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Original Article

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The Effect of Lower Extremity Strengthening Exercise Using Sliding Stander on Balance and Spasticity in Chronic Stroke: A Randomized Clinical Trial

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Purpose: Generally, patients with stroke present with decreased balance and increased spasticity following weakness of the paralyzed muscles. Muscle weakness caused by stroke has two causes. This is caused by a decrease in motor output and an adaptive muscle change, resulting in muscle weakness and muscle paralysis. The purpose of this study was to investigate the effect of strengthening exercise on balance and spasticity in chronic stroke patients and to suggest the basis of clinical treatment.
Methods: Twenty subjects were divided into two groups: a lower-extremity strengthening group (experimental group) and a general physical therapy group (control group). The sliding stander equipment was used for the experimental group and a regimen of warm-up exercise, the main exercise routine, and cool-down exercise were used for the muscle strengthening exercise program. Balance and spasticity were measured before and after the training period. Balance ability was measured by the Berg balance scale, the Timed up and Go test and the weight distribution of the paralyzed muscles by the Spacebalance 3D. Spasticity was measured by the Biodex system.
Results: After the training periods, the experimental group showed a significant improvement in BBS, weight distribution of the paralyzed muscles, and decreased spasticity when compared to the control group ($p<0.05$).
Conclusion: This study supported the hypothesis that lower-extremity strengthening exercise improves the balance and decreases the spasticity of stroke patients. If it is combined with conventional neurologic physiotherapy, it would be effective rehabilitation for stroke patients.

Keywords: Balance, Spasticity, Strengthening, Stroke

INTRODUCTION

Stroke patients experience balance and walking disorders due to multiple functional disorders, indicating limitations of functional activities required for independent daily living.[1] In particular, muscle weakness is an element limiting the functional rehabilitation of stroke patients and affects balance and walking ability, thus becoming a treatment goal of assessing functional ability.[2] Muscle weakness caused by stroke has two causes. The first cause is a reduction in the number of motor units that can be mobilized as a result of a decrease in motor output. The second cause is both a lack of muscle activity and lack of exercise.[3] This is caused by a decrease in motor output and an adaptive muscle change, resulting in muscle weakness and muscle paralysis.[4]

In general, hemiplegia patients with stroke lose weight on the lower extremities when standing due to musculoskeletal problems, such as sensory impairment and muscle weakness. This results in a asymmetric position characteristics.[5] In addition, patients with stroke have over-used the paralyzed side for an extended period. This results in weakness of the upper and lower limbs on the paralyzed side.[6] Abnormal muscle recruitment also reduces the endurance required for weight-bearing and during activity, as the center of pressure is concentrated on the less paralyzed side and the postural sway increases.[7]

Spasticity has positive aspects, such as stability in standing or walking, maintaining muscle mass, and maintaining bone density.[8]

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On the other hand, there is a difficulty in maintaining balance due to interfering with the motor function by increasing the synergy pattern, resulting in negative outcomes such as joint contracture, pain, and muscle spasms.[8,9] Therefore, a treatment that minimizes the adverse effects of spasticity after brain lesions is an important goal in clinical practice.[10]

To minimize the negative effects of balance disorders and spasticity in patients with stroke, clinical strength training was conducted at the clinic. Progressive resistance exercise of the lower limbs conducted through the application of functional performance in stroke patients has had significant effects on lower-limb strength, balance, and walking ability.[11,12] Byun et al.[13] reported that after applying the sliding rehabilitation device for the treatment of stroke patients with hemiplegia, improved strength, stiffness, walking ability, balance, and ability to perform daily activities resulted. In patients with stroke, progressive resistance exercise[14] and isokinetic muscle strengthening exercises[15] increased muscle strength without increasing stiffness and contraction. Repeated muscle strengthening exercise has been shown to maintain muscle length and effectively reduce spasticity.

However, most of the previous studies on the effects of muscle strengthening exercise have not focused on spasticity and balance-related issues that negatively affect the daily life activities of stroke patients. In addition, even in studies related to spasticity, there was no quantitative measurement of spasticity measured using the modified Ashworth scale. The purpose of this study was to investigate the effect of strengthening exercise on balance and spasticity in chronic stroke patients and to suggest the basis for clinical treatment.

METHODS

1. Subjects

The research subjects were 20 patients diagnosed with strokes at the hospital in K hospital in Jeonju of Korea. The subjects sufficiently understood the study procedure and submitted informed written consent to participate in this study. The study was conducted in accordance with the Declaration of Helsinki.

The inclusion criteria for the subjects who had a stroke were (1) more than 6 months after the onset of stroke and less than 2 years, (2) the ability to walk for 10 minutes or longer on a treadmill, (3) absence of neurotic diseases such as amblyopia, vertigo, and abnormal vestibular function, (4) Subjects had no orthopedic problems that could affect exercise in the lower limbs, (5) cognitive function allowing an understanding of researchers' instructions. Table 1 summarizes the subjects general characteristics (Table 1).

Table 1. General characteristics of subjects

	Experimental group (n=10)	Control group (n=10)
Age (yr)	53.1±13.4	54.0±9.1
Gender (Male/Female)	8/2	8/2
Time since stroke (Month)	20.3±14.4	15.8±10.2
Type of lesion (%)		
Hemorrhagic	7 (70)	3 (30)
Infarction	3 (30)	7 (70)
Side of lesion (Rt/Lt)	3/7	5/5
Height (cm)	167±8.2	164.4±9
Weight (kg)	65.6±7.4	66.1±6.9
MAS (Score)	2.2±0.6	2.2±0.7

Mean±standard deviation. MAS: Modified ashworth scale.

2. Experimental methods

1) Experimental procedures

Subjects who participated in this study were randomly assigned to two groups, which paired subjects with similar physical abilities. Lower-extremity strengthening (experimental) group consisted of 10 people, and the general physical therapy (control) group consisted of 10 people. Both the experimental group and the control group received neurodevelopment therapy. However, the experimental group performed additional lower-extremity strengthening training for 30 minutes, five times a week, for six weeks.

The experimental group performed lower-extremity strength training on the MET 300 (Met 300, CyberMedic Co., Ltd., Iksan, Korea). The subjects bent their knees 90 degrees in a comfortable position on the backrest mat, supported the footrest, and bent the elbows of the two arms in a lying position to fix the hands to the chest. After observing the frontal positions, the upper body was kept intact, and the knee flexion and extension were repeated. The warm-up exercise and cool-down exercise were performed on the MET 300 with knee flexion and extension repeated for five minutes with 25% of 1 RM force. In the main exercise, based on Holten's study, we performed a total of three sets of 15 to 20 repeated for twenty minutes with 70% power of 1 RM.[12] The MET 300 angle was adjusted to maintain 70% of 1 RM with increasing muscle strength (Figure 1). In the event that a subject complained of fatigue during training, a break was provided to minimize his/her fatigue level. In addition,

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Figure 1. Lower-extremity strengthening exercise using sliding stander. (A) Start position, (B) End position.

one physical therapist assisted each subject to safety.

The control group corrected the abnormal postures and movements as well as promoted the lower-extremity normal exercise pattern and joint movement exercise, balance training, and gait training, respectively. If a subject complained of fatigue, a break was given to minimize his/her fatigue level, and physical therapist assisted each subject to safety.

2) Assessment

The Berg balance scale (BBS) and timed up and go (TUG) tests were used to measure functional balance ability. In order to measure the static balance ability of all subjects, the weight-bearing distribution of the paretic side was measured by subjects maintaining a standing position on a Spacebalance 3D (Spacebalance 3D, CyberMedic Co., Ltd., Iksan, Korea). This study evaluated the weight-bearing distribution on the paretic side during static standing with eyes open and closed to confirm the weight-bearing distribution of the standing posture.

The Biodex system (Biodex Medical System Inc., NY, USA) was used to measure spasticity. The subject is allowed to sit on a Biodex system chair and the knee joint of the lower leg is fixed at 30° flexion. The axis of the ankle joint were aligned with the axis of the Biodex system. The isokinetic manual extension exercise was performed at an angular velocity of 60°/sec, 180°/sec, and 240°/sec, and five times per velocity at a joint angle range of 30° to an ankle plantar flexion and 20° of an ankle dorsi flexion. Eccentric torques were measured and had a five-second rest period at each speed between manual extension exercise.[16]

3. Statistical analysis

PASW 18.0 version for Window (PASW Inc., Chicago, IL, USA) was used for statistical analysis of the measured values of the subjects. Descriptive statistics were used to present each variable as mean ± standard deviation. The Kolmogorov-Smirnov test was used to test the normality. To examine the differences in general characteristics between the two groups, the independent t-test were used. To verify the differences within each group between pre-test and post-test balance ability, spasticity the paired t-test was used, and the independent t-test was used to verify the differences between the two groups. The significance level was set to 0.05.

RESULTS

1. Functional balance ability

Among the functional balance ability, the results of a comparison before and after the training showed that both group's BBS statistically significantly increased ($p < 0.05$). After the training, the results

Table 2. Berg balance scale (BBS) and Timed up and go (TUG) test results for the experimental and control groups

	Experimental group		Changes	Control group		Changes	p
	Before	After		Before	After		
BBS	45±5.7	50.2±4.5*	5.2±2.6	45.5±8.3	48.3±8*	2.8±1.1	0.01†
TUG	29.9±19.8	25.6±17.7*	-4.3±3.1	31.9±23.8	29.6±21.9*	-2.2±2.4	0.11

Mean±standard deviation. Significant difference between pre and post intervention within the group (*p<0.05), significant difference between the change values among the groups (†p<0.05).

Table 3. Affected weight distribution results for the experimental and control groups

	Experimental group		Changes	Control group		Changes	p
	Before	After		Before	After		
Affected weight distribution (open eyes)	44.9±3.4	48±2.2*	3±2.2	45.5±3.1	46.7±3.4*	1.2±1.3	0.04†
Affected weight distribution (closed eyes)	43.8±2.2	48±2.4*	4.2±2.3	43.8±2.3	46.1±2.3*	2.3±1.2	0.03†

Mean±standard deviation. Significant difference between pre and post intervention within the group (*p<0.05), significant difference between the change values among the groups (†p<0.05).

Table 4. Spasticity results for the experimental and control groups

	Experimental group		Changes	Control group		Changes	p
	Before	After		Before	After		
60°/sec (%)	39.2±14.4	31.6±12*	7.7±6.6	27.5±9.5	24.5±7.8	3±4.2	0.07
180°/sec (%)	43.7±14.5	33.1±10.8*	10.5±8.4	31.4±10.9	28.5±9.4*	2.9±3.6	0.02†
240°/sec (%)	42.9±14.2	32.5±9.1*	10.4±8.4	31.4±10.9	27.8±8.9*	3.7±4.4	0.04†

Mean±standard deviation. Significant difference between pre and post intervention within the group (*p<0.05), significant difference between the change values among the groups (†p<0.05).

of a comparison between the two groups showed that the experimental group's BBS statistically significantly increased compared to the control group ($p<0.05$).

The results of a comparison before and after the training showed that both group's TUG statistically significantly decreased ($p<0.05$). After the training, no statistically significant differences were observed between the two groups ($p<0.05$)(Table 2).

2. Static balance ability

The results of a comparison before and after the training showed that both group's weight distribution of the paralyzed at the eyes open and the eyes closed statistically significantly increased ($p<0.05$). After the training, the results of a comparison between the two groups showed that the experimental group's weight distribution of the paralyzed statistically significantly increased compared to the control group ($p<0.05$)(Table 3).

3. Spasticity

The results of a comparison before and after the training showed that the experimental group's spasticity statistically significantly decreased at an angular velocity of 60°/sec, 180°/sec, and 240°/sec ($p<0.05$). The results of a comparison before and after the training showed that the control group's spasticity statistically significantly decreased at an angular velocity of 180°/sec, and 240°/sec ($p<0.05$). After the training, the results of a comparison between the two groups showed that the experimental group's spasticity statistically significantly decreased compared to the control group at an angular velocity of 180°/sec, and 240°/sec ($p<0.05$)(Table 4).

DISCUSSION

This study intended to suggest an effective clinical method of training stroke patients to improve their balance and decrease their spasticity with and without lower-extremity strengthening.

As a result, BBS and TUG, which were measured to evaluate functional balance ability showed a statistically significant improvement after the intervention. After the training, a comparison between the two groups showed that the experimental group's BBS showed a statistically significant increase as compared to the control group. Similar to the results of this study, Tung et al.[17] reported that strengthen-

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ing exercise through sit-to-standing training was effective in improving the balance of stroke patients. On the other hand, Mercer et al.[18] reported that when the hip abductor strengthening exercise was applied to stroke patients, paralyzed and non-paralyzed muscles improved, but no significant change in BBS score was observed. This is due to muscle strengthening exercise that was limited to only the hip abductors. In order to maintain balance, muscle strength is required not only in the hip joint but also in multiple joints.[19] Both a previous study and this study reported that muscle strengthening exercise is effective in improving balance ability. It is believed that BBS and TUG have improved results because they are various muscle movements of the muscles related to both the knee joint and ankle joint, and not focusing on one joint muscle.

In the static balance ability evaluation, based on the weight distribution of the paralyzed subjects at the time of standing, the results from static standing with both the eyes-open and eyes-closed showed statistically significant improvement compared with those before the intervention. After the training, the results of a comparison between the two groups showed that the experimental group's weight distribution showed a statistically significant increase compared to the control group. Similarly, muscle strengthening exercise through sit-to-standing training for stroke patients has been reported to improve the weight distribution on the paralyzed side.[2,17] Muscle strength associated with the knee joint and ankle joint is important in performing sit-to-standing exercise.[20] The weight distribution on the paralyzed side is improved due to increased muscle strength related to the paralyzed knee joint and ankle joint through sit-to-standing training. However, performing sit-to-standing training can be challenging for stroke patients. Therefore, it is necessary to perform strength training in a stable state. In this study, the muscle strength of the knee joint and ankle joint muscles was improved and the weight distribution of the paralyzed side was changed by the muscle-strengthening exercise performed with the MET instrument.

Spasticity was statistically significantly decreased after intervention applied to both groups at an angular velocity of 180°/sec and 240°/sec. After the training, the results of a comparison between the two groups showed that the experimental group's spasticity showed a statistically significant decrease compared to the control group at an angular velocity of 180°/sec, and 240°/sec. This means that lower-extremity strengthening exercise is effective in reducing spasticity. Engardt et al.[21] argued that the spasticity of a stroke patient was exacerbated by muscle weakness and progressive strengthening exercise can lead to a reduction in spasticity due to the maintenance of muscle length. In this study, we also confirmed that spasticity reduction was achieved through lower-extremity strengthening exercises, resulting from the repetition contraction and elongation caused by the muscle-strengthening exercise; this improved neurological control and maintained the length of the muscles. In addition, compared with the control group, the decrease in spasticity in the experimental group was thought to be due to the repeated strengthening exercise reduction of the knee joint and ankle joint muscles through MET 300.

Methods for assessing spasticity in clinical settings include a subjective method of assessing the degree of resistance when the joint is manually moved, such as the modified Ashworth scale,[22] the tendon reflex test using the spinal cord reflex, and an indirect method using ground reaction force during walking.[23] There is also a method using isokinetic muscle strength.[16] Eccentric torques measured by the isokinetic muscle strength were a clinical indicator of spasticity and significantly correlated with the modified Ashworth scale, which is an index reflecting the degree of spasticity.[16] The isokinetic manual extension exercise was performed at an angular velocity of 60°/sec, 180°/sec, and 240°/sec, at a joint angle range of 30° to an ankle plantar flexion and 20° of an ankle dorsi flexion and measured eccentric torques. It is possible to objectively evaluate the spasticity of patients with stroke objectively, but other methods should be considered, as this method is limited to objectively evaluating the spasticity in the absence of isokinetic muscle strength in clinical practice.

This study had certain limitations. The number of subjects was small, and there was a marked difference in functional levels among the subjects, which is selecting the subjects, considered only the duration of the disease and the degree of spasticity. In addition, no confirmation was made whether the effect of treatment remained constant after the intervention. Long-term studies with more subjects will be needed for future studies to determine how well various enhancement methods for stroke patients can provide more effective rehabilitation.

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