Effects of Virtual Reality Treadmill Training on Balance and Balance Self-efficacy in Stroke Patients with a History of Falling

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Abstract. [Purpose] The purpose of this study was to investigate the effects of virtual reality treadmill training on balance and balance self-efficacy in stroke patients with a history of falling. [Subjects] Twenty-one stroke patients with a history of falling were allocated into 2 groups: a virtual reality treadmill training group (experimental group, n = 11), and control group (n = 10). [Methods] We measured patients’ balance function and balance self-efficacy before and after 3 weeks of virtual reality treadmill training. [Results] Balance and balance self-efficacy were significantly higher in the experimental group. Furthermore, balance and balance self-efficacy significantly increased after 3 weeks in both groups compared with the baseline values. [Conclusion] Virtual reality treadmill training significantly improves balance and balance self-efficacy in stroke patients who are able to participate in physical balance training.

Key words: Virtual reality, Stroke, Balance

INTRODUCTION

Functional recovery is important after a stroke that causes cognitive, sensory, and motor deficits. Because of decreased balance ability, falls are common after stroke. Falls occur in 43–70% of stroke patients, and 5–27% of stroke patients fall more than twice. Stroke patients who have experienced repeated falls continue to fear that it will happen again, and their activity level decreases by about 25%. Moreover, self-efficacy is considered as important as physical ability influencing human movement and improvement of falls self-efficacy in stroke patients is associated with enhancement of balance and motor function.

Treadmill training is used for stroke patients in clinical settings, and when combined with conventional therapies and other training, treadmill training improves not only gait but also balance.

Virtual reality (VR) is typically defined in terms of technological hardware. Recently, virtual reality technology has been implemented to provide a life-like environment for physical therapy in stroke patients. Through interactions and feedback, participants acquire a variety of techniques to improve postural control and balance. Yang et al. reported that 3 weeks of virtual reality treadmill training was more effective than treadmill training in improving balance control. Walker et al. reported that virtual reality treadmill training improves dynamic balance in stroke patients.

However, the study of Walker et al. lacked a control group, and it was not clear whether balance was improved by treadmill training or by virtual reality training. The studies also provide insufficient information about the effects of combining treadmill training with virtual reality training. Therefore, this study implements virtual reality treadmill training for stroke patients who have experienced a fall and compares virtual reality treadmill training with treadmill training alone with the aim of developing a more effective balanced rehabilitation program for stroke patients.

SUBJECTS AND METHODS

This study used a randomized, pretest-posttest control group design. We recruited 25 stroke patients with a history of falling who were receiving outpatient management services at a community welfare center. These patients volunteered to participate in the study. The inclusion criteria were as follows: (1) history of falling; (2) occurrence of first hemiparetic stroke 6 months before the study; (3) ability to walk independently for more than 30 minutes; (4) no cognitive impairment (<24 in a mini-mental state examination); (5) Brunstrom stage, >4; and (6) no cardiovascular, orthopedic, or other neurologic conditions that may interfere with the study. Four patients were excluded because they were unable to walk for 30 minutes. The patients were randomly allocated into 2 groups by drawing lots: the experimental...
group (n = 11) and the control group (n = 10). This study was single blinded: the physical therapist inputting the evaluation and data analysis was unaware of the group of each patient, and the subjects and their therapist were blinded to the experimental group. All participants were evaluated before training and at the end of the 3-week training period.

The experimental group performed virtual reality treadmill training 30 minutes a day, 5 times a week, for 3 weeks. The control group received treadmill training, without control over the slope of the treadmill, on the same schedule.

Subjects receiving virtual reality treadmill training wore a head-mounted device (HMD), watched the virtual reality program on the screen of the HMD, and walked on the treadmill. The virtual reality program simulated a park stroll. Computer hardware on the HMD recorded output data (Mybud, Accupix, Gyeonggi-do, Korea). The HMD consisted of a 100-inch screen and built-in earphones. All subjects started each training session at a self-selected, comfortable walking speed. The treadmill speed was increased by 0.1 km/h each time the patient was able to walk stably for more than 20 seconds[12]. All subjects wore a non-weight-bearing harness (Shuma DA-2000, Daean medical, Seoul, Korea) for safety purposes.

Test evaluators received 1 week of training and were blind to the experimental group and control group assignments. A timed up and go test (TUG) was used to evaluate dynamic balance. Each patient was asked to stand up, walk at a comfortable speed to a point marked 3 m away from their chair, turn around, walk back, and sit down on their chair. The total time required to complete this process was measured with a stopwatch. Three trials were performed, and the mean time was recorded[15]. The cut-off value for the TUG indicating a normal versus below normal performance is 12 seconds[16]. The intrarater reliability ($r = 0.99$)[17] and interrater reliability ($r = 0.98$) were high[15]. The Activities-Specific Balance Confidence (ABC) scale is a questionnaire that asks individuals to rate their levels of confidence in performing 16 ambulatory activities on a scale ranging from 0 (no confidence) through 100 (complete confidence)[18]. The sum of the 16 ratings is divided by 16 and multiplied by 100 to obtain a percentage[19]. The test-retest (intraclass correlation=0.85) reliability was high[20].

SPSS 12.0 was used for data analysis. The Mann-Whitney test was used to compare the difference in scores between each group. The Wilcoxon signed-rank test was used to compare the difference in the scores between each task. The $\alpha$ level was set at 0.05.

RESULTS

Demographic data are summarized in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>VR TR</th>
<th>TR</th>
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</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Age (years)</td>
<td>60.5 ± 8.6</td>
<td>63.6 ± 5.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.2 ± 8.4</td>
<td>66.5 ± 8.5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.9 ± 6.6</td>
<td>166.9 ± 7.3</td>
</tr>
<tr>
<td>MMSE (score)</td>
<td>26.4 ± 2.2</td>
<td>26.3 ± 2.1</td>
</tr>
<tr>
<td>Post-stroke duration (months)</td>
<td>12.6 ± 3.3</td>
<td>15.4 ± 4.7</td>
</tr>
</tbody>
</table>

Note. All variables are means ± standard deviation (SD). VR TR: virtual reality treadmill training group. TR: treadmill training group.

Table 2. Differences in dynamic balance and balance self-efficacy between groups

<table>
<thead>
<tr>
<th></th>
<th>VR TR</th>
<th>TR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUG (sec)†</td>
<td>21.9 ± 3.5</td>
<td>23.8 ± 4.9</td>
</tr>
<tr>
<td>Post</td>
<td>19.2 ± 4.5</td>
<td>23.0 ± 5.2</td>
</tr>
<tr>
<td>Change</td>
<td>–2.7 ± 1.9†</td>
<td>–0.8 ± 0.7†</td>
</tr>
<tr>
<td>ABC scale (%)†</td>
<td>43.3 ± 5.7</td>
<td>47.0 ± 5.0</td>
</tr>
<tr>
<td>Post</td>
<td>52.8 ± 6.5</td>
<td>51.3 ± 5.6</td>
</tr>
<tr>
<td>Change</td>
<td>9.5 ± 6.0†</td>
<td>4.3 ± 3.3†</td>
</tr>
</tbody>
</table>

Note. All variables are means ± standard deviation (SD). VR TR: virtual reality treadmill training group. TR: treadmill training group. TUG: timed up and go test. ABC scale: Activities-Specific Balance Confidence scale. †Statistically significant difference between VR TR and TR (p<0.05). ††Statistically significant difference between pre- and post-test values (p<0.05).

DISCUSSION

This study was performed to identify the effect of virtual reality treadmill training on balance and balance self-efficacy in stroke patients with a history of falling. After 3 weeks of virtual reality treadmill training, subjects in the experimental group showed a greater improvement in balance and balance self-efficacy than did subjects in the control group.

Treadmill training is a task-oriented and repetitive activity[21] that improves strength[5] and symmetry[22] in the lower extremities as the slope progressively increases. It also reorganizes motor regions of the central nervous system and activates the cerebral cortex to cause motor learning in the limbs and eventually improves motor learning and balance[23]. Lau et al. implemented speed-dependent treadmill training for subacute stroke patients and reported that treadmill training improves dynamic balance[24]. Matjačić reported...
that treadmill training for a patient with an incomplete C5 level spinal cord injury, American Spinal Injury Association (ASIA) Impairment Scale of D and lower-extremity motor score of 34/50 significantly improved the patient’s gait and dynamic balance.

Many recent studies have utilized virtual reality programs. By increasing subjects’ interest and rate of participation, virtual reality training programs increase functional activity and influence brain reorganization. Brain reorganization through virtual reality training plays a major role in increasing neural plasticity in stroke patients and spreads brain activation on the side opposite the injury. It eventually affects functional recovery of the lower extremity on the paretic side and ultimately improves locomotion and symmetry in the lower extremity. Therefore, this improved locomotion and symmetry in the lower extremity improves dynamic balance. Kim et al. implemented virtual reality training for chronic stroke patients using an interactive rehabilitation and exercise system (IREX) and reported significantly more improvement in dynamic balance compared with that in patients receiving conventional therapy. Moreover, Walker et al. reported that virtual reality treadmill training has a significant effect on dynamic balance in chronic stroke patients. Since the results of our study agree with those of the previous studies, one can conclude that virtual reality treadmill training has a positive effect on dynamic balance in stroke patients.

Motor learning during virtual reality treadmill training— including a variety of environments, control of task grade, and sensory feedback—motivates patients and influences their psychological stability. It eventually improves gait and balance, leading to improved balance self-efficacy. Yang et al. implemented virtual reality treadmill training for chronic stroke patients and reported greater improvement (ABC scale) than that after treadmill training. Since our study shows similar results, virtual reality treadmill training certainly has an effect on balance self-efficacy of stroke patients.

This effect certainly applies to stroke patients with a history of falls. Based on the results of this experiment, we are more than confident that this training can be used as an effective rehabilitation program for stroke patients who have a fear of falling.

Our study has the following limitations that can be improved in future studies: a small sample and short duration. Therefore, further controlled clinical studies with a larger study population and longer duration are required to verify the clinical benefits of virtual reality treadmill training.

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