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Original Article

Therapeutic effects of reaching with forward bending of trunk on postural stability, dynamic balance, and gait in individuals with chronic hemiparetic stroke

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Abstract. [Purpose] The objective of this study was to perform forward bending of the trunk and reaching training in chronic stroke patients and to investigate subsequent changes in trunk control, dynamic balance, and gait. [Subject] Twenty-three chronic stroke patients were randomly divided into two groups, with 10 patients in the forward bending of the trunk and reaching group and 13 patients in the control group. [Methods] Both groups underwent 30 minutes of rehabilitation therapy, five days a week, for four weeks. The forward bending of the trunk and reaching group additionally performed forward bending of the trunk and reaching training five times a week for four weeks, which involved four sets of pressing buttons 35 times, for a total of 140 button presses per session. The subjects were tested before and after training using the Trunk Impairment Scale, Berg Balance Scale, Timed Up and Go Test, Six-Minute Walking Test, and 10-Meter Walking Test. Trunk control, dynamic balance, and walking ability were compared between the two groups. [Result] The results of the study showed that the results of the Trunk Impairment Scale, Berg Balance Scale, Timed Up and Go Test, Six-Minute Walking Test improved significantly in the FBR group, while there were no significant differences in the control group. [Conclusion] This study results suggest that forward bending of the trunk and reaching training can be an effective exercise method for chronic stroke patients.

Key words: Postural control, Stroke, Trunk

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INTRODUCTION

Stroke generally leads to greater postural instability, a shift of balance to the non-paralyzed side, an asymmetrical posture, and muscle weakening compared with healthy individuals[1)]. This is usually a result of neurological damage to the sensory and motor processes of the postural control system, which leads to a decline in the awareness of physical balance required to maintain a precise orientation of the trunk[2)]. Such postural control deficits following stroke impair walking ability and interfere with a functionally independent lifestyle; furthermore, they cause a high risk of falling, because of impairments in voluntarily shifting the center of mass during the performance of activities of daily living and everyday tasks[3–5)].

Neurological damage to sensory and motor processes has a negative effect on activities of daily living. In order to minimize this, stroke patients receive diverse rehabilitation therapies to improve their ability to lead a functionally independent lifestyle[6–8)]. In particular, the loss of balance control in stroke patients resulting from loss of trunk control leads to declining motor function in the upper and lower limbs on the paralyzed side, leading to secondary impairments, such as in walking[9, 10)], thereby requiring recuperative training to increase trunk control and improve balance and walking ability.

The movement of bending the trunk forwards while keeping the arms extended has been used in clinical rehabilitation as postural control training for tasks, and clinical therapists have attempted to develop 'reach for taget' activities to help stroke patients adapt their posture after paralysis. This can promote postural movements in stroke patients according to the position of the target to be reached and the distance and direction, and so it is assumed to improve the ability to solve daily postural difficulties[11)]. In stroke patients, performing external tasks, such as reaching for a target while considering direction and distance, promotes sensory and motor performance, and by finding ways to adapt to changes in posture, these exercises can improve posture and prevent falling[12–14)].

Several researchers have studied the effect of target distance (near vs. far in the sagittal plane) when performing the

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action of bending forwards and extending the arms in postural activities[14–16]. Functional movements, such as moving the torso while extending the arms, require movements of the trunk[17], so they can help to develop the trunk muscles in hemiparesis patients[18, 19], while actions that require extending the arms to touch external targets in different directions and distances have been found to improve sensory processes and adaptation to postural changes[12–14].

The aims of this study were to implement training in chronic stroke patients involving extending the arm in a seated or standing position while varying the direction and distance of the target in relation to the frontal and sagittal planes and to investigate the effects of this training on trunk control, dynamic balance, and walking.

SUBJECTS AND METHODS

The subjects in this study were 23 patients who were diagnosed with hemiparesis resulting from chronic stroke, and were receiving physical therapy at E Hospital in Seoul, Republic of Korea (Table 1). The study was performed in accordance with International Ethical Guidelines and Declaration of Helsinki and was approved by a local institutional review board. The selection criteria were as follows: more than six months since stroke, so as to minimize the effects of natural recovery; ability to follow and understand the researcher's instructions and sufficient cognitive ability as demonstrated by a score of over 24 points on the Mini-mental State Examination-Korean (MMSE-K); ability to walk at least 10 m, irrespective of the use of assistive tools; and sufficient eyesight to perform the exercises. The exclusion criteria were lower motor neuron disease and orthopedic disease.

The subjects were divided randomly into a forward bending of the trunk and reaching (FBR) group and a control group. Pre-testing was conducted before training and post-testing was conducted after training. The FBR group and control group both underwent the same ordinary rehabilitation therapy of five 30-minute sessions a week for four weeks, while the FBR group additionally underwent FBR training, which involved four sets of pressing a button 35 times for a total of 140 presses per session, five sessions a week, for four weeks.

For the FBR training group, we adapted the movements from the experiment of Chern et al. with modifications. Using SuperLap 2.04 (Cedrus, San Pedro, CA, USA), the patients performed random button pressing training by watching a laptop screen and pressing six buttons (3 directions × 2 distances) on a table set at knee-height. The laptop was placed on top of the table at an adjustable height, so that the exercise could be performed while watching the laptop screen. After setting the height of the table to the subject's knee height, the distances to the buttons were set at 10% and 30% of the subject's height, and the directions were set at straight ahead and 45° to either side of the midline. The buttons were connected to the laptop running SuperLap program, and each button was fixed to the table at one of the six locations (2 distances × 3 directions).

The laptop screen depicted six circles on a white background, with the positions of the circles corresponding to those of the buttons on the table. When a button turned red, the subject was to press the corresponding button on the table and then stand upright. Each time circle turned red, which occurred in random order, the subject was to press the corresponding button on the table and then stand upright. The training program was conducted for four weeks, five sessions a week, with each session consisting of four sets of 35 button presses, for a total of 140 button presses per day. The experiment was conducted for a total of six weeks, with both groups undergoing assessment three days before and after training.

Table 1. General characteristics of the subjects (N=26)

	FBR (n=10)	Control (n=13)
Age (yrs)	59.8±7.9[a]	59.1±10.4
Height (cm)	165.4±9.9	166.9±10.4
Weight (kg)	64.0±12.2	61.9±11.0
Paretic side (right/left)	4/6	7/6
Duration (months)	16.3±7.3	17.0±10.0

[a]Mean±standard deviation

In order to assess the stroke patients' trunk impairments, we used the Trunk Impairment Scale (TIS), which has proven reliability and validity[7]. It is composed of 17 items, and is a tool used to assess static and dynamic control and coordination of the trunk in a seated position, in which posture can be assessed for trunk movement disorders. Static balance consists of three items and has a max score of 7 points, dynamic stability consists of ten items and has a max score of 10 points, and coordination consists of four items and has a max score of 6 points; the max total score is 23 points. Higher scores signify better trunk control.

To assess the patients' balance, we used the Berg Balance Scale (BBS), which has high intra-rater and inter-rater reliability[20]. The assessment items consist of three domains, sitting, standing, and postural change. With a minimum of 0 points and a maximum of 4 points for each of the 14 items, the max total score is 56. A higher score signifies better balance. The Timed Up and Go (TUG) test is an instrument with proven intra-rater and inter-rater reliability and can quickly measure functional mobility, movement capability, and balance. It involves measuring the time to get up from a chair with armrests, walk forward 3 m, turn around, walk back to the chair and then sit back down in the chair[21].

This study performed the Six-Minute Walking Test to evaluate the level of movements and endurance whilst walking. In the Six-Minute Walking Test, subjects repeat walking 30 m in a straight line to cover the greatest distance possible in six minutes. Walking speed and rest time were left for the individual to control in keeping with their own ability. In order to eliminate confounding errors from motivational stimulation during walking, the only words spoken were the remaining time and a phrase allowed by the guidelines: "Keep going"[22]. This test was reported to have high reliability[23].

We performed the 10-Meter Walking Test to measure walking speed[24]. The subjects walked a total of 13 m at the speed that they felt was most stable and comfortable, and

Table 2. Comparison of TIS, BBS, TUG, Six-minute walk and 10-Meter Walk results within groups and between groups (N=23)

	Values				Change values	
	FBR (n=10)		Control (n=13)		FBR	Control
	Before	After	Before	After		
TIS	11.7±3.8	15.6±4.0*	14.0±2.6	13.7±3.1	3.9±2.5†	0.3±2.1
BBS	37.3±6.5	44.4±6.3*	36.2±8.1	36.3±8.0	7.1±3.9†	0.1±1.4
TUG	34.3±22.1	30.0±18.0*	26.7±13.1	27.5±15.8	4.8±5.5	0.8±7.8
6MWT	134.3±77.2	152.3±81.7*	184.7±107.8	186.3±104.8	18.1±9.5†	1.6±19.6
10MWT	29.6±20.4	28.9±17.2	26.5±14.0	26.9±13.3	0.7±6.9	0.4±5.3

[a]Mean±standard deviation TIS: Trunk Impairment Scale; BBS: Berg Balance Scale; TUG: Timed Up and Go Test; 6MWT: 6 Minute Walk Test; 10MWT: 10-Minute Walk Test
*Significantly different from before ($p<0.05$)
†Significantly different from control ($p<0.05$)

the time required to traverse the middle 10 m was measured, excluding the 1.5 m at the start and end-points.

To analyze the collected data, this study used SPSS ver. 12.0 for all data processing. For the subjects' general characteristics, we used descriptive statistics. In order to investigate intergroup differences, we performed a Mann-Whitney U test, and in order to compare pre-AFE training and post-training results in both groups, we performed a Wilcoxon signed-rank test. The statistical significance level for all data was chosen as $\alpha=0.05$.

RESULTS

In the TIS, the FBR group showed a significant improvement after training ($p<0.05$), whereas the improvement in the control group was not significant. After the experiment, the amount of change in the TIS between the two groups was significant ($p<0.05$). In the BBS and TUG examinations, the FBR group showed a significant improvement in the BBS after training ($p<0.05$), and a significant decrease in time in the TUG examination ($p<0.05$). There were no significant differences in either test for the control group. The difference in change between the two groups was significant for the BBS but not for the TUG. For the Six-Minute Walking Test and the 10-Meter Walking Test, the FBR group only showed a significant improvement in the Six-Minute Walking Test. After the experiment, the amount of change in the Six-Minute Walking Test between the two groups was significant ($p<0.05$). The control group showed no significant difference in either test, and the difference in change between the two groups after the experiment was not significant for the 10-Meter Walking Test (Table 2).

DISCUSSION

In stroke patients, the decline in balance and control of posture causes difficulties in maintaining stability and in motor functions[9, 25]. Accordingly, rehabilitation therapy is required for improving balance and postural control in patients with hemiparesis following a stroke. In this study, we divided stroke hemiparesis patients into a group performing ordinary physiotherapy and FBR training five times a week for four weeks and a group performing only ordinary physiotherapy, to investigate the effects of FBR training on trunk control, dynamic balance, and walking.

The movement of reaching out an arm towards a target varying in distance and direction during the performance of everyday tasks requires adaptation of postural changes through the action of the nervous and musculoskeletal systems in order to maintain a stable dynamic posture[12–14]. Voluntary movement of the upper limb when sitting or standing provides stability to the center of the trunk[26].

According to the results of this study, the group that underwent FBR training showed a significant increase of 3.9 points in the TIS, from 11.70±3.77 points before training to 15.60±4.01 points after training, meaning that trunk control improved significantly. The control group that only underwent ordinary physiotherapy did not show a significant increase, and when the before-after change was compared between the two groups, the FBR training group showed a significantly greater change. Regarding dynamic balance, the FBR training group showed a significant increase in the BBS from 37.30±6.53 points before training to 44.40±6.26 points after training, while it showed a significant decrease in the TUG test, from 34.29±22.05 point before training to 30.0±17.95 points after training. The control group showed no significant difference for either test. The difference in before-after change between the training and control groups was significant only for the BBS. This shows that the FBR training also improved dynamic balance significantly.

Activation and strengthening of the trunk muscles is required for functional recovery of impaired trunk control in stroke patients[27]. Functional movements, such as extending the arm, have been shown in previous studies to improve trunk movements and muscle strength in hemiparesis patients because they require movement of the trunk[17–19]. Among assessments of trunk control, the TIS consists of items evaluating coordination when emphasizing lateral rotation of the pectoral girdle and the pelvis, and the separate upper and lower limb movements that follow from this[8]. The training in this study, bending the trunk forwards and reaching out the arm straight ahead, 45° to the right or 45° to the left, to press a button in a horizontal plane, involved lateral movements of the trunk through rotation of the pelvis and pectoral girdle and simultaneous separate movements of the upper and lower limbs, such as reaching out with the upper limb and squatting with the lower limbs. This is similar to the items in the TIS examining at coordination, and the significant improvement that the FBR training group showed in the TIS before and after training is thought to indicate improvement in trunk control resulting from improved movement and strength of the trunk muscles.

The movement of extending the arm while using the whole trunk is similar to the movement of extending the arm forwards from a squat position[15]. This is a position that requires dynamic balance, like postures commonly required in everyday life, such as using the toilet, sitting on a chair, walking down stairs, and picking up an object from the top of a shelf[28]. In a study by Yao[29], stroke patients with large movements in center of pressure trajectory were reported to have higher BBS scores, and in a study by Chern et al., BBS scores were also reported to be higher for stroke patients performing dynamic movements that used the whole trunk, such as arm extension, compared with maintaining a static posture. With similar training movements to those used in this study, there was no significant increase in BBS in the control group before and after training, but in the FBR group showed a significant increase in BBS and a significantly greater before-after change compared with the control group, demonstrating that dynamic balance improved. There was no significant decrease in the TUG test in the control group before and after training, but there was a significant decrease in the FBR training group. This is similar to the results of a study by Karatas et al.[30], in which dynamic balance improved with improved strength of the trunk flexion muscles. In the training for this study, when bending forwards and extending the arm, movement of the trunk flexion muscles was required, and in the TUG test[31], abdominal and trunk rotation muscles were required to walk 3 m, turn around, return to the original position, and sit down. In the training for the current study, bending forward and extending the arm for each of the 140 presses required flexion and rotation of the trunk. The significant decrease of the FBR training group in the TUG test, which assesses dynamic balance, demonstrates an improvement in dynamic balance.

In the walking tests, the FBR training group showed a significant improvement in the Six-Minute Walk Test from 134.30 m before training to 152.30 m after training, but the control group did not show any significant difference. In 10-Meter Walk Test, neither the FBR training group nor the control group showed a significant difference, but the time required to walk 10 m decreased in the FBR training group. The Six-Minute Walk Test reflects endurance in walking and is used to assess patients with limited walking ability due to stroke, including that resulting from muscular weakness, stiffness, and impaired control and balance in the lower limb[22, 32]. The movement of extending the arm forwards from a squatting position, like in this study, requires simultaneous movement of the trunk and lower limbs, so it can increase trunk movements and lower limb muscle strength in stroke patients, making symmetrical movements of the body easier[17–19]. Hausdorff et al.[33] reported that asymmetrical movements when walking can increase energy consumption and that increases in symmetrical movements in stroke patients reduce the effort required to walk, so these movements can improve walking ability. In relation to this, after training, patients showed a significant increase in endurance during walking, and walking speed also increased, although this increase was not significant.

Because this study was conducted on only a limited group of hemiparesis patients, it has limitations in terms of generalization to all hemiparesis patients. The small number of patients and the lack of sufficient control for other movements in the subjects' daily lives outside of training are also possible confounding factors of this study. In the future, more research will be required to investigate the clinical improvement effects of FBR on trunk control, dynamic balance, and walking.

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