1. Introduction

Stroke is defined as a damage of brain function from a disturbance in the blood supply to the brain. Stroke a common neurological disorder is one of the leading causes of mortality. In addition, stroke can cause long-term disability of functional movement and daily activities. In particular, balance instability may cause stroke patients to have a short duration of weight support on the paralyzed side and stride differences between sides, deteriorating physical ability and slowing gait speed, all of which interrupt daily activities. Decrease in balance ability can cause frequent falls due to secondary functional disorders, which include muscle weakness, sensory defect, gait disturbance, cognitive function, and spatial sense. Falling may lead to an increase period of hospitalization, medical expenses, and dependence on care giver. To maintain postural balance, it is required to maintain and coordinate the following balance function: Visual information, vestibular function, somatosensory, proprioception, musculoskeletal, and cognitive function. However, there is no multiply sensory system training. Recently, with the advancements of science and technology, virtual reality training programs began to be incorporated into the rehabilitation process to increase balance ability and decrease fear of falling. Virtual reality balance exercise programs aid the recovery of posture change, voluntary movement, lower weight bearing, and speed of movement. Cho et al. reported a significant improvement in the dynamic balance function after virtual reality training for 6 weeks in chronic stroke patients. Mirelman et al. found improvement in the fall efficacy after virtual reality training for 3 weeks to 20 Parkinson patients who experienced a fall. In conclusion,
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for patients with post-stroke hemiparesis, rehabilitation regaining mobility and balance function a major goal. Although numerous studies on virtual reality balance training have been reported, there have been only a few studies investigating the effect of balance and fall efficacy in stroke patients. Therefore, herein, we investigate the effectiveness of a virtual reality balance exercise program to improve the balance function and fall efficacy in stroke patients.

2. Methods

2.1 Subjects

The sample size was calculated using the G-Power 3.1 software (University of Dusseldorf, Dusseldorf, Germany), with a power of 0.80, alpha level of 0.05, and effective size of 0.08 as the baseline. The calculation results showed a sample size of 10 subjects for each group. The inclusion criteria were as follows: 1. Patients diagnosed with stroke-induced hemiplegia that occurred at least 6 months earlier; 2. Patients capable of communicating on their own with a score of ≥ 21 points in the Korean version of Mini-Mental State Examination (MMSE-K); 3. The absence of serious visual impairment or a hearing disorder; and 4. The ability to walk 10m independently with or without an assistive device. The exclusion criteria consisted of the following: 1. Patients with joint contracture or limited range of joint motion; 2. Patients who were unable to perform the exercise program due to neurological or psychiatric problems; and 3. Participation in other studies or rehabilitation programs. Eleven subjects were recruited per group from the rehabilitation centers belonging to the Workers' Compensation and Welfare Service. Among the 22 recruited subjects, 2 patients were excluded; one due to a sudden deterioration in health condition, and the other patient due to an inability to participate regularly. The remaining 20 patients were randomly assigned using a computer-generated table of random numbers to either the experimental group that will receive Virtual reality balance training program (n = 10) or the control group that will receive general occupational therapy (n = 10). The general characteristics of the subjects are shown in Table 1. Each subject gave a written informed consent after being provided an explanation of all the experimental protocols and procedures. The protocol of this study was approved by the Institutional Review Board of Daegu University.

2.2 Procedure and Interventions

This study was designed as a single-blinded, randomized controlled study. Both the experimental and control groups received general occupational therapy consisting of five 30-min sessions per week for a duration of 6 weeks. The experimental group received an additional 30 min of VR balance training, while the control group received an additional 30 min of general occupational therapy for each session over the same time period of time. Figure 1 represents a flow diagram of this study. The general occupational therapy comprised of a stretching exercise to promote flexibility in the upper and lower extremity of the affected side, neurodevelopmental exercise to promote normal postural reaction. The Bio Rescue (RM Ingenierie, Rodez, France), which was the virtual reality device used in this study for the static and dynamic balance,
comprised of a television monitor, software, safety guard and a pressure sensitive platform (610㎜ × 580㎜ × 10㎜) capable of moving in any direction on a 3D plane shown in Figure 2. Subjects can move freely in the real world while manipulating the virtual objects in a 3D virtual world. To improve the symmetry of weight-bearing, movement, and left/right standing balance of stroke patients, a total of 4 functional movement programs were applied - the “rally driving”, “fill a flask”, “downhill ski”, and “maze passing”. The degree of difficulty in the movement program varied from stage 1, very easy, to stage 5, very difficult, which depended on the condition of patients. Patients received appropriate audiovisual feedback from the monitor and speaker while performing the exercise game. In this study, the program was administered with the patient standing on the platform with the monitor placed at 1~1.5 m in front of him. Four types of movement programs, which were appropriate for the condition of each patient, were applied for 7 min each, for a total of 30 min.

Figure 1. Virtual reality program exercise.

3. Measurements

Assessments were made by an experienced occupational therapist who was blinded to the group assignment and did not take part in the general occupational therapy. Berg Balance Scale (BBS) was divided into three sections—sitting, standing, and changing posture. BBS is valid and reliable instrument to measure both the static and dynamic aspects of balance in elderly people after stroke. BBS consists of a 5-point scale that ranges from 0 (unable to perform) to 4 (normal performance). BBS scores range from 0 to 56 points, and higher scores indicate better balance. Limit Of Stability (LOS) was measured using a posturography in a silent room. We used BioRescue, which includes a platform equipped with 1,600 pressure sensors ensuring precise analysis, software, and a monitor. Biorescue shows the Center Of Pressure (COP) trajectory, measuring its weight bearing, sway length, anterior, posterior, right and left range Limit Of Stability (LOS) in a static standing position. Fall Efficacy Scale (FES) is a validated 10-item questionnaire of fall efficacy of the person in various ADL and community activities. For each item, the scores are given between 1 and 10 points in accordance with the level of fear of falling, where 1 indicates no confidence at all and 10 indicates very high confidence. The maximum is 100 points. The FES appears to be a reliable and valid method to measure fear of falling. This instrument may be useful in assessing the independent contribution of fear of falling.

3.1 Statistical Analysis

The collected data were analyzed using SPSS version 21.0 (IBM Corp., Armonk, NY). Independent t-test was used to compare the initial pre-treatment BBS, LOS and FES scores between the two groups. Paired t-test was performed to make a comparison between the experimental and control groups with respect to changes in pre- to post-treatment BBS, LOS and FES scores, while an independent t-test was performed to compare the magnitude of change between the experimental and control groups. P value of less than .05 was considered statistically significant.

4. Results

There was no significant difference between the experimental and control groups with respect to pre-treatment BBS, LOS and FES scores (P > .05). Both the experimental and control groups showed a statistically significant increase in the post-treatment BBS, LOS and FES scores as compared with the pre-treatment scores (P < .05). Intergroup comparisons showed a statistically significant increase in the scores of all assessments in the experimental group as compared with the control group (P < .05; Table 4).
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Table 2. Change in experiment group before and after treatment

<table>
<thead>
<tr>
<th>Virtual Reality Therapy Group (Mean ± SD)</th>
<th>Before treatment</th>
<th>After treatment</th>
<th>Mean difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBS</td>
<td>41.80±5.92¥</td>
<td>49.70±7.19*</td>
<td>7.90±5.38*</td>
</tr>
<tr>
<td>LOS</td>
<td>4448.30±3480.23</td>
<td>9166.20±3722.22</td>
<td>4717.90±638.28*</td>
</tr>
<tr>
<td>FES</td>
<td>66.50±14.73</td>
<td>77.00±11.42**</td>
<td>10.50±4.47*</td>
</tr>
</tbody>
</table>

¥MEAN±SD, *p<0.05, **p < 0.01

Table 3. Change in control group before and after treatment

<table>
<thead>
<tr>
<th>Occupational Therapy Group (Mean ± SD)</th>
<th>Before treatment</th>
<th>After treatment</th>
<th>Mean difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBS</td>
<td>40.10±6.42¥</td>
<td>42.30±7.39*</td>
<td>2.20±1.98*</td>
</tr>
<tr>
<td>LOS</td>
<td>3707.20±2697.37</td>
<td>5954.90±2955.18</td>
<td>2247.70±1074.19</td>
</tr>
<tr>
<td>FES</td>
<td>61.20±11.63</td>
<td>66.10±10.21*</td>
<td>4.90±5.38*</td>
</tr>
</tbody>
</table>

¥MEAN±SD, *p<0.05, **p < 0.01

5. Discussion

VR application can provide visual, auditory, and haptic inputs. This multisensory feedback enhances motor leaning through problem solving, while promoting the performance of multiple repetition of movement. In our study, statistically significant improvements were seen in post-treatment BBS and LOS scores when compared with the pre-treatment scores. In addition, the experimental group showed a statistically significant improvement in the balance function when compared with the control group. Kim et al. stated that virtual reality therapy for rehabilitating the balance function enhanced the balance and locomotor recovery in adults with hemiparetic stroke. Moreover, Barcala et al. reported that applying visual biofeedback therapy on the balance of patients with stroke was effective in increasing body symmetry and balance control. Llorens et al. additionally reported that virtual reality-based interventions that promote motor learning mechanisms may offer additional benefits to balance recovery compared with conventional therapy in hemiparetic chronic stroke. Furthermore, the balance function may improve through repetitive training and the VR having the ability to provide a similar environment to the actual movement, which is the ultimate goal of the training program. Regarding the fear of falling, the FES scores showed a significant increase from pre- to post-treatment in both the experimental and control groups, with the experimental group showing statistically significant improvement over the control group. Singh et al. performed a study and showed that using a VR greatly improved the fear of falling and fall risk. In addition, Thorntom et al. reported that applying VR therapy to the balance of traumatic brain injury patients psychologically improved the confidence and provided enjoyment. VR therapy provides positive in general by participants and improve balance and confidence improvement. Limitations of this study include a small sample size that may result in a weak generalizability of the findings to all hemiplegic patients. Moreover, due to diverse conditions of the participating patients, it was difficult to apply the same tasks with the BioRescue device to all patients. Therefore, future studies are deemed necessary to determine which tasks from the BioRescue device are more effective for each different condition of patients.

6. Conclusions

The results of this study showed that when VR therapy providing functional tasks to the upper extremity was co-administered with general occupational therapy, greater improvement in the balance function and in the fear to falling FES was seen in hemiplegic patients, as compared with the administration of occupational therapy alone. Therefore, VR therapy may provide clinical usefulness as a treatment method to improve balance function and decrease the fear to falling FES in patients with stroke-induced hemiplegia.

7. Acknowledgment

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8. References