J. Phys. Ther. Sci.
27: 655–658, 2015

Original Article

Effects of community-based virtual reality treadmill training on balance ability in patients with chronic stroke

Nara Kim, PT, MSc[1)], YuHyung Park, PT, MSc[1)], Byoung-Hee Lee, PT, PhD[2)*]

[1)] *Graduate School of Physical Therapy, Sahmyook University, Republic of Korea*
[2)] *Department of Physical Therapy, Sahmyook University: 815 Hwarang-ro, Nowon-gu, Seoul 139-742, Republic of Korea*

Abstract. [Purpose] We aimed to examine the effectiveness of a community-based virtual reality treadmill training (CVRTT) program on static balance abilities in patients with stroke. [Subjects and Methods] Patients (n = 20) who suffered a stroke at least 6 months prior to the study were recruited. All subjects underwent conventional physical therapy for 60 min/day, 5 days/week, for 4 weeks. Additionally, the CVRTT group underwent community-based virtual reality scene exposure combined with treadmill training for 30 min/day, 3 days/week, for 4 weeks, whereas the control group underwent conventional physical therapy, including muscle strengthening, balance training, and indoor and outdoor gait training, for 30 min/day, 3 days/week, for 4 weeks. Outcome measurements included the anteroposterior, mediolateral, and total postural sway path lengths and speed, which were recorded using the Balancia Software on a Wii Fit™ balance board. [Results] The postural sway speed and anteroposterior and total postural sway path lengths were significantly decreased in the CVRTT group. Overall, the CVRTT group showed significantly greater improvement than the control group. [Conclusions] The present study results can be used to support the use of CVRTT for effectively improving balance in stroke patients. Moreover, we determined that a CVRTT program for stroke patients is both feasible and suitable.
Key words: Stroke rehabilitation, Community-based virtual reality, Balance

(This article was submitted Aug. 21, 2014, and was accepted Oct. 10, 2014)

INTRODUCTION

To maintain balance, simultaneous and continuous processing of data from multiple systems, including sensory information from visual, vestibular, and proprioception stimuli is required[1)]. Moreover, cognitive integration, cerebellar function, and sensory and motor feedback are essential for maintaining balance[2)]. Balance disorders due to deficits in multiple mechanisms are frequently encountered in patients with stroke. Balance is an important predictor of outcome in stroke rehabilitation. The utility of balance and gait status in predicting overall outcomes, such as the length of hospital stay and discharge destination, is recognized[3)]. In patients with stroke, postural stability impairments may manifest during quiet stance as increased postural sway[4)].

After stroke, difficulties in balance control may be caused by several factors, such as muscle weakness, impaired proprioception, asymmetry in weight bearing, spasticity, and impaired motor control[5, 6)]. Compared with a normal person in the same age group, an individual with stroke has a nearly double the body sway and reduced stability[7)]. In particular, the movement of the center of gravity is slowed due to asymmetric weight bearing, resulting in postural imbalance, which markedly compromises the walking ability of a stroke patient[8)]. Balance-related deficits are significant factors contributing to the delayed recovery of activities of daily living, considering the limited ability to stand or walk following a stroke. Decreased postural stability and balance decreases an individual's confidence in movement and restricts participation in physical activities. Furthermore, it increases an individual's risk of falling and promotes sedentary lifestyles, which ultimately result in secondary disability[9)].

To ensure safe walking and successful physical activity in stroke patients, patients should be able to maintain balance and avoid obstacles when unexpected changes occur[7)]. Therefore, improving walking ability is one of the most important goals in patients undergoing stroke rehabilitation.

Various training programs have been implemented to ameliorate balance impairment; however, the reported training effects are difficult to generalize[4, 10)]. In particular, training effects are expected to be different between a clinical setting and community environment. One frequently used training device is the treadmill, which can promote optimum balance control during locomotion. Balance training combined with treadmill training reportedly results in excellent improvement in terms of increased balance ability compared with

*Corresponding author. Byoung-Hee Lee (E-mail: 3679@syu.ac.kr)

traditional rehabilitation methods in patients with stroke[10]. Cho et al.[11] reported that treadmill training was effective for improving standing balance in patients with stroke. However, treadmill training is primarily set up for level-ground walking; hence, training involving level-ground walking on a treadmill would not represent various daily activities, such as walking on an irregular surface, avoiding obstacles, and turning. Thus, it may be incorrect to state that basic treadmill training enables patients to walk successfully in real life, because environmental factors are not sufficiently simulated in this training. To compensate for the drawbacks of such rehabilitation programs, virtual reality (VR) training is proposed as an alternative measure[12].

VR, occasionally referred to as immersive multimedia, is a computer-simulated environment that can simulate the physical presence of real or imagined places. VR can recreate sensory experiences, such as taste, sight, smell, sound, and touch[13]. VR has been applied in neurologic rehabilitation programs, by using equipment combined with environments similar to the real world[10]. Furthermore, VR has the ability to create an interactive and motivational environment that can be manipulated by the therapist to provide individualized treatment in a safe environment[14].

In the present study, we aimed to investigate the effects of treadmill training combined with community-based VR training on static balance in patients with chronic stroke.

SUBJECTS AND METHODS

Twenty chronic stroke patients voluntarily participated in the study. The subjects met the following inclusion criteria: history of stroke onset of >6 months prior to the study, in order to minimize the effects of natural recovery; ability to walk without using a walking aid for a minimum of 15 m; Mini-Mental State Examination score of >24 out of 30; and ability to comprehend and follow simple instructions. Individuals were excluded if they had a neurological condition, orthopedic disease, or visual impairment.

The present study was approved by the Sahmyook University Institutional Review Board (SYUIRB2011-003). Each participant was able to follow instructions and provided informed consent by signing an approval form.

The 20 subjects were randomly assigned to either the community-based VR treadmill training (CVRTT) group or the control group. All subjects were assessed using the Balancia Software system (Balancia Software, version 1.0, Minstosys, Seoul, Republic of Korea, 2011) connected to a Wii balance board (Nintendo, Kyoto, Japan, 2012), in order to measure their static balance ability before and after intervention.

All subjects underwent conventional physical therapy 1 hour/day, 5 days/week, for 4 weeks. In addition, the patients in the CVRTT group underwent VR scene exposure combined with treadmill training for 30 min/day, 3 days/week, for 4 weeks, whereas those in the control group underwent conventional physical therapy, including muscle strengthening, balance training, and indoor and outdoor gait training, for 30 min/day, 3 days/week, for 4 weeks. Of the 20 randomized participants, 17 completed the 4-week training program. The participants who were excluded from the control group included 1 patient who was discharged from the hospital and 2 patients who had low participation rates (<80%).

The CVRTT system included VR image and adjustable inclination treadmill equipment (WNT-2000i, Wellness Track, Republic of Korea, 2009), laptop (NT-P210, Samsung, Republic of Korea, 2009), video projector (PLC-XW55, Sanyo, Japan, 2006), and a 210 × 180 cm (width × height) screen. VR technology was used to control the speed of optic flow for each user by adjusting the VR video for the treadmill speed. A VR video was displayed on a screen 3 m in front of the treadmill using a video projector. When the study participants increased their speed, the speed of the VR video was also increased, using a laptop interface, in accordance with the optic flow, to match the participant's real speed. This VR video comprised images of community ambulation, such as walking on sidewalks, level walking, slope walking, and walking over obstacles. The individuals in the CVRTT group performed treadmill training with each VR video for 5 min, followed by 2 min of rest to minimize fatigue. In addition, emergency stop devices were attached to each participant to ensure safety.

Control group training consisted of overground walking, stair walking, slope walking, and unstable surface walking for 570 m. An assistant helped to ensure the participant's safety on the paralyzed side.

Static balance ability was assessed according to the postural sway path length and speed at the center of pressure (COP) by using the Balancia Software system connected to a computer, and a Wii balance force platform with 4 load cells. To measure static balance, the subjects were asked to place their feet on a Wii Fit™ balance board with their feet spread apart at shoulder width. The subjects were then asked to maintain their balance for 30 s while looking at a point on a wall 3 m away. The static balance ability was measured by the postural sway path length and speed at the COP using the Balancia software.

The SPSS 17.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The Kolmogorov-Smirnov test was used to test the distribution of general characteristics and outcome measures of the subjects; among these measures, gender and paretic side were evaluated using the χ^2 test. A paired t-test was used to compare pre- and post-test measurements of balance within groups, and the independent t-test was used to compare the difference in balance before and after training between groups. The significance level was set at 0.05 for all analyses.

RESULTS

The CVRTT group showed a significant improvement in the anteroposterior postural sway path length, which decreased from 0.46 cm before training to 0.40 cm after training ($p < 0.05$), whereas the control group demonstrated no significant improvement in anteroposterior postural sway path length, which increased from 0.39 cm before training to 0.47 cm after training. The mediolateral postural sway path length was not significantly different between the 2 groups. However, the CVRTT group demonstrated a significantly improved total postural sway path length, which decreased from 68.37 cm before training to 63.02 cm after

Table 1. Comparison of static balance ability within and between the groups (N=17)

Parameters		Values				Change values	
		CVRTT group (n=10)		Control group (n=7)		CVRTT group (n=10)	Control group (n=7)
		Pre	Post	Pre	Post	Post-Pre	Post-Pre
PSPL (cm)	A-P	0.46 (0.21)	0.40 (0.21)**	0.39 (0.10)	0.47 (0.10)	–0.06 (0.05)†	0.08 (0.14)
	M-L	0.48 (0.47)	0.36 (0.49)	0.24 (0.06)	0.33 (0.15)	–0.12 (0.19)†	0.09 (0.11)
	Total	68.37 (19.11)	63.02 (13.56)*	59.52 (10.36)	62.01 (10.67)	–5.35 (6.72)‡	2.49 (2.32)
APSS (cm/s)		2.28 (0.64)	2.10 (0.45)*	1.99 (0.35)	2.07 (0.36)	–0.18 (0.22)‡	0.08 (0.08)

Values are mean (SD), CVRTT: community-based virtual reality treadmill training; PSPL: postural sway path length; APSS: average postural sway speed; A-P: anteroposterior; M-L: mediolateral. *p<0.05; **p<0.01; significant difference within group, †p<0.05; ‡p<0.01; significant difference between group

training ($p < 0.05$). The total postural sway path length did not significantly improve in the control group (59.52 cm before training to 62.01 cm after training). Furthermore, the postural sway speed significantly improved in the CVRTT group (2.28 cm/s before training to 2.10 cm/s after training; $p < 0.05$), but not in the control group (1.99 cm/s before training to 2.07 cm/s after training). The CVRTT group showed significantly greater improvements in multiple balance measures ($p < 0.05$) compared with the control group, which suggests that the CVRTT program improves the static balance ability in patients recovering from stroke (Table 1).

DISCUSSION

Balance is a complex process that mitigates postural instability by minimizing the center of mass in proportion to the base of support[15], and maintains posture during voluntary processes by appropriately responding to perturbation[16]. Balance is also essential for performing various activities of daily living and community ambulation[17].

Balance can be negatively affected by proprioception dysfunction, muscle weakness, joint immobility, pain, visual deficits, or loss of proprioception[18]. Significant impairments in balance are observed in patients with neurologic problems, such as stroke and spinal cord damage. Approximately 25–75% of stroke patients have experienced a fall, and approximately 10–25% of these cases require intensive medical treatment[19].

Symptoms of postural imbalance in stroke patients are evident during standing, due to increased weight bearing towards the non-paretic side. Decreased standing balance and loss of the ability to shift weight towards the paretic leg can also develop after a stroke[20]. Difficulties in shifting weight towards the paretic side can impair important functional movements, such as standing up from a chair, moving, walking, turning, and walking upstairs[21].

Thus, limitations in movements can decrease the range and amount of physical activities that can be completed, and could lead to further decreases in postural balance, which may ultimately result in the deterioration of physical health. Balance is an essential part of life for stroke patients because it can prevent falls, promotes daily activities, and supports independent lifestyles[19].

In a previous study, Park et al.[22] reported that general treadmill training was not more effective at improving the balance ability of stroke patients than conventional physical therapy. In another study, Cho et al.[23] selected 22 chronic stroke patients and assigned them to either a treadmill group with VR or without VR. Both groups participated in each intervention for 30 min/day, 3 times/week, for 6 weeks. However, there was no significant difference in anteroposterior and mediolateral postural sway speeds and lengths between the treadmill groups with VR and without VR. In contrast, in a recent study on the effect of a VR treadmill program on static balance, Kim et al.[24] reported that the Berg Balance Scale score was significantly increased to a greater extent in the VR training group compared with the control group without VR training.

In the present study, we examined the effects of CVRTT on static balance in chronic stroke patients. In a recent study, Yang et al.[19] conducted a balance skill program using VR treadmill training for 3 weeks, and reported that mediolateral postural sway was more significantly improved in the VR treadmill group than in the control group ($p = 0.038$). According to their results, VR treadmill training improved the mediolateral postural sway to a greater extent than that noted in the control group.

In the present study, the CVRTT group showed a significant change in anteroposterior postural sway path length (CVRTT group, from 46 cm to 0.40 cm), total postural sway path length (CVRTT group, from 68.37 cm to 63.02 cm), and average postural sway speed (CVRTT group, from 2.28 cm/s to 2.10 cm/s) compared with the control group. Furthermore, the static balance in the CVRTT group was significantly improved as compared with the control group ($p < 0.05$), which was similar to the findings of previous studies.

Based on the findings from our study, VR treadmill training with various community environment conditions could yield increased static balance, which involves the maintenance of a neutral position (i.e., midline orientation of body) in response to internal and external postural perturbations. Moreover, motor learning during CVRTT, including various environmental conditions, control of task grade, and sensory feedback, will influence the motivation of patients as well as static balance for maintaining their body within the limits of stability. According to the results of this study, we confirmed that VR treadmill training has a positive effect on static balance measures and is an effective treatment regimen for improving static balance in stroke patients.

This study has several limitations. First, a relatively small sample size was used for this study. Second, there was a lack of diversity in the dependent variables, because we only measured static balance ability. Hence, future research with supplemental measures of dynamic balance and gait ability should be conducted. Furthermore, to confirm the findings of the present study, a follow-up study comparing groups performing VR treadmill training, general treadmill training, and community gait training is needed.

REFERENCES

1) Park YH, Lee CH, Lee BH: Clinical usefulness of the virtual reality-based postural control training on the gait ability in patients with stroke. J Exerc Rehabil, 2013, 9: 489–494. [Medline] [CrossRef]
2) Ng SS, Hui-Chan CW: The timed up & go test: its reliability and association with lower-limb impairments and locomotor capacities in people with chronic stroke. Arch Phys Med Rehabil, 2005, 86: 1641–1647. [Medline] [CrossRef]
3) Wee JY, Wong H, Palepu A: Validation of the Berg Balance Scale as a predictor of length of stay and discharge destination in stroke rehabilitation. Arch Phys Med Rehabil, 2003, 84: 731–735. [Medline] [CrossRef]
4) Nichols DS: Balance retraining after stroke using force platform biofeedback. Phys Ther, 1997, 77: 553–558. [Medline]
5) Mercier L, Audet T, Hébert R, et al.: Impact of motor, cognitive, and perceptual disorders on ability to perform activities of daily living after stroke. Stroke, 2001, 32: 2602–2608. [Medline] [CrossRef]
6) Geiger RA, Allen JB, O'Keefe J, et al.: Balance and mobility following stroke: effects of physical therapy interventions with and without biofeedback/forceplate training. Phys Ther, 2001, 81: 995–1005. [Medline]
7) Perry J, Garrett M, Gronley JK, et al.: Classification of walking handicap in the stroke population. Stroke, 1995, 26: 982–989. [Medline] [CrossRef]
8) Jung GU, Moon TH, Park GW, et al.: Use of augmented reality-based training with EMG-triggered functional electric stimulation in stroke rehabilitation. J Phys Ther Sci, 2013, 25: 147–151. [CrossRef]
9) Salbach NM, Mayo NE, Robichaud-Ekstrand S, et al.: The effect of a task-oriented walking intervention on improving balance self-efficacy poststroke: a randomized, controlled trial. J Am Geriatr Soc, 2005, 53: 576–582. [Medline] [CrossRef]
10) Yoo HN, Chung E, Lee BH: The effects of augmented reality-based otago exercise on balance, gait, and falls efficacy of elderly women. J Phys Ther Sci, 2013, 25: 797–801. [Medline] [CrossRef]
11) Cho KH, Lee WH: Virtual walking training program using a real-world video recording for patients with chronic stroke: a pilot study. Am J Phys Med Rehabil, 2013, 92: 371–380, quiz 380–382, 458. [Medline] [CrossRef]
12) Yang YR, Tsai MP, Chuang TY, et al.: Virtual reality-based training improves community ambulation in individuals with stroke: a randomized controlled trial. Gait Posture, 2008, 28: 201–206. [Medline] [CrossRef]
13) Kim NG, Yoo CK, Im JJ: A new rehabilitation training system for postural balance control using virtual reality technology. IEEE Trans Rehabil Eng, 1999, 7: 482–485. [Medline] [CrossRef]
14) Sveistrup H: Motor rehabilitation using virtual reality. J Neuroeng Rehabil, 2004, 1: 10–18. [Medline] [CrossRef]
15) Rose DL: *Fall proof.* Illinois: Human Kinetics, 2003: 4–15.
16) Berg KO, Maki BE, Williams JI, et al.: Clinical and laboratory measures of postural balance in an elderly population. Arch Phys Med Rehabil, 1992, 73: 1073–1080. [Medline]
17) Tyson SF, Hanley M, Chillala J, et al.: Balance disability after stroke. Phys Ther, 2006, 86: 30–38. [Medline]
18) Rosén E, Sunnerhagen KS, Kreuter M: Fear of falling, balance, and gait velocity in patients with stroke. Physiother Theory Pract, 2005, 21: 113–120. [Medline] [CrossRef]
19) Yang S, Hwang WH, Tsai YC, et al.: Improving balance skills in patients who had stroke through virtual reality treadmill training. Am J Phys Med Rehabil, 2011, 90: 969–978. [Medline] [CrossRef]
20) Srivastava A, Taly AB, Gupta A, et al.: Post-stroke balance training: role of force platform with visual feedback technique. J Neurol Sci, 2009, 287: 89–93. [Medline] [CrossRef]
21) Eng JJ, Chu KS, Kim CM, et al.: A community-based group exercise program for persons with chronic stroke. Med Sci Sports Exerc, 2003, 35: 1271–1278. [Medline] [CrossRef]
22) Park SW, Lee KJ, Shin DC, et al.: The effect of underwater gait training on balance ability of stroke patients. J Phys Ther Sci, 2014, 26: 899–903. [Medline] [CrossRef]
23) Cho KH, Lee WH: Effect of treadmill training based real-world video recording on balance and gait in chronic stroke patients: a randomized controlled trial. Gait Posture, 2014, 39: 523–528. [Medline] [CrossRef]
24) Kim IC, Lee BH: Effects of augmented reality with functional electric stimulation on muscle strength, balance and gait of stroke patients. J Phys Ther Sci, 2012, 24: 755–762. [CrossRef]