J. Phys. Ther. Sci. 29: 673–676, 2017

The Journal of Physical Therapy Science

Original Article

Changes of gait parameters following constrained-weight shift training in patients with stroke

Seok Hyun Nam, MS, PT[1)], Sung Min Son, PhD, PT[2)], Kyoung Kim, PhD, PT[1)*]

[1)] *Department of Physical Therapy, College of Rehabilitation Science, Daegu University: 15 Jilyang, Gyeongsan-si, Kyeongbuk 712-714, Republic of Korea*
[2)] *Department of Physical Therapy, College of Health Science, Cheongju University, Republic of Korea*

Abstract. [Purpose] This study aimed to investigate the effects of training involving compelled weight shift on the paretic lower limb on gait parameters and plantar pressure distribution in patients with stroke. [Subjects and Methods] Forty-five stroke patients participated in the study and were randomly divided into: group with a 5-mm lift on the non-paretic side for constrained weight shift training (5: constrained weight shift training) (n=15); group with a 10-mm lift on the non-paretic side for constrained weight shift training (10: constrained weight shift training) (n=15); or the control group (n=15). Both, the 5 constrained weight shift training and 10 constrained weight shift training groups underwent constrained weight shift training 5 times per week for 4 weeks, whereas the control group performed ergometer exercises for lower limb muscle strengthening. [Results] The 10 constrained weight shift training group showed a significant increase in the contact surface and impulse of the hindfoot compared to the control group, and the step length and walking speed were significantly longer and faster. [Conclusion] We found that constrained weight shift training on the paretic lower limb is an effective treatment method for improving normal gait pattern in stroke patients.

Key words: Compelled weight shift, Stroke, Gait

(This article was submitted Mar. 21, 2016, and was accepted Jan. 10, 2017)

INTRODUCTION

A major characteristic of post-stroke hemiplegic gait is spatial and temporal asymmetry[1)]. An asymmetrical gait pattern may increase energy expenditure and the risk of falls and cause loss of bone density in the affected leg[2, 3)]. These deficits can restrict post-stroke functional mobility and have a negative impact on the quality of life. Thus, restoration of gait symmetry is an important goal in stroke rehabilitation[4)].

To assist hemiparetic patients in experiencing a dynamic and desirable gait pattern, task-specific, intensive, and progressive gait training programs using a treadmill, body-weight support system, and robotics have been developed[5, 6)]. However, hemiparetic patients can employ compensatory motor strategies using the non-affected leg for performing a bipedal gait even in these rehabilitation settings[7)].

Recent studies suggested that weight-bearing symmetry in stance improved gradually with the use of a lift in the shoe of the non-affected lower limb[8, 9)]. Forced use of the paretic limb as a therapeutic measure during training may lead to improved balance and improved ability to tolerate postural perturbations[8)]. However, no study has reported the effects of compelled weight shift training on gait parameters and plantar pressure in stroke patients. Therefore, this study aimed to investigate whether training involving compelled weight shift on the paretic lower limb enhances gait and plantar pressure in stroke patients.

*Corresponding author. Kyoung Kim (E-mail: kykim257@hanmail.net)

Table 1. Baseline characteristics of each group

Variable	10CWST group	5CWST group	Control group
Gender (male/female)	13/2	12/3	12/3
Age (years)	56.3 ± 10.7	56.3 ± 15	55.5 ± 12.1
Paretic side (right/left)	7/8	7/8	8/7
Time since Stroke Onset (months)	8.13 ± 3.36	9.27 ± 3.53	8.73 ± 3.81
Height (cm)	166.5 ± 6.5	169.3 ± 8.8	169.4 ± 7.6
Weight (kg)	61.9 ± 10.6	69.2 ± 10	65.5 ± 10

Values are presented as mean ± SD.
10CWST: 10 mm constrained weight shift training; 5CWST: 10 mm constrained weight shift training

SUBJECTS AND METHODS

Forty-five individuals with hemiparesis participated in the study after discharge from an inpatient rehabilitation unit. The patients were randomly assigned to: group with a 5 mm lift on the non-paretic side for constrained weight shift training (5CWST) (n=15); group with a 10 mm lift on the non-paretic side for CWST (10CWST) (n=15); or control group (n=15).

The inclusion criteria were hemiparesis due to a cerebrovascular accident and the ability to stand independently without an assistive device or an ankle-foot orthosis (AFO) for up to 5 minutes with no rest break. The exclusion criteria were visual or vestibular deficits (such as hemianopia, neglect, and pusher syndrome), inability to understand the informed consent form because of impaired cognitive function (Mini-Mental State Examination [MMSE] score <24), history of lower extremity orthopedic problems, and a neurological condition other than stroke. Each subject gave written consent for the experimental procedure, which was approved by the institutional review board of the local ethics committee.

To achieve a compelled weight shift, the participants in the 5CWST and 10CWST groups were provided with 5-mm or 10-mm shoe lifts, respectively, that were fabricated from a medium hard foam material made of ethylene vinyl acetate. Thus, a 5-mm or 10-mm outsole was inserted on the unaffected side. CWST was performed in 3 sets of 5 min each, with a rest period of 1 min between sets. Both the 5CWST and 10CWST groups participated in the training 5 times per week for 4 weeks. The participants in the control group maintained their routine activities and performed ergometer exercises for lower limb muscle strengthening for 15 min. In addition, all participants in the 3 groups underwent conservative physical therapy for 30 min per day, 5 days per week, for a period of 4 weeks.

The plantar pressure distributions, step length of the unaffected side, and walking velocity were measured by the RS-scan system (Footscan 3D 2 m system, RSscan International). The pressure plate consists of 16,384 force sensitive resistors in an active measuring surface of 1.95 × 0.32 m (2.6 sensors/cm^2). The system measures at a maximum frequency of 500 Hz and is connected to a portable computer equipped with Gait Scientific software (RSscan International). The system is calibrated to adjust for the subject's weight before each measurement. Measurements are taken when the patient is walking on a flat surface at a comfortable walking speed. Plantar pressure, step length, and walking velocity were recorded for 3 walking sessions of approximately 3 strides each in the middle of the test walk, and the mean values were calculated. To assess the plantar pressure distribution, both feet were divided into 3 regions: forefoot (FF), midfoot (MF) and hindfoot (HF), representing 40%, 30%, and 30% of the total foot length, respectively. The parameters of contact area (CA) and contact impulse (CI) were calculated and averaged for each foot region as the stance phase of gait progressed from heel-strike to toe-off.

All the data were analyzed using separate univariate 3 × 2 ANOVA analysis with repeated measures. When interactions were detected, a post hoc analysis with Bonferroni adjustment was employed. Data were analyzed with the SPSS version 18.0, and a significance level of 0.05 was chosen for all analyses.

RESULTS

Table 1 presents the demographic information of the patients in the 3 groups. No significant differences were observed among them in terms of gender, age, height, weight, paretic side, type of stroke, and time since stroke onset (p>0.05).

Table 2 presents the pre-test and post-test plantar pressure distributions, step length of the unaffected side, and walking velocity for each group. Two-way repeated measures ANOVA revealed a significant difference only in CA and CI of the HF. CA and CI of the HF showed significantly large main effects of group (p<0.05), time (p<0.05), and group-by-time interaction (p<0.05). The post hoc analyses indicated that after intervention, the 10CWST group showed more significant change in the CA and CI of the HF than the control group. In addition, a significant difference was found in the step length of the unaffected side and walking velocity. The step length of the unaffected side and walking velocity showed significantly large main effects of group (p<0.05), time (p<0.05), and group-by-time interaction (p<0.05). The post hoc analyses indicated that after intervention, the 10CWST group showed a more significant change in the step length of the unaffected side and walking velocity than the control group.

Table 2. Comparisons of mean gait parameters of the 3 groups

Parameter		10CWST group		5CWST group		Control group	
		Pre	Post	Pre	Post	Pre	Post
CA (%)	FF	54.4 ± 7.9	48.9 ± 5	52.4 ± 10.5	49.9 ± 5.7	54.3 ± 9.2	53.9 ± 9.4
	MF	24.7 ± 6.6	23.0 ± 4.1	24.4 ± 9.2	28 ± 8.8	22.3 ± 9.9	23.1 ± 9.9
	HF	21 ± 7.1	28.11 ± 4.2*†‡	22.5 ± 6	24.7 ± 6.8	23.8 ± 5.8	24.4 ± 5.8
CI (%)	FF	75.7 ± 5.8	72.7 ± 5.1	74.9 ± 5.9	73.0 ± 4.5	76.3 ± 3.6	76.1 ± 4.9
	MF	3.4 ± 1.6	3.6 ± 1.4	3.4 ± 1.4	3.8 ± 1.8	3.1 ± 1.3	3.6 ± 1.6
	HF	20.9 ± 6.1	23.7 ± 5.0*†	21.8 ± 5.6	23.4 ± 4.6	20.3 ± 3.9	21.0 ± 4.2
Walking speed		0.66 ± 0.15	0.87 ± 0.2*†	0.67 ± 0.22	0.77 ± 0.23	0.6 ± 0.09	0.63 ± 0.09
Step length		36.4 ± 6.2	40.2 ± 6.1*†	34.2 ± 6.9	37 ± 7.6	35.6 ± 7	36.5 ± 7.7

*Significant difference between pre- and post-test ($p<0.05$).
†Significant difference compared with the control group ($p<0.05$).
‡Significant difference between the 5CWST and 10CWST group ($p<0.05$).
CA: Contact Area; CI: Contact Impulse; FF: Forefoot; MF: Midfoot; HF: Hindfoot

DISCUSSION

In the current study, we investigated the effects of training involving compelled weight shift on the paretic lower limb on gait parameters and plantar pressure in stroke patients. Both training groups showed significant improvements in step length, gait velocity, and CA and CI of the HF in the affected foot compared with the control group. These results suggested that compelled weight shift on the paretic lower limb may be an effective method for improving gait ability in stroke patients.

Possibilities for the effectiveness of compelled weight shift training can be explained by 2 main factors. First, this improvement may be a result of the compelled weight shift on the paretic side achieved by adding a lift to the shoe on the non-affected lower limb. Several studies have indicated that with the shoe lift, the center of gravity shifts from the affected limb to the midline, which subsequently leads to increased stability[9–11]. This results in more equal weight distribution over the non-affected and affected lower limbs.

Second, the effectiveness of CSWT could be related to improved sensation in the affected foot as a direct result of the sensory input secondary to the 5 mm and 10 mm lifts applied to the shoe of the non-affected lower limb. The repetitive feedback from load receptors during the training is used as extensor reinforcing feedback while walking[12]. A recent study on the role of ankle-foot load afferents revealed that the stance phase load produced a significant increase in peak hip extensor moment in subjects with spinal cord injury as well as nondisabled subjects[13]. Thus, a lift under the shoe of the affected limb provides an additional tool for improving plantar pressure distribution during walking.

The clinical implication of our findings is that compelled weight shift on the paretic lower limb leads to improved gait parameters and plantar pressure distribution in patients with stroke. The limitations of this study were that other kinematic data were not assessed regarding electromyography. Further studies are required to identify the effectiveness of CSWT using kinematic measurements related to motor function of the paretic lower limb.

REFERENCES

1) Patterson KK, Parafianowicz I, Danells CJ, et al.: Gait asymmetry in community-ambulating stroke survivors. Arch Phys Med Rehabil, 2008, 89: 304–310. [Medline] [CrossRef]
2) Di Fabio RP, Kurszewski WM, Jorgenson EE, et al.: Footlift asymmetry during obstacle avoidance in high-risk elderly. J Am Geriatr Soc, 2004, 52: 2088–2093. [Medline] [CrossRef]
3) Zamparo P, Francescato MP, De Luca G, et al.: The energy cost of level walking in patients with hemiplegia. Scand J Med Sci Sports, 1995, 5: 348–352. [Medline] [CrossRef]
4) Chen G, Patten C, Kothari DH, et al.: Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds. Gait Posture, 2005, 22: 51–56. [Medline] [CrossRef]
5) Pohl M, Mehrholz J, Ritschel C, et al.: Speed-dependent treadmill training in ambulatory hemiparetic stroke patients: a randomized controlled trial. Stroke, 2002, 33: 553–558. [Medline] [CrossRef]
6) Werner C, Von Frankenberg S, Treig T, et al.: Treadmill training with partial body weight support and an electromechanical gait trainer for restoration of gait in subacute stroke patients: a randomized crossover study. Stroke, 2002, 33: 2895–2901. [Medline] [CrossRef]
7) Hase K, Suzuki E, Matsumoto M, et al.: Effects of therapeutic gait training using a prosthesis and a treadmill for ambulatory patients with hemiparesis. Arch Phys Med Rehabil, 2011, 92: 1961–1966. [Medline] [CrossRef]
8) Chaudhuri S, Aruin AS: The effect of shoe lifts on static and dynamic postural control in individuals with hemiparesis. Arch Phys Med Rehabil, 2000, 81: 1498–1503. [Medline] [CrossRef]

9) Rodriguez GM, Aruin AS: The effect of shoe wedges and lifts on symmetry of stance and weight bearing in hemiparetic individuals. Arch Phys Med Rehabil, 2002, 83: 478–482. [Medline] [CrossRef]
10) Suzuki M, Fujisawa H, Machida Y, et al.: Relationship between the Berg Balance Scale and Static Balance Test in hemiplegic patients with stroke. J Phys Ther Sci, 2013, 25: 1043–1049. [Medline] [CrossRef]
11) Kobayashi M, Takahashi K, Sato M, et al.: The characteristics of multi-directional step distance and the association between stepping laterality and walking ability of patients with stroke. J Phys Ther Sci, 2015, 27: 905–909. [Medline] [CrossRef]
12) Duysens J, Clarac F, Cruse H: Load-regulating mechanisms in gait and posture: comparative aspects. Physiol Rev, 2000, 80: 83–133. [Medline]
13) Gordon KE, Wu M, Kahn JH, et al.: Ankle load modulates hip kinetics and EMG during human locomotion. J Neurophysiol, 2009, 101: 2062–2076. [Medline] [CrossRef]