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Effect of Bridge Exercise Combined with Functional Electrical Stimulation on Trunk Muscle Activity and Balance in Stroke Patients

Background: Stroke patients have weak trunk muscle strength due to brain injury, so a single type of exercise is advised for restoring functionality. However, even after intervention, the problem still lies and it is suggested that another intervention method should be applied with exercise in order to deal with such problem.
Objectives: To Investigate the effect of bridge exercise combined with functional electrical stimulation (FES) on trunk muscle activity and balance in stroke patients.
Design: Randomized controlled trial.
Methods: From July to August 2020, twenty stroke patients was sampled, ten patients who mediated bridge exercises combined with functional electrical stimulation were assigned to experiment group I, and ten patients who mediated general bridge exercises were assigned to experiment groupII. For the pre-test, using surface EMG were measured paralyzed rectus abdominis, erector spinae, transverse abdominis/internal oblique muscle activity, and using trunk impairment scale were measured balance. In order to find out immediate effect after intervention, post-test was measured immediately same way pre-test.
Results: Change in balance didn't show significant difference within and between groups, but muscle activity of trunk was significant difference rectus abdominis and erector spinae within groups I (P<.01), also between groups was significant difference (P<.05).
Conclusion: Bridge exercise combined with FES could improve trunk function more effectively than general bridge exercise due to physiological effect of functional electrical stimulation.

Keywords: *Stroke; Bridge exercise; Functional electrical stimulation; Trunk muscle activity; Balance; Surface EMG; Trunk impairment scale*

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INTRODUCTION

Dyskinesia, in which the muscle function of one side of the body is partially or entirely lost, is one of the main symptoms of stroke.[1] In particular, the impaired sensation and motor ability of the trunk interfere with functional activities and cause defects in balance control, thereby substantially affecting activities.[2] Trunk posture control is closely related to maintaining upright postures against gravity so that tasks required according to the surrounding environment can be smoothly performed[3] and balance can be maintained.[4] Therefore, if trunk muscle weakening occurs, as with stroke subjects with paralysis on one side of the body, the person not only will have difficulties in performing tasks but also will be seriously vulnerable to falls due to poor balance. Therefore, trunk training is a crucial element of the approach of exercise therapy.[5]

Muscles that provide trunk stabilization are divided into global muscles and local muscles,[6] among which global muscles such as rectus abdominis and erector spinae mainly generate overall stability and strength, local muscles such as the transverse abdominis and internal oblique are mainly connected between verte–bral segments to maintain posture and provide delici–ate control and stability of trunk.[7] Trunk training methods for stroke subjects include stabilization exercise methods that train various muscles of the trunk and the pelvis to harmoniously activate the muscles of the abdomen and the spine.[8] The repre–sentative exercises are pelvic tilt exercise, quadruped exercise, abdominal hollowing, and bridge exercise.[9] The bridge exercise is an exercise performed to pre–vent damage to the tissues around the spine by way of training to absorb the loads imposed on the lumbar vertebrae and to improve the coordination ability of the muscles during limb movements.[10] This exercise is frequently used because it is helpful for rehabilitation that requires low–intensity exercise[11] and increases stability through strengthening of the trunk and pelvic muscles.[12] However, since the recovery of the functions of stroke subjects is slowed as time goes on due to problems that remain in the mechanical receptors of the body,[13] it is necessary to intervene by combining new techniques with various existing exercise methods in order to compensate for the remaining physical problems even when the subjects perform exercises.[14,15]

Many previous studies have suggested intervention methods that combine certain exercises with electrical stimulation. Functional electrical stimulation (FES) has effects relating to increase in muscle strength and endurance in the periphery, decrease in muscle rigidity in the periphery,[16,17] and relearning at the cerebral cortex and spinal cord level in the center.[18] In addition, it has been reported that since exercises combined with FES stimulate proprioceptive sensa–tion, thereby facilitating the improvement of trunk stability,[19,20] such exercises are effective for the relearning of the peripheral and central nervous sys–tems.[17]

Although there are many studies on the effects of trunk stabilization exercise on stroke subjects, func–tional problems remain even after interventions are performed due to the neurological and mechanical damage of stroke subjects. However, previous studies conducted only one intervention method for stroke patients, so it is difficult to bring about a more effec–tive treatment effect. Therefore, to compensate for the problems, it is necessary to combine existing exercise methods with other intervention methods. Accordingly, in this study, based on the re–learning effect of the central nervous system in stroke patients, the physiological effects of functional elec–trical stimulation that can increase muscle strength and muscular endurance and reduce muscle stiffness, as well as the stability of the trunk muscles through strengthening. The purpose of this study is to provide clinical basic data for the approach to trunk move–ment in stroke patients in the future by examining the effect on trunk muscle activity and balance in stroke patients by combining bridge movement.

SUBJECTS AND METHODS

Subjects

In this study, after receiving approval from the institutional review board (SH–IRB 2020–59), twenty stroke patients who understood the purpose of this study and agreed to participate in the study were randomly selected through draw lots from among those who were hospitalized and treated at J Hospital located in Jeollanam–do from July to August 2020. The criteria for selection of the subjects of this study were hemiplegia subjects diagnosed with stroke at least six months but not more than two years earlier, who were rated to be G2 or lower with the modified ashworth scale (MAS), had no orthopedic diseases in the lower extremities, had no hearing problem or visual defects, scored at least 24 points in the korean simple mental state test (MMSE–K), and were smooth in communication. Subjects excluded from this study were those with contraindications to func–tional electrical stimulation, elderly patients over 85 years of age, and those unable to communicate due to cognitive decline (Table 1).

Outcome Measures

Measurement of muscle activity

Three channels of the sEMG MP 100 system (Biopac, USA) were used; the sampling rate for signal collection was set to 1,000 ㎐; and the frequency band filter was set to 30-450 ㎐. The subject took a posi–tion of sitting on the bed with their arms laid down comfortably on the side of their body. The recording electrodes were attached 2 cm below the inside of the anterior superior iliac spine (ASIS), where the trans–verse abdominis and the internal oblique overlap on the paretic side, the rectus abdominis 5 cm below and 3 cm outside the xiphoid process, and the erector spinae 3 cm outside the lumbar vertebrae. The ground electrode was attached to a nearby area where

Table 1. General characteristic

Items	Experimental Ⅰ (n=10) M±SD	Experimental Ⅱ (n=10) M±SD	*P*
Age (years)	59.40 ± 6.72	60.70 ± 6.29	.660
Height (cm)	167.90 ± 8.28	166.50 ± 8.63	.716
Weight (kg)	65.70 ± 8.86	66.30 ± 8.81	.881
BMI (kg/m^2)	23.28 ± 2.28	23.86 ± 1.61	.527
Onset (months)	14.74 ± 3.24	13.46 ± 2.53	.402
Infarction/Hemorrhage	5 / 5	6 / 4	
Paralyzed side (Rt./Lt.)	3 / 7	4 / 6	
MAS (Grade 0/1/1$^+$/2)	4 / 3 / 3 / 0	3 / 5 / 1 / 1	
MMSE–K (score)	25.31 ± 1.25	26.28 ± 1.34	.635

BMI: Body mass index, MAS: Modified ashworth scale
MMES–K: Mini mental state examination–korea version

it would not interfere with movements.[21] In order to normalize the EMG signals of the subjects, the %RVC method that standardizes EMG signals using a certain movement as the reference contraction was used. When the reference movement was measured, the activity of the trunk muscles on the paretic side was obtained for 5 sec using a metronome while the subject was in a upright standing position,[22] and when a certain movement was measured, the activity of the trunk muscles on the paretic side was measured using a metronome while the subject was maintaining the posture in which the angle of the hip joint became 0° for 5 sec when the subject was performing bridge exercise.[23] Using the measured values, the %RVC value was calculated as the average value of the RMS amplitude value during the movement or as the average value of the RMS amplitude value during the reference movement x 100. The subjects took rest for 2 minutes between measurements to prevent muscle fatigue.

Balance measurement

The trunk impairment scale (TIS) was used to measure the subjects' balance. The TIS is scored in the range of 0 to 23 points and is composed of three items: static balance ability (7 points) intended to evaluate whether it is possible to maintain balance in a large sitting position with the non-paralyzed leg crossing over the paralyzed leg, dynamic balance ability (10 points) intended to evaluate the separate movements above and below the trunk in a sitting position through the lateral flexion of the trunk, and coordination ability (6 points) intended to measure the horizontal rotational movements of the shoulder girdle and pelvic girdle in a sitting position. Higher scores mean better trunk control ability. The intertester reliability of this scale for stroke subjects is (r=.96), indicating that it is a highly reliable test tool.[24]

Interventions

Bridge exercise combined with FES

As a starting position before applying the intervention of experimental group Ⅰ, the subject took a supine position on a mat, laid down the arms comfortably, kept their back on a neutral stable supporting plane, took a posture with 60° flexion of both knee joints, and raised the pelvis. Then, the subject raised the hip joint until it achieved 0° flexion, maintained the posture for 7 seconds using a metronome, and took rest for 3 seconds.[25] FES was applied while the subject performed the bridge exercise. Electrodes were attached to the rectus abdominis and the erector spinae of the subject; single-phase waveforms were used; the intensity was around 25-40 mA so that it would not cause discomfort to the subject;[26] and a total of three sets consisting of 10 times were carried out. A rest time of 2 minutes was applied per set (Figure 1).

Figure 1. Bridge exercise combined with FES

General bridge exercise

As a starting position before applying the intervention of experimental group Ⅱ, the subject took a supine position on a mat, laid down the arms comfortably, kept their back on a neutral stable supporting plane, took a posture with 60° flexion of both knee joints, and raised the pelvis. Then, the subject raised the hip joint until it achieved 0° flexion, maintained the posture for 7 seconds using a metronome, and took rest for 3 seconds. A total of three sets consisting of 10 times of the foregoing were carried out. A rest time of 2 minutes was applied per set.[25]

Data and Statistical Analysis

For the data processing of this study, Window's SPSS (20.0 version) was used to calculate the average value and standard deviation on the list of measurement and normality test was done through Shapiro–Wilk algorithm. Furthermore, Levene's test was used to assess the homogeneity of general characteristics of the subject. The Paired t–test was used to compare the changes within the group while the ANCOVA was performed to compare the changes between the groups. The level of significance was set as α=.05.

RESULTS

Comparison of intra–group changes in trunk muscle activity and balance in experimental group I

There were significant differences only in the rectus abdominis and the erector spinae with regard to changes in trunk muscle activity (P<.01), and there was no statistically significant difference in the balance evaluation (TIS) (Table 2).

Comparison of intra–group changes in trunk muscle activity and balance in experimental group II

There was no significant difference in any of the muscles with regard to changes in trunk muscle activity, and there was no statistically significant difference in the balance evaluation (TIS) either (Table 3).

Comparison of inter–group changes in trunk muscle activity and balance

There were significant differences in the rectus abdominis and the erector spinae with regard to changes in trunk muscle activity (P<.05), and there was no statistically significant difference in the balance evaluation (TIS) (Table 4).

Table 2. Comparison of intra–group changes in trunk muscle activity and balance in experimental group I

Items		Experimental group I (n=10)		t	P
		Pre–test (M±SD)	Post–test (M±SD)		
%RVC	RA	158.85 ± 32.92	176.86 ± 28.94	–4.720	.001*
	TRA/IO	29.68 ± 7.51	37.57 ± 9.64	–1.937	.085
	ES	163.78 ± 15.56	179.76 ± 18.19	–3.761	.004*
TIS (score)		7.80 ± .92	8.20 ± 1.23	–1.500	.168

*P<.01, Paired t–test

RVC: Reference voluntary contraction, RA: Rectus abdominis, TRA/IO: Transverse abdominis/Internal oblique

ES: Elector spinae, TIS: Trunk impairment scale

Table 3. Comparison of intra-group changes in trunk muscle activity and balance in experimental group II

Items		Experimental group II (n=10)		t	*P*
		Pre-test (M±SD)	Post-test (M±SD)		
%RVC	RA	154.58 ± 27.61	156.05 ± 20.81	-.212	.837
	TRA/IO	26.78 ± 6.35	31.16 ± 6.67	-1.688	.126
	ES	171.43 ± 20.87	174.24 ± 29.21	-.700	.502
TIS (score)		7.90 ± 1.00	8.00 ± .82	-.246	.811

Paired t-test, RVC: Reference voluntary contraction, RA: Rectus abdominis, TRA/IO: Transverse abdominis/Internal oblique
ES: Elector spinae, TIS: Trunk impairment scale

Table 4. Comparison of inter-group changes in trunk muscle activity and balance

Items			Pre-test (M±SD)	Post-test (M±SD)	F	*P*
%RVC	RA	E-group I	158.85 ± 32.92	176.86 ± 28.94	-.212	.837
		E-group II	154.58 ± 27.61	156.05 ± 20.81		
	TRA/IO	E-group I	158.85 ± 32.92	176.86 ± 28.94	-1.688	.126
		E-group II	26.78 ± 6.35	31.16 ± 6.67		
	ES	E-group I	163.78 ± 15.56	179.76 ± 18.19	-.700	.502
		E-group II	171.43 ± 20.87	174.24 ± 29.21		
TIS (score)		E-group I	7.80 ± .92	8.20 ± 1.23	-.246	.811
		E-group II	7.90 ± 1.00	8.00 ± .82		

$^{*}P<.05$, ANCOVA
RVC: Reference voluntary contraction, RA: Rectus abdominis, TRA/IO: Transverse abdominis/Internal oblique
ES: Elector spinae, TIS: Trunk impairment scale

DISCUSSION

In stroke subjects, the trunk muscles are weakened leading to not only decrease in the motor ability of the arms and legs but also adverse effects on balance ability, thereby bringing about discomfort in daily life.[27] To relieve such symptoms, FES that induces repetitive muscle contraction by promoting plastic changes in the central nervous system with increases in the excitability of the corticospinal tract and bridge exercise that can increase the coordination ability of the trunk were applied as interventions,[28] and the effects of such interventions on the muscle activity and balance ability of the trunk are discussed in the following.

Among previous studies on trunk muscle activity, Stevens et al.[25] reported that bridge exercise leads to stability of the trunk because it is easy and simple and does not require a separate tool. Therefore, it is widely used as an intervention program for improving trunk muscle strength and harmonizing trunk muscles. A study conducted by Moon et al.[29] reported that when a bridge exercise was applied to healthy adults for four weeks as an intervention and trunk muscle activity was examined, statistically significant increases in trunk muscle activity were observed, indicating that bridge exercise was effective for achieving increases in trunk muscle activity. Based on such previous studies, Park[30] applied an asymmetric bridge exercise in which the angles of the knee joint on the paretic side and that of the knee joint on the non-paretic side were different from each other and to hemiplegic subjects as an intervention. The researcher examined the effects of the intervention on trunk muscle activity and found increases in the muscle activity of the rectus abdominis, erector spinae, and oblique abdominis. Kahanovits et al.[31] reported that when adult females were selected as subjects and FES was applied to the trunk muscle, the application led to improvements in muscle strength and muscular endurance. In this study, when intra-group changes in muscle activity in experimental group Ⅰ following the application of bridge exercise combined with FES as an intervention and in experimental group Ⅱ with a general bridge exercise were compared, the muscle activity statistically significantly increased only in the rectus abdominis and the erector spinae only in experimental group Ⅰ. The reason is judged to be the fact that FES is effective for increases in the maximum voluntary isometric contraction and mobilization of motor units.[32] However, there was no significant difference in trunk muscle activity in experimental group Ⅱ, which seems to have been derived because the muscle activity that appears immediately after mediating only a single bridge movement was measured. Jung[33] applied FES to the trunk muscles of children with cerebral palsy to study the effect of FES on trunk muscle activity and reported larger changes in trunk muscle activity in the experimental group with FES applied. Newsam & Baker[32] reported that treatment combined with FES was more effective for recovery from functional impairment compared to general treatment because FES stimulates muscles. When muscle activity was compared between groups in this study, significant differences appeared only in the rectus abdominis and erector spinae, the reason is thought to be due to the physiological effects of FES, such as igniting sensory and motor neurons, increasing muscle strength and endurance through re-learning of the cerebral cortex, and decreasing muscle length and connective tissue elongation and muscle stiffness.[18] Trunk stabilization training is closely related with balance. Among related studies, Song et al.[34] compared a group of stroke subjects with bridge exercise for four weeks and a group with bridge exercise combined with the abdominal drawing technique and reported that static balance and dynamic balance significantly increased in both groups. Shim[35] reported that when stroke subjects were given PNF trunk pattern combined with EMG-induced FES as an intervention for four weeks and TIS scores before and after the intervention were compared, significant differences were observed in TIS scores. In this study, there was no statistically significant difference in TIS scores in experimental group Ⅰ or experimental group Ⅱ or between the groups. The reason is thought to be the fact that whereas previous studies determined the duration of intervention and measured pre- and post-tests so that significant differences could be shown, this study did not determine the duration of the intervention for experimental group Ⅰ and experimental group Ⅱ but conducted post-test immediately after applying the intervention following the pre-test.

As for limitations of this study, although stroke subjects were targeted, the subjects were limited to stroke subjects who were being treated at one medical institution, and the medications and daily lives of the subjects were not completely controlled. Therefore, the findings of this study cannot be generalized. Studies hereafter should be conducted to address such limitations.

CONCLUSION

The result of this study showed that both the muscle activities of erector spinae and rectus abdominis increased significantly in experimental group I and no statistically significant differences were found for balance measured on the trunk impairment scale (TIS). However, results of experimental group II suggested that no significant differences were found on both trunk muscle activities and balance. Therefore, it was significant that the bridge exercise combined with functional electrical stimulation used in experimental group I was effective to improve trunk muscle strength due to physiological effects induced by functional electrical stimulation to cause muscle contraction. Thus, it can be suggested that such exercise is considered effective for trunk muscle training for stroke patients.

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