Effect of Horseback Riding Simulation Machine Training on Trunk Balance and Gait of Chronic Stroke Patients

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Abstract. [Purpose] The purpose of this study was to assess the effect of horseback riding simulation machine training on trunk balance and gait of patients with chronic stroke. [Subjects and Methods] The subjects were 20 patients hospitalized for treatment after being diagnosed with stroke. Horseback riding simulation training was provided for 30 minutes, 5 times a week, for 6 weeks. Trunk balance was assessed using the Trunk Impairment Scale (TIS) and a balance measuring device (Biorescue, RM ingenierie, France), and gait ability was measured using the Functional Gait Assessment (FGA) and a gait analyzer (GAITRite, CIR system Inc., USA). [Results] There were significant changes in movement area, distance and velocity of body sway as measured by the TIS and the balance measuring device, and in gait velocity, cadence, stride length and double limb support as measured by the FGA and gait analyzer. [Conclusion] Horseback riding simulation training improved the trunk balance and gait of chronic stroke patients. This present study provides preliminary objective data for future research, and useful clinical information for physical therapists using horseback riding simulation machines as a treatment modality for patients with chronic stroke.
Key words: Horseback riding simulation machine training, Trunk balance, Gait

(This article was submitted Jun. 18, 2013, and was accepted Jul. 22, 2013)

INTRODUCTION

Stroke is a major disease causing brain impairment. Most stroke survivors experience changes in the level of consciousness, loss of motor and sensory functions, language disorder, and loss of cognitive and perceptual abilities. In addition, performance of activities of daily living becomes limited and participation in social activities decreases[1, 2]. In particular, functional activities are limited by stroke-induced impairment of movement, including balance, an important performance factor in functional activities[3].

In general, the stability of the body is achieved by actively adjusting physical stability and reacting to gravity, the support surface, visual perception, and the external environment through the interaction of various sensory and motor neurons[4, 5]. A reduction in balance ability leads to a decrease in the weight-bearing ratio of the lower limbs, or to paralysis, and acts as a factor in abnormal gait, affecting gait characteristics such as gait velocity, stride length, and cadence[6, 7]. Gait ability is defined as the mobility in performing activities of daily life[8]. Hence, gait recovery is one of the most important goals in the rehabilitation of stroke patients[9].

The trunk muscles play an important role in functional activities such as balance and gait[10, 11]. They participate in voluntary trunk movement as agonists and synergists[12], automatically responding to unpredictable perturbations[13], and preparing for instability induced by upper and lower limb movements. They also play a role in adapting the trunk in space so that proper movement can be achieved[14]. However, stroke patients are unable to keep their weight on both feet evenly, owing to loss of trunk muscle strength and trunk control ability[15], and have difficulties in performing functional activities because of a decrease in balance ability[11]. Therefore, improvement of trunk control ability can result in balance and functional recovery of the extremities, and predict functional improvement in activities of daily living. Training in a sitting position was reported to be effective at improving trunk control ability[16, 17]. In the study by Encheff et al., 10 weeks horseback riding therapy was performed by 11 children whose mobility was decreased due to nerve damage. Following the therapy, the position of the hip joint in the sagittal plane was greatly improved during the early stance and pre-swing phases. Moreover, the trunk became more upright, and in consequence, pos-

tural adjustment in walking improved[18]. In the study by Silkwood-Sherer, 15 multiple sclerosis patients performed horseback riding therapy once a week for 14 weeks, and the outcome was assessed using the Berg Balance Scale (BBS) and Performance-Oriented Mobility Assessment (POMA). The efficacy of horseback riding therapy for the improvement of balance ability was confirmed, with increases in the BBS and POMA scores of 9.15 and 10.38 points, respectively[19]. In addition, 20 stroke patients performed a 16-week horseback riding therapy, and improvements in their Fugl-Meyer Assessment Scale–lower limbs and BBS scores were observed[20]. However, it is a fact that horseback riding therapy is difficult for many people to perform and its outcomes are impossible to generalize because of the high costs and difficulty of creating an environment for horseback riding therapy, issues which outweigh its benefits.

The horseback riding simulator accurately reproduces the movements of a horse, has the same physiological effect as horseback riding therapy, and activates muscles for postural maintenance; it also eliminates many of the disadvantages of the horseback riding therapy[21, 22]. Present study aimed to examine the impact of horseback riding therapy program on the trunk balance and gait of chronic stroke patients, using a horseback riding simulator.

SUBJECTS AND METHODS

The subjects of this study were 20 patients hospitalized for the treatment of stroke in 2 hospitals located in South Korea (Table 1). This study complied with the ethical standards of the Declaration of Helsinki. All the subjects and their guardians voluntarily agreed to participate in the study after receiving explanations regarding the purpose and procedures of the experiment, and signed an informed consent statement before its start. The criteria for selecting the subjects were as follows: more than 6 months since the onset of non-traumatic and unilateral stroke, a Brunnstrom stage higher than 4, a Functional Ambulation Category (FAC) higher than stage 3, no visual or hearing loss, and a Mini-Mental State Examination-K score of 21 or higher. Patients with cardiovascular diseases, uncontrolled diabetes, psychiatric problems, and bilateral stroke were excluded from the experiment.

To assess the static and dynamic balance abilities in a sitting position and trunk coordination ability, we made assessments of the trunk impairment scale (TIS) in 3 replicates and recorded the highest score[28]. The TIS score has a maximum of 23 points, and higher scores are given for better trunk performance. A balance assessment device (Bio-Rescue, RM ingenierie, France), consisting of a force plate equipped with sensors, was used for static balance assessment in a standing position. The subjects stood with their feet set apart at approximately 30 degrees on the force plate,

and a description was provided by an image on the monitor installed in front of the subjects. Measurement was performed after the demonstration. The movement area (mm^2), distance (cm), and velocity (cm/s) of body sway were measured while maintaining standing with the eyes open and closed for 30 seconds each. The mean value of the measurements from 3 replicates was calculated.

To assess gait ability, we used the Functional Gait Assessment (FGA)[24] and a gait analyzer (GAITRite, CIR Systems Inc., USA) to measure the spatiotemporal gait[25, 26]. The functional gait assessment, 10 items were measured on walkway, which was 6 m long and 30 cm wide and marked every 1.5 m. Each item was scored from 0 to 4, with overall scores ranging from 0 to 30. In the gait analysis, velocity, cadence, stride length, and double limb support were measured When he subjects walked at a comfortable speed on the sensor-equipped electronic gait plate, which was 5 m long, 60 cm wide, and 0.6 cm high. The collected information was processed using the GAITRite GOLD Version 3.2b software. To exclude acceleration and deceleration artifacts, data were collected 2 m from the start until 2 m from the end of the gait plate[27]. In the gait measurement, the mean value was calculated of the measurements obtained when subjects walked over gait plate 3 times.

The simulated horseback riding therapy was performed for 30 minutes, 5 times a week for 6 weeks. The horseback riding simulator used for this experiment exactly reproduces the movement of the saddle and has speeds adjustable to 9 levels, ranging from 1.4 to 3.6 seconds/cycle (JOBA EU6414, National, Ltd., Japan). For the safety of the subjects, a frame was set to install a safety belt, and a physical therapist observed the patients While standing by their affected side. The 30-minute intervention consisted of a 5-minute warm-up, 20-minute horseback riding simulation training, and 5-minute cool-down. In the warm-up, the patients were asked to load their lower limbs in a sitting position and perform a turn task, looking back. The levels of load and turn were gradually increased. In the cool-down, the patients were asked to catch balls thrown from various directions. These exercises were performed at levels ranging from "fairly light (11)" to "somewhat hard (13)" on ratings of perceived exertion[23].

PASW 18.0 for Windows was used for all the statistical analysis in this study. The Kolmogorov-Smirnov test was used to test the data normality, and the paired t-test was used to compare outcome measures between before and after the training. Statistical significance was accepted for values of p less than 0.05.

RESULTS

The changes in trunk balance ability were determined based on the TIS scores and pre- and post-experimental

Table 1. General characteristics of subjects

Gender	Age (years)	Post-stroke duration (month)	Height (cm)	Weight (kg)
male: 10, female: 7	63.9 ± 8.7	23. 6 ± 2.8	165.7 ± 2.9	64.0 ± 4.3

values of the sway area, distance, and velocity, with the eyes open and closed (Table 2). Significant the differences in the TIS scores were observed between before and after training: 10.82 ± 2.21 points and 14.17 ± 2.48 points (p < 0.05). Moreover, with the eyes open, significant differences in sway area, distance, and velocity were found between before and after training, 129.16 ± 8.50 mm^2 and 126.37 ± 7.25 mm^2, 51.03 ± 4.74 cm and 46.55 ± 8.13 cm, and 1.77 ± 0.58 cm/s and 1.51 ± 0.54 cm/s, respectively (p < 0.05); whereas with eyes closed, significant differences were observed between before and after training of 214.05 ± 5.83 mm^2 and 211.17 ± 5.79 mm^2, 79.68 ± 2.80 cm and 76.56 ± 2.74 cm, and 2.84 ± 0.27 cm/s and 2.50 ± 0.33 cm/s, respectively (p < 0.05).

Gait ability was examined by measuring changes in FGA score, gait velocity, cadence, stride length of the affected and unaffected sides, and double limb support of the affected and unaffected sides between before and after training. Significant differences were found in FGA score, 16.35 ± 2.17 points and 19.94 ± 2.27 points (p < 0.05); gait velocity, 39.80 ± 14.75 cm/s and 49.73 ± 18.69 cm/s; cadence, 77.90 ± 12.97 steps/min and 82.25 ± 13.68 steps/min; stride lengths of the affected and unaffected sides, 60.32 ± 17.19 cm and 66.12 ± 16.23 cm, and 59.15 ± 17.06 cm and 64.06 ± 17.39 cm; and double limb support of the affected and unaffected sides, $55.27 \pm 13.81\%$ and $47.84 \pm 11.36\%$, and $54.00 \pm 13.07\%$ and $49.95 \pm 13.19\%$ (p < 0.05), respectively (Table 3).

DISCUSSION

A decrease in trunk function due to stroke affects balance adjustment and gait, and leads to functional changes that are constraints on social participation. Therefore, various approaches to the assessment and treatment of trunk control performance have been developed for stroke patients, because both are regarded as important elements in the rehabilitation of stroke patients[14,16–17].

The present study investigated the effects of a 6-week horseback riding simulation training on trunk balance of stroke patients. As a result of the training, the trunk control ability in a sitting position improved, as determined by the TIS. In a study by Silva et al., not only the postural control ability in a seated position but also the motor function of children with cerebral palsy was improved after horseback riding simulation training. Furthermore, the subjects reported in a quality-of-life assessment that they were more satisfied because the training was more interesting and fun

than their previous treatment[21]. In another study, Herrero et al. conducted horseback riding simulation training, once a week for 10 weeks, for 38 children with cerebral palsy, and reported their sitting balance improved (effect size, 0.36; 95% confidence interval [CI], 0.01–0.71). In particular, the training had a major impact on the group with severe disabilities (effect size, 0.80; 95% CI, 0.13–1.47). In the evaluation of their balance ability in a standing position, decreases were observed in sway area, distance, and velocity of the center of pressure with the eyes open and closed[29]. Yasuhiro et al. also conducted horseback riding simulation training, twice a week for 12 weeks, for 23 elderly people aged 65 years and older, and reported their performance of the subjects in the one-leg standing with eyes open task of the Functional Reach Test improved[28].

In the functional gait assessment of our present study, changes in gait ability and improvements in gait velocity, cadence, stride length, and double limb support were observed. Beinotti et al. studied the effects of horseback riding in 20 stroke patients who performed horseback riding therapy once a week for 16 weeks in addition to ordinary physical therapy. Their Fugl-Meyer Assessment Scale–lower limbs, BBS, and FAC scores improved from 14.7 to 18.5 points, 46.1 to 49.0 points, and 3.6 to 3.8 points, respectively. Compared with the control group, the scores in the assessment items for the lower limbs of the Fugl-Meyer Assessment Scale and BBS were improved by the horseback riding therapy. Their results demonstrate that performing the horseback riding therapy in addition to the ordinary physical therapy has a positive effect on gait training[20].

Table 2. Changes in trunk balance measured by the TIS and balance measuring device

Parameter		Pre-test	Post-test	
TIS		10.82 ± 2.21	14.17 ± 2.48	*
Biorescue-EO	Sway area (cm)	129.16 ± 8.50	126.37 ± 7.25	*
	Sway length (mm^2)	51.03 ± 4.74	46.55 ± 8.13	*
	Sway speed (cm/s)	1.77 ± 0.58	1.51 ± 0.54	*
Biorescue-EC	Sway area (cm)	214.05 ± 5.83	211.17 ± 5.79	*
	Sway length (mm^2)	79.68 ± 2.80	76.56 ± 2.74	*
	Sway speed (cm/s)	2.84 ± 0.27	2.50 ± 0.33	*

TIS: trunk impairment scale, EO: Eyes open, EC: Eyes close, * p-value <0.05, paired t-test

Table 3. Changes in gait measured by the FGA and gait analyzer

Parameter		Pre-test	Post-test	
FGA		16.35 ± 2.17	19.94 ± 2.27	*
Gaitrite	velocity (cm/s)	39.80 ± 14.75	49.73 ± 18.69	*
	cadence (steps/min)	77.90 ± 12.97	82.25 ± 13.68	*
	Stride (affected) (cm)	60.32 ± 17.19	66.12 ± 16.23	*
	Stride (non-affected) (cm)	59.15 ± 17.06	64.06 ± 17.39	*
	double support (%)	55.27 ± 13.81	47.84 ± 11.36	*
	double support (non) (%)	54.00 ± 13.07	49.95 ± 13.19	*

FGA: Functional Gait Assessment, * p-value <0.05, paired t-test

Moreover, when elderly people who experienced a fall performed horseback riding simulation training, an improvement was observed in the 5-m walking test at a comfortable speed, number of steps in the 5-m gait at a fast speed, flexion angle of the lumbar spine, and the tilt angle of the sacral vertebrae. The training was found to improve the balance ability necessary for gait and contributed to gait improvement[28]. In addition, Uchiyama et al. performed a comparative 3-dimensional analysis of gait using 50 healthy adults and 11 horses. The results for both were quantitatively and qualitatively similar. Furthermore, only slight differences in heart rate, respiratory rate, and blood pressure were observed after 127 adults performed gait and horseback riding at a speed with similar acceleration patterns. Therefore, the optimal therapeutic effect of horseback riding therapy has been demonstrated for patients with gait disorders, because it provides a similar stimulus to that generated by human gait[28].

The trunk control ability of stroke patients is an index which is used to indicate the recovery of performance in activities of daily living, and it is closely related to balance and gait[17]. Horseback riding therapy improves trunk balance and postural adjustment by utilizing the repeated stimuli of a horse's movement to enhance the muscles around the pelvis, abdomen, and waist which are used to maintain posture[30]. However, horseback riding therapy is not feasible for many patients because of practical difficulties such as economic burden, lack of facilities for horseback riding therapy, shortage of professional therapists, fear of horses, and allergy. Therefore, horseback riding simulation training was developed to reproduce its advantages and address the disadvantages. Its efficacy for children with cerebral palsy and elderly people who have experienced a fall has been studied[21, 28]. Recent reports indicate that it could be a therapeutic alternative for stroke patients. The present study provides information on the efficacy of horseback riding simulation training for chronic stroke patients, and demonstrated that it improved their trunk balance and gait. However, our study was limited in terms of generalization, because we enrolled only a small number of subjects, and we could not completely control their activities of daily living. Regardless of these limitations, our study was able to demonstrate that horseback riding simulation training has potential as a therapeutic method for improving the trunk balance and gait of stroke patients. However, future research studies with a larger number of subjects, longer application period, and assessment of functional levels of patients are required to validate our results.

REFERENCES

1) Hyndman D, Ashburn A: People with stroke living in the community: attention deficits, balance, ADL ability and falls. Disabil Rehabil, 2003, 25: 817–822. [Medline] [CrossRef]
2) Langhorne P, Coupar F, Pollock A: Motor recovery after stroke: a systematic review. Lancet Neurol, 2009, 8: 741–754. [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) Wade MG, Jones G: The role of vision and spatial orientation in the maintenance of posture. Phys Ther, 1997, 77: 619–628. [Medline]
5) Horak FB: Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? Age Ageing, 2006, 35: ii7–ii11. [Medline] [CrossRef]
6) Shumway-Cook A, Anson D, Haller S: Postural sway biofeedback: its effect on reestablishing stance stability in hemiplegic patients. Arch Phys Med Rehabil, 1988, 69: 395–400. [Medline]
7) Mathias S, Nayak US, Isaacs B: Balance in elderly patients: the "get-up and go" test. Arch Phys Med Rehabil, 1986, 67: 387–389. [Medline]
8) Turnbull GI, Charteris J, Wall JC: A comparison of the range of walking speeds between normal and hemiplegic subjects. Scand J Rehabil Med, 1995, 27: 175–182. [Medline]
9) Bohannon RW, Horton MG, Wikholm JB: Importance of four variables of walking to patients with stroke. Int J Rehabil Res, 1991, 14: 246–250. [Medline] [CrossRef]
10) Farley BG, Koshland GF: Trunk muscle activity during the simultaneous performance of two motor tasks. Exp Brain Res, 2000, 135: 483–496. [Medline] [CrossRef]
11) Moseley AM, Stark A, Cameron ID, et al.: Treadmill training and body weight support for walking after stroke. 2003, 34: 3006.
12) Le Bozec S, Lesne J, Bouisset S: A sequence of postural muscle excitations precedes and accompanies isometric ramp efforts performed while sitting in human subjects. Neurosci Lett, 2001, 303: 72–76. [Medline] [CrossRef]
13) Hodges PW, Richardson CA: Contraction of the abdominal muscle associated with movement of the lower limb. Phys Ther, 1997, 77: 132–142. [Medline]
14) 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]
15) Chou SW, Wong AM, Leong CP, et al.: Postural control during sit-to stand and gait in stroke patients. Am J Phys Med Rehabil, 2003, 82: 42–47. [Medline] [CrossRef]
16) Verheyden G, Vereeck L, Truijen S, et al.: Additional exercises improve trunk performance after stroke: a pilot randomized controlled trial. Neurorehabil Neural Repair, 2009, 23: 281–286. [Medline]
17) Verheyden G, Vereeck L, Truijen S, et al.: Trunk performance after stroke and the relationship with balance, gait and functional ability. Clin Rehabil, 2006, 20: 451–458. [Medline] [CrossRef]
18) Encheff JL, Armstrong C, Masterson M, et al.: Hippotherapy effects on trunk, pelvic, and hip motion during ambulation in children with neurological impairments. Pediatr Phys Ther, 2012, 24: 242–250. [Medline] [CrossRef]
19) Silkwood-Sherer D, Warmbier H: Effects of hippotherapy on postural stability, in persons with multiple sclerosis: a pilot study. J Neurol Phys Ther, 2007, 31: 77–84. [Medline] [CrossRef]
20) Beinotti F, Correia N, Christofoletti G, et al.: Use of hippotherapy in gait training for hemiparetic post-stroke. Arq Neuropsiquiatr, 2010, 68: 908–913. [Medline] [CrossRef]
21) Silva e Borges MB, Werneck MJ, da Silva Mde L, et al.: Therapeutic effects of a horse riding simulator in children with cerebral palsy. Arq Neuropsiquiatr, 2011, 69: 799–804. [Medline] [CrossRef]
22) Kitagawa T, Takeuchi T, Shinomiya Y, et al.: Cause of active motor function by passive movement. J Phys Ther Sci, 2001, 13: 167–172. [CrossRef]
23) Verheyden G, Nieuwboer A, Van de Winckel A: Clinical tools to measure trunk performance after stroke: a systematic review of the literature. Clin Rehabil, 2007, 21: 387–394. [Medline] [CrossRef]
24) Wrisley DM, Marchetti F, Kuharsky K, et al.: Reliability, internal consistency, and validity of data obtained with the functional gait assessment. Phys Ther, 2004, 84: 906–918. [Medline]
25) McDonough AL, Batavia M, Chen F, et al.: The validity and Reliability of the GAITRite system's measurement: a preliminary evaluation. Arch Phys Med Rehabil, 2001, 82: 419–425. [Medline] [CrossRef]
26) Van J, Besser, P: Test-retest reliability of temporal and spatial gait characteristics measured with an instrumented walkway system (GAITRite). BMC Musculoskelet Disord, 2004, 5.
27) Menz HB, Latt M, Tiedemann A, et al.: Reliability of the GAITRite walkway system for the quantification of temporo-spatial parameters of gait in young and older people. Gait Posture, 2004, 20: 20–25. [Medline] [CrossRef]
28) Mitani Y, Doi K, Yano T, et al.: Effect of exercise using a horse-riding simulator on physical ability of frail seniors. J Phys Ther Sci, 2008, 20: 177–183. [CrossRef]
29) Herrero P, Gómez-Trullén EM, Asensio A, et al.: Study of the therapeutic effects of a hippotherapy simulator in children with cerebral palsy: a stratified single-blind randomized controlled trial. Clin Rehabil, 2012, 26: 1105–1113. [Medline] [CrossRef]
30) Uchiyama H, Ohtani N, Ohta M: Three-dimensional analysis of horse and human gaits in therapeutic riding. Appl Anim Behav Sci, 2011, 135: 271–276. [CrossRef]