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

INTRODUCTION

Stroke is caused by apoptosis of brain cells due to cerebral infarction or hemorrhage¹). Primary risk factors for stroke include high blood pressure, diabetes, lack of physical activity, and alcohol consumption²), and the main symptoms of stroke are headache, difficulty in walking, seizures, impaired vision, and dysesthesia³). The prevalence of stroke is increasing with the incidence of cardiovascular disease⁴, ⁵). In some European countries, this incidence is predicted to increase until 2020⁶). 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 burdens⁷–⁹).

The outcome of stroke patients with an asymmetric trunk posture is unsatisfactory¹⁰). Weakening of trunk flexor and extensor muscles after stroke obstructs functional ability, safety, and balance¹¹). Decreased exterior trunk muscle ac-

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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 Conventiional 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.

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 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 ± 4.14     |
| 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.
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, or 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

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*|
| Control   | 24.94 ± 3.40| 26.80 ± 4.39*|
| External SET| 16.66 ± 2.42| 17.89 ± 2.65*|
| oblique abdominis | 17.22 ± 2.21| 18.75 ± 2.31*|
| Erector spinae SET| 11.71 ± 1.56| 12.95 ± 2.18*|
| 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.
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\(^\text{19}\). 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\(^\text{24}\). 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\(^\text{23}\). 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)\(^\text{20}\). 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\(^\text{23}\); 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.

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