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The Effects of Stair Walking Training on the Balance Ability of Chronic Stroke Patients

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Abstract. [Purpose] The purpose of this study was to evaluate the effects of stair walking training on balance ability of chronic stroke patients. [Subjects and Methods] Forty stroke patients were allocated equally and randomly to an experimental group and a control group. The experimental group undertook 30 minutes of training therapy and 30 minutes of walking exercise on stairs with flat surfaces. The control group undertook 30 minutes went of training therapy and 30 minutes of walking exercise on a flat surface. All the participants had five training sessions each week for four weeks. A Biorescue system was used to measure the weight-bearing footprint, anterior length in the limit of stability, posterior length in the limit of stability, surface area ellipse of Romberg, and length of Romberg before and after the training. [Results] With regard to changes in the weight-bearing footprint, the anterior length in the limit of stability, and the posterior length in the limit of stability, there were significant differences on both the paretic and nonparetic sides, and there were also significant differences in the surface area ellipse of Romberg and length of Romberg after the intervention. [Conclusion] The experiment results showed that walking exercise on stairs is effective in enhancing balance performance. The same exercise can be applied to patients with other types of neurological disorders to improve their balance.

Key words: Strokes, Balance, Stair gait

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INTRODUCTION

Patients with hemiplegia due to stroke develop asymmetric postures the lower limbs on their paretic sides support only 25–43% or less of their weight in a standing position[1)]. Such postures reduce their ability to maintain their balance and affect their equilibrium and orientation in responses to serious problems[2)]. They also increase the risk of falls and cause serious complications in stroke patients[3, 4)]. Improving the balance abilities of stroke patients is vital for the prevention of falls, daily living activities, and independent living[5)].

Walking is an indispensable element for their self-reliance in hemiplegia patients that will make them independent from others when they perform daily living activities and is something that must be emphasized in treatment processes for these patients[6)]. Walking and balance in stroke patients are ability are very closely related. Therefore, walking training is considered to greatly affect the locomotion of stroke patients[7)].

Stroke patients frequently use stairs during their daily lives. Walking on stairs has been reported to require more dynamic effort compared with walking on a flat surface because each step begins from the toes and the sole rather than the heel. In addition, upward and forward forces are required to support the person's weight, and the ability to control against falls is required when going down the stairs. Thus, a sense of balance and the power are required when walking on stairs during[8)].

Improving the balance of stroke patients is an important objective in treatment programs for patients. Previous studies have used diverse balance training methods involving, for example, lateral weight training[9)], balls[10)], methods in which the foot on the patient's nonparetic side foot is placed on a foothold of a certain height[7)], visual feedback[11)], and auditory feedback[12)], but studies on balance involving stair walking training are lacking. Therefore, the purpose of the present study was to examine the effects of stair walking training on the balance ability of stroke patients.

SUBJECTS AND METHODS

This study was conducted in Hospital K in Daegu City, Korea, from March 1 to March 30, 2013. Forty stroke patients who had been diagnosed with the disease by computed tomography (CT) or magnetic resonance imaging (MRI) at least six months previously were allocated randomly and equally to an experimental group and a control group. A sufficient explanation of this study was provided, and all consented to participate. Only those whose mini-mental

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state examination-Korean version (MMSE-K) scores were 24 or higher were selected, Patients who were able to walk independently, who did not need drug treatment to mitigate spasticity, and who could understand and follow the researchers' instructions were recruited. This study was approved by the university institutional review board and was conducted in accordance with the ethical standards of the Declaration of Helsinki. The general characteristics of both groups are presented in Table 1.

The experimental group and the control group undertook walking exercise five times a week for four weeks. The therapy room was soundproof, and the indoor temperature was kept at 25±5 °C to maintain a stable condition of paralysis. The stair walking training in the therapy room was carried out on stairs with steps that were 0.8 m wide and 10 cm high and treads that were 38 cm deep. Before the experiment, the study was explained to study the subjects, and they agree to participate.

Prior to the walking exercise, the participants in both groups received 30 minutes of general physical therapy that consisted of a joint exercise, muscle strengthening exercise, and a stretching exercise. The experimental group then undertook stair walking training with a physical therapist for 30 minutes in the therapy room.

Each subject in the experimental group stood in front of the stair walking training apparatus and the therapist then assisted the patient during stair climbing by fixing the ischium on the patients paretic side, helping popliteal flexion, and supporting the ankle if the ankle joint was unstable. During stair descent, patient with left hemiplegia maintained stability by supporting the lower limb above the knee joint with his/her left hand while the physical therapist held the waist of the patient with his/her hand. When the patient's foot came into contact with the stairs, the forefoot was placed first to assist weight bearing by the knee. To prevent falls, the patient was permitted to hold the safety bar on the stairs if nesessary[13]. When any patient complained of pain or showed abnormalities of breathing, feelings of fatigue, or vertigo after the beginning walking training, the walking training was immediately stopped. The control group carried out 20 m reciprocating walking training for 30 minutes on an flat indoor flat surface, which was hard and free of obstacles.

In the present study, a balance ability measuring and training system (analysis system using biofeedback, AP1153 BioRescue, France) was used to measure the balance ability of the subjects. The balance ability measuring and training system is suitable for static and dynamic measurement of the balance ability of patients, general people, and athletes. This system can be used to observe the moving path line of the center of pressure during certain movements to determine the length (mm) of the moving path line, the average speed of the movements (cm/s), and the area of the movements. In the present study, the patient was instructed to spread his/her legs to around 30° in an upright standing position and look forward. The measuring method was explained via the monitor and demonstrated before measurement. The patient was instructed to keep his/her balance for one minute while looking forward. The distribution of weight bearing on the paretic and nonparetic sides, the total distance of movements of the center point of the body, and the area of the movements were then measured. To compare the patient's static balance, the limit of stability in a static standing position within which the patient could maximally move his/her center of gravity while keeping balance in the direction instructed by the monitor using the ankle strategy in an upright standing position was measured.

Table 1. General characteristics of the subjects

	EG (n=20)	CG (n=20)
Sex (male/female)	8/12	7/13
Age (years)	61.7±3.6	59.3±3.2
Height (cm)	165.7±1.8	167.2±3.7
Weight (kg)	61.3±3.4	64.3±3.2
Paretic side (right/ left)	14/6	12/8
Onset duration (months)	28.4±5.3	37.3±6.4
Brunnstrom stage (level)	4.8±0.4	5.1±0.3

Values are means ± SD, EG; experimantal group; CG; control group

For data analysis, SPSS Win 12.0 was used. A t-test of corresponding samples was conducted to determine the balance ability index of the two groups before and after the exercise. For comparative analysis between the groups before and after the training, a t-test of independent samples was conducted. The significance level (α) was set at 0.05.

RESULTS

With regard to changes in the weight-bearing of footprint, there was significant difference on both the paretic and nonparetic sides ($p<0.05$), in the experimental group, whereas the control group did not experience significant changes ($p>0.05$). There were significant differences in weight-bearing footprint between the two groups after the experiment ($p<0.05$). Regarding changes in the anterior length in the limit of stability, the experimental group experienced significant increases on both the paretic and the nonparetic sides ($p<0.05$), but the control group did not show significant changes ($p>0.05$). There were significant differences in the anterior length in the limit of stability on the affected side between the two groups after the experiment ($p<0.05$). With regard to changes in the posterior length in the limit of stability, the experimental group exhibited significant increases on both the paretic and nonparetic sides ($p<0.05$), whereas the control group did not experience significant changes ($p>0.05$). There were significant differences in the posterior length in the limit of stability between the two groups after the experiment ($p<0.05$). The experimental group showed significant decreases in the surface area ellipse of Romberg after the intervention ($p<0.05$), whereas the control group experienced no significant changes ($p>0.05$). There were significant differences in the surface area ellipse of Romberg between the two groups after the experiment ($p<0.05$). Regarding changes in the length of Romberg, the experimental group showed significant decreases after the intervention ($p<0.05$), but the

Table 2. Comparison of the gait ability of the experimental and control subjects

		EG		CG	
		Pretest	Posttest	Pretest	Posttest
Weight-bearing footprint (%)	A	41.0±6.1	46.0±7.7*[a]	51.6±14.4	51.0±15.2[a]
	N	59.0±5.5	54.0±12.5*[a]	48.4±14.0	49.0±15.2[a]
Anterior length in limit of stability (cm^2)	A	19.2±1.6	24.1±1.3*[a]	20.5±1.6	17.8±1.7[a]
	N	21.5±1.6	44.9±14.9*	25.1±1.1	25.8±1.8
Posterior length in limit of stability (cm^2)	A	23.9±1.8	29.1±2.3*[a]	30.3±3.1	28.2±1.7[a]
	N	29.2±2.0	33.4±2.0*[a]	26.5±2.8	27.9±2.5[a]
Surface area ellipse of Romberg (mm^2)		179.1±41.9	102.2±24.6*[a]	84.7±27.0	88.6±25.8[a]
Length of Romberg (cm)		38.6±4.9	30.0±4.0*	30.5±2.4	39.0±2.4

Mean±SE, *Significant difference compared with before therapy at <0.05. [a] Significant difference in gains between the two groups at $p<0.05$.

control group did not show significant changes ($p>0.05$). There were no significant differences in the length of Romberg between the two groups after the experiment ($p>0.05$) (Table 2).

DISCUSSION

The present study examined changes in the balance ability of hemiplegia patients before and after they took park in stair walking training (experimental group) or walking training on a flat surface (control group) for four weeks.

With regard to changes in balance ability, the weight-bearing footprint of the experimental group showed significantly larger differences than that of the control group. The anterior length in the limit of stability, and the posterior length in the limit of stability showed significant increase on both the paretic and nonparetic sides ($p<0.05$), and significantly smaller differences than those of the control group were observed for the surface area ellipse of Romberg and length of Romberg ($p<0.05$). The movement of the distribution of weight bearing on the paretic and nonparetic sides toward the center of gravity is the experimental group in likely due to the ankle strategy. Using this strategy in a static standing position in which the maximum degree of voluntary weight bearing is high improves balance ability by enhancing the proprioceptive sense of the ankle joint or the function to appropriately distribute weight so that the distance of static movements of weight can be increased.

The assessment of the speed, accuracy, and support level of weight shifts of stroke patient's is the only information used to examine the recovery of balance ability in stroke patients[14)]. Patients with hemiplegia due to stroke not only develop asymmetric standing postures because of difficulties in postural balance control but also show postural sway. As a result, the postures of these patient's becomes more unstable, leading to them concentrating their weight on the nonparetic side. This causes deterioration in the ability to maintain postural balance[15)]. Therefore, the most important focus in the treatment of hemiplegia patients is on improving balance by imposing weight loads on the lower limb on the paretic side, leading to symmetric standing postures[16)]. Jeong[17)] reported that symmetric weight distribution affects the limit of stability, which is important for postural and balance control. Eng et al.[18)] stated that the ability of stroke patients to support weight is was related to the ability to perform functional activities. They also noted that the ability of stroke patients to move weight asymmetrically to the left and right in static standing positions is closely related to motor functions and stages of independent living as well as the period of hospital stay. This is because the ability to shift weight bearing forward, backward, leftward, and rightward in a standing positions from the paretic side is directly connected to walking. Lay et al.[19)] reported that the quadriceps femoris muscle was strengthened when ascending a slope slope way ascending and that it reduced diverse postural sway in a static standing position. You et al.[20)] reported improved results of safety limit indexes for balance in chronic stroke patients after the application of one stair climbing training session. After the stair walking training, lower limb on the paretic side was able to support more weight in functional postures and in the middle of stance phases during walking, providing more stable support. The findings of You et al. are consistent with those of the present study. In contrast to previous studies that examined improvements in stability limit indexes after single-session experiments, the present study investigated the ability of four weeks of training to improve the weight distribution, stability limit indexes, and sway of stroke patients.

The balance ability of the stroke patients in the present study was improved through stair walking training. The stair walking training likely improved the stability of the patient's pelvis and trunk and contributed to an increase in lower limb muscle strength. It also improved the weight-moving ability of the other side during stance phases, thereby increasing the patient's balance ability. Clinicians can use the results of the present study to improve the balance ability of stroke patients through balance training. The results also provide objective evaluation data for the prediction of the functional activities and quality of life of stroke patients.

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