

The effects of balance training and ankle training on the gait of elderly people who have fallen

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Abstract. [Purpose] The aim of this study was to examine the effects of balance training and muscle training around the ankle joints on the gait of elderly people who have experienced a fall. [Subjects] Twenty-six elderly people with a risk of falling and a Berg Balance Scale score of 37 to 50 points who had experienced a fall in the last year were randomly and equally assigned to either a balance training group or an ankle training group. The balance training group received training on a hard floor, training while maintaining balance on a cushion ball in a standing position, and training while maintaining balance on an unstable platform in a standing position; the ankle training group received training to strengthen the muscles around the ankle joints and conducted stretch exercise for the muscles around the ankle joints. [Results] There were significant changes in gait velocity, step length, and stride length in the balance training group after the intervention; there were significant changes in gait velocity, cadence, step time, cycle time, step length, and stride length in the ankle training group after the intervention. In a between-group comparison, the gait velocity of the balance training group showed a significant improvement compared with the ankle training group. [Conclusion] Both balance training and ankle joint training are effective in enhancing the gait ability of elderly people with a risk of falling; in particular, balance training is effective in improving the gait velocity of elderly people who have experienced a fall compared with ankle joint training.

Key words: Elderly people, Balance training, Ankle training

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INTRODUCTION

When a person falls, they drop down to a position on the floor, a lower position than their original body position, because of an abrupt unintentional postural change, except for in the case of falling due to acute paralysis or external force^{1, 2)}. Factors that may trigger a fall include age, gender, changes in physical strength such as balance hypoesthesia, weakened lower limb muscles, reduced flexibility, reduced activities of daily living, visual deficits, peripheral nerve disorders, cognitive impairment, emotional problems like depression, residential environment, drug intake, drinking, urinary incontinence, past history of a fall, arthritis, and chronic diseases like cardiovascular disease^{3–6)}.

Falls are frequent among elderly people⁷⁾. Elderly people who have experienced a fall may suffer from a series of severe complications including hip joint fractures, which increase their morbidity and mortality rates and waste medical resources⁸⁾. Among the diverse methods of preventing falls, regular and appropriate exercise slows down decreases in

physical strength such as balance ability, muscle strength, and flexibility³⁾, and exercises that prevent falls are known to reduce their frequency^{9–12)}.

Balance is a dynamic phenomenon that requires stability and mobility to be in good harmony, and in order to properly maintain body balance, the ability to integrate the neurological and musculoskeletal systems is important¹³⁾. All the stimuli coming from various sensory receptors such as visual sensory, somatic sensory, proprioceptive, skin, joint, and vestibular sensory receptors are integrated in different levels of the central nervous system, affecting an individual's ability to maintain balance through efficient muscle tone, muscle strength and endurance, and flexibility of the joints^{14, 15)}.

Recovery of balance according to postural sway is achieved by an ankle strategy, a hip strategy, or both strategies in combination¹⁶⁾. An ankle joint strategy is ordinarily used when there is a small amount of body sway on a solid base of support. It is the first postural adjustment strategy to be used and refers to primarily recovering upright standing balance through muscular contraction of the ankle joints^{13, 17, 18)}. Training programs to ameliorate balance include aerobic, muscle strengthening, and balance exercises. Balance exercise programs include aerobic exercise for the purpose of improving stability, exercise to enhance muscle strength, and a method to ameliorate balance using different sensory inputs¹³⁾.

Research on gait stability is deeply related to research on

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falls. In study of falls associated with age, the postural sway that appeared when maintaining postural balance became serious, and the stability limit significantly decreased¹⁹). As individuals age, the step width and gait speed in the gait process decrease, and the double-support stance phase during the gait cycle lengthens. Such growth in the double-support stance phase increases the step width, which is related to gait instability and is a factor for falls^{20, 21}). In addition, a reduction in gait speed in elderly people means that their ability to perform movement in ordinary life decreases²²). In order to enhance gait stability, lower limb muscle strength training and balance training are frequently used. Previous research in which elastic resistance exercises were applied to the lower extremities for 14 weeks showed that an elderly group that conducted such exercises saw greater improvements in gait speed and ankle flexor muscle strength than an elderly group that did not conduct such exercises²³). In addition, resistance and balance exercises changed the gait patterns of elderly people who had experienced a fall^{24, 25}). Most prior studies have concerned fall prevention or balance ability improvements. In this study, balance training and muscle training were applied around the ankle joints by changing the base of support to improve the balance ability of elderly people who have already experienced a fall, and the authors examined how such training affected their gait ability.

SUBJECTS AND METHODS

The Subjects for this research were selected from the patients of a retirement community located in Youngdeok-gun, Gyungbuk, South Korea during the period of January 4 to February 28, 2014. The criteria for inclusion were as follows: those who had not participated in any regular exercise program for the past six months, those who had no special disease that may affect the experiment, those who had normal cognitive function with a mini-mental state examination-Korean version score of 24 points or higher, and those with a Berg Balance Scale score of 37 to 50 points. Twenty-six elderly people who had experienced a fall in the past year were selected as the subjects for this study. All of the subjects were given an overview of the study and participated after providing consent. The Ethics Committee of Namseoul University, South Korea, also approved the study. The IRB approval number is Research-131104-2. The general characteristics of subjects are provided in Table 1.

The subjects received either a balance training program or an ankle training program three times per week, 50 minutes per time, for eight weeks. A balance training program aimed at improving balance was applied by referring to the methods presented by Lee²⁶) and Park²⁷). It consisted of warm-up exercise for five minutes, balance training for 30 minutes, and cool-down exercise for five minutes. The main portion of the training was composed of exercises performed while standing on a hard floor (slowly raising and lowering both heels, raising and lowering the front parts of both feet, and alternately standing on one leg); an exercise consisting of maintaining your balance while standing on a cushion ball; and an exercise consisting of maintaining

Table 1. General characteristics of the subjects

	BEG (n=13)	AEG (n=13)
Sex (male/female)	3/10	3/10
Age	73.0±3.9	73.4±3.8
Weight (kg)	56.0±4.3	57.69±4.3
Height (cm)	159.2±3.4	159.15±4.3
MMSE-K	24.7±0.8	24.6±0.6
BBS	43.0±2.3	42.8±3.2

Values are means ±SD. $p < 0.05$.

BEG: balance exercise group, AEG: ankle exercise group

your balance while standing on an aero step. The exercise done on a hard floor was done in two sets, each for three minutes. The subjects were instructed to keep their eyes open for one set and closed for the other set. They did two sets of the exercises on the cushion ball and the aero step, each set taking two minutes. After each set, they sat on a chair and rested for two minutes. The ankle training program was comprised of warm-up exercise for five minutes, an ankle training exercise for 30 minutes, and cool-down exercise for five minutes. For the main exercise, the subjects conducted muscle stretch exercises around the ankle joints for fifteen minutes each time and then muscle resistance exercises around the ankle joints for fifteen minutes each time. For the stretch exercise, the subjects conducted static stretching of the ankle dorsiflexor and ankle plantarflexor. They performed resistance exercises using yellow (resistance power of 1.0 kg when extended by 40 cm) and red (resistance power of 1.6 kg when extended by 40 cm) elastic bands 30 minutes per day. Considering that they were elderly people, the exercise intensity was set with the rating scale of perceived exertion at 13 to 14.

A GAITRite system(CIR Systems Inc., Clifton, NJ, USA) was used to measure gait performance. All of the subjects in both groups rested for 30 minutes before and after the training, and their gait ability was measured after practicing their gait twice at their own speed.

SPSS 18.0 was used for data analysis. In order to compare gait performance prior to and after the exercises in each group, a Wilcoxon signed-rank test was conducted; in order to compare the gait performances of the two groups, a Mann-Whitney U test was carried out. The statistical significance level was set at $p < 0.05$.

RESULTS

A comparison of gait ability according to training indicated that the balance training group had statistically significant changes in gait velocity, step length, and stride length and no statistically significant changes in step time and cycle time ($p < 0.05$) (Table 2). The ankle training group had statistically significant changes in gait velocity, cadence, step time, cycle time, step length, and stride length ($p < 0.05$) (Table 2). According to a comparison of between-group differences, the balance training group showed a statistically significant improvement in gait velocity compared with the ankle training group.

Table 2. Comparison of the gait performance of the postural strategy and ankle joint exercise groups

	BEG		AEG	
	Before	After	Before	After
Gait velocity (cm/sec) **	76.5±1.4	93.8±1.9*	81.4±2.3	88.8±2.6*
Cadence (steps/min)	103.8±2.3	99.0±1.3*	107.7±2.1	96.9±1.0*
Step time Lt (sec)	0.5±0.0	0.6±0.0	0.5±0.0	0.6±0.0*
Step time Rt (sec)	0.5±0.0	0.6±0.0	0.5±0.0	0.61±0.0*
Cycle time Lt (sec)	1.1±0.0	1.2±0.0	1.1±0.0	1.2±0.0*
Cycle time Rt (sec)	1.1±0.0	1.2±0.0	1.1±0.0	1.2±.01*
Step length Lt (cm)	44.2±1.0	57.0±1.2*	45.6±0.9	55.1±1.1*
Step length Rt (cm)	44.5±1.1	56.6±1.2*	44.9±0.8	54.4±1.2*
Stride length Lt (cm)	89.1±2.0	113.9±2.3*	90.8±1.7	110.0±2.3*
Stride length Rt (cm)	88.3±2.1	113.2±2.4*	90.4±1.8	109.3±2.3*

Values are means±SD, * $p < 0.05$, significant difference between before and after training, BEG: balance exercise group, AEG: ankle exercise group

DISCUSSION

Falls are a major cause of deaths in elderly people, and those who have experienced a fall once are afraid of falling again, which results in decreased activity²⁸). Therefore, it is crucial to enhance the movement of elderly people who have experienced a fall through exercise. To improve their balance ability and basic gait, aerobic exercise and other diverse exercise methods aimed at increasing balance and muscle strength need to be applied²⁹). Accordingly, this study examined the effects of balance and muscle exercises targeting the ankle joints on the gait of elderly people who have experienced a fall.

A comparison of gait ability according to training demonstrated that there were statistically significant differences in the gait velocity, step length, and stride length of the balance training group ($p < 0.05$). In the ankle training group, there were statistically significant differences in gait velocity, cadence, step time, cycle time, step length, and stride length between before and after the training ($p < 0.05$).

In general, gait speed may be affected by neurological control of such things as balance ability and physical and physiological characteristics like reciprocal coordination of the lower limb muscles and vital capacity³⁰). Moreover, improving muscle functioning through regular exercise increases the number of steps and gait speed^{31, 32}). Persch et al.³³) reported that a 12-week lower limb muscle strength training program enhanced muscle strength, which resulted in gait speed being improved by 11.1% and gait ability being improved by 44%. In the present study, similar to previous research results, the gait velocity of the balance and ankle joint training groups increased after eight weeks of exercise. Steadman et al.³⁴) noted that reduced balance ability in elderly people was related to reductions in gait velocity and balance ability. In the present study, the gait speeds of both the balance training group and the ankle joint training group increased, and the eight-week exercise programs had a positive effect on balance in the elderly subjects.

In the gait, increases in cadence, step length, and stride length affect the increase in gait speed³⁵). Coa et al.³⁶) observed that the reason elderly people's gait speed decreases is because their step width decreases. Ferrandez et al.³⁷) re-

ported that reductions in step width negatively influenced other aspects of gait—decreases in arm swing and rotation of the hip, knees, and ankles—and lengthened double-limb support time, triggering reduced gait speed. According to the present findings, the balance training group had increases in step length and stride length, and the ankle joint training group experienced improvements in cadence, step length, and stride length. In both groups, gait velocity increased, consistent with previous research results.

According to the between-group comparison, there were statistically significant changes in the gait velocity of the balance exercise group relative to the ankle joint exercise group ($p < 0.05$). Balance ability and gait ability are known to have a high correlation³⁸). Continuous postural adjustment is necessary between one lower limb and the other and between the lower extremities and the upper extremities on a base of support that is unstable and changes during gait³⁹). Among the activities of daily living, gait is one that is performed at different speeds and in diverse directions, not just in one direction. A change in gait direction slows forward motion and triggers movement in a new direction, and balance should be well controlled to prevent falling and to maintain a stable gait in the new direction and speed⁴⁰). Balance during gait is an important element, and therefore the balance exercise group's gait speed increased significantly more than that of the ankle joint exercise group.

This study has several limitations. The number of subjects was small, and various physical traits of the subjects were not sufficiently taken into account; therefore, it will be difficult to generalize the results to all elderly people. Besides, the variety of chronic diseases was not considered, and the effects of chronic degenerative physical traits cannot be excluded. The subjects of this study were elderly people who were able to independently walk without aid. However, physical capabilities such as visual perception ability or space perception ability that may have affected the results were not taken into consideration. Accordingly, future research that reflects individual traits should be carried out on the association between physical characteristics and functional levels and should utilize a larger number of subjects over a longer time period.

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