

Original Article

Immediate effects of the activation of the affected lower limb on the balance and trunk mobility of hemiplegic stroke patients

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Abstract. [Purpose] The purpose of this study was to determine the effects of the activation of the affected lower limb on balance and the trunk hemiplegic mobility of stroke patients. [Subjects] The gait group (GG) consisted of 6 subjects with hemiplegia and the non-gait group (NGG) consisted of 6 hemiplegic subjects. [Methods] The subjects in both groups were given foot facilitation training once for 30 min. The Spinal Mouse was used to measure the spinal alignment and the Berg balance scale (BBS) and sensory tests were also performed. [Results] In the GG, the sacral hip in upright to flexion, the lumbar spine in upright to extension, and the sacral hip and lumbar spine in flexion to extension showed significant increases in their angles after the intervention. In addition, there was a significant increase in the angle of the lumbar spine during extension from an upright position in the NGG. The BBS scores of both groups also increased significantly. [Conclusion] The intervention resulted in improvements in the angle of anterior pelvic tilt in the GG, and subjects in the NGG showed more extension of the thorax, which was regarded as compensation to avoid falling forward when flexing from an upright position. However, when extending backward from an upright position, both groups tended to control balance by using more lumbar flexion to keep the center of mass (COM) within the base of support (BOS). Both groups had better BBS scores.

Key words: Balance, Stroke, Trunk

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INTRODUCTION

Patients after a stroke have difficulties maintaining their center of mass (COM) within their base of support (BOS). They use compensation strategies involving a posterior tilt of the pelvis during trunk movements. These strategies are performed at the upper trunk level and for the pelvis, even when the BOS is unstable. These factors limit functional performance, decreasing the range of motion (ROM) and resulting in stiffness¹⁾. Factors which need correcting are postural tone regulation, particularly the extensor antigravity musculature, and accurate foot placement²⁾. The human body has many interconnected body segments from the feet to the head. Accordingly, a problem in one segment may influence the alignments of the other body parts. Postural control is diminished in patients with hemiplegia and hemiparesis³⁾. Hemiplegia can decrease a patient's limit of stability, which is defined as the maximal distance that an individual can

move his or her body weight in any direction without balance failure⁴⁾. Therefore, an intervention that focuses on the affected foot should influence the spinal angles, aiming to improve patients' control of balance. The quality and quantity of external sensory information transmitted to the body segment through the feet is very important for increase of balance and spinal movement; therefore, we hypothesized that the sensory test score would improve after an intervention, and that increased movement of the pelvis and lumbar spine would increase the limits of stability and postural control. Therefore, this study aimed to determine the immediate effects of the activation of the affected lower limb on the balance and trunk mobility of patients with hemiplegia.

SUBJECTS AND METHODS

This study was conducted with two groups: 5 males and 1 female in the gait group (GG), and 4 males and 2 females in the non-gait group (NGG). The subjects in the GG were able to walk unassisted, but the subjects in the NGG were unable to walk alone. The mean ages of each group were 61 and 63 years old, respectively. The mean time since stroke onset was 12 months in the GG, and 27 months in the NGG. Five patients had left hemiplegia and 1 patient had right hemiplegia in the GG, and 4 patients had left hemiplegia and 2 patients had right hemiplegia in the NGG. There was no

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Table 1. Pre- and post-intervention values of spinal range of motion in the sagittal plane of both groups during standing (N=12)

($^{\circ}$)	GG (n=6)		NGG (n=6)	
	Pre	Post	Pre	Post
U-F				
SH	48.00±16.23	52.67±16.55*	37.92±22.20	37.75±21.72
TS	7.83±23.65	9.25±16.26	21.33±36.17	0.00±25.61
LS	54.25±11.53	50.33±11.72	31.83±14.26	34.83±13.08
I	97.50±20.95	99.58±20.34	68.33±31.06	69.42±26.67
U-E				
SH	-0.50±11.34	-3.75±15.79	-1.42±9.53	-3.33±5.21
TS	0.17±14.39	-1.25±9.38	3.58±38.19	-10.92±9.89
LS	-9.25±12.27	1.17±15.42*	-5.58±8.49	-0.17±6.37*
I	2.40±-12.00	-1.92±21.62	-6.17±2.25	-6.33±1.86
F-E				
SH	48.50±13.69	60.33±20.06*	39.25±28.47	41.33±25.17
TS	7.67±14.44	12.00±20.56	17.67±17.61	9.33±25.12
LS	63.50±11.41	52.50±10.24*	37.58±13.57	37.75±8.08
I	106.42±21.90	108.83±23.78	74.25±32.28	78.42±24.38

*p<0.05; mean±SD; SD: standard deviation; SH: sacral hip; TS: thoracic spine; LS: lumbar spine; I: Inclination; U-F: upright-flexion; U-E: upright-extension; F-E: flexion-extension; GG: gait group; NGG: non-gait group

significant difference in the general characteristics of the two groups, indicating they were homogenous. The subjects met the following inclusion criteria: unilateral stroke with hemiparesis, medically stable, and ability to comprehend the test procedures. The exclusion criteria were: active implants (e.g. pacemaker), peripheral neuropathy, or orthopedic problems. Both groups were recruited at D Hospital in Jeonjoo, and the pre- and post-assessments and the interventions were performed between 15 September to 17 October, 2014. All the recruited subjects gave their informed consent beforehand, and this study conformed to the principles of the Declaration of Helsinki. Tests were conducted before and immediately after the interventions for both groups. This study assessed trunk alignment and sensory input. The Spinal Mouse (Idiag, Volkswill, Switzerland)⁵⁾ and Berg balance scale (BBS)⁶⁾ were used to measure spinal ROM and assess static balance, respectively, and Touch-Test Sensory Evaluators (Semmes-Weinstein Monofilaments)⁷⁾ were used to determine sensory input. A physical therapist with 11 years of clinical experience provided the intervention of 30 min, once for each subject. Before performing the intervention, all the subjects were informed about the procedure to ensure subject safety. In this study, the subjects first sat in an optimal sitting position on a plinth, and the tibiofibular alignment was adjusted with either internal or external rotation of the shin⁸⁾. After stretching the intrinsic muscles of the affected foot, the tibialis anterior, extensor hallucis longus, and extensor digitorum longus were facilitated using a combination of distraction, compression, and movement of the toes to elicit toe extension. Then, the soleus was lengthened while the gastrocnemius was held. The affected foot was repeatedly flexed and extended with the ankle in eversion and dorsiflexion to activate the distal part of the rectus femoris. Then, the patient was asked to stand up and apply a weight shift to the

affected side. All data were analyzed using SPSS version 18 (Statistical Package for Social Sciences). The Kolmogorov-Smirnov test was used to test for a normal distribution. All data are presented as the mean± standard deviation (SD). Differences in spinal parameters measured by Spinal Mouse, BBS, and sensory testing within each group were tested using the Wilcoxon signed-rank test. A significance level of $\alpha=0.05$ was used in all statistical tests.

RESULTS

In the GG, the sacral hip in movement from upright to flexion, the lumbar spine in movement from upright to extension, and the sacral hip and lumbar spine in movement from flexion to extension showed significant increases in their angles after the intervention. There was also a significant increase in the angle of the lumbar spine when extending backward from an upright position in the NGG. Table 1 shows the results. A significant difference was also found between the BBS scores of both groups, as well as between the sensory test results of the 5th-toe in GG. Table 2 shows the results.

DISCUSSION

The natural curvature of the vertebral column is not fixed and is dynamic and changeable during movements and postural adjustment. Extension of the vertebral column accentuates lumbar lordosis and reduces thoracic kyphosis. In contrast, flexion of the vertebral column decreases or flattens lumbar lordosis and accentuates thoracic kyphosis⁹⁾. In this study, subjects in the GG showed increased anterior pelvic tilt after the intervention with increased flexion of the thorax and increase of lumbar lordosis when flexing from an upright

Table 2. Pre- and post-intervention values of BBS and the sensory test of the affected side foot of each group (N=12)

	BBS		Dorsal		I-toe		5-toe	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
GG (n=6)	46.17±8.84	49.33±6.98*	4.23±1.22	4.26±.32	4.26±1.32	4.03±0.68	5.02±1.31	4.07±0.71*
NGG (n=6)	21.00±10.95	28.33±9.96*	5.67±1.62	6.65±0.00	5.75±1.41	5.52±1.24	5.91±1.15	5.56±1.19

*p<0.05; mean±SD; SD: standard deviation; GG: gait group; NGG: non-gait group; BBS: Berg Balance Scale

position. However, inclination was moved more forward. The reason for the increased lumbar extension was that the lumbar region participated in postural control adjustments to prevent falling forward. However, subjects in the NGG showed no change in pelvic tilt and increased extension of the thorax and lumbar flexion more. As a result, inclination, was a bit increased. Subjects in the NGG used more extension in the thorax as a compensatory movement to avoid falling forward. The results of this study differ from Neumann's hypothesis⁹⁾, which is that in trunk flexion, thoracic kyphosis increases, and lumbar lordosis decreases. In this study, the subjects with hemiplegia who were able to walk controlled their balance through a lumbar strategy when the COM moved forward, and the subjects with hemiplegia who were unable to walk adjusted their balance using the thorax, especially when extending. Also, the subjects in the GG showed an increase in pelvic posterior tilt, thoracic extension, and lumbar flexion when extending backward from an upright position. Therefore, inclination was moved posteriorly. The subjects in the NGG showed the same result as those in the GG. The reason is that when extending from an upright position, both groups tried to control balance using more lumbar flexion. The COM moved posteriorly because both groups had insufficient eccentric contraction to maintain the COM in the BOS. Therefore, the subjects may have used hip flexor muscles to compensate. According to Neumann⁹⁾, in trunk extension, the direction of pelvic movement is posterior, the same direction as that of spinal movement, and thoracic kyphosis should reduce and lumbar lordosis should increase. In a previous study, a significant deficit in the mobility of the lumbar spine and the mobility of spinal inclination was found in fall groups compared to the non-fall group¹⁰⁾, as well as in elderly people¹¹⁾. In terms of total ROM, from flexion to extension, the intervention affected the ROMs of the pelvis and the lumbar regions. Especially, the subjects in the GG showed a larger intervention effect. Determining the standing balance and motor and sensory deficits are significant aspects of the process of assessing stroke patients, as such patients usually present with reduced tactile sensation. Niam et al.¹²⁾ found a positive relationship between sensation and deficit in postural control. It was suggested that people without any compensation strategy adjust themselves on the support surface using somatosensory information coming from the feet¹³⁾. In this study, the postural control ability of both groups improved significantly in response

to tactile stimuli, and the affected foot became better. This result concurs with previous suggestions that sensory information from the feet determines how people correct themselves on the support surface. Lower extremity sensory deficits might influence trunk activities¹⁴⁾. According to the results of this study, the feet are very significant body parts influencing trunk movements as well as postural control. To reduce the various compensation the strategies encountered in rehabilitation sessions, therapists should pay more attention to the affected foot in order to restore proper alignment of the trunk. Future studies should use electromyography to assess the ankle extensors and hip flexors and extensors.

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