J Korean Soc Phys Med, 2017; 12(3): 99-104
http://dx.doi.org/10.13066/kspm.2017.12.3.99

Online ISSN: 2287-7215
Print ISSN: 1975-311X

Research Article

Open Access

Effects of Step-up Training on Walking Ability of Stroke Patients by Different Support Surface Characteristics

Geun-Sik Oh, PT, BSc・Yu-Ran Choi, PT, MS・
Dae-Hyouk Bang, PT, PhD[1]・Yong-Jun Cha, PT, PhD[2†]

Dept. of Physical Therapy, Graduate School, Daejeon University
[1]Dept. of Physical Therapy, Oriental Hospital, Wonkwang University
[2]Dept. of Physical Therapy, College of Health and Medical Science, Daejeon University

Received: July 19, 2017 / Revised: July 20, 2017 / Accepted: July 25, 2017

| Abstract |

PURPOSE: Gait disturbances in patients with hemiplegic stroke involve asymmetry of stance time. Step box training is used to supplement the limitations of stair walking training and increasing the torque value of the paralyzed lower leg's strength. This study aimed to investigate whether step-up training on unstable support could change walking ability in patients with chronic stroke.

METHODS: Thirty stroke patients were randomly assigned to the step-up training group (experimental group), that performed training on an unstable surface, and the control group, that performed training on a stable surface. Walking speed, step length, and cadence were measured before and after training. Paired t-tests were used to compare pre- and post-intervention data, while the independent samples t-test was used to determine intergroup differences. Values of $p < .05$ were considered statistically significant.

RESULTS: There was a significant difference in walking ability before versus after the intervention in both groups, although the experimental group showed greater differences than the control group (walking velocity by 8.1%; step length of the non-paralyzed side by 6.9%, respectively; $p<.05$).

CONCLUSION: Step-up training might be more effective on an unstable surface than on a stable surface for increasing walking speed and step length of the non-paralyzed side.

Key Words: Step-up training, Stroke, Unstable surface, Walking ability

Ⅰ. Introduction

Stroke impairs motor, sensory, visual, and cognitive function, thus limiting daily life (Laver et al., 2015). More than 80% of stroke patients suffer from walking disorders at stroke onset involving muscle strength and coordination, mainly due to impaired motor function (Tyson et al., 2006; de Rooij et al., 2016). Walking disorders not only cause limitations in daily life activities but decrease quality of life because they decrease independence (Khaw, 1996;

† Corresponding Author : cha0874@dju.kr

O'Brien et al., 1996). Therefore, the restoration of ability acts as an essential function restoration factor in the rehabilitation of stroke patients (Bohannon et al., 1991).

Gait disturbances in stroke patients involve asymmetry of stance time in which the stance of the non-paralyzed side becomes relatively long due to the short stance of the paralyzed side (Ryerson and Levit, 1997). Walking speed also decreases due to a decreased weight transfer ability (Sousa et al., 2011).

Walking on the stairs is a movement that requires greater lower-limb strength and balance than walking on the ground (Christina and Cavanagh, 2002). In particular, as stair height increases, increased strength and balance are needed (Eun, 2003). Therefore, stair walking training in the rehabilitation of stroke patients involves high exercise difficulty and a greater risk of falling than that of walking on a flat surface (Seo and Kim, 2013; Jun and Park, 2015).

Step box training is used to supplement the limitations of stair walking training. Stepping training using a step box is reportedly effective in increasing the muscle mass gain of the paralyzed lower limbs of stroke patients (Mansfield et al., 2011), improving walking speed and balance ability (Park, 2016) and increasing the torque value of the paralyzed lower leg's strength (Kim, 2014).

Functional training with unstable support is useful for increasing exercise difficulty because unexpected proprietary sensory information and reaction forces in various directions are induced compared to training methods on a stable support surface (Di Fabio and Badke, 1990; Lee, 2007; Lee, 2009). In particular, walking on an unstable support surface such as a balance pad requires more muscle strength and movement around the ankle joint, thereby improving walking speed (Kim, 2009; Lee et al., 2010).

Step-up training is a way to supplement some of the limitations of gait training on the stairs, while functional training on an unstable support surface is the next step of the exercise training on a stable support surface. However, studies on the improvement of walking ability of stroke patients by combining the two intervention methods have not been conducted to date. The purpose of this study was to compare the effect of step-up training on walking ability in unstable and stable support training for chronic stroke patients to determine which is more effective.

Ⅱ. Methods

1. Subjects

The subjects of this study were adult stroke patients who were hospitalized at D hospital in J city for ≥6 months after receiving the diagnosis of stroke due to hemiplegia. The inclusion criteria were receipt of the diagnosis of stroke > 6 months prior, ability to walk > 15 m without the help of a walking aid, ability to complete the Korean Mini-Mental Status Test, and ability to understand and follow the directions of the researcher. The exclusion criteria included a visual or auditory abnormality, vertigo, orthopedic disorder, or cardiovascular disease.

A total of 30 subjects who fully understood the study purpose and contents and agreed to participate in the study were finally selected as target subjects. The participants were randomly divided into the experimental group (n = 15) with unstable support and the control group (n = 15) with stable support. The Daejeon University Institutional Ethics Committee approved this study.

2. Step-up training

In both groups, 1 hour of general neurological physiotherapy plus step-up exercise was performed five times a week over a total of 5 weeks: physiotherapy was performed for 30 minutes, followed by 30 minutes of step-up training consisting of 10 minutes of warm-up exercise, 15 minutes of step-up training, and 5 minutes of cool-down exercise to reduce exercise fatigue and prevent accidents.

Balanced pads (Airex, Seoul, Korea; 50 cm × 41 cm

× 6 cm) were used for step-up training on the unstable support surface, while wooden plates (45 cm × 35 cm × 6 cm) were used for step-up training on the stable support surface. On the unstable or stable support surface, the knee joint of the paralyzed lower limb was bent at 20-30 degrees, while foot on the non-paralyzed side was placed in the front aerobic step box (Body sculpture, China; 70 cm × 28 cm × 12 cm) and then returned to its original position. A 30-sec rest period was allowed after 1 minute of training, and safety bars were used and trained supervisors were present on the paraplegic side to prevent falls.

3. Test of walking ability

Spatial gait variables were measured using the GAITRite system (CIR systems Inc., NJ, USA) to assess functional recovery and walking ability before and after step-up training in both groups. The gait analysis equipment used in this study collected the pressure information obtained from the electronic walking board on a computer connected with a serial interface cable at a sampling rate of 80 Hz. The collected variables were automatically processed by GAITRite GOLD software.

In this study, data on the step lengths of paralyzed and non-paralyzed side and walking speed, which were judged to be most compatible with the study purpose, were analyzed. Each subject performed three round trips at a normal speed without a walking aid on a gait analysis board 8.3 m long and .89 m wide. The average value of three walking values was calculated and analyzed.

4. Data analysis

The subjects' general characteristics are expressed as mean and standard deviation using descriptive statistics. The Shapiro-Wilk test was used to verify the normality of the acquired data. A t-test was used to compare walking variables before and after the intervention, while an independent sample t-test was used to compare differences between the two groups before and after the intervention. SPSS version 18.0 was used for the analysis, and all statistical significance levels were set at .05.

Ⅲ. Results

1. Subjects' general characteristics

Table 1 shows the subjects' general characteristics by group in this study. There were no significant intergroup differences in sex, age, body weight, height, paralysis, duration of stroke (p>.05).

2. Comparison of walking variables within and between groups

Table 2 shows the mean ± SD pre- and post-intervention values in the experimental and control groups.

Table 1. General characteristics of the study subjects

	Experimental group (n=15)	Control group (n=15)	*p*
Gender (male/female)	7/8	9/6	.46
Paretic side (right/left)	8/7	7/8	.72
Stroke type (hemorrhage/infarction)	6/9	5/10	.71
Onset (month)	11.47±2.45	12.13±2.88	.50
Age (years)	58.87±6.73	57.53±6.86	.60
Height (cm)	162.53±5.62	164±7.96	.56
Weight (kg)	64.8±5.14	64.13±5.59	.74

Values are expressed as means ± standard deviations or numbers.

1) Step length of paralyzed side

In the experimental group, the step length of the paralyzed side before the intervention was 30.58±2.04 cm, while that after the intervention was 35.36±1.91 cm. In the control group, the mean pre-intervention value was 30.05±1.19 cm, while the mean post-intervention value was 33.72±1.97 cm. In both groups, there was a significant increase in the step length of the paralyzed side post- versus pre-intervention ($p<.05$). There was no statistically significant difference between the two groups in post-intervention changes ($p>.05$).

2) Step length of non-paralyzed side

The step length of the non-paralyzed side of the experimental group was 31.38±2.17 cm before the intervention versus 37.37±2.97 cm after the intervention. The values of the control group were 31.38±2.07 cm before the intervention and 34.73±2.44 cm after the intervention. There was a significant increase in step length after versus before the intervention in both groups ($p<.05$). Comparisons of changes in step length of the non-paralyzed side after the intervention revealed a 6.9% increase in the experimental group compared to the control group ($p<.05$).

3) Walking velocity

The mean walking speed of the experimental group was .46±.04 m/s before the intervention and .63±.04 m/s after the intervention. The mean walking speed of the control group was .45±.04 m/s before the intervention and .58±.04 m/s. Both groups showed a significant increase in walking speed after versus before the intervention ($p<.05$). Compared with the control group, the experimental group showed an 8.1% increase in the change of walking speed before and after the intervention ($p<.05$).

4) Cadence

In the experimental group, the mean number of steps was 62.65±2.6 steps/min pre-intervention versus 68.26±

Table 2. Comparison of gait variables before and after training within and between the two groups

		Experimental group (n=15)	Control group (n=15)	*p*
Walking velocity (m/s)	Before	.46±.04	.45±.04	
	After	.63±.04	.58±.04	.002
	p	.001	.001	
	change	.16±.05	.13±.03	.034
Cadence (steps/min)	Before	62.65±2.6	62.24±2.15	
	After	68.26±2.17	66.24±2.68	.031
	p	.001	.001	
	change	5.61±2.12	4.01±2.49	.067
[a]Step length (cm)	Before	30.58±2.04	30.05±1.19	
	After	35.36±1.91	33.72±1.97	.028
	p	.001	.001	
	change	4.78±1.19	3.68±1.87	.065
[b]Step length (cm)	Before	31.78±2.17	31.38±2.07	
	After	37.37±2.97	34.73±2.44	.013
	p	.001	.001	
	change	5.59±2.38	3.35±2.78	.025

Values are expressed as means ± standard deviations.
[a]: paralyzed side, [b]: non-paralyzedside.

2.17 steps/min post-intervention. In the control group, the mean cadence was 62.64±2.15 pre-intervention versus 66.24±2.68 steps/min post-intervention. Both groups showed a significant increase in cadence after the intervention ($p<.05$). There was no statistically significant difference between the two groups in post-intervention changes ($p>.05$).

Ⅳ. Discussion

This study aimed to investigate whether step-up training on an unstable or stable surface can change the walking ability of patients with chronic stroke and, if there is a change, which approach is more effective for increasing the walking ability of stroke patients. We found that step-up training performed on an unstable or stable support surface improved the walking ability of chronic stroke patients and that step-up training on the unstable surface increased walking velocity by 8.1% on and increased non-paralytic step length by 6.9%. These results suggest that the step-up training reflects the effects of stair walking training and the functional training on unstable support.

Step-up training in patients with stroke requires strong propulsion on the paraplegic side and strong support on the paraplegic side. Therefore, it is reported that the step - up training is advantageous for increasing the strength of the knee extensor muscles (Kim, 2015). In addition, increased knee extensor muscular strength is closely related to the improvement of walking speed (Zane et al., 2017). In this study, step - up training on unstable support significantly improved walking speed than step - up training on stable support. These results suggest that the step-up training on the unstable support surface has a more positive effect on the increase of the strength of the knee extensor muscle of the paralyzed lower limb. Lee et al. (2010) performed functional training on an unstable or stable support surface with 10 stroke patients for 30 minutes six times per week for 6 weeks. The 10-m walking time of the unstable support group was significantly shorter than that of the stable support group. The results of that study are consistent with the results of the current study, which showed that the step-up training on an unstable support surface was more effective than that on a stable support surface. In addition, Seo and Kim (2013) and Wi (2011), which compared the effects of walking on flat ground, on a ramp, and on the stairs, reported that gait training on the stairs was most effective at improving step length, walking velocity, and stance time. Step-up training, which was applied similarly to stair walking training, partially supports the result of this study, which showed that it was effective at improving the walking ability of stroke patients.

The step-up training performed in this study is limited by the fact that the two lower limbs are not stepped up alternately. However, this study is clinically meaningful because it identified the effect of step-up training using the advantages of stair walking training on an unstable support surface. We would like to clarify in future studies whether step-up training can be applied more generally to treat other conditions.

Ⅴ. Conclusion

This study investigated the effect of step-up training on an unstable versus stable support surface on the gait ability of chronic stroke patients. As a result, the step-up training on an unstable support was more effective at improving gait function than training on a stable support surface. Therefore, step-up training improves the gait function of stroke patients.

References

Bohannon RW, Horton MG, Wikholm JB. Importance of four variables of walking to patients with stroke. Int J

Rehabil Res. 1991;14(3):246-50.
Christina KA, Cavanagh PR. Ground reaction forces and frictional demands during stair descent: effects of age and illumination. Gait Posture. 2002;15(2):153-8.
de Rooij IJ, van de Port IG, Meijer JG. Effect of virtual reality training on balance and gait ability in patients with stroke: systematic review and meta-analysis. Phys Ther. 2016;96(12):1905-18.
Di Fabio RP, Badke MB. Extraneous movement associated with hemiplegic postural sway during dynamic goal-directed weight redistribution. Arch Phys Med Rehabil. 1990;71(6):365-71.
Eun SD. Biomechanical effect of the stair heights on the lower extremity joints in stair-ascent activity of elderly persons. Doctor's Degree. Seoul National University. 2003.
Jun JY, Park MC. The effect of stair exercise with restriction blood flow on knee extensor muscle. J Korean Soc Phys Med. 2015;10(4):9-14.
Khaw KT. Epidemiology of stroke. J Neurol Neurosurg Psychiatry. 1996;61(4):333-8.
Kim DW. The effects of realignment to unilateral stepping exercise training on balance and walking in the patients with stroke. Master's Degree. Yongin University. 2014.
Kim EJ. The effects of gait training on treadmill and unstable surface and muscular activity in stroke patients. Master's Degree. Daegu University. 2009.
Kim HS. The effect of type of treads for step training on trunk and lower extremity muscle activity and balance of chronic stroke patients. Doctor's Degree. Daegu University. 2015.
Laver KE, George S, Thomas S, et al. Virtual reality for stroke rehabilitation. Cochrane Database Syst Rev. 2015(2): Cd008349.
Lee JY, Kim YS, Kim JS, et al. The effects of balance in stroke patients after exercise on the unstable surface. J Rehabil Sci. 2010;28(1):27-38.
Lee SC. The influence of unstability of supporting surface on trunk and lower extremity muscle activities during bridging exercise combined with core-stabilization exercise. Master's Degree. Hanseo University. 2009.
Lee SH. The Differences between Aero step Exercises and Weight training on Posture, Physical Fitness, Balance, and Hormone Levels in the Elderly. Master's Degree. Ewha Womans University. 2007.
Mansfield A, Inness EL, Komar J, et al. Training rapid stepping responses in an individual with stroke. Phys Ther. 2011;91(6):958-69.
O'Brien CF, Seeberger LC, Smith DB. Spasticity after stroke: epidemiology and optimal treatment. Drugs Aging. 1996;9(5):332-40.
Park KD. The effect of stair square step exercise on gait and balance ability in stroke patients. Master's Degree. Korea National University of Transportation. 2016.
Ryerson S, Levit K. Functional movement reeducation: a contemporary model for stroke rehabilitation. Churchill Livingstone. 1997.
Seo KC, Kim HN. The effects of gait ability in the stroke patients after stair gait exercise and lamp gait exercise. J Korean Soc Phys Med. 2013;8(3):397-406.
Sousa CO, Barela JA, Prado-Medeiros CL, et al. Gait training with partial body weight support during overground walking for individuals with chronic stroke: a pilot study. J Neuroeng Rehabil. 2011;8:48.
Tyson SF, Hanley M, Chillala J, et al. Balance disability after stroke. Phys Ther. 2006;86(1):30-8.
Wi GS. The effects of stair and ramp gait training on a static balance and gait in patients with stroke. Master's Degree. Daegu University. 2011.
Zane AC, Reiter DA, Shadell M, et al. Muscle strength mediates the relationship between mitochondrial energetics and walking performance. Aging Cell. 2017;16(3):461-8.