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Original Article

Effects of Sling Exercise Therapy on Trunk Muscle Activation and Balance in Chronic Hemiplegic Patients

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Abstract. [Purpose] Weakening of trunk muscles in stroke patients hinders functional ability, safety and balance. To confirm whether strengthening trunk muscles could facilitate rehabilitation of stroke patients, we investigated the effectiveness of sling exercise therapy (SET) using closed kinetic chain exercises to activate trunk muscles and improve balance in stroke patients. [Subjects and Methods] Twenty stroke patients with chronic hemiplegia were equally divided into 2 groups, a SET group and a control group that performed regular exercises on a mat with the assistance of a table. Patients in both groups exercised for 30 min, three times per week for 4 weeks. Trunk muscle activity was measured using surface electromyography, whereas balance was measured using the Berg Balance Scale, Frailty and Injuries Cooperative Studies of Intervention Technique, Timed Up & Go test, and BioRescue before and after the 4-week experimental period. [Results] Trunk muscle activity and balance before and after intervention in both groups were significantly different. However, no significant differences were observed between the 2 groups. [Conclusion] Although SET was not more effective than regular exercise, significant improvement was observed before and after SET. Therefore, SET can be considered effective in strengthening trunk muscles in stroke patients with chronic hemiplegia.
Key words: Chronic stroke patients, Sling exercise therapy, Trunk muscles

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INTRODUCTION

Stroke is caused by apoptosis of brain cells due to cerebral infarction or hemorrhage[1)]. Primary risk factors for stroke include high blood pressure, diabetes, lack of physical activity, and alcohol consumption[2)], and the main symptoms of stroke are headache, difficulty in walking, seizures, impaired vision, and dysesthesia[3)]. The prevalence of stroke is increasing with the increase in the aged population, especially with the increase in the number of survivors of cardiovascular disease[4, 5)]. In some European countries, this incidence is predicted to increase until 2020[6)]. Better management of the disease has enabled long-term survival of stroke patients; however, the associated increase in the number of patients, along with their families has resulted in an increase in social and economic burdens[7–9)].

The outcome of stroke patients with an asymmetric trunk posture is unsatisfactory[10)]. Weakening of trunk flexor and extensor muscles after stroke obstructs functional ability, safety, and balance[11)]. Decreased exterior trunk muscle activity causes even more left–right asymmetry, leading to decreased quality of balance and walking[12, 13)]. Recent studies on hemiplegic patients have focused on the problems of walking and balance as well as related factors, particularly muscle strength, including myologic parameters[14, 15)]. Problems related to balance in stroke patients are due to a loss of muscle activation; thus, balance can be improved via improvement of muscle activation[16)]. Accordingly, trunk muscle activation is essential for restoring functional ability, safety, and balance in stroke patients.

Several exercise methods have been proposed for trunk muscle activation, including sling exercise therapy (SET). SET is expected to improve trunk muscle activation based on performance of active exercises with the aid of sling exercise equipment. This exercise method involves the use of a dangling rope and auxiliary equipment to improve physical disabilities. It can be used in open and closed kinetic chain exercises including those for diagnosis of muscle limitations through gradual weight bearing. SET aims at muscle relaxation, increasing range of motion and traction, and stabilizing musculature as well as sensorimotor exercises[17)]. In addition, this therapy is based on the neuromuscular activation (Neurac) principle via high-strength static and dynamic contraction exercises[18)].

Because of the loss of trunk flexibility and various related problems, retraining muscles is particularly important in stroke patients. Despite this fact, there is a lack of re-

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search on the usefulness of SET in such patients. Accordingly, this study investigated the effectiveness of SET on activating trunk muscles and improving balance ability in stroke patients based on the concept of closed kinetic chain exercises.

SUBJECTS AND METHODS

Subjects

This study involved 20 stroke inpatients at the M Convalescent Hospital in Suncheon, Jeollanam-do, South Korea. Study participants were selected if they met the following criteria: more than 24 months since diagnosis of stroke with chronic hemiplegia, Korean mini-mental state examination score higher than 21, independent walking, ability to communicate, and no neurologic disease besides stroke. All subjects voluntarily consented to participate in this study prior to its initiation. Data were collected after obtaining approval from the Institutional Review Board of Dongshin University.

Methods

After the 20 participants passed the pretest, they were randomly allocated to either the SET group or the regular exercise (i.e., control) group (Table 1). Exercise therapy in both groups was performed for 30 min, 3 times per week for 4 weeks. Interventions were discontinued if participants experienced any pain, and all the exercise commands were given orally.

SET for strengthening trunk muscles comprised 3 types of exercises: bridge exercises in the supine, prone, and lateral decubitus positions. In each exercise, the position was maintained for 7 s followed by 10 s of relaxation; each set was repeated 10 times, and a total of 3 sets were performed. The rest interval between sets was 60 s. At the beginning of the intervention, an auxiliary elastic rope was used. However, after half the time had elapsed, it was removed, and the weight load was increased.

Similar to the SET regimen, the regular exercise included 3 types of exercises—bridge exercises in the supine, prone, and lateral decubitus positions—performed with the help of an auxiliary table. The durations of maintaining the position and breaks were also the same as those in for the SET group. Regular exercise was performed with the pelvis elevated with the help of a wedge and roll.

Surface electromyography (EMG; Bagnoli EMG system; Delsys Inc., Boston, MA, USA) was used to measure trunk muscle activity during the interventions. To minimize skin resistance, impurities were eliminated from the areas where electrodes were placed. The recording electrode for the straight abdominal muscles was placed 3 cm from the outside of the navel, that for the external oblique abdominal muscle was placed 15 cm from the outside of the navel, and that for the backbone erector was placed 2 cm from the spinous process of the first lumbar vertebra. To ensure precise placement of the electrodes during repeated measurements, the areas of placement were marked. EMG signals were saved and analyzed by calculating the root mean square (RMS) with the help of acquisition and analysis software (Delsys Inc.).

Table 1. General characteristics of subjects

	Sling exercise therapy (n = 10)	Control (n = 10)
Age, y	63.40 ± 4.94	62.50 ± 8.48
K-MMSE score	25.7 ± 4.24	26.1 ± 1.41
Height, cm	167.3 ± 4.94	163.7 ± 4.24
Weight, kg	63.7 ± 5.65	66.2 ± 1.41

Values are shown as means ± SD. K-MMSE, Korean mini-mental state examination

To evaluate balance function, the Berg Balance Scale (BBS), Frailty and Injuries Cooperative Studies of Intervention Technique (FICSIT-4), Timed Up & Go (TUG) test, and BioRescue were used. The BBS is used to evaluate balance function in elderly persons and adults with disabilities. This measurement instrument is strongly correlated with walking speed. It has a maximum score of 56 points; scores less than 44 points indicate a high risk of falling. The BBS comprises 14 tasks, including changing position from sitting to standing, standing unsupported, sitting unsupported, transfers, standing with the eyes closed, standing with the feet together, reaching forward while standing, retrieving objects from the floor while standing, turning the trunk while standing (feet fixed), turning 360°, stool stepping, tandem standing, and standing on one leg. To prevent falling during measurement and to decrease mistakes, patients received information about the postures prior to the test.

The FICSIT-4 is an instrument for assessing static balance ability. It has a maximum score of 28 points and comprises the following 7 tasks: feet close together (eyes open/closed), semi-tandem (eyes open/closed), full-tandem (eyes open/closed), and one-leg standing. To prevent falls during measurement and to decrease mistakes, patients received information about the postures prior to the test.

The TUG test is a dynamic balance test for quickly assessing balance problems in stroke and elderly patients. On the command "go," the participant is instructed to stand up from a chair and walk 3 m at the safest and most convenient speed. When the participant reaches the 3-m point, he/she turns, walks back to the original location, and sits on the chair. The total time is recorded with a stopwatch.

BioRescue (RM Ingenierie, France) measures the moving distance and speed of the participant's center of gravity with weights placed on both legs. Screens are placed such that the participant cannot see the instructor to prevent visual feedback. To decrease errors related to changes in foot placement during repeated measurements, the feet are placed consistently.

All values were calculated as mean ± SD values. All statistical analyses were carried out using SPSS version 18.0 for Windows. A test of normality was applied to the general characteristics of the participants. To compare the results before and after therapy, matched paired t-tests were used. To investigate differences between the 2 groups, independent sample t-tests were used. The level of statistical significance for all data was set at $p < 0.05$.

Table 2. Changes in root mean square after neuromuscular activation using a sling (μV)

	Group	Pre	Post
Rectus	SET	25.98 ± 2.41	27.21 ± 3.02*
abdominis	Control	24.94 ± 3.40	26.80 ± 4.39*
External	SET	16.66 ± 2.42	17.89 ± 2.65*
oblique abdominis	Control	17.22 ± 2.21	18.75 ± 2.31*
Erector	SET	11.71 ± 1.56	12.95 ± 2.18*
spine	Control	11.03 ± 1.64	12.92 ± 2.14*

SET: sling exercise therapy. Values are shown as means ± SD. * p <0.005

Table 3. Changes in Berg Balance Scale score after neuromuscular activation using a sling

Groups	Before intervention	After intervention
SET	39.00 ± 5.41	40.00 ± 5.84***
Control	41.20 ± 9.47	43.80 ± 8.89***

***p < 0.001. SET: sling exercise therapy. Values are shown as means ± SD.

Table 4. Changes in Frailty and Injuries Cooperative Studies of Intervention Technique score after neuromuscular activation using a sling

Group	Before intervention	After intervention
SET	15.70 ± 3.80	16.70 ± 3.71***
Control	16.30 ± 6.16	18.30 ± 6.68***

***p < 0.001. SET: sling exercise therapy. Values are shown as means ± SD.

Table 5. Changes in Timed Up & Go test score after neuromuscular activation using a sling

Groups	Before intervention	After intervention
SET	23.06 ± 14.98	21.88 ± 14.34***
Group	24.20 ± 16.65	22.05 ± 15.96***

***p < 0.001. SET: sling exercise therapy. Values are shown as means ± SD. unit: (sec)

Table 6. Changes in BioRescue score after neuromuscular activation using a sling

	Groups	Before intervention	After intervention
Length, cm	SET	15.92 ± 7.19	14.30 ± 7.14**
	Control	22.12 ± 6.44	18.26 ± 6.94**
Speed, cm/s	SET	0.67 ± 0.43	0.58 ± 0.40**
	Control	0.79 ± 0.25	0.59 ± 0.27**

**p < 0.01. SET: sling exercise therapy. Values are shown as means ± SD.

RESULTS

No significant difference was observed in trunk muscle (i.e., rectus abdominis, external oblique, or erector spinae) activity before intervention between the 2 groups. Both groups exhibited a significant difference in trunk muscle activity after the intervention compared with that before the intervention ($p < 0.05$). However, no significant differences were observed between the 2 groups for any of the parameters ($p > 0.05$) (Table 2). In addition, there was no significant difference in balance function, according to the BBS, FICSIT-4, TUG test, or BioRescue, before intervention between the 2 groups. Both groups exhibited a significant difference in balance function after the intervention compared with that before the intervention ($p < 0.05$). However, there was no significant difference between the 2 groups ($p > 0.05$) (Tables 3–6).

DISCUSSION

The present study measured trunk muscle activity by using surface EMG and balance function by using the BBS, FICSIT-4, TUG test, and BioRescue in order to investigate the effectiveness of SET on trunk muscle activation and balance in chronic hemiplegic patients. After 4 weeks of intervention, both groups exhibited a significant difference in trunk muscle activation compared with that before the intervention. However, there was no significant difference in trunk muscle activation between the groups.

Vasseljen[19], who studied the effects of 8 weeks of sling exercise in patients with lumbar pain, found no significant differences in the thicknesses of the transverse abdominis, internal or external oblique, or lateral transverse abdominis muscles of patients who underwent the intervention compared with the muscles of those who performed regular exercises. Thus, the results of the present study are comparable to those of previous studies, although structural changes in the muscle are not always necessary for enhanced muscle strength, but rather reflect changes in a muscle's electrical activity[20, 21].

Some studies have demonstrated significant differences in improvement between sling and regular exercise therapies. A study of patients with lumbar pain who used a sling for 4 weeks revealed a significant improvement in contraction power of the trunk extensor muscles after sling therapy compared with that of patients who performed mat exercises[22]. In addition, a cross-over study of trunk stabilization training that used a sling showed significant differences in improvement between groups with respect to contraction power of the rectus abdominis, external oblique, and erector spinae[23] muscles.

The discrepancy between these studies may stem from differences in intervention time, measurement tools, and/or measured items. First, studies in the literature confirm that muscle activity measured using EMG, namely muscle contraction power, exhibits early changes within several days after intervention due to neural adaptation[19]. Accordingly, studies measuring maximum muscle contraction power using EMG show significant differences in improvement between groups, even with a shorter intervention time. On the other hand, previous studies also confirm that when ultrasound, computed tomography, or magnetic resonance imaging is used, muscle hypertrophy can be measured for in more than 10 weeks after intense strengthening exercises[24]. This may explain why no significant difference in trunk muscle thickness was observed between our groups after the intervention. Because the outcomes of measurement differ depending on the intervention period when muscle activity is measured, different measurement tools must be used for different intervention periods. It is also advisable to simultaneously use tools that measure muscle thickness and muscle activity.

This study also investigated the influence of SET on balance function. The results of the BBS, FICSIT-4, TUG test, and BioRescue showed that both the SET and control groups exhibited significant differences before and after intervention, though there was no significant difference in improvement between the groups after intervention. In another study of hemiplegic patients, the experimental group, which performed both regular exercises and strengthening and trunk stabilization exercises with the use of a sling board, exhibited a significant improvement in Mettler-Toledo International balance ability (MTD-balance) compared with the control group, which performed only regular exercises[25]. On the other hand, in a study of hemiplegic patients who used SET, there was no significant difference in improvement between the experimental and control (i.e., rehabilitation) groups with respect to balance ability (BBS, PASS)[26]. Thus, it appears that differences in results may stem from differences in intervention methods involving the use of sling equipment. The balance ability of stroke patients is related to trunk intersegmental movement[27]; therefore, significant differences in improvement between groups after intervention must be due to the use of intersegmental exercise. Correspondingly, when no intersegmental exercise is used, no significant difference in improvement is observed between groups.

In this study, patients performed sling exercise therapy. The results indicate that intervention methods should be changed based on the expected results. Furthermore, different measurement tools are required depending on the intervention period. This study is limited by the short intervention period and the small number of participants. Therefore, further studies on the effects of SET using various measurement tools and sufficiently long interventions are required.

Four weeks of sling exercise therapy in stroke patients provides no significant benefit in muscle activation or balance ability compared with regular exercise. Although no difference in improvement in trunk stability and balance was noted between patients belonging to the control and sling exercise therapy group, significant differences in these parameters were noted before and after sling exercise therapy. Therefore, sling exercise therapy can strengthen trunk muscles in stroke patients.

REFERENCES

1) Sturm JW, Dewey HM, Donnan GA, et al.: Handicap after stroke: how does it relate to disability, perception of recovery, and stroke subtype?: the north North East Melbourne Stroke Incidence Study (NEMESIS). Stroke, 2002, 33: 762–768. [Medline] [CrossRef]
2) Boysen G, Nyboe J, Appleyard M, et al.: Stroke incidence and risk factors for stroke in Copenhagen, Denmark. Stroke, 1988, 19: 1345–1353. [Medline] [CrossRef]
3) Rathore SS, Hinn AR, Cooper LS, et al.: Characterization of incident stroke signs and symptoms: findings from the atherosclerosis risk in communities study. Stroke, 2002, 33: 2718–2721. [Medline] [CrossRef]
4) Williams GR: Incidence and characteristics of total stroke in the United States. BMC Neurol, 2001, 1: 2. [Medline] [CrossRef]
5) Niessen LW, Barendregt JJ, Bonneux L, et al. The Technology Assessment Methods Project Team: Stroke trends in an aging population. Stroke, 1993, 24: 931–939. [Medline] [CrossRef]
6) Struijs JN, van Genugten ML, Evers SM, et al.: Modeling the future burden of stroke in The Netherlands: impact of aging, smoking, and hypertension. Stroke, 2005, 36: 1648–1655. [Medline] [CrossRef]
7) Brønnum-Hansen H, Davidsen M, Thorvaldsen P, Danish MONICA Study Group: Long-term survival and causes of death after stroke. Stroke, 2001, 32: 2131–2136. [Medline] [CrossRef]
8) Thommessen B, Aarsland D, Braekhus A, et al.: The psychosocial burden on spouses of the elderly with stroke, dementia and Parkinson's disease. Int J Geriatr Psychiatry, 2002, 17: 78–84. [Medline] [CrossRef]
9) Miller CE, Quayyum Z, McNamee P, et al. SIVMS Steering Committee: Economic burden of intracranial vascular malformations in adults: prospective population-based study. Stroke, 2009, 40: 1973–1979. [Medline] [CrossRef]
10) Taylor D, Ashburn A, Ward CD, et al.: Asymmetrical trunk posture, unilateral neglect and motor performance following stroke. Clin Rehabil, 1994, 8: 48–52. [CrossRef]
11) Karatas M, Cetin N, Bayramoglu M, et al.: Trunk muscle strength in relation to balance and functional disability in unihemispheric stroke patients. Am J Phys Med Rehabil, 2004, 83: 81–87. [Medline] [CrossRef]
12) Nichols DS, Miller L, Colby LA, et al.: Sitting balance: its relation to function in individuals with hemiparesis. Arch Phys Med Rehabil, 1996, 77: 865–869. [Medline] [CrossRef]
13) Loewen SC, Anderson BA: Predictors of stroke outcome using objective measurement scales. Stroke, 1990, 21: 78–81. [Medline] [CrossRef]
14) MacIntyre NJ, Rombough R, Brouwer B: Relationships between calf muscle density and muscle strength, mobility and bone status in the stroke survivors with subacute and chronic lower limb hemiparesis. J Musculoskelet Neuronal Interact, 2010, 10: 249–255. [Medline]
15) Kluding P, Gajewski B: Lower-extremity strength differences predict activity limitations in people with chronic stroke. Phys Ther, 2009, 89: 73–81. [Medline] [CrossRef]
16) Kirker SG, Simpson DS, Jenner JR, et al.: Stepping before standing: hip muscle function in stepping and standing balance after stroke. J Neurol Neurosurg Psychiatry, 2000, 68: 458–464. [Medline] [CrossRef]
17) Kirkesola G: Sling exercise therapy (S-E-T): a total concept for exercise and active treatment of musculoskeletal disorders. J Korean Acad Orthop Man Ther, 2001, 7: 87–106.
18) Kirkesola G: Neurac—a new treatment method for long-term musculoskeletal pain. Fysioterapeuten, 2009, 76: 16–25.
19) Vasseljen O, Fladmark AM: Abdominal muscle contraction thickness and function after specific and general exercises: a randomized controlled trial in chronic low back pain patients. Man Ther, 2010, 15: 482–489. [Medline] [CrossRef]
20) Mooney V, Gulick J, Perlman M, et al.: Relationships between myoelectric activity, strength, and MRI of lumbar extensor muscles in back pain patients and normal subjects. J Spinal Disord, 1997, 10: 348–356. [Medline] [CrossRef]
21) McMeeken JM, Beith ID, Newham DJ, et al.: The relationship between EMG and change in thickness of transversus abdominis. Clin Biomech (Bristol, Avon), 2004, 19: 337–342. [Medline] [CrossRef]
22) Yoo YD, Lee YS: The effect of core stabilization exercises using a sling on pain and muscle strength of patients with chronic low back pain. J Phys, 2012, 24: 671–674.
23) Kang H, Jung J, Yu J: Comparison of trunk muscle activity during bridging exercises using a sling in patients with low back pain. J Sports Sci Med,

2012, 11: 510–515. [Medline]
24) Danneels LA, Vanderstraeten GG, Cambier DC, et al.: Effects of three different training modalities on the cross sectional area of the lumbar multifidus muscle in patients with chronic low back pain. Br J Sports Med, 2001, 35: 186–191. [Medline] [CrossRef]
25) Jang KH, Kim KY: The effects of intensive trunk stabilizing training on balance and gait in patient with hemiplegia. J Korea Acad Industr Coop Soc, 2011, 12: 1244–1252. [CrossRef]
26) Park SJ, Shin YA, Hong SM: Effects of sling exercise on functional balance, walk power and independence in chronic stroke patients. J Sport Leis Stud, 2012, 49: 737–748.
27) Hacmon RR, Krasovsky T, Lamontagne A, et al.: Deficits in intersegmental trunk coordination during walking are related to clinical balance and gait function in chronic stroke. J Neurol Phys Ther, 2012, 36: 173–181. [Medline] [CrossRef]