J. Phys. Ther. Sci.
27: 1079–1082, 2015

Original Article

Effects of activation of the foot on trunk mobility of patients with hemiplegia

Young-dong Kim, DPT, PT[1)]

[1)] *Human Movement Research: 497 Wolpyeong-dong, Seo-gu, Daejeon 302-281, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to determine the effects of activation of the foot on the trunk mobility of patients with hemiplegia. [Subjects] Sixteen subjects with hemiplegia took part in the immediate group (IG), and 14 subjects with hemiplegia participated in the 2-month group (2MG). [Methods] The subjects in IG were given one leg stance training through activation of the foot only once, and 2MG received the same intervention for 30 minutes 3 times a week for, 8 weeks. The Spinal Mouse was used to collect spinal alignment data. Also, the trunk Impairment Scale (TIS) and Sensory test were used as functional tests. [Results] Sacral hip (SH), lumbar spine (LS) and thoracic spine (TS) angles in IG improved significantly, but not inclination (I), and 2MG showed increased angles of SH, LS and I, but not TS. Also, TIS Dynamic, TIS Coordination and Sensory test results of 2MG increased significantly. [Conclusion] One leg stance training through activation of the foot was effective at improving sensory input and alignment of the spine, therefore trunk mobility was improved.
Key words: Alignment, Stroke, Trunk

(This article was submitted Oct. 20, 2014, and was accepted Dec. 4, 2014)

INTRODUCTION

Lack of trunk adjustment ability is one of the problems post-stroke patients have[1)]. A reduction in the trunk muscle strength on the affected side would result in loss of trunk control[2)]. Patients with hemiparesis use a protective strategy for their balance control, because of deficits in their muscle strength which result in reduced pelvic mobility[3)]. In rehabilitation the acquisition of trunk control is prioritized for recovery of postural control, and when postural control has been achieved, the rehabilitation therapy can proceed to treatment of the extremities[4)]. Patients with hemiparesis show less center of pressure (COP) displacement than healthy persons, particularly in the anterior direction. Less displacement of COP with less weight bearing on the feet results in less displacement of center of mass (COM) during trunk flexion in persons with hemiparesis. Patients after a stroke have difficulties in controlling their COM within their base of support (BOS). Posterior tilting of the pelvis during trunk movements is used in compensation strategies. This limits the functional performance, for example, a decreasing range of motion and causing stiffness. Contributory factors which need to be improved are postural tone regulation, in particular in the extensor antigravity musculature and accurate foot placement[5)]. Recently, the lumbar, thoracic and sacral spinal curvatures and ROM have been measured using a new computer-aided skin surface device (Spinal Mouse)[6)]. Clinical observations suggest the ability to extend the toes contributes to selective dorsiflexion[7)]. The human body is comprised of many interconnected body segments from the feet to the head. Thus, a problem in one segment may influence the alignment of the other body segments. Therefore, an intervention which focuses on proper alignment in the one-leg stance of the affected side of the body would influence the antigravity muscles of the trunk, aligning the trunk closer to the line of gravity, and not only antigravity muscle contraction but also range of motion of the hip joint and spine would be improved. Moreover, trunk function and sensory input would be better after performing the intervention. The results of this study show the importance of trunk mobility, which should be considered as a priority in treatment and they also suggest that foot activation is related not only to sensory input but also to trunk alignment.

SUBJECTS AND METHODS

This study was performed to determine the effects of activation of the foot on the trunk mobility of patients with hemiplegia. This study was conducted with 2 groups. There were 12 males (75%) and 4 females (25%) in the immediate group (IG), and 11 males (78.6%) and 3 females (21.4%) in the 2-month group (2MG). The mean ages of each group were 60 in IG and 56 years old in 2MG. The mean time since stroke onset was 13 months in IG and 29 months in 2MG. Nine patients had left hemiplegia and 7 patients had right hemiplegia in IG. There was no significant difference in the 2 groups, in general characteristics. The subjects provided their written informed consent to participation in this study

Corresponding author. Young-dong Kim (E-mail: exptkyd@daum.net)

which conformed to the ethical principles of the Declaration of Helsinki. The subject inclusion criteria were: unilateral stroke with hemiparesis; medically stable; no medical contraindication to gait; dorsiflexion of less than 8 degrees[8]; and ability to understand the test procedures. The exclusion criteria were: active implants (e.g. pacemaker), peripheral neuropathy, orthopedic problems, pregnancy or an acute diagnosis. The subjects in IG were recruited at D hospital in Jeonjoo and the assessments were completed on Sundays, a total of 8 times, from 27 January to 31 March, 2013. The subjects in 2MG were recruited at D hospital in Daejoen. They were assessed and received the same intervention from 9 June to 18 October 2013. The intervention was the same as that conducted for IG, 3 times a week for a total of 8 weeks. All the recruited subjects gave their informed consent before participating in the study. Tests were conducted immediately before and after the intervention for both IG and 2MG. This study assessed trunk alignment and sensory input. The Spinal Mouse (Idiag, Volkerswill, Switzerland) and Trunk Impairment Scale (TIS) were used to evaluate spinal range of motion (ROM) and the trunk mobility, respectively, and Touch-Test Sensory Evaluators (Semmes-Weinstein Monofilaments) were used to evaluate Sensory input. The assessment of trunk ROM using the Spinal Mouse was performed as described in a previous study[9, 10]. TIS is composed of three subscales: static sitting balance, dynamic sitting balance, and co-ordination. The score of TIS ranges from 0 to 23[11]. The Touch-Test Sensory Evaluators (Semmes-Weinstein Monofilaments) give a non-invasive assessment of tactile sensation levels throughout the body[12].

In this study the period following the intervention was called "Activation of the Foot" as an operational definition[7] (Figs. 1–3).

All data were analyzed using SPSS version 18 (Statistical Package for the Social Science). The Kolmogorov-Smirnov test was used to test the normality of data distributions. All data are presented as the mean with standard deviation (SD). Variations in spinal parameters obtained by Spinal Mouse and parameters of TIS and the Sensory test within each group were tested with the paired t-test. The level of significance used for all statistical tests was α=0.05.

Fig. 1. Tactile stimulation

Fig. 2. Distraction of the 1 and 5 toes

Fig. 3. Guiding dorsiflexion

RESULTS

After the intervention, the lumbar lordotic angle of the immediate group (IG) showed a significant reduction when extending the spine in an upright position. The 2-month group (2MG) also showed a reduced lumbar spinal lordotic angle but the reduction was less than that in IG. Sacral hip (SH), lumbar spine (LS) and thoracic spine (TS) angles of IG improved significantly, but not that of inclination (I). 2MG also showed increased angles of SH, LS and I, but not TS. However, in the comparison of the results of IG and 2MG, the angles of 2MG were much bigger because of improved sensory input and the frequency of the intervention. Both groups had increased TIS Static scores but the difference was not significant. However, the TIS Dynamic, TIS Coordination and Sensory test results of 2MG increased significantly (Tables 1 and 2).

DISCUSSION

In terms of range of spinal motions, the subjects in IG extended the range of spinal motions of SH, TS and LS. There were also improved range of motions of SH, LS and I in 2MG. In previous studies, there were significant decreases in mobility of the lumbar spine and spinal inclination of the falls groups compared to the no-falls group[13] and to elderly people[14]. The intervention, which was focused on restoring ankle joint dynamic stability, influenced the total range of motion of SH and LS in both IG and 2MG. Importantly, this facilitated the foot and ankle joint, changing the range of motion of the lumbar spine and hip joint. It is notable that even subjects in IG who received treatment only once showed improvement, even though the increase in the range of motion was not as large as in 2MG. In our lives, human beings live with gravity, and erecting the spine against gravity is crucial for making efficient movements and preventing falls. Optimal postural control is achieved by using an ankle strategy and aligning the spine with the mid-line of

Table 1. Within-group changes in spinal range of motion in the sagittal plane while standing (N=30)

	IG (n=14)		2MG (n=16)	
(˚)	Pre	Post	Pre	Post
U-F				
SH	50.38±15.15	51.97±16.29	33.79±25.82	36.25±21.73**
TS	−2.00±30.94	12.06±15.26	7.86±9.56	16.21±15.18
LS	45.31±14.40	43.38±13.05	32.21±19.06	41.79±18.07**
I	92.22±21.02	93.38±21.75	63.57±37.52	74.46±34.96**
U-E				
SH	−2.66±9.21	−4.44±10.01	0.96±7.43	−1.43±5.00*
TS	−5.41±14.08	−4.22±10.39	−4.64±8.75	−10.21±11.25
LS	−8.06±10.00	−1.31±10.16**	−7.25±10.53	−3.75±7.34**
I	−10.97±4.29	−6.25±13.46	−6.29±4.76	−6.82±4.41*
F-E				
SH	52.94±16.27	57.84±17.89*	32.71±23.90	37.64±21.80**
TS	3.28±24.24	16.78±16.87*	12.43±10.75	26.36±13.95
LS	53.25±15.00	45.97±14.79*	39.46±21.82	45.68±21.57**
I	103.13±21.54	102.34±24.78	69.93±40.70	81.21±38.10**

*p<0.05, **p<0.01, 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; IG: Immediate Group; 2MG: 2-month Group

Table 2. Changes in TIS and sense of the affected side foot in each group (N=30)

	TIS_Static		TIS Dynamic		TIS Coordination	
	Pre	Post	Pre	Post	Pre	Post
IG (n=14)	6.44±0.63	6.63±0.50	6.38±2.28	8.25±1.98**	3.13±1.45	3.69±1.49
2MG (n=16)	5.64±1.01	5.86±1.03	5.57±2.79	8.64±2.02**	1.50±0.94	2.64±1.01**
	Dorsal sensory		1-toe sensory		5-toe sensory	
mm	Pre	Post	Pre	Post	Pre	Post
IG (n=14)	4.23±1.09	4.10±0.89	4.23±0.88	4.20±1.14	4.67±1.27	4.23±1.15*
2MG (n=16)	5.09±1.03	3.98±0.39**	5.07±1.04	3.95±0.41**	5.02±1.10	3.88±0.38**

*p<0.05, **p<0.01, mean±SD. SD: Standard Deviation; IG: Immediate Group; 2MG: 2-month Group; TIS: Trunk Impairment Scale

the body. The subjects in 2MG realigned the body closer to the line of gravity. Significant differences in TIS dynamic and TIS coordination results were observed in this study. In previous studies, analysis of weight distribution between the buttocks and the feet showed that patients with hemiparesis had a tendency to maintain more weight on the buttocks and less weight on the matching active foot/feet depending on the direction of movement[3)]. This shows that, it is not easy for people with hemiparesis to use the upper extremities or trunk because center of mass of the body is located more posteriorly than in healthy subjects. Thus, the reason why TIS dynamic and coordination improved in this study was that the subjects regained the ability to place both feet on the floor and erect the trunk with the spine better aligned against gravity allowing then to move their upper arm and trunk to the affected side and move the contralateral upper limb with the ipsilateral lower limb at the same time. A previous study suggested weakness and sensation are the most significant factors affecting postural control. That study showed there was a significant difference between a group of people who could sit or stand[15)]. Achieving standing balance and resolving motor and sensory deficits is a significant aspect of the rehabilitation process for patients with stroke. Such patients usually present with reduced tactile sensation. Niam et al.[16)] found a positive relationship between sensation and deficit in postural control. Persons with hemiparesis scarcely use their affected foot for weight bearing during trunk movement and reaching tasks[17)]. It has been suggested that people without any disorders adjust balance by themselves using the support surface with somatosensory information coming from the feet. It is possible that trunk movements are affected by lower limb sensory deficits.[3)] In this study, the test of tactile sense of the affected foot showed that there were significant differences after intervention in all areas of the affected foot e.g. dorsal, 1-toe and 5-toe, in 2MG. After 2 months of intervention the subjects had improved sensory input at the affected foot. Therefore, 2 months is sufficient time to increase the tactile information the affected foot receives. However, the present results cannot be generalized because of the small number of patients in this study. Future research should perform surface electromyography to verify the activation of the muscles around the ankle joint and the hip joint after the intervention and recruit with more subjects.

REFERENCES

1) Park JH, Hwangbo G: The effect of trunk stabilization exercises using a sling on the balance of patients with hemiplegia. J Phys Ther Sci, 2014, 26: 219–221. [Medline] [CrossRef]
2) Karatas M, Cetin N, Bayramoglu M, et al.: Trunk muscle strength in relation to balance and functional disability in unihemispheric stroke patients. Am J Phys Med Rehabil, 2004, 83: 81–87. [Medline] [CrossRef]
3) Messier S, Bourbonnais D, Desrosiers J, et al.: Dynamic analysis of trunk flexion after stroke. Arch Phys Med Rehabil, 2004, 85: 1619–1624. [Medline] [CrossRef]
4) Bobath B: evaluation and treatment. In: Adult hemiplegia. London: Heinemann, 1974.
5) Grillner S, Georgopoulos AP, Jordan LM: Selection and Initiation of Motor Behaviour. In: Neurons, Networks and Motor Behaviour. Stein PSG, Grillner S, Selverston A, Stuart DG (eds). Cambridge: MIT, 1997, pp 4–19.
6) Kellis E, Adamou G, Tzilios G, et al.: Reliability of spinal range of motion in healthy boys using a skin-surface device. J Manipulative Physiol Ther, 2008, 31: 570–576. [Medline] [CrossRef]
7) Raine S, Meadows L, Lynch-Ellerington M: Theory and Clinical Practice in Neurological Rehabilitation. Singapore: Blackwell Publishing, 2009, pp 117–149.
8) Lin PY, Yang YR, Cheng SJ, et al.: The relation between ankle impairments and gait velocity and symmetry in people with stroke. Arch Phys Med Rehabil, 2006, 87: 562–568. [Medline] [CrossRef]
9) Post RB, Leferink VJ: Sagittal range of motion after a spinal fracture: does ROM correlate with functional outcome? Eur Spine J, 2004, 13: 489–494. [Medline] [CrossRef]
10) Muyor JM, López-Miñarro PA, Alacid F: Spinal posture of thoracic and lumbar spine and pelvic tilt in highly trained cyclists. J Sports Sci Med, 2011, 10: 355–361. [Medline]
11) Verheyden G, Nieuwboer A, Mertin J, et al.: The Trunk Impairment Scale: a new tool to measure motor impairment of the trunk after stroke. Clin Rehabil, 2004, 18: 326–334. [Medline] [CrossRef]
12) http://www.ncmedical.com/wp-ntent/uploads/2011/07/Touch-Test- Sensory-Evaluator_11_web.pdf (Accessed Jan, 2. 2013)
13) Lynn SG, Sinaki M, Westerlind KC: Balance characteristics of persons with osteoporosis. Arch Phys Med Rehabil, 1997, 78: 273–277. [Medline] [CrossRef]
14) Kasukawa Y, Miyakoshi N, Hongo M, et al.: Relationships between falls, spinal curvature, spinal mobility and back extensor strength in elderly people. J Bone Miner Metab, 2010, 28: 82–87. [Medline] [CrossRef]
15) Tyson SF, Hanley M, Chillala J, et al.: Balance disability after stroke. Phys Ther, 2006, 86: 30–38. [Medline]
16) Niam S, Cheung W, Sullivan PE, et al.: Balance and physical impairments after stroke. Arch Phys Med Rehabil, 1999, 80: 1227–1233. [Medline] [CrossRef]
17) Yoon JY, Kim KM, Chang MY, et al.: Foot pressure and trunk muscle activity during reaching tasks performed by seated hemiplegia patients. J Phys Ther Sci, 2011, 23: 525–529. [CrossRef]