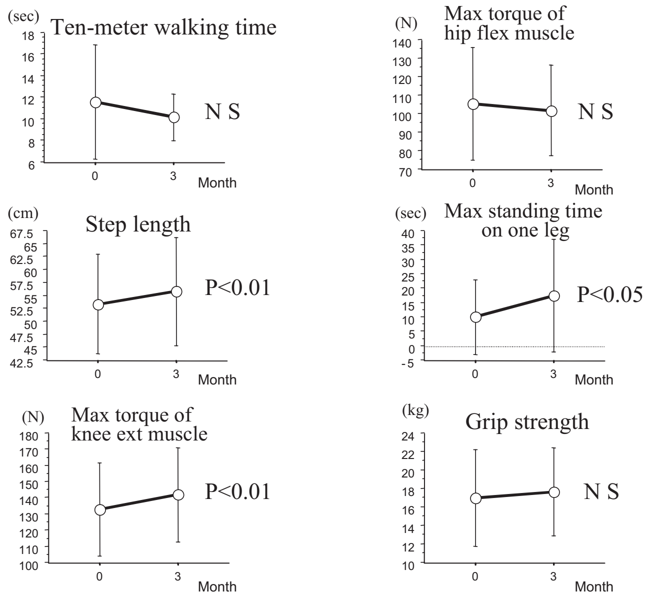

Fig. 2 Changes in physical fitness. All the data are presented as means ± SD. The longitudinal changes in the ambulatory competence and grip strength were examined by one-way analysis (ANOVA) with repeated measurements. The step length, maximum torque of the knee extensor muscle, and maximum standing time on one leg were found to have significantly increased, while the ten-meter walking time and maximum torque of the hip flexor muscle were not significantly altered.

cardiovascular symptoms were observed in any participant.

Our training program increased the step length, knee extensor muscle strength, and maximum standing time on one leg, but no improvements were found in the walking speed or hip flexor muscle strength. We tried to measure the hip abductor muscle strength, but could not obtain any valuable data in most of the participants, because of severe age-related impairment of the hip abductor muscle. With regard to the effect of exercise on the ambulatory competence in the elderly, a few studies have been reported.[1,15,16] Buchner *et al.*[15] reported that the combination of aerobic and anaerobic training in the elderly with mild gait disturbance prevented falls despite no significant improvement of muscle strength and body balance. On the other hand, Runge *et al.*[1] reported that whole-body vibration training with Galileo decreased chair rising time as a result of increased muscle power caused by reflex muscle stimulation in geriatric patients without serious adverse events. Muto *et al.*[16] reported that their original training program consisting of various types of gymnastic training protocols, improved the walking speed and maximum standing time on one leg. Thus, the reported effects of exercise on the ambulatory competence vary among different studies. The reason for this could be the different type of exercise training protocols and different parameters assessed among different studies. Muscle weakness and poor balance underlie most falls, and strength training against resistance and dynamic balance training have been suggested to improve both strength and balance.[3] Thus, combination training with strength and balance training appears to be required to prevent falls.

Because our training program consisted of the combination of three types of exercise training, it remains uncertain which one most significantly improved balance and muscle strength. Half-squat training (resistance training) was aimed at increasing knee extensor muscle strength, while Flamingo exercise (static balance training) was aimed at increasing maximum standing time on one leg. Whole-body vibration training (dynamic balance training) was aimed at stimulating neuromuscular system, promoting balance, and possibly increasing the muscle strength in the lower extremities. Thus, the increases in the knee extension muscle strength and standing time on one leg might have been a result of the combined effects of all three types of training.

On the other hand, the reason for the increase in the step length remains uncertain. Basically, each stride during walking consists of the stance and swing phases. Thus, increased maximum standing time on one leg and knee extensor muscle strength can produce a more stable gait. That is, the more the stance phase of each leg was stabilized by training, the greater the swing of the other leg became, resulting in an increase in step length. Because impaired gait in the elderly is possibly associated with decreased step length, the increased step length may also indicate improved ambulatory competence. In order to significantly increase the walking speed, endurance training using bicycle or walking training might be needed.

The limitations of the present study should be discussed. First, there were no control groups. Thus, only longitudinal changes of ambulatory competence from the baseline were available only in the trained subjects. Second, the sample size might have been too small for detecting the significance of the longitudinal increases in the walking speed. Third, the duration of the training program might have been too short for the efficacy of our program for fall prevention to be unequivocally established. Further studies may be needed to confirm the efficacy of our program for musculoskeletal health in elderly women.

In conclusion, the present preliminary study shows that our training program may have the potential to promote ambulatory competence in elderly women.

Acknowledgments: We thank Drs. Tadashi Ugajin, Koichi Kurakami, Michiko Kameda, and Tistuo Morita for collecting the data on the physical fitness of the participants.

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