ORIGINAL ARTICLE

Effect of whole-body vibration exercise and muscle strengthening, balance, and walking exercises on walking ability in the elderly

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Abstract. **The present study was conducted to determine the beneficial effect of whole-body vibration (WBV) exercise in addition to muscle strengthening, balance, and walking exercises on the walking ability in the elderly. Sixty-seven elderly participants were divided into two groups; the WBV exercise plus routine exercises group (n=40) and the routine exercises alone group (n=27). WBV exercise was performed on a Galileo machine (Novotec, Pforzheim, Germany) at an intensity of 12–20 Hz, for a duration of 4 minutes, once every week. All the participants in both the groups were similarly instructed to undergo routine exercises such as balance and muscle strengthening trainings, and take walking exercise twice a week. The period of this study was 2 months to evaluate the acute effects of WBV exercise. The mean age of the participants was 72.0 years (range, 59–86 years). At baseline, there were significant negative correlations between age and the walking speed, step length, and maximum standing time on one leg. After the 2-month exercise program, the walking speed, step length, and the maximum standing time on one leg were significantly improved in the WBV exercise plus routine exercises group, while no significant changes in these parameters were observed in the routine exercises alone group. Thus, the present study showed the beneficial effect of WBV exercise in addition to muscle strengthening, balance, and walking exercises in improving the walking ability in the elderly. WBV exercise was safe and well tolerated in the elderly.** (Keio J Med 56 (1) : 28–33, March 2007)

Key words: elderly, fall, muscle power, body balance, walking ability

Introduction

Impairment of muscle strength and power of the lower extremities, balance/postural control, and of the walking ability have been found to be important risk factors for falls.[1] These parameters are known to become progressively more impaired with aging, and the age-related decrease in the muscle strength and power are known to be much more marked in the lower extremities than in the upper extremities.[2] Fall-related injuries, including head injuries and fractures, are serious problems in the elderly, as they often lead to prolonged/permanent disability. Thus, prevention of falls and therefore, of the injuries associated with them would reduce disability, improve the quality of life, and reduce the costs of health care.

Exercise is generally accepted to be effective for the prevention of falls in the elderly. A meta-analytic study has demonstrated that exercise is effective for lowering the risk of falls in the elderly and that the consequent reduction in the incidence of fall-related injuries reduces health care costs; however, there is little available information on the costs associated with the program replication, that is, the cost-effectiveness of the exercise programs aimed at preventing falls.[3] With respect to exercise programs that appear to be effective for the above-mentioned purposes, a systematic review has demon-

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strated that muscle strengthening and balance exercises and Tai Chi are effective for preventing fractures in the elderly; the respective relative risk reduction rates for falls with the two exercise programs have been reported to be 20% and 51%[4]; thus, Tai Chi is probably the most effective for decreasing the risk of falls.[4–6]

Recently, whole-body vibration (WBV) exercise has been developed as a new modality in the field of physiotherapy. It has been suggested that WBV exercise increases muscle power and strength and improves muscular performance and body balance.[7,8] These effects of WBV exercise have been recognized immediately after the exercise,[7,8] and seem to be more marked in elite athletes than in non-elite athletes.[9] Thus, WBV exercise may be more effective in subjects with higher neuromuscular performance, and its efficacy still remains to be well established in the elderly. We have previously reported that 3-month WBV exercise combined with balance (standing on one leg) and muscle strengthening (half-squat) exercises improved the step length, knee extensor muscle strength, and maximum standing time on one leg in elderly women.[10] However, this study had no control group, and the effects on walking ability were not distinguished between WBV exercise and balance and muscle strengthening exercises. The present study was conducted to determine the beneficial effect of whole-body vibration (WBV) exercise in addition to muscle strengthening, balance, and walking exercises on the walking ability in the elderly.

Methods

Sixty-seven patients (4 men and 63 postmenopausal women) who visited our clinic (Kawashima Orthopaedic Clinic, Chiba, Japan) between April 2005 and May 2006 were recruited to our trial. The physical activity level at baseline was considered to be low in all of the participants, because none of them were laborers or had been engaged in any sporting activities. They were divided into two groups; the WBV plus routine exercises group (n=40) and the routine exercises alone group (n=27), according to their intention to perform WBV exercise. WBV exercise was performed on a Galileo machine (Novotec, Pforzheim, Germany), at an intensity of 12–20 Hz, for a duration of 4 minutes, once every week. The Galileo machine 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 legs upwards and downwards, thereby promoting lengthening 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 with no serious adverse events. All participants in the both groups were similarly instructed to undergo routine exercises such as balance (standing on one leg and tandem gait) and muscle (the calf, quadriceps, hamstrings, and gluteus medius) strengthening trainings and take a walking exercise (30 minutes) twice a week. The period of this study was 2 months to evaluate the acute effect of WBV exercise in addition to routine exercises on the walking ability in the elderly. Informed consent was obtained from each of the subjects prior to their participation in the study. The study was carried out at Kawashima Orthopaedic Clinic, and the protocol was approved by the Ethical Committee of Kawashima Orthopaedic Clinic.

The data are presented as means ± standard error (SE). Data comparison between two groups was performed by unpaired t-test. Correlations between the age and ten-meter walking time, step length, and maximum standing time on one leg were examined by simple linear regression analysis. The longitudinal changes in the parameters were evaluated by one-way analysis of variance (ANOVA) with repeated measures. All 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

Characteristics of the study subjects

Table 1 shows the baseline characteristics of the study subjects. The mean age of the participants was 72.0 years (range, 59–86 years). There were no significant differences in any of the baseline characteristics between the WBV exercise plus routine exercises group and the routine exercises alone group.

Table 1 Characteristics of the study subjects

	WBV+Routine Ex (n=40)	Routine Ex (n=27)	P values (Unpaired t-test)
Age (year)	71.8±0.9	72.3±1.4	0.7491
Male/Female	1/39	3/24	
10-m walking time (sec)	9.0±0.7	7.3±0.5	0.1001
Step length (cm)	61.2±1.7	65.8±2.1	0.1027
Maximum standing time on one leg (sec)			
Right side	18.3±2.7	18.7±6.6	0.9372
Left side	16.7±2.9	19.6±7.6	0.6714

Data are expressed as means ± standard error (SE). WBV: whole-body vibration, Ex: exercises. There were no significant differences in age, 10-m walking time, and maximum standing time on one leg between the two groups (unpaired t-test).

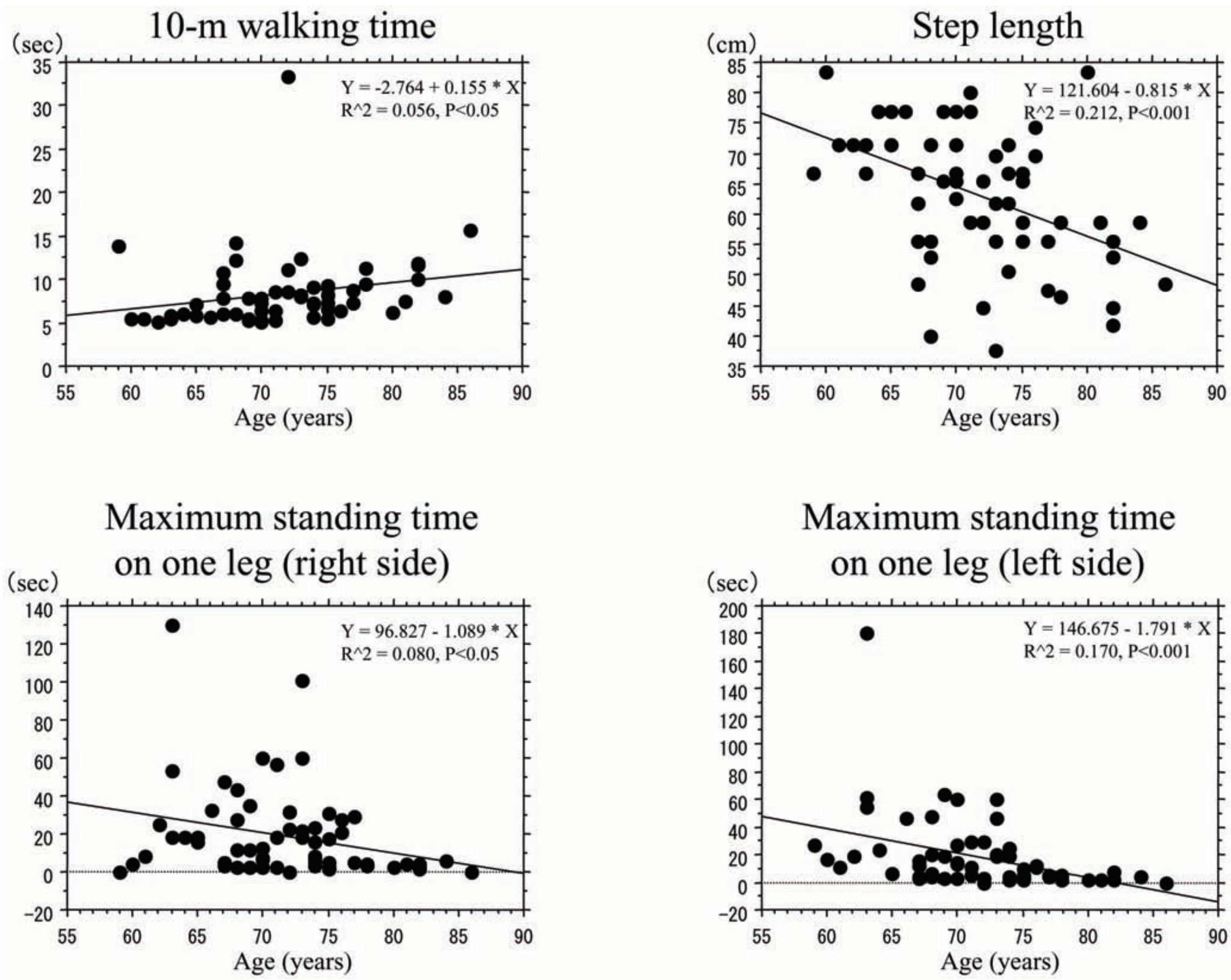

Fig. 1 Correlation between age and the walking ability.
Simple linear regression analysis was used to examine the correlation between age and the walking ability. There was a significant positive correlation between age and the 10-m walking time. There were also significant negative correlations between age and the step length and maximum standing time on one leg.

Correlation between age and the walking ability

Fig 1 shows the correlation between age and the walking ability. There was a significant positive correlation between age and the ten-meter walking time (R^2=0.056, $P<0.05$). There were also significant negative correlations between age and the step length (R^2=0.212, $P<0.001$) and maximum standing time on one leg (right leg, R^2=0.080, $P<0.05$; left leg, R^2=0.170, $P<0.001$).

Effect of WBV exercise on the walking ability

Fig 2 shows the effect of WBV exercise in addition to routine exercises on the walking ability in the subjects. Although the values of ten-meter walking time and step length seem to differ between the two groups because the data are expressed as means ± SE, the differences were not statistically significant as shown in Table 1. After the 2- month program, the ten-meter walking time, step length, and maximum standing time on one leg were significantly improved in the WBV exercise plus routine exercises group, while these parameters did not change significantly in the routine exercises alone group. The percent changes in the ten-meter walking time, step length, and maximum standing time on one leg for the right and left side following WBV exercise plus routine exercises were -14.9%, +6.5%, +65.0% (right side) and +88.4% (left side), respectively. During the study period, no serious adverse events, such as fall-related injuries or adverse cardiovascular effects were observed.

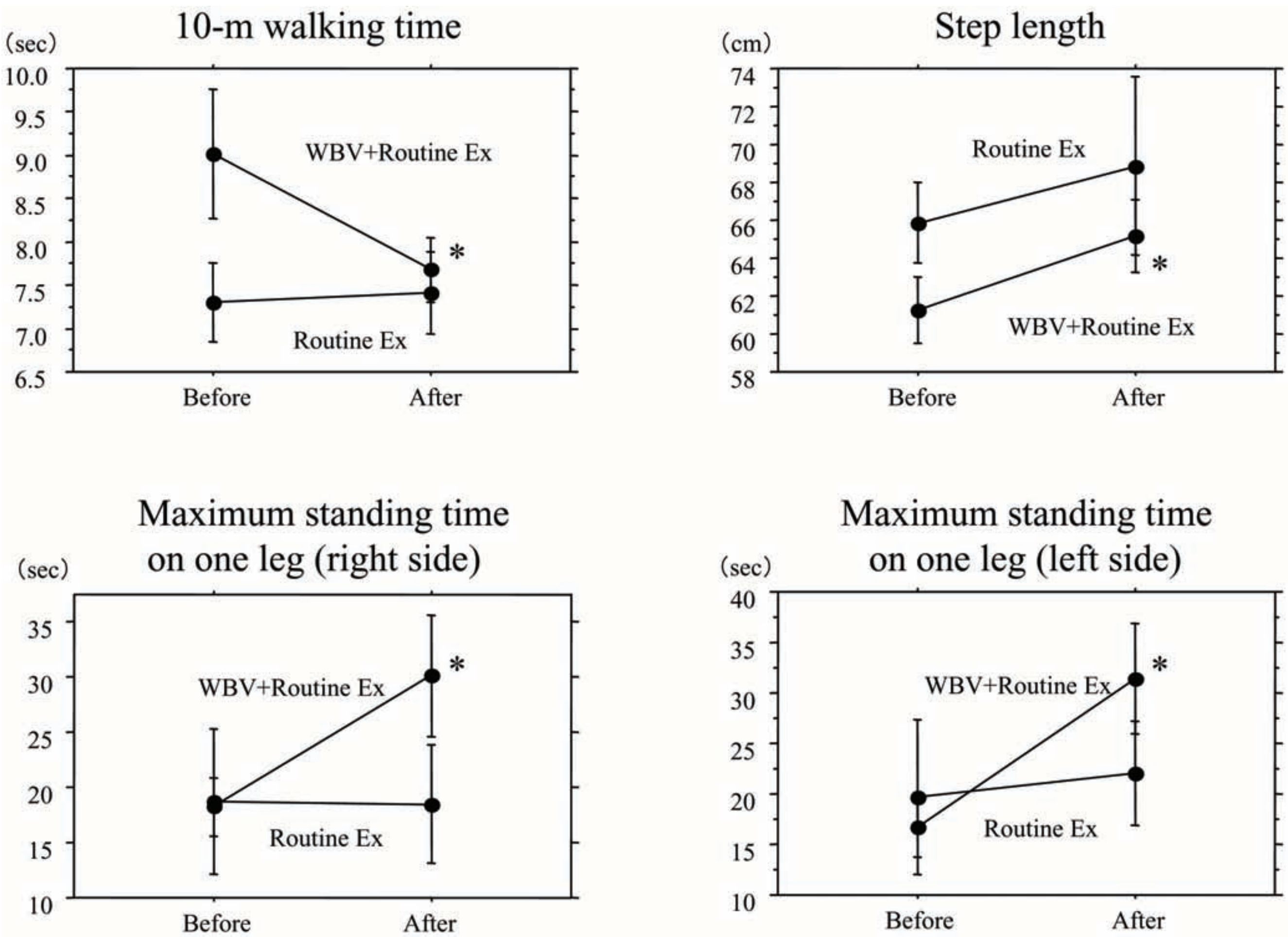

Fig. 2 Effect of WVB exercise on the walking ability.
The data are presented as means ± standard error (SE). Although the values of 10-m walking time and step length seem to differ between the two groups, the differences were not statistically significant as shown in Table 1 (unpaired t-test). One-way analysis of variance (ANOVA) with repeated measurements was used to examine the longitudinal changes in the parameters. After the 2- month program, the 10-m walking time, step length, and maximum standing time on one leg were significantly improved in the WBV exercise group, while these parameters did not change significantly in the control group. * $P<0.05$. WBV: whole-body vibration, Ex: exercises.

Discussion

The present study confirmed the existence of age-related impairment of the walking ability, including the walking speed, step length, and maximum standing time on one leg in the elderly. Muscle strength should be distinguished from muscle power; muscle strength is defined as the force or tension that the muscle can exert against a resistance, while muscle power is defined as the speed of movement or the rate at which a resistance can be moved per unit of time. Because walking speed could be considered as one of the indices of muscle power and maximum standing time on one leg as one of the indices of body balance, our results suggest the existence of age-related impairment of muscle power, step length, and body balance.

A consensus has been reached with respect to exercise programs for the elderly; that is, a combination of muscle strengthening exercises of the back and lower extremities, balance exercises, and walking may be effective to prevent vertebral and non-vertebral fractures.[11] However, our routine exercises alone did not improve the walking speed (an index of muscle power), step length, and maximum standing time on one leg (an index of body balance), suggesting short-term routine exercises such as muscle strengthening, balance, and walking exercises were not always effective for significantly improving the walking ability in the elderly. Although this kind of exercise program is popularly performed for the elderly in many countries, physicians should confirm the efficacy of their own exercise programs and then put them in practice.

However, WBV exercise plus routine exercises significantly improved the walking speed (an index of muscle power), step length, and maximum standing time on one leg (an index of body balance) in the present study, suggesting the beneficial effect of WBV exercise in addition to routine exercises in improving the walking ability. Numerous studies have confirmed the beneficial effects of WBV exercise on the musculoskeletal system. It has been shown to improve the knee extensor strength, vertical jump height (jumping power), chair-rising time, timed up & go, body balance, chronic back pain, and hip bone mineral density, and also to increase the serum levels of testosterone and growth hormone.[1,7–10,12–18] Vertical jumping height, chair-rising time, and timed up & go are considered possibly to be indices of muscle power. On the other hand, our routine exercises were performed aiming at improving muscle strength, body balance, and walking speed (an index of muscle power) in the elderly, although we did not obtain any significant neuromuscular effect of routine exercise alone. The present study showed the short-term beneficial effect of WBV exercise plus routine exercises on a muscle power index in terms of the walking speed, as well as the body balance in the elderly. WBV exercise was well tolerated and no serious adverse events, such as fall-related injuries or adverse cardiovascular effects were observed in any of the subjects during the WBV exercise program.

WBV exercise plus routine exercises also increased the step length, however the reason for this remains uncertain. Basically, each stride during walking consists of the stance and swing phases. Thus, increased maximum standing time on one leg can produce more stable walking. That is, the more the stance phase of each leg was stabilized by the WBV exercise plus routine exercises, the greater the swing of the other leg becomes, resulting in an increase in the step length. Because impaired walking ability is associated with decreased step length,[19] increased step length may also indicate improved the walking ability. Because it is important for the elderly to increase the step length to touch the ground with the heel during walking in order to prevent falls caused by stumbling of toes, we believe that improvement of the step length could also lead to a reduction in the fall risk.

The efficacy of WBV exercise plus routine exercises for walking ability might result from either the effect of WBV exercise itself or the combined effect of two exercises. WBV has been reported to have both beneficial acute and chronic training effects on muscle strength and power enhancement.[9] However, the mechanism underlying the acute effects of WBV exercise on the musculoskeletal system remains uncertain. WBV has been shown to elicit acute hormonal profile and neuromuscular performance responses immediately after the exercise.[8] It has also been reported that low-intensity resistance exercise with vascular occlusion rapidly increases the serum levels of growth hormone, suggesting that certain kinds of exercise may rapidly stimulate the secretion of growth hormone.[20] Thus, one of the possible mechanisms for explaining the acute beneficial effect of WBV exercise plus routine exercises on the musculoskeletal system is the rapid stimulation of growth hormone secretion after WBV exercise, because it has been reported that WBV exercise is associated with increased serum levels of growth hormone and testosterone which have anabolic actions on the muscle, immediately after the exercise.[8] Further studies are needed to confirm this contention.

We applied WBV exercise, at an intensity of 12–20 Hz, for a duration of 4 minutes, once every week, for two months. The intensity was set according to individual ability to undergo the WBV exercise. However, the intensity and frequency might be low and the duration might be short, because this exercise program was simply conducted to determine if the elderly could safely undergo and easily continue the exercise. Therefore, one criticism is that it remains uncertain whether the dose of WBV exercise might be enough to observe an improvement of the walking ability in the present study. Thus, another possible mechanism for explaining the efficacy of WBV exercise plus routine exercises may be that WBV exercise might enhance the effect of routine exercises on the walking ability in the elderly, even if WBV exercise itself did not significantly affect the walking ability.

The limitations of this study should be discussed. First, the study period might have been too short and the age of the subjects too low to arrive at any reasonable conclusion of the beneficial effect of WBV exercise plus routine exercises on the incidence of falls. Flexibility, body balance, and muscle power and strength are important factors that must be considered while evaluating the risk of falls in the elderly.[1] Thus, further studies on older subjects with a longer study period are needed to definitively determine the efficacy of WBV exercise on a Galileo machine in addition to routine exercises on all of these parameters and the incidence of falls and fall-related injuries. Second, this study is not a randomized controlled trial and the choice to have WBV exercise was decided by the patients themselves. Therefore, the motivation to improve the walking ability might have differed between the two groups, and the difference in such attitude to comply the program might have affected the results. Further randomized controlled studies are needed to confirm the results of the present study.

In conclusion, the present study showed the beneficial effect of WBV exercise in addition to muscle strengthening, balance, and walking exercises in improving the walking ability in the elderly. WBV exercise was safe and well tolerated in the elderly.

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