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Original Article

The effects of stepper exercise with visual feedback on strength, walking, and stair climbing in individuals following stroke

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Abstract. [Purpose] This study investigated the effect of stepper exercise with visual feedback on strength, walking, and stair climbing in stroke patients. [Subjects] Twenty-six stroke patients were divided randomly into the stepper exercise with visual feedback group (n = 13) or the stepper exercise group (n = 13). [Methods] Subjects in the experimental group received feedback through the mirror during exercise, while those in the control group performed the exercise without visual feedback; both groups exercised for the 30 min thrice per week for 6 weeks. The hip extensor and knee extensor strength, 10-m walking test results, and 11-step stair climbing test results were evaluated before and after the intervention. [Results] The stepper exercise with visual feedback group showed significantly greater improvement for hip extensor strength and the 10-m walking test. The knee extensor strength and 11-step stair climbing in both groups showed significantly greater improvement after the intervention, but without any significant difference between groups. [Conclusion] The findings of this study indicate that the stepper exercise with visual feedback can help improve the strength of the hip extensor and the 10-m walking test; the stepper exercise alone may also improve the knee extensor strength and stair climbing ability.
Key words: Stroke, Stairs, Visual feedback

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INTRODUCTION

Loss of functional movement is a common consequence of stroke[1)]. Therefore, the activity level of stroke patients is reduced, which further reduces muscle tone[2–29)]. The loss of a normal degree of strength is an important factor that limits the functional activity of these patients[3)]. Strengthening exercises, such as walking and stair climbing, have been reported to improve functional movement[4)]. Stair climbing has been used as an important measure in the evaluation of the active independent and community lives of stroke patients[5)]. However, when the stair climbing and walking activities of these patients were evaluated, lack of strength, coordination, balance, and physical activity were found to be the most common problems they faced[5–28)]. For patients to successfully climb stairs, they must strengthen the appropriate muscles to improve the balance ability of the lower extremities[6)]. Another method adopted for improving motor function was that of combining treadmill training with repetitive training; further, strength training exercises along with aerobic exercise or task-oriented exercises were found to lead to improvements in functional behavior, such as walking or stair climbing[7–9)].

The most common interventions used for the rehabilitation of stroke patients include training on several exercise bikes and treadmills[10–13)]. However, when measuring the exercise intensity (i.e., the rated perceived exertion (RPE)), the energy consumption ratio of stationary bike training was found to be lower than that of the stepper exercises and treadmill training. In other words, stepper or treadmill training exercises are equally effective[14)]. Strength training of the muscles is necessary for carrying out the stair climbing function as well as maintaining the correct gait; aerobic exercise has also been found to improve a person's stair climbing ability[7)].

Therefore, we proposed a training program featuring a combination of aerobic exercise and strength training involving stepper training for climbing stairs. Stepper training engages the hip joint, so it increases lower extremity strength[13)]. However, stroke patients find it difficult to perform new exercises, including stepper training. Stroke patients may need to relearn various movements[15)]. Learning efficient movement is an important factor for improving sensory feedback and repetition[16)]. Due to inherent damage to the intrinsic feedback mechanism in stroke patients, extrinsic feedback assumes an important role in motor learning.

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Visual feedback and extrinsic feedback improve movement performance, thereby increasing the efficacy of rehabilitation interventions[17, 18].

Thus, the purpose of this study was to investigate the effect of the stepper exercise with visual feedback on lower extremity strength and functional movement of patients with stroke.

SUBJECTS AND METHODS

This study followed a 2-group pre-test-post-test design. Patients were divided randomly into the 2 groups to minimize the likelihood of bias. Thirty patients with stroke were recruited at the Stroke Rehabilitation S Hospital in Seoul. This study was approved by the Ethics Committee of Sahmyook University. Before the experiment began, participants were provided with sufficient explanation about the study. All participants signed an informed consent form. The inclusion criteria were as follows: unilateral stroke that occurred 6 months prior to the study; the ability to perform 10-m independent gait and independent stair climbing; no sight impairment; and Mini-Mental Status Examination (MMSE) score of over 24 points. The exclusion criteria were orthopedic, medical, and/or painful conditions; aphasia; cardiovascular disease, and previous participation in a similar experiment.

The pre-tests included a 10-m walking test and the climbing of 11 stairs. The Borg's scale was used to measure the intensity of the exercise.

All participants performed the stepper exercise for 30 minutes, thrice per week for 6 weeks. The participants were divided into the stepper exercise (SE, n = 13) or the stepper exercise with visual feedback (SEV, n = 13) group. The SEV group performed the exercise in front of a full-length mirror and watched their own movements in the mirror; another mirror was placed behind them so they could view the placement of their foot on the foot pedal. Both groups performed the exercise for the same amount of time and at the same intensity. All the participants performed the 30-minute stepper exercise, thrice per week for 6 weeks.

SPSS version 19.0 software was used for statistical analyses. The pre-test data of the subjects were subjected to normality tests. The t-test and Mann-Whitney U test were used to compare the participants' characteristics. The paired t-test compared values obtained before and after the intervention exercise. Data were also analyzed using the independent t-test to examine differences in the results between the SEV and SE groups. Statistical significance was set at $p < 0.05$.

RESULTS

While 30 subjects were recruited, only 26 (SEV group, 13; SE group, 13) participated in this study. The demographic and clinical characteristics of the 2 groups did not differ significantly (Table 1). The data regarding hip joint muscle strength, the 10-m walking test, and stair climbing, both within groups and between groups, are summarized in Table 2. Significant improvements were noted in the non-paralyzed hip joint strength and also for the paralyzed hip joint strength of the SEV group ($p < 0.05$) as well as the 10-m walking and 11-stair climbing tests ($p < 0.05$).

Table 1. Characteristics of study participants

Parameters		SEV (n=13)	SE (n=13)
Age, years		71.9 (6.92)	69.8 (9.76)
Weight, kg		55.4 (9.00)	56.5 (6.00)
Height, cm		156.3 (8.44)	156.9 (9.59)
Disease duration, months		13.8 (6.96)	11.2 (5.35)
MMSE-K		26.8 (1.74)	25.6 (1.94)
Gender	Male	3 (23%)	4 (31%)
	Female	10 (77%)	9 (69%)
Case of disease	Cerebral infarction	8 (62%)	10 (77%)
	Cerebral hemorrhage	5 (38%)	3 (23%)
Attack site	Right	7 (54%)	4 (31%)
	Left	6 (46%)	9 (69%)

Values are mean (SD), MMSE-K: Mini-Mental State Examination Korea; SEV: stepper exercise with visual feedback; SE: stepper exercise

DISCUSSION

The stepper exercise was performed on the p-bar to ensure that the patients were safe, as this method allowed them to support themselves using both hands. The SEV group received visual feedback by means of mirrors placed in the front and rear. The front mirror enabled the participants to check the alignment of the trunk when performing the exercise, while the rear mirror allowed them to verify that they were using the stepper pedal correctly[7]. The SEV group showed significant improvements in the hip joint muscle strength of both the paralyzed and non-paralyzed sides, and the strength of the hip joint extensor muscle showed more improvement in the SEV group than the SE group. After the stepper training, both groups confirmed the activation of the hip joint extensor muscle[13]. However, this study only identified significant improvement in the hip joint extensor muscle in the SEV group.

Treatment using the mirror was the result of extensive research on the recovery of patient upper extremity function and pain[19–21]. Only 2 previous studies have reported the recovery of the exercise capacity of the lower extremity involving exercises with visual feedback, such as the use of a mirror[22]. First, the patients were moved to the non-paralyzed side of the mirror to influence the attack side, which compensated for the proprioceptive sensory loss[23]. Second, watching one's own movement in the mirror stimulates the mirror neuron system[24]. The visual-motor neuron, a neuron of the mirror neuron system, is activated when observing motion and motion execution. The mirror-neuron system generally involves learning through visual observation. Therefore, the present study aimed to activate the visual feedback using a mirror, where patients could observe their movements in the mirror, thereby increasing the efficacy of the stepper exercise. In particular, the rear mirror's location helps patients visualize their exact steps, thereby inducing the benefit of the hip joint extension movement of the stepper and strengthening the hip joint extensor muscle[13].

Table 2. Comparison of hip joint extensor muscle, knee joint extensor muscle and 10 m walking test and 11stair climbing test

Parameters		Values				Change Values	
		SEV (n=13)		SE (n=11)		SEV (n=13)	SE (n=11)
		Pre	Post	Pre	Post	Post-pre	Post-pre
Muscle strength (kg)							
HJEM	NA	7.58 (2.09)	9.15 (3.09)**	8.59 (2.22)	8.88 (2.08)	1.57 (1.84)*	0.29 (1.21)
	A	4.32 (1.99)	6.35 (1.99)***	5.07 (1.94)	5.68 (2.27)	2.03 (1.64)*	0.60 (1.75)
KJEM	NA	8.08 (2.44)	10.20 (3.18)**	8.59 (3.43)	9.99 (2.72)*	2.12 (2.57)	1.40 (2.25)
	A	5.01 (2.54)	6.35 (2.44)*	495 (2.86)	6.17 (3.15)**	1.35 (2.10)	1.22 (0.95)
10 m walking test (m/s)		0.46 (0.25)	0.62 (0.24)***	0.48 (0.28)	0.53 (0.34)*	0.15 (0.15)*	0.05 (0.08)
11 stair climbing test (second)		34.39 (16.41)	25.44 (15.15)***	37.11 (20.29)	32.62 (19.17)**	−8.95 (8.79)	−4.49 (5.76)

Values are mean (SD), *p<0.05, **p<0.01, ***p<0.001
SEV: stepper exercise with visual feedback; SE: stepper exercise; HJEM: hip joint extensor muscle; KJEM: knee joint extensor muscle; NA: non paralyzed-side; A: Affected-side

After the training, there was a significant improvement in the knee joint extensor muscle strength in both the SEV and SE groups but no significant difference between the groups in this regard. In a previous study on stroke patients that involved a stair climbing exercise, the exertion of the hip joint extensor muscle and muscle strength consumption of both sides of the knee joint extensor muscle, ankle joint, and plantar flexor muscle of the non-paralyzed side were higher than that reported in our study[25)]. The stepper exercise is similar to stair climbing, leading to strengthening of the knee joint extensor muscle. The stepper exercise with visual feedback was found to be more effective in strengthening the hip joint extensor muscle than the stepper exercise alone.

Improved muscle strength based upon changes in the functional activity was examined to investigate the walk test and the 11-stair climbing task. To determine the effectiveness of the exercise program, the participants were subjected to the 10-m walk test; both groups showed a significant increase in the results compared to the pre-test data. However, the improvement was higher in the SEV group than in the SE group. In another study, the increase in the walking speed of stroke patients was thought to be caused by improved muscle strength; approximately 75% of the improvement in walking speed was attributed to muscle strength training and an increase in the strength of either the hip joint extensor muscle, the ankle joint planter flexor muscle, or both[26)]. The significant difference in the walking speed between the SEV and SE group in the 10-m test is thought to have been caused by improvement in bilateral hip joint extensor muscle strength. To examine the different functional changes, the participants were also subjected to an 11-step stair-climbing test; both groups showed a significant increase in the test results after the exercise program, but there were no significant differences in the scores between the 2 groups. In a previous study on cardiorespiratory capacity reduction of chronic stroke patients, it was shown that the patients found it extremely difficult to climb stairs[25)]. Another study reported that more specialized training was needed in these patients to improve functional movements, such as climbing stairs[27)]. In yet another study, stair climbing combined with strength training was found to improve the patients' ability to climb stairs[7)]. However, the stair climbing performance of patients from a previous study was compared the experimental and control group. As a result, the hip joint extensor muscle strength costs were similar. Both sides of the knee joint extensor muscle and the non-paralyzed side of the dorsiflexor muscle strength costs were also higher[25)]. Thus, in both groups, a significant improvement was observed in the 11-step stair-climbing test results owing to an improvement in the knee joint extensor muscle and the cardiovascular effects of the stepper exercise, albeit with no significant difference in the scores between the 2 groups. The reason behind this observation could be that the hip joint extensor muscle was not improved to a great extent despite the enhanced visual feedback with the use of the mirror[25)].

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