Original Article

The effect of step climbing exercise on balance and step length in chronic stroke patients

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Abstract. [Purpose] The objective of this study was to examine the effect of step climbing exercise on the walking ability of stroke patients. [Subjects and Methods] Among hospitalized stroke patients, 24 were selected based on the study criteria and randomly divided into two groups: an experimental group (12 patients) and a control group (12 patients). The patients in both groups participated in 15-minute exercise sessions three times a week for eight weeks. To analyze the effect of the exercise, muscle strength, the Timed Up and Go test, and step length were measured before and after the exercise. [Results] step climbing exercise improved the muscle strength in the lower limbs of the stroke patients, as well as their Timed Up and Go results and step lengths. [Conclusion] The effects were similar to a stair gait exercise, and thus, step climbing may be more broadly applied to the treatment of stroke patients.
Key words: Stroke, Step climbing, Muscle strength

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INTRODUCTION

After a stroke, a hemiplegic stroke patient experiences symptoms such as weakened muscle strength, stiffness, pain, language disability, and circulation problems as well as functional problem with walking, walking up the stairs, standing up, turning around, and maintaining balance[1)]. Walking ability is a key indicator of a hemiplegic patient's advanced motor functions and his or her recovery[2, 3)]. Enhancing independent walking ability is among the primary goals of treatment. Recovery of walking ability in the rehabilitation program is important because walking is a complex form of exercise that requires a high level of harmony among coordination, balance, kinesthetic sense, proprioception, and integrated working of joints and muscles. Walking is also among the important indicators of independent functionality[4, 5)]. Recovering and improving walking ability is a key goal and plays an important role in rehabilitation of stroke patients so that they can eventually return to the workforce and society[6)]. in Particular, walking up and down stairs is a basic activity in daily life, but only 5–25% of stroke patients are capable of this activity when they are discharged from a rehabilitation center[7)]. A Stair gait exercise is among the exercises that strengthen the lower limbs of stroke patients, and it is frequently used for transportation and walking on flat ground. Compared with flat-area walking, stair climbing requires more energy and muscle strength in the lower limbs, as it involves horizontal movement and vertical ascent at the same time, while keeping the body balanced. These days, steppers are widely used for lower limb exercise and rehabilitation, which has benefit of reducing stress on the knee joints[6, 8)]. They are also recommended for use in aerobic exercise similar to stair walking, which builds muscle strength[9)].

However, few studies have been conducted on the effect of step climbing on stroke patients. In this paper, we examine the effect of step climbing and stair gait exercises on walking in stroke patients to determine determine a more effective therapy for the rehabilitation of stroke patients.

SUBJECTS AND METHODS

For the study, 24 stroke patients were selected who had had hemiplegia for six months or longer, had been diagnosed based on CT or MRI scanning at S Hospital in the city of Daegu, and were capable of independent indoor walking a supporting device, which indicates the capability to understand and follow the researcher's instructions. The participants were given an explanation of the research purpose and provided consent prior to the study. Among the 24 participants, 12 were randomly assigned to a step climbing exercise group, and 12 were randomly assigned to a stair gait exercise group.

Their average duration of disease was 35.04±13.99 months, their average height was 161.8±11.9 cm, and their average weight was 58.08±7.76 kg. Subject characteristics were homogeneous at baseline ($p>0.05$).

The two groups participated in the training three times a week for a total of eight weeks. Each session lasted 15 minutes and began after basic exercise therapy. The step

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Table 1. Comparison of muscle strength, TUG time, and step length

		Before	After	Difference	Difference between groups	Before
Muscle strength	RF	SC	6.42±1.06	8.05±0.89	1.63±0.53*	0.00*
		SUD	6.59±1.83	7.2±1.74	0.61±0.43*	
	GCM	SC	3.76±1.02	5.0±0.91	1.24±0.45*	0.22
		SUD	4.98±1.43	6.5±1.55	1.51±0.6*	
	TA	SC	3.53±1.16	4.9±1.3	1.37±0.58*	0.01*
		SUD	4.39±1.26	6.41±1.21	2.02±0.64*	
TUG		SC	23.08±5.9	19.83±5.7	3.25±0.62*	0.07
		SUD	23.75±8.09	21.08±7.84	2.66±0.88*	
Step length		SC	23.45±12.16	17.66±10.92	5.78±4.75*	0.25
		SUD	23.12±9.05	19.2±8.17	3.92±2.68*	

SC: Step climbing exercise group, SUD: Stair gait exercise group, RF: rectus femoris, TA: tibialis anterior, GCM: gastrocnemius, TUG: Timed Up and Go test

climbing exercise group were doing a cross-exercise of the lower limbs, a patient stepped on the stepper, pushed down one side, and switched to the other side before the foot pad touched the frame. For safety, the subjects held a handrail during the climbing exercise, and a therapist oversaw the process and corrected the posture of the patients without directly touching them. Stair gait exercise group performed a stair exercise. For this exercise, a set of five wooden steps was made that was 0.8 m in width, with each step being 28 cm deep and 10 cm long. A therapist assisted patients if their balance was poor, and patients held a support bar when necessary.

To test the muscle strength of the lower limbs, a Manual Muscle Tester (Model01163, Lafayette Instrument Company, Lafayette, IN, USA) was used on the rectus femoris (RF), tibialis anterior (TA), and gastrocnemius (GCM) of the stroke-affected side. The RF was measured while the patients sat down on a chair with a back, with the pressure plate put against the front of the ankle an instruction was given to straighten the knee. The TA and GCM were measured on the knee in a long-sitting position. The pressure plate was placed against the distal side of the foot instep to measure the dorsiflexion of the ankle joint and against the distal side of the foot sole to measure the plantar flexion. In measuring muscle strength, the patient's stiffness and compensation mechanism were kept at a minimum level using a posture and method that enabled a measurement of the target muscles as accurately as possible[10]. Measurements were taken three times, and the average was used. For Timed Up and Go (TUG) test, the time taken for a patient to sit up from a 46 cm high chair with an armrest, move 3 m forward, move 3 m back, and sit down on the chair was measured. It was measured twice, and the average of was used. The patients were allowed to wear their daily shoes or support device, but they could not receive aid from their caretaker or therapist[11]. To measure the difference in step length between the stroke-affected side and the unaffected side, a gait checker (Gait Checker, GHiWell, Seoul, Republic of Korea) was used. The step length was measured three times, and the average was used for comparative analysis.

PASW Statistics 18.0 for Windows was used for statistical analysis of the data; a paired t-test was conducted to examine the changes before and after the exercise in each group; an independent t-test was conducted to examine changes among the groups based on the changes before and after the exercise. The level of statistical significance (α) was set at 0.05.

RESULTS

Muscle strength changed significantly in both groups after the exercise ($p<0.05$). In an intergroup comparison, the RF showed a significant change in the step climbing exercise group, and the TF showed a significant change in the stair gait exercise group ($p<0.05$). The TUG results improved significantly in both groups after the exercise ($p<0.05$), but there was no significant difference in the changes in TUG results between the two groups ($p>0.05$). Step length improved significantly in both groups after the exercise ($p<0.05$), but there was no significant difference in the results between the two groups ($p>0.05$) (Table 1).

DISCUSSION

Walking dysfunction is the most significantly affected by a stroke. Among early-stage stroke patients, 80% lose walking ability, and they begin to recover it within six months. Enhancing walking ability to restore functions and social activities of stroke patients is one of the key goals of treatment, and the ability to walk independently is an important goal of rehabilitation for stroke patients and therapists[12]. The stair gait exercise is part of the rehabilitation program to efficiently restore the walking ability of stroke patients[13], and previous experiments showed similar effects of the stair gait exercise and step climbing exercise on strengthening of the lower limbs of stroke patients when changes in muscle activity were examined using electromyography(EMG)[14]. In comparing the muscle strengths of patients among different groups, an EMG analysis showed an increase in the muscle strengths of the RF, GCM, and TA, both in step climbing exercise and stair gait exercise groups[14]. Similarly, in this study, patients in both groups showed significant in-

creases in muscle strength after eight weeks of exercise. A comparison between the groups showed that the strength of the RF increased more in the step climbing exercise group than in the stair gait exercise group, while the strength of the TA increased more significantly in the stair gait exercise group than in the step climbing exercise group. MacCulloch reported that dorsiflexion of the ankle joint occurs when a person climbs up stairs in stair gait exercise and showed that maximum dorsiflexion occurs in the swing phase[15]. Compared with the stair gait exercise, which repeatedly stimulates the TA, a person participating in the step climbing exercise does not need ankle dorsiflexion to climb to the next step, so the muscle strength of the TA increases relatively less. Damiano reported that in a cross-exercise of lower limbs, the short moment arm of the bent knee joint is increased with the extension of the knee to support one's weight, which exerts significant stress on the knee extensor to stabilize the knee joint[16]. Lu showed that an increased moment arm requires greater force, and thus, the muscle activity of the knee extensor is greater than in other walking conditions[17]. The step climbing exercise extends the knee opposite to the stepping foot, and this could be more effective in strengthening the RF than stair gait exercise. In comparison of the TUG results, a significant improvement was observed in both groups after the exercise, but no significant difference was shown between the two groups. Kim reported that an exercise that increases the muscle strength of the foot instep joint decreases center of pressure sway in stroke patients[18]. Park showed that a proprioceptive exercise for the ankle increased muscle strength and improved the dynamic balance of the affected patients but that the TUG time fell from 20.47 seconds to 15.27 seconds after six weeks of exercise[19]. Kim reported that the step exercise results in significant improvements in ankle balance and that step exercise could be effective as an early-stage walking exercise for stroke patients[14]. Similarly, in this study, both groups showed improved TUG results after the exercise due to increased muscle strength in the lower limbs and improved dynamic balance. In a comparison of walking ability between the two groups, patients in both groups showed significant improvements, but no significant difference was observed between the two groups. Many studies have been performed on the correlation between the muscle strength of the lower limbs and walking ability[20, 21]. Persch demonstrated increased muscle strength and improvement in walking-related variables after lower limb strengthening exercise[22]. Suzuki reported that five months after a stroke, the muscle strength of the lower limbs on the stroke-affected side affected the walking speed in 54% of patients[23]. Park reported that, increased step length and walking speed because of increased dorsiflexion, contributed to the prevention of foot drop and lower limb stability upon initial contact in the swing phase and explained that a stable walking pattern could enhance both static and dynamic stability by reducing postural sway[19]. Flansbjer argued that improved knee extensor strength is a significant predictor of the 6 m walking distance and endurance and that improved extensor strength led to an increased walking speed[24]. Kim reported that a step exercise could facilitate a patient's walking pattern when conducting a stepping motion and it could increase walking speed, as found with the stair gait exercise[14].

The results of our study showed that a step climbing exercise affects the muscle strength, balance, and step length of stroke patients in a manner similar, similar to the stair gait exercise. Therefore, it can be used as a more efficient treatment for stroke patients. Future research should be conducted using a larger group of patients.

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