

Effects of 3D Visual Feedback Exercise on the Balance and Walking Abilities of Hemiplegic Patients

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Abstract. [Purpose] The purpose of this study was to determine the effects of 3-dimensional exercise with visual feedback on stroke patients. [Subjects] Twenty-two patients with hemiplegia were randomly allocated to either a 3D exercise group (3DG) consisting of 11 members or a weight shifting exercise group (WSG), also of 11 members. [Methods] The 3DG received neurophysiological treatment and performed 3D exercise and the WSG received neurophysiological treatment and performed weight shifting exercise, 5 times a week for 6 weeks. The Berg Balance Scale and 10m walking time were used to evaluate the patients' balance and walking abilities. [Results] Balance and gait abilities of patients improved in both the 3DG and the WSG. A comparison of the two groups found that the 3DG showed a greater improvement in balance ability than the WSG. [Conclusion] 3- dimensional exercise with visual feedback is effective at improving the balance and gait of stroke patients.

Key words: Visual feedback exercise, Balance, Walking

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INTRODUCTION

Most stroke patients experience a movement of the center of pressure epicenter to the unaffected side, and show a problem in maintaining standing balance as the truncal sway increases¹⁾. The truncal sway increases even when they maintain their weight on the unaffected side in a static standing position. In addition, their ability to shift weight to the affected side decreases, and they display an abnormal postural reaction. Difficulty in moving weight to the affected side greatly affects functional movements such as standing up from a chair, moving, walking, turning and climbing stairs²⁾.

The walking speed sensitively reflects the improvement of standing balance ability over time. For stroke patients to walk in a stable and independent manner, basic elements such as the stability and advancement of the lower limbs and the ability to balance the body are required. To address the difficulties in balance and walking of stroke patients, many studies have been conducted including those involving neurophysiological treatment³⁾, weight-support treadmill training⁴⁾, task-specific training²⁾, training with visual feedback⁵⁾, and the use of aids such as a cane and wedges in shoes⁶⁾. Visual information can compensate for the loss of sensorimotor function through training and boost

the therapeutic effect by providing information to the central nervous exercise program⁷⁾. Moreover, visual feedback of weight distribution is effective at making the standing position of stroke patients symmetrical⁸⁾. Also, patients who are trained with visual feedback can perform the tasks with interest in the therapeutic process and the motivation effect is maximized throughout the treatment process⁹⁾. Furthermore, as patients perform repetitive training and learning by themselves and can instantly check the results of task performance evaluation, it is an appropriate training for stroke patients¹⁰⁾.

Three-dimensional exercise can effectively improve patients' neuromuscular control ability, promote the proprioceptors, improve balance ability, and stabilize the trunk by inducing positional changes in 8 directions by combining the forward, backward, left, and right directions with four diagonal directions¹¹⁾. The posterior oblique sling connects the latissimus dorsi muscle, the gluteus maximus muscle, and the thoracolumbar fascia;. The anterior oblique sling connects the obliquus externus abdominis muscle, the obliquus internus abdominis muscle, the anterior abdominal fascia and the adductor of thigh;. The longitudinal sling connects the peroneal muscle, the biceps femoris muscle, the sacrotuberal ligament and the deep erector spinae muscle of the thoracolumbar fascia;. The lateral sling

consists of the stabilization muscles of the hip joint such as the gluteus medius muscle, the gluteus minimus muscle and the tensor fasciae latae muscle and the external stabilization muscles of the thoracic-pelvic part. Together they stabilize the pelvic part from the chest to the legs. These muscles play their respective roles independently, but they also work together. Muscular contraction delivers its force beyond the origin and static parts of active muscles, which is conveyed to other muscles tendons, fascias, ligaments and cysts that are connected horizontally. These integrated muscle systems form a chain of force that helps in the movement of force¹²⁾. Three-dimensional exercise generates movements in a total of 8 directions including the forward, backward, left, and right directions, and 4 diagonal directions. To maintain weight in the middle range without being biased to any one side, the above-mentioned four slings must act appropriately in such a way as to stabilize the trunk. However, studies of 3D exercise have focused on the truncal stabilization of normal people^{11,13)}, and studies of the balance training of hemiplegic patients are insufficient in number.

Three-dimensional exercise with visual feedback for stroke patients is an effective intervention for the improvement of balance and walking abilities. Thus, this study investigated the effects of 3D exercise with visual feedback on the balance and walking of hemiplegic patients.

SUBJECTS AND METHODS

The study subjects were stroke patients who were hospitalized or received treatment as outpatients at Y Hospital in Gyeongsangnam-do, Korea, between December 2010 and March 2011. Those who were diagnosed with hemiplegia due to cerebral infarction or cerebral hemorrhage, whose length of disease was at least 3 months, whose Mini-Mental State Exam-Korea (MMSE-K) score was 24 or higher, who had no problem in looking at a monitor, who had no hemineglect, who could walk at least 15 m, and who could understand and follow the researcher's instructions were chosen. We adequately explained the purpose and process of this study to them and received their voluntary consent. Ethical approval was given by the Pusan National University Yangsan Hospital Committee of Medical Ethics, and consent was obtained from patients or their guardians prior to their inclusion in the study. The 22 patients with hemiplegia were randomly allocated to either a 3D exercise group (3DG) consisting of 11 members or a weight shifting exercise group (WSG), also of 11 members. The general and historical characteristics of the subjects are shown in Table 1.

The 3DG received neurophysiological treatment for 30 min and performed 3D exercise for 20 min, 5 times a week for 6 weeks. The WSG received neurophysiological treatment for 30 min and performed weight shifting exercise for 20 min, 5 times a week for 6 weeks. The 3D exercise used the 3D Thera-Balance (Tonus, Germany), which enables rotational exercise in 8 directions at a maximum of 45° to the front and back and a maximum of 80° to the left and right with a fixed pelvis. Using this device, metered

Table 1. Characteristics of subjects

Characteristics		3DG (n =11)	WSG (n =11)
Sex	male	6 (45.5 %)	8 (72.7 %)
	female	5 (54.5 %)	3 (27.3 %)
Age (years)		61.9 ± 14.4	54.6 ± 11.9
Height (cm)		162.6 ± 9.4	165.6 ± 6.3
Weight (kg)		64.4 ± 14.5	62.8 ± 10.8
Cause	infarction	8 (72.7)	8 (72.7)
	hemorrhage	3 (27.3)	3 (27.3)
Affected side	Rt	4 (36.4)	5 (45.5)
	Lt	7 (63.6)	6 (54.5)
Length of disease (month)		16.9 ± 10.1	14.3 ± 4.3
MMSE-K (score)		27.3 ± 2.1	27.0 ± 1.7

3DG: 3D exercise group; WSG: Weight shifting exercise group.

forces on the trunk can be applied by tilting the whole body from neutral upright to the horizontal position or any position in between. Subjects are fixed at the feet, thighs and hips, while the trunk remains unsupported. During tilt, the person stabilizes his or her upper body in the body axis. No active movements are necessary because subjects are simply compensating for gravity. To ensure consistent conditions throughout the investigation, subjects held their arms crossed against their chests. This also averted any co-contraction initiated by arm movements. Exact positioning throughout the whole investigation was controlled by the examiner. Subjects performed two programs of left and right movements and middle position maintenance for 10 min each, as displayed on the monitor in front of them. In the left-right movement program, the aim is to move white balls in a rectangle to the arrows at the left and right ends. The patient must shift their weight to the left to move them to the left arrow, and to the right to move their weight to the right arrow. In the middle position maintenance program, the patient must move a ball into the innermost rectangle and keep it at that position. To keep the ball at the center, they must make continuous movements in a total of 8 directions including forward, backward, left, and right directions, and 4 diagonal directions.

The WSG stood with their knee and hip joints extended and were encouraged to carry their weight on the affected lower limbs. They were asked not to make unnecessary movements with their upper limbs and trunk¹⁴⁾. Depending on the patient's condition, the therapist held their pelvis and helped their weight movement.

The Berg Balance Scale and 10 m walking time were used to evaluate the patients' balance and walking abilities. The Berg Balance Scale measures the static and dynamic balance abilities¹⁵⁾ using 14 items in 3 domains of standing, sitting and positional change in daily life on a scale of 5 points (0–4) for each item. A score of 0 indicates inability to balance, and a score of 4 indicates the ability of independent performance. A total score of 41 to 56 indicates a low danger of falling while a total score of 0 to 20 indicates a high danger of falling¹⁶⁾. The 10 m walking time evaluates the recovery of the subject's mobility. It is generally used for evaluation of the walking speed of patients with a neurologic deficit. In this study, the method of Dean et al.¹⁷⁾ was used. The subjects were asked to walk

Table 2. Comparison of Balance and Walking Speed (N=22)

Variable	Group	pre	post
BBS (score)	3DG**	37.3 ± 6.9	48.6 ± 5.6**
	WSG**	34.4 ± 5.2	37.9 ± 5.1
10m walking time (seconds)	3DG**	24.2 ± 11.6	18.7 ± 11.0
	WSG*	23.1 ± 11.9	20.9 ± 10.4

* p<0.05, ** p<0.01; BBS: Berg balance scale; 3DG: 3D exercise group; WSG: Weight shifting exercise group.

at a comfortable speed for a total of 14 m. The first 2 m and the last 2 m were not timed to eliminate the effects of acceleration and deceleration. Two measurements were made and their averages was determined. A digital readout stopwatch (Sammons Preston, USA) was used to measure the time to walk 10 m.

The data acquired in the experiment were analyzed using SPSS for Windows version 12.0, and the significance level, α , was 0.05. Descriptive statistics were conducted for the general and historical characteristics of the subjects. The results before and after the interventions were compared using the paired t-test. The independent samples t-test was used to compare the two groups.

RESULTS

The Berg Balance Scale scores of the 3DG and the WSG significantly increased after 6 weeks of the interventions ($p<0.01$), and the 10 m walking time significantly decreased ($p<0.05$). Thus, both the 3DG and the WSG showed improved balance and walking abilities (Table 2).

The balance and walking speed were compared between the 3DG and the WSG. The homogeneity of the two groups was verified as the two groups showed no differences before the experiment. The Berg Balance Scale (BBS) scores and the 10 m walking time were compared after 6 weeks of the interventions. The BBS scores showed a significant difference between the two groups, but the 10m walking times did not (Table 2) ($p<0.05$). Thus, the 3DG showed a greater improvement in balance ability than the WSG.

DISCUSSION

This study investigated the changes in balance and walking abilities of stroke patients after 3D exercise with visual feedback. The results show that balance ability improved in both the 3DG and the WSG. A comparison of the two groups found that the 3DG showed a greater improvement in balance ability than the WSG. Srivastava et al. (2009)⁵ conducted a study of stroke patients and reported that their balance improved after force plate exercise with visual feedback. In addition, Cheng et al. (2004)¹⁸ found that symmetrical standing position training with visual feedback reinforced the symmetrical weight distribution ability of stroke patients. These results are in agreement with those of the present study. However, Park et al. (1997)¹⁹, compared the effects of visual feedback on healthy people and claimed that it was not possible to

determine whether or not visual feedback had an effect on balance training.

The walking of stroke patients with brain injury is characterized by a slow walking cycle and speed, a difference in stride length between the affected side and the unaffected side, a short stance phase, and a relatively longer swing phase on the affected side²⁰. In this study, both the 3DG and the WSG showed improved walking ability, but without significant difference between them. Van Peppen et al. (2006)²¹ reported that a group that had performed weight shift training with visual feedback showed a greater improvement in walking ability. Walker et al. (2000)²² reported that the weight shift exercise with visual feedback doubled the walking speed over 10 m. Moreover, Winstein et al. (1989)²³ reported that both a group who used visual feedback and a group who did not showed significant improvement after training but there was no significant difference between the two groups. These findings are similar to those of the present study, which demonstrated that 3D exercise with visual feedback had an effect on the balance and walking abilities of stroke patients, and on balance in particular. However, only two basic programs were used for visual feedback, and studies applying more diverse programs are needed.

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