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The Effects of Visual Feedback Training on Sitting Balance Ability and Visual Perception of Patients with Chronic Stroke

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Abstract. [Purpose] The purpose of this study was to investigate the effects of visual feedback training (VFT) in the sitting position on sitting balance ability and visual perception of chronic stroke patients. [Subjects] Twenty-two hospitalized subjects who had experienced a stroke more than six months earlier were included in this study. [Methods] Subjects in both the experimental group (n=12) and the control group (n=10) participated in a conventional rehabilitation program involving a 60-minute session five days per week for a period of four weeks. Subjects in the experimental group additionally practiced VFT 30-minute sessions, five days per week, for a period of four weeks. [Results] After the intervention, the experimental group showed significantly improved static sitting balance ability (left·right, anterior·posterior moment, and velocity moment), and dynamic sitting balance ability (anterior·lateral moment). In visual perception tests, motor free visual perception test (MVPT) scores showed a significant increase of approximately 17% in the experimental group after the intervention. [Conclusion] The results of this study demonstrate the effectiveness of VFT in enhancing body function, as evidenced by improved sitting balance and visual perception of chronic stroke patients.
Key words: Visual feedback, Sitting balance, Stroke

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INTRODUCTION

Stroke is a serious health problem worldwide[1)], and is accompanied by motor function deficits and decline in sensory function[2)]. Stroke patients support their body weight on the affected side; therefore, they tend to experience difficulty in achieving balance when standing or sitting[3, 4)]. In addition, these balance difficulties are worsened by increase of postural sway[5)]. Therefore, after stroke, balance exercise with postural control is considered an important means of restoring patients' motor function during rehabilitation. Decline in balance causes postural sway, asymmetric weight distribution, and reduction in the ability to shift weight and stand normally[6, 7)]. In addition, it increases the risk of falls, creates social problems, and is associated with considerable cost[8, 9)]. In particular, a decline in sitting balance affects standing balance, reduces transfer and walking abilities, limits activities of daily living, creates fear and increases the risk of falls. A decline in sitting balance also causes mental problems, a major cause of decline in quality of life[10–12)].

Maintenance of physical balance requires proper control of the center of gravity and movement, and involves the processing of complex sensory and motor inputs[13)].

Several interventions have been devised to improve balance, such as balance training in a sitting position, task oriented training[14)], training in a standing position[15)], training using a gym ball, a balance ball or, a balance board[16)], and treadmill training[17)]. In addition, some methods have been devised to increase sitting balance, such as trunk performance training[18)], task oriented training[19)], and dual task training using a ball[20)].

VFT using a force plate allows patients to check in real time their positions and the location of the center of gravity during postural changes, which enables patients to perceive postural information and use it to control and maintain their posture[21)]. In particular, VFT has been reported to improve asymmetric standing balance of stroke patients effectively facilitating their posture control[22, 23)].

A VFT program was recently devised based on a computer game, and it has been reported to increase patient's practice volume and attention span during training, and reduce the number of falls by patients with a balance problem after cerebellar surgery[24)]. Si Hyung et al.[25)], who conducted VFT for acute stroke patients attempting to improve their motor function and visual perception function, reported significantly improved motor function and visual perception. In addition, VFT for peripheral neuropathy or stroke patients with accompanying balance problems effectively improved activity levels, transfer ability, motor recovery, and balance[26, 27)]. Many recent studies conducted VFT for chronic stroke patients in the standing position[7)]. Pilot studies have also been conducted with patients with spinal cord or traumatic brain injuries[28)], but, as yet, the effect of VFT in the sitting position has not been clarified for

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these patient groups. In addition, the effects of VFT in the sitting position on static balance and visual perception have not been determined.

Therefore, in the current study, we investigated the effect of VFT in the sitting position on sitting balance and visual perception of chronic stroke patients.

SUBJECTS AND METHODS

The study subjects were chronic stroke inpatients at the S Medical Center (Seoul) more than six months after stroke. Subjects who could sit independently for at least 30 minutes, who had a Korean Mini Mental State Examination (MMSE-K) score of > 21 points, who had not participated in any balance training program during the previous six months, who had no orthopedic problems, such as a fracture, deformity, or severe osteoarthritis, and who were not taking any drugs for balance maintenance were included. Written informed consent, after providing an explanation of the study purpose, as well as the experimental method and processes, was obtained from all patients.

Of the 30 patients initially considered, four were excluded because of a visual disability (one patient) and orthopedic conditions (three patients). The remaining 26 patients were randomly assigned to either the experimental group (n = 13) or the control group (n = 13). Random allocation software was used to randomly allocate the subjects[29].

Subjects in both the experimental group and the control group participated in a general physical therapy program, consisting of 60-minute sessions, five days per week for a period of four weeks. Subjects in the experimental group additionally participated in the VFT program, consisting of 30-minute sessions, five days per week for a period of four weeks.

During the study period, one patient in the experimental group and three patients in the control group withdrew from the study due to discharge. Therefore, 12 patients in the experimental group and 10 patients in the control group were included in the final analysis.

In order to prevent loss of concentration due to external interference, VFT was performed individually in a dedicated room containing the required equipment. The VFT program was conducted by a researcher and three assistants who were trained in use of the equipment and performance of evaluation measurements. In order to eliminate experimenter bias, the assistants did not have knowledge of the purpose of the study or its effects. VFT was performed using BIORescue (RM INGENIERIE, Rodez, France) equipment, which consists of a computer, a monitor, and a force plate. This force plate detects the posture and movements made by subjects and this information is transferred to the computer, and processed for display on the monitor. This system encourages adoption of the correct posture by providing visual feedback and allows for design of customized exercise programs based on pre-test data. The system also allows different exercise times and intensities for selected games, and within-session variable rest times. In the study, the participants sat 1–1.5 m away from the monitor on a pressure platform. Patients performed the given task by moving their bodies as required by the program. Patients received instructions about the program and safety beforehand. The training sessions were composed of four exercises of 6 minutes 30 seconds each with a one-minute rest period between exercises. Four types of exercise were performed during each session. The first exercise was training for stability and weight shift by balancing the amount of water in a flask. The second was training for stability and weight shift by driving a vehicle. The third exercise was skiing, which involved shifting the body in the anterior, posterior, left, and right directions in three-dimensional space; and the fourth exercise used a memory recall program, during which the patient had to remember four pictures and to match the picture. Five exercise levels were incorporated, which allowed for variation of speed, number of obstacles, number of picture cards, weight maintenance, and weight shift sensitivities. An appropriate level was initially chosen by the examiner and this was subsequently increased.

General exercises were performed for 60 minutes, five times per week for a period of four weeks. A physical therapist conducted range of motion exercises for 10 minutes, strengthening exercises for 10 minutes, and posture control and walking exercises for 10 minutes, and an occupational therapist focused on the functional activities required for daily living for 30 minutes.

Static sitting balance, dynamic sitting balance, and visual perception were tested before and after the interventions. A Good Balance System (Metitur Ltd, Finland, 2008) was used to measure static balance. This equipment measures the balance of senile and stroke patients, and is widely available[30]. Using the test-retest method, the intrarater reliability of the Good Balance System was reported as having intraclass correlation coefficients ranging from r=0.51–0.74 (anterior posterior speed), and r=0.63–0.83 (right/left speed)[31]. Static balance was measured with the patients sitting on the force plate with their feet approximately shoulder width apart and their eyes open. Patients were asked to look at a red point of 10 cm in diameter 1 m in front of them for 30 seconds while their balance was measured; the test was repeated three times. The same procedure was followed three times with patients' eyes closed for 30 seconds. The average values of both measurement conditions were recorded.

Dynamic balance in the sitting position was measured using a modified version of the Functional Reach Test. The inter-rater reliability of this modified functional reach test was reported as r=0.97, indicating excellent reliability[32]. A standard scale that measures the distance was set at patients' acromion height and fixed on the wall, while patients sat comfortably on a stool. The patient's hip joints and knee joints were flexed at 90°, the chair and popliteal area were 5 cm apart, and the feet were in contact with the ground. For anterior measurements, the shoulder joint was flexed at 90° with the elbow joint in maximum extension, so that the arm was in line with the hand. The patient moved his/her upper extremity and trunk forward as much as possible, and the distance from the starting position to the ending position of the middle finger tip was measured on the standard scale. For lateral measurements of the unaffected sides, the shoulder joint was abducted at 90° with the elbow joint extended maximally so that the arm was straight. The patient moved his/her upper extremity and trunk toward the unaffected side as much as possible, and the distance from the starting position to the ending position of the middle finger tip was measured on the standard scale. All evaluations were performed three times and average values were recorded.

Visual perception was measured using the motor free visual perception test (MVPT). MVPT is a standard tool used for diagnosis and research purposes and evaluates overall visual perception performance among children and adults with high test-retest reliability (r=0.77: 0.91) and validity[33].

MVPT consists of 36 multiple-choice items that involve the use of two-dimensional configurations. It evaluates five types of visual perception skills, including visual discrimination, figure-ground discrimination, spatial relationships, visual closure, and visual memory. Each item is scored as correct or incorrect, and a point is given for each correct item. The total score ranges from 0 to 36 points. Higher scores reflect fewer deficits in general visual perceptual function. The Shapiro-Wilk test was used to test variables for normality, and the independent t test was used for comparison of static and dynamic sitting balance, and visual perception between the experimental and control groups. Comparisons between pre- and post-treatment data within each group were analyzed using the paired t test. SPSS 18.0 for Windows version was used to perform all the analyses, and p values of < 0.05 were regarded as significant.

RESULTS

Twenty-six patients participated in this study, but only 22 patients completed the intervention and assessments. The comparison of the characteristics of the two groups is shown in Table 1. No significant differences in terms of age, body weight, height, gender, Korean version of mini mental state examination (MMSE-K), sitting balance, visual perception, or hemiplegic side were found between the two groups.

After the intervention, the speed of right and left sway and anterior and posterior sway were significantly lower in the experimental group, regardless of vision. The control group showed an increase in speed of sway, but it was not significant. Differences in pre- and post-intervention speeds of sway (left·right, anterior·posterior) were significantly different between the two groups, regardless of vision ($p<0.05$) (Table 2).

Velocity moment was significantly lower in the experimental group ($p<0.05$), whereas it showed a non-significant increase in the control group, regardless of vision. Differences in velocity moments with eyes open and eyes closed between pre- and post-intervention differed significantly between the two groups ($p<0.05$).

After intervention, anterior and lateral reach significantly higher in the experimental group ($p<0.05$) and was non-significantly higher in the control group. Differences in anterior and lateral reach between pre- and post-intervention differed significantly between the two groups ($p<0.05$) (Table 3).

MVPT was significantly higher post-intervention in the experimental group and was non-significantly higher in the control group. Diffrences in motor free perception between pre- and post-intervention differed significantly between the two groups ($p<0.05$) (Table 4).

DISCUSSION

This study was designed to investigate the effects of VFT on static and dynamic sitting balance and visual perception of stroke patients while in the sitting position.

At the end of the four-week training period, VFT had improved static sitting balance by 30% with the eyes open and by 44.4% with the eyes closed. These results are in agreement with those of previous studies. Karthikbabu et

Table 1. Subject characteristics

	Experimental	Control
Gender (male/female)	12 (4/8)	10 (2/8)
Age (years)	60. 6±8.8	63.7±4.7
Height (cm)	163.4±6.0	163.1±7.2
Weight (kg)	66.3±9.6	67.5±9.9
Hemiplegic side (right/left)	12 (2/10)	10 (4/6)
MMSE-K (score)	23.5± 3.1	25.5±3.1

Values are expressed as mean ± SD

Table 2. Comparison of sway speed and velocity moment within groups and between groups

		Experimental (n=12)		Control (n=10)	
		EO	EC	EO	EC
Right/Left Sway (mm/s)	Pre	3.00±1.23	3.45±1.60	3.24±1.37	3.59±2.38
	Post	2.38±1.01*	2.99±1.83*	3.41±1.27	3.73±2.70
	Pre−Post	−0.61±0.88*	−0.46±0.62*	−0.17±0.30	0.14±0.65
Anterior/Posterior Sway (mm/s)	Pre	2.86±1.15	3.12±1.14	2.59±0.69	2.98±1.29
	Post	2.15±0.91*	2.70±1.05*	2.72±0.72	3.02±1.37
	Pre−Post	−0.35±0.48*	−0.42±0.44*	0.13±0.27	0.03±0.48
Velocity Moment (mm^2/s)	Pre	2.69±1.70	3.83±2.59	2.05±0.94	4.14±4.01
	Post	1.88±1.22*	2.13±1.49*	2.13±0.71	4.30±4.70
	Pre−Post	−0.81±1.05*	−1.70±2.23*	0.07± 0.79	0.17±1.52

Values are expressed as mean ± SD. * significant change between pretest and posttest. Eyes open (EO). Eyes close (EC).

Table 3. Comparison of modified functional reach test within groups and between groups

		Experimental (n=12)	Control (n=10)
MFRT Anterior (mm)	Pre	313.5±118.5	307.2±126.6
	Post	341.1±126.6*	310.2±126.7
	Pre−Post	27.6±32.9	2.9±7.3
MFRT Lateral (mm)	Pre	181.0±55.7	161.5±76.5
	Post	202.9±66.1*	162.6±74.0
	Pre−Post	21.9±28.8*	1.2±10.0

Values are expressed as mean ± SD. * significant change between pretest and posttest. Modified functional reach test (MFRT).

Table 4. Comparison of motor-free visual perception within groups and between groups

		Experimental (n=12)	Control (n=10)
MVPT (score)	Pre	22.3±5.0	22.0±4.6
	Post	26.1±4.4*	22.7±4.3
	Pre−Post	3.8±2.0*	0.7±1.8

Values are expressed as mean ± SD. * significant changes between pretest and posttest. Motor-free visual perception test (MVPT).

al.[20] reported an improvement in static sitting balance after dual task training the trunk impairment scale (TIS). In the current study, a force plate was used to measure static balance. Due to differences between the measurement equipment used in the present study and in the previous study of Karthikbabu et al., direct comparisons are not possible. Nevertheless, since trunk balance training using visual feedback produced results similar to those observed with balance training using a dynamic ball, both studies suggest the possibility of the clinical application of VFT.

In a previous study, static sitting balance testing of stroke patients was performed with their feet off the ground and the back of the chair removed. Greater impairment was found in co-contractions of the rectus abdominis and latissimus dorsi, which control flexion and extension movement of the trunk, than of co-contractions of the internal and external oblique muscles, which control lateral movement of the trunk ($p<0.05$)[33]. Greater impairment of the muscles controlling flexion and extension of the trunk resulted in greater increase of anterior and posterior sway speed than right and left sway speed. However, in the current study, testing was performed with the feet in contact with the ground, and the speed of anterior-posterior sway was lower than the speed of right-left sway in both study groups. We consider that an ankle joint strategy may compensate for anterior and posterior sway speed, whereas right and left sway speed was dependent only on trunk control[34]. In addition, in a previous study, right and left balance control was found to show substantial correlation with the Berg balance scale[35], indicating that right and left balance control should be considered as an important target of rehabilitation.

In the current study, the decrease in right and left sway speed was greater than the decrease in anterior and posterior sway speed after VFT in the sitting position, which suggests the stroke patients' balance was improved. We suggest that the right and left weight shift training elements of the visual feedback program, that is, the flask, vehicle, and skiing exercises, were responsible for the improvement in right and left sway speed of the trunk. Our results suggest that, VFT provides an effective additional means of improving the static sitting balance of stroke patients.

In the current study, a modified functional reach test was used to evaluate improvements in dynamic balance in the sitting position. This test measures dynamic movement of the trunk and it allows easy assessment of the effects of training[32]. The average anterior reach of adults between 40 and 50 years old is 421 mm, and that of adults between 60 and 70 years old is 346 mm. The average lateral reach of adults between 40 and 50 years old is 262.00 mm, and that of adults between 60 and 70 years old is 206 mm[35]. In the current study, pre-intervention, anterior reach and lateral reach of the experimental group and control groups were below the normal adult averages for 60 to 70 years old. This result indicates both the experimental and control groups had impaired balance. However, post-intervention, the experimental group had values close to the normal adult average for anterior and lateral reach, and these improvements were significant ($p<0.05$). This result demonstrates that the VFT in sitting position is a useful intervention for improving of dynamic sitting balance.

Currently, visual feedback, cognitive training, and dual task training programs are used to improve the visual perception ability of stroke patients, and these methods have been reported to be effective[25]. However, few studies have been conducted on the effects of intervention methods that simultaneously combine a visual perception program and exercise for stroke patients[36]. Si Hyun et al.[25] conducted a visual perception program using a computerized visual feedback system for the experimental group and a cognitive program for the control group. In their study, MVPT was used to measure visual perception in both the experimental and control groups. After intervention, the MVPT score had increased by 32% in the experimental group. Compared to the intervention method used in the current study, the method used by Si Hyun et al.[25] appears to have been more effective at improving the visual perception improvement in stroke patients. However, their study subjects were acute stroke patients who had possibility of spontaneous recovery; therefore, direct comparison with our present study should be avoided.. Nonetheless, based on the results reported by Si Hyun et al.[25] and our present results, it is evident that VFT effectively improves the visual perception of stroke patients. In particular, we suggest that VFT can be used to the improve static and dynamic sitting balance of chronic stroke patients. The results of this study show that VFT in the sitting position improves static and dynamic sitting balance and visual perception of chronic stroke patients. The VFT used in the current study increased patient interest and participation, and, thus, we believe that the method we described could be used in clinics as an effective way of improve sitting balance of stroke patients. The present study was limited by the small number of subjects, which prevents generalizations, and total rehabilitation training times differed in the experimental and control groups. To rectify this situation, a larger study with equal training time for the experimental and control groups is required.

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