Original Article

The effects of ankle joint strategy exercises with and without visual feedback on the dynamic balance of stroke patients

Si-Nae Jeon, PT, MS[1], Jung-Hyun Choi, PT, PhD[1]*

[1] Department of Physical Therapy, Institute for Elderly Health and Welfare, Namseoul University: 21 Maeju-ri, Sungwan-eup, Seobuk-Gu, Chonan-Si 331-707, Republic of Korea

Abstract. [Purpose] The aim of this study was to examine the effects of visual feedback training on the balance of stroke patients performing ankle joint strategy exercises. [Subjects and Methods] In this study, 26 stroke patients were randomly and equally assigned to a visual feedback group (VFG) and a visual disuse group (VDG). They performed ankle joint strategy exercises for 30 minutes, three times per week for six weeks. The patients' balance ability was measured before and after the exercises to compare the effects of visual feedback. To assess balance ability, the limits of stability (LOS) and the distance the center of pressure (CoP) moved were measured using a BT4 portable force platform. The Berg balance scale (BBS) and the timed up and go (TUG) test were also used to assess balance before and after the exercises. [Results] Changes in LOS were significant in the anterior, posterior, left, and right directions in each group, and the interactions between the two groups were significant in the posterior, left, and right directions. The changes in TUG and BBS results between pre-test and the post-test were statistically significant in the two groups, and also between the groups. [Conclusion] Visual feedback training had a positive effect on balance when ankle joint strategy exercises were performed by stroke patients to improve balance.
Key words: Ankle strategy, Visual feedback, Balance

INTRODUCTION

Stroke is a disease that causes damage to parts of the brain due to infarction or hemorrhage in the blood vessels that supply blood to the brain[1]. More than 85% of stroke patients experience hemiplegia immediately after a stroke and 55–75% of survivors suffer permanent disorders, such as mobility defects, that degrade the quality of their lives[2]. Patients with hemiplegia caused by stroke suffer sensory disorders and decreased balance ability. They tend to put a smaller weight load on the paretic leg when in the standing position and this results in asymmetric posture which in turn negatively affects their activities of daily living, gait, and movement[3].

Balance disorders of stroke patients have various causes, such as loss of muscle strength, restricted joint movement, changes in muscle tone, sensory changes, and loss of coordination[4]. Balance disorders are highly correlated with restricted functional mobility[5, 6]. Hemiplegic patients with balance disorders show longer their recovery times than those without balance disorders. Loss of balance ability

negatively affects gait[7].

An ankle strategy is typically used when there is a small amount of body sway on a solid base of support. In this strategy, the control of changes in the body's center of gravity is performed by muscles near the ankle joints, within the limits of stability (LOS). The LOS is defined as the maximal distance a subject can lean while maintaining balance without raising the feet from the ground. This is the postural control strategy that occurs first[3]. However, stroke patients' proprioceptive sense of ankle strength is impaired and their postural sway increases in the anterior, posterior, left, and right directions, which negatively affects their balance and gait[8]. Previous research concerning ankle strategies has shown that ankle strategy exercises help improve control ability in the anterior and posterior directions[9]. According to a study by Park, ankle strategy exercises and balance exercises performed by hemiplegic patients improve their balance ability[10].

Visual feedback is a method which uses an optical illusion in which the movement of the paralyzed limbs appears to be normal through the reflection in a mirror of the movements of the non-paretic limb[11]. Based on the neuroplasticity principle, this is one method used to treat patients with cerebral nerve damage[12]. Mirror therapy for stroke patients is a new method of re-learning motor function through visual feedback of images of movement. It is an intervention which enhances hemiplegic patients' physical functions[13]. Ji et al. conducted functional electrical stimulation and mirror therapy for stroke patients and reported improvements in

*Corresponding author. Jung-Hyun Choi (E-mail: rightmind@nsu.ac.kr)

step length and stride length, which are important elements of gait[14]. Mirror therapy uses visual imaging to improve the movement of the paretic side with visual information of movement of the non-paretic side reflected in a mirror[15]. Other studies have shown that physical movement and balance ability improve with visual feedback[16, 17].

The purpose of this study was to contribute to effective intervention in stroke patients' balance training by examining the effects on balance of training with and without visual feedback.

SUBJECTS AND METHODS

The subjects of this study were 26 chronic stroke patients (14 males, 16 females) who were hospitalized at or visited K Hospital in Seongnam City, Gyeonggi-do, Korea. All subjects consented to participate in this study. The subjects were randomly and equally assigned to a visual feedback group (VFG) and a visual disuse group (VDG). The inclusion criteria were as follows: 1) hemiplegia caused by a stroke occurring six months or longer ago; 2) a score on the Korean version of the Mini-Mental State Examination-Korea (MMSE-K) of 24 points or higher; 3) a Brunnstrom recovery stage of stage three or higher; 4) the ability to stand up independently; 5) no musculoskeletal damage affecting balance in a standing posture and no degenerative disease; 6) a Berg balance scale (BBS) score of 41 points or higher and a low risk of fall; and 7) caregivers understanding of the purpose of this study and agreement to participation. Written informed consent was obtained from each subject. The Ethics Committee of Namseoul University, South Korea approved the study. The IRB approval number is Research-140616-2. The characteristics of the subjects are shown in Table 1.

The VFG and the VDG underwent tests, such as the LOS test, the functional reach test (FRT), the BBS test, and the timed up and go (TUG) test, and their training comprised ankle strategy exercises for 30 minutes, three times per week for six weeks. The ankle joint strategy exercises consisted of an exercise performed while standing on a hard surface, and an exercise using aero-step equipment[18]. Regarding the ankle joint strategy, the movements of the other joints were intentionally restricted by an experimenter, and the whole process was observed and guided by a therapist. The exercise program lasted for 30 minutes and it was preceded by a warm-up exercise (five minutes) and followed by a cool-down exercise (five minutes). The ankle joint strategy program is described in Table 2. To provide visual feedback during the ankle joint strategy movement, a full-length mirror 60 cm wide and 180 cm high was used, and it was placed a distance of 1.5 m away for safety. The VDG faced the wall in a standing posture in the same location. A safety mat was spread out and a therapist stood by in case of an accident during the training. In order to measure LOS, which tests movement of the center of pressure (CoP), a BT4 portable force platform (Hur Laps Oy, Tampere, Finland) was used. Measurements were taken before and after the experiment. The subjects stood on the platform in their bare feet, and leaned the body anteriorly, posteriorly, to the left, and to the right using only their ankle joints. They maintained the LOS in each direction for eight seconds for the measurement. Three sequential measurements were taken and the average values were recorded. In order to evaluate the changes in balance ability, the LOS, BBS, and TUG tests were conducted again after the intervention. All evaluations were conducted by three physical therapists with at least three years of experience, and the average values of three time measurements

Table 1. General characteristics of the subjects

	VFG (mean±SD)	VDG (mean±SD)
Gender (male/female)	7/6	7/6
Age (years)	67.8±11.9	67.6±14.4
Height (cm)	164.5±9.7	166.3±7.1
Weight (kg)	62.5±11.7	63.3±14.0
Stroke type (number) Ischemic / Hemorrhagic	8/5	10/3
Affected side (number) Left / Right	8/5	8/5
Time since stroke (month)	16.2±8.7	14.6±7.6
MMSE-K (score)	26.0±1.1	26.3±2.0
Brunnstrom (stage)	3.8±0.3	3.7±0.4

Values are shown as the mean±SD, $p<0.05$.
VFG: visual feedback group, VDG: visual disuse group, MMSE-K: Korean version of the Mini-Mental State Examination

Table 2. Ankle joint strategy exercise program

Classification	Exercise program	Duration of exercise
Warm-up exercises	Stretching exercises	5 minutes
Ankle strategy exercises	Movement to stand on a stable surface	
	slowly raise and lower both heels	5 minutes
	slowly raise and lower both forefeet	5 minutes
	A shift in ankle strategy to the one leg stand	5 minutes
	Movement on a unstable surface (aero-step)	
	balance and static standing for ankle strategy	5 minutes
	anterior·posterior, left·right and diagonal inclination of the body during static standing	10 minutes
Cool-down exercises	Breathing and stretching exercises	5 minutes

were recorded. Those who tested the subjects did not take part in training them.

The data collected in the present study were analyzed using SPSS version 18. The general characteristics of the subjects are expressed as averages and standard deviations. In order to verify the homogeneity of the subjects and the normal distribution of the data, the Levene F-test and the Kolmogorov-Smirnov test respectively used. Two-way repeated measures analysis of variance was conducted in order to compare differences in the variables of the LOS, BBS, and TUG tests according to group (VFG, VDG) and time (before and after the intervention). The paired t-test was used to examine significant differences between pre-test and the post-test. A statistical significance level of α=0.05 was used.

RESULTS

Table 3 shows the values of LOS at pre-test and post-test of both groups. According to the statistical analysis, interactions between the groups and time were not significant for any of the variables, but interactions were significant in the anterior, posterior, left, and right directions. In addition, interactions between the groups were significant in the posterior, left, and right directions.

Changes in TUG and BBS between pre-test and post-test were statistically significant in both groups and there was an interaction between the groups and time.

DISCUSSION

Balance refers to the ability to maintain the center of gravity within the base of support and physical posture in response to changes in the environment when moving the body[19]. Interaction between the body and the environment made using sensorimotor training and perception requires nerve roots in stages and of coordination of the body former part[20]. Patients who have impaired balance ability need diverse training, such as visual feedback, and efficient interventions utilize visual feedback in conjunction with exercise for the ankle joint, which plays a crucial role in the balance adjustment of stroke patients.

In this study, the effects of training with and without visual feedback on balance were investigated. The changes in LOS with and without visual feedback were significant in the anterior, posterior, left, and right directions. In addition, differences in the improvement between the two groups were significant in the posterior, left, and right directions.

Lee studied the balance ability of elderly people with impaired balance who performed ankle joint strategy exercises for eight weeks. Their subjects showed increases in functional reach and decreased postural sway[18]. Another study examined the effects of six weeks of ankle joint strategy exercises and balance exercises on the balance of 30 stroke patients, and showed that balance ability improved in the ankle joint strategy exercise group compared to the control group[10]. Pajala et al. compared an ankle joint strategy exercise group and an ankle muscle strengthening exercise group and reported that postural sway decreased in the ankle joint strategy exercise group compared to the ankle muscle strengthening exercise group[21]. In a study that examined the effects of age, visual sense, and somatic sensory input on postural sway in a standing posture, Navrag et al. noted that visual input was effective at improving anterior and posterior sway in conjunction with ankle joint strategies for maintaining balance[22]. Moreover, training using visual information improved the balance function of stroke patients by improving the weight-loading ratio on the lower limbs[23]. In a study by Yun, sub-acute stroke patients practiced standing up from a sitting position with and without visual feedback and in balance a significant difference was found between the visual feedback group and the group that did not receive visual feedback[24]. Redfern et al. observed that the support rate of the affected side improved from 30% to 43% with balance training using visual feedback[25]. Another study noted that 30 stroke patients who received symmetric standing posture training with visual feedback improved the symmetry of weight-loading on the lower limbs[26]. In the present study, the LOS of the group with visual feedback increased. This result is considered important as performance of the exercise using visual feedback enabled self-correction through continuous visual information and provided repetitive stimuli to the brain, thus inducing neural recovery[27]. In a study that investigated change in static and dynamic balance ability after visual feedback training of stroke patients, the TUG times of mediolateral weight-shifting significantly decreased after the intervention; indices of CoP sway and the FRT also improved significantly[28]. Song used virtual reality and tetra-

Table 3. Changes in LOS, TUG, BBS according to the presence or absence of visual feedback

	VFG		VDG	
	Pre-test	Post-test	Pre-test	Post-test
Anterior (cm)	2.83±0.83	3.75±1.29[†]	2.03±0.67	3.47±0.83[†]
Posterior (cm)[‡]	2.51±0.87	4.07±1.99[†]	1.90±0.79	2.97±0.62[†]
Left (cm)[‡]	2.81±1.57	4.36±1.33[†]	2.07±1.25	3.20±1.43[†]
Right (cm)[‡]	3.40±1.58	4.11±2.35[†]	1.95±0.92	3.16±1.15[†]
TUG (sec)[‡]	15.62±4.89	9.93±3.93[†]	21.84±12.61	19.33±12.07[†]
BBS (score)[‡]	44.89±3.73	52.00±3.87[†]	44.68±3.26	46.54±4.27[†]

Values are shown as the mean±SD, *$p<0.05$. [†] Significant difference between the pre- and post-tests within each group, $p<0.05$. [‡] Significant difference between the improvements shown by the two groups, $p<0.05$, VFG: visual feedback group, VDG: visual disuse group, TUG: Timed Up and Go, BBS: Berg Balance Scale

ataxiometric posturography programs to train stroke patients and reported their stability index and weight distribution index significantly improved compared to a control group[29]. In the present study, there were significant differences between the TUG and BBS improvements of VFG and VDG. It is our opinion that the dynamic balance ability of the VFG increased because improvements in postural adjustment function in this group decreased postural sway[30].

The present study found that the use of visual feedback during ankle strategy exercises improved balance ability, likely because visual feedback enabled physical self-control through continuous visual information that activated the motor areas of the brain. Therefore, more research into which motor area is activated should be conducted.

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