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The effects of multidirectional stepping training on balance, gait ability, and falls efficacy following stroke

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Abstract. [Purpose] The purpose of this study was to determine whether a multidirectional stepping training improves balance, gait ability, and falls efficacy in stroke patients. [Subjects] Forty patients who met the selection criteria and agreed to participate in research at hospital N were randomly allocated and enrolled in this study. Twenty of the subjects were assigned to an experimental group that participated in combined stepping exercise, and the other twenty subjects were assigned to a control group that received general physical therapy. [Methods] In the two groups, balance was measured using the Berg Balance Scale, gait ability was measured using the 10-m Walk Test, and falls efficacy was measured using the Falls Efficacy Scale before training and after 6 weeks of training. [Results] Comparative analysis of the experimental group's pretest and post-test results showed statistically significant differences in the Berg Balance Scale, 10-m Walk Test, and Falls Efficacy Scale scores. There were significant between-group differences in the Berg Balance Scale, 10-m Walk Test, and Falls Efficacy Scale scores. [Conclusion] The results suggest that a combined stepping exercise can be an effective intervention to improve the balance, gait ability, and falls efficacy in stroke patients.

Key words: Stroke, Multidirectional stepping training, Falls efficacy

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INTRODUCTION

After onset of stroke, patients commonly show symptoms of hemiplegia and loss of visuospatial perception due to impairment of the function of the central nervous system with respect to integration of visual information with information about the sense of position received through the proprioceptor[1)]. Consequently, these patients exhibit asymmetric body balance, gait, and weight shifts, as well as defects in voluntary movements. In particular, as the center of gravity shifts to the unaffected side, symmetric weight shifts against external sway do not occur, leading to reduced balance ability[2)]. Hemiplegic stroke patients show conditions in which approximately 61% to 80% of the entire body weight is concentrated on the lower extremity on the unaffected side in standing postures[3)]. These asymmetric postures reduce gait velocity, obstruct independent gait, and may result in falls[4)]. Falling is one of the most common complications in stroke patients[5)]. Falls can result from such declines in physical functions, including balance and gait abilities, and psychological functions, such as falls efficacy. Reports indicate that after experiencing a fall, a patient's fear of falling again, that is a decline in falls efficacy, increases the his/her risk of falling even if the he/she has not previously sustained any physical injury[6)].

Falls efficacy is an individual's power to continue certain behaviors, in other words, the self-confidence to successfully perform certain behaviors[7)], and refers to the confidence or will not to fall during activities. Recently, it has been reported that, in the case of stroke patients residing in communities, the variable of fall related self-efficacy is predominant over

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*Corresponding author. Jin-Uk Choi (E-mail: break10739@naver.com) physical functions such as spasticity, motility, balance, and paretic side muscle strength8) and is closely related to balance ability and quality of life9).

As development of methods for improving hemiplegic patients' balance and gait ability has been ongoing there have been increasing reports on weight shift training based on neurodevelopmental scientific treatment methods, 3D visual feedback, gait training through task-oriented approaches, and obstacle stepping training10–12).

When walking, patients with hemiplegia due to stroke should feel confident that the leg on the paretic side is prepared to generate the muscle force necessary to accommodate the entire body weight or step at a speed concordant with the leg on the non-paretic side13). In the performance of appropriate motions, muscle force is associated with the interaction between voluntary stepping control and automatic body balance control14). Because the decrease in the bearing surface while one leg is lifted may cause a critical reduction in balance12), muscle force is useful in improving balance ability. Therefore, in the present study, to prevent falls that may suddenly occur in the course of daily living, stepping exercises were used to improve muscle force as well as balance ability through posture alignment, whole body muscle strength, paretic side recognition ability, and functional motility, including control of direction changes13).

Most studies that have been conducted on the improvement of gait ability in hemiplegic patients have had a tendency to concentrate on specific training using expensive equipment. The present study, however, aimed to implement combined stepping exercises, which are low in cost and maximize temporal and spatial efficiency, to determine their effects on hemiplegic patients' balance and gait abilities and falls efficacy.

SUBJECTS AND METHODS

Subjects

The present study was conducted on 40 patients at N hospital located in Chungcheongbuk-do, Republic of Korea. The subjects were assigned either to a combined stepping training treatment group of 20 subjects or to a control group of 20 patients who received general physical therapy and respective training programs were implemented.

The inclusion criteria were as follows: (1) individuals diagnosed with hemiplegia due to stroke, (2) individuals who had been affected for at least six months, (3) individuals whose scores on the Korean version of the Mini-Mental State Examination were at least 25 points, (4) individuals who could walk independently for at least 10 m, (5) individuals who could understand the purpose of the present study and could perform the movements as instructed, and (6) individuals who agreed to participate in the study. All subjects provided written informed consent prior to participation according to the ethical standards of the Declaration of Helsinki.

Methods

Weight shift training for 10 minutes followed by multidirectional stepping training for 20 minutes was applied in the experimental group. Combined stepping was used in the designs of two training exercises: (1) In the first exercise, stair-shaped footholds (10 cm) were placed in the 12 o'clock and 3 o'clock (or 9 o'clock) directions, and the non-paretic side foot was placed on the footholds in the two directions alternately and moved back to the original position repeatedly while the paretic side foot was fixed on the ground. (2) In the second exercise, a weight rod (2 cm in diameter and 100 cm in length) was placed between the two feet, and the non-paretic side foot was repeatedly moved to cross the weight rod, placed next to the paretic side foot, then moved back to the original position. Subjects were allowed to rest for two minutes between the two tasks. This training was implemented for 30 minutes per session, five times per week for four weeks.

The control group received general physical therapy, including gait and balance training, for 30 minutes per session, five times per week for four weeks (the same schedule as applied in the experimental group).

Balance ability was measured using the Berg Balance Scale (BBS)15). The BBS is used clinically for patients with senile disease or hemiplegia resulting from a stroke to evaluate their balance ability either in a standing position or during movement. This scale consists of 14 items, each with a score from 0 to 4, giving a possible total maximum score of 56.

The Timed Up and Go (TUG) test was also used to evaluate balance. This test is used to evaluate movements that require dynamic balance by evaluating balance ability, as well as the abilities to stand up and move, walk short distances, and rotate, by measuring the time it takes for the subject to stand up from a sitting position in an arm chair, walk 3 m on a flat surface, pass the halfway point, come back, and once again sit in the armchair16, 17).

The 10-m Walk Test (10-m WT) was used to evaluate gait ability. This test generally evaluates the gait velocity of patients with neurological damage17) and shows high inter-rater and intra-rater reliability (r=0.89–1.00)18). In the present study, the subjects were instructed to comfortably walk 13 m; the time taken for 10 m, excluding the first 1.5 m and the last 1.5 m, which take into account acceleration and deceleration, was measured in units of seconds19).

The Falls Efficacy Scale (FES) developed by Tinetti et al.20) was used to evaluate falls efficacy. This scale measures an individual's degree of confidence related to fall prevention in daily living using a total of 10 questions. The score can range from 10 to 100 points; higher scores mean higher levels of falls efficacy. The reliability of this scale when it was developed was high (Cronbach's α= 0.84).

The experimental subjects in the present study were randomly selected in order to enhance the study's objectivity and reliability. All statistical analyses of the collected data were performed using IBM SPSS Statistics for Windows (ver. 20.0;

IBM Corp., Armonk, NY, USA). and the statistical significance level was set to 0.05. Differences between before and after the training in each group were analyzed by conducting paired t-tests, and the changes in individual groups were compared by conducting independent sample t-tests. All statistical significance levels for the data were set to 0.05.

RESULTS

A total of 40 subjects participated in this study, with 20 subjects in the experimental group and 20 subjects in the control group. The general characteristics of the study subjects are summarized in Table 1.

Values measured in the TUG tests before and after training in each group were compared, as shown in Table 2. The values measured in the experimental group showed a statistically significant decrease from 23.28 ± 3.42 s before training to 21.50 ± 3.35 s after training ($p<0.05$), and the values measured in the control group also showed a statistically significant decrease, decreasing from 24.65 ± 2.71 s before training to 23.53 ± 2.93 s after training ($p<0.05$). The change values were significantly different between the groups: 1.78 ± 0.86 s in the experimental group and 1.12 ± 0.63 s in the control group ($p<0.05$).

The BBS scores before and after training in each group were compared as shown in Table 2. The BBS scores in the experimental group showed a statistically significant increase from 42.45 ± 1.35 points before training to 45.46 ± 1.70 points after training ($p<0.05$), while those measured in the control group did not change significantly—the scores were 41.01 ± 1.29 points before training and 41.56 ± 1.15 points after training. The change amounts were significantly different between the groups: 3.01 ± 1.19 points in the experimental group and 0.55 ± 0.52 points in the control group ($p<0.05$).

Values measured in the 10-m WT before and after training in each group were compared as shown in Table 2. The values measured in the experimental group showed statistically significant decrease from 23.31 s before training to 21.30 s after training ($p<0.05$), and the values in the control group also showed a statistically significant decrease, decreasing from 23.77 s before training to 22.72 s after training ($p<0.05$). The change values were significantly different between the groups: 2.01 s in the experimental group and 1.05 s in the control group ($p<0.05$).

The FES scores before and after training in each group were compared as shown in Table 2. The FES values in the experimental group showed a statistically significant increase from 41.10 ± 16.13 points before training to 62.30 ± 25.00 points after training ($p<0.05$), and those measured in the control group also showed a statistically significant increase, increasing from 44.12 ± 19.80 points before training to 55.15 ± 24.52 points after training ($p<0.05$). The change values were significantly different between the groups: 21.20 ± 17.76 points in the experimental group and 11.03 ± 15.13 points in the control group ($p<0.05$).

Table 1. The subjects' characteristics

	Experimental group (n = 20)	Control group (n = 20)
Gender (male/female)	20 (11/9)	20 (12/8)
Age (years)	54.1 ± 14.2	63.4 ± 9.3
Height (cm)	163.0 ± 11.4	161 ± 7.2
Weight (kg)	62.6 ± 14.3	58.8 ± 10.1

Values are expressed as the mean ± SD.

Table 2. Comparison of the BBS, TUG, 10-m WT and FES scores between the experimental and control groups

Variable		Pre	Post	Post-Pre
		Mean±SD	Mean±SD	Mean±SD
BBS (score)	EG	42.5±1.4	45.5±1.7	3.0±1.2
	CG	41.0±1.3	41.6±1.2	0.6±0.5*
TUG (s)	EG	23.3±3.4	21.5±3.4	1.8±0.9
	CG	24.7±2.7	23.5±2.9	1.1±0.6*
10-m WT (s)	EG	23.3±3.4	21.30±3.04	2.01±0.72
	CG	23.8±2.6	22.72±2.60	1.05±0.41*
FES (score)	EG	41.1±16.1	62.3±25.0	21.2±17.8
	CG	44.1±19.8	55.2±24.5	11.0±15.1*

*$p<0.05$.
EG: experimental group; CG: control group; BBS: Berg balance scale; TUG: Time up & Go; 10-m WT: 10-m Walk test; FES: Falls Efficacy Scale

DISCUSSION

The present study aimed to examine whether a four-week multidirectional stepping training intervention would affect stroke patients' balance and gait abilities.

According to the results of the study, the experimental group that received combined stepping training showed greater improvement in balance and gait abilities and self-efficacy than the control group that received general physical therapy.

In the present study, the BBS and TUG test were used as measures of balance ability. Changes in the BBS scores between before and after training both in the experimental and control groups were compared; the results indicated a significant difference (3.01 ± 1.19 points in the experimental group and 0.55 ± 0.52 points in the control group) ($p<0.05$). The changes in the TUG values between before and after training in the experimental and control groups were compared, and the results showed a significant difference between the two groups—1.78 ± 0.86 s and 1.12 ± 0.63 s in the experimental and control groups, respectively ($p<0.05$). These results are considered attributable to the fact that, when crossing obstacles, the experimental subjects subconsciously adapted to implement motor skills and their central nervous systems automatically developed strategies to maintain body balance and apply mobility patterns to actual requirements21). Chang et al.22) studied the correlation between plantar pressure and gait velocity and reported that the improvement of weight bearing ability of the lower extremity on the paretic side increased gait velocity. Consistent with this report, a significant difference was found when changes in the 10-m WT results between before and after training in the experimental and the control groups were compared (2.01 s and 1.05 s, respectively ($p<0.05$). Olney et al.23) argued that gait velocity may be improved by increases in stride length or step count per minute. After implementing functional strength training, Kreb et al.24) reported that increases in gait velocity were the result of improvement in the weight bearing ratio of the two lower extremities following improvement in balance control ability.

The improvement in gait velocity of subjects in the experimental group in the present study is considered attributable to the fact that the unilateral combined stepping exercises using a foothold and a weight rod enhanced the level of mobility of the lower extremity on the non-paretic side the movement of which had been restricted after the onset of stroke. Through dynamic movement of the lower extremity of the non-paretic side, the subjects improved balance ability by bearing weight on the lower extremity of the paretic side, and the weight shift exercises improved gait ability through improvement of muscle strength25), thereby enhancing automatic development of the ability to control the two lower extremities and the trunk. These balance and gait abilities are closely related to the risk of falling26). In the present study, after the interventions using a foothold and weight rod, the changes in the falls efficacy scores between before and after training in the experimental and control groups were compared, and the results showed a significant difference: 21.20 ± 17.76 points and 11.03 ± 15.13 points, respectively ($p< 0.05$).

This result is considered to be attributable to the fact that improvement in balance and gait abilities through step training in diverse directions led to an increase in the subjects' confidence.

The training program with repeated steps in diverse directions used in this study is not restrictive in terms of time and space and is not burdensome in terms of cost. Most stroke patient treatments implemented with passive postural control and weight shift training led by a therapist result in low satisfaction in terms of cost and efficiency. Therefore, new exercise programs that are cost-effective and efficient and that enable active patient participation should be developed based on the results of the present study, which confirms the positive effects of such programs.

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