



Original Article

Effects of sling exercise on postural sway in post-stroke patients

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Abstract. [Purpose] To examine the effects of sling exercise on the balance of post-stroke patients. [Subjects and Methods] A total of 18 post-stroke patients (13 men; mean age, 55.3 years) were recruited, and randomly assigned them into sling exercise (n=10) and control exercise (n=8) groups. The Good Balance System was used for measurement of velocity (anteroposterior and mediolateral, mm/s), velocity moment (mm²/s) of the movement of the center of pressure, and distance (anteroposterior and mediolateral, mm) between the center of pressure and the center point. The changes in mediolateral velocity, anteroposterior velocity, and velocity moment were compared between two groups in addition to the comparison of distance between the center of pressure and the center point of postural sway. [Results] The sling exercise group showed more significant improvements in anteroposterior velocity, mediolateral velocity, velocity moment, anteroposterior distance, and mediolateral distance than the control exercise group. [Conclusion] Sling exercise improved post-stroke balance performance and could be used as a therapeutic strategy to improve post-stroke functional recovery.

Key words: Sling exercise, Stroke, Balance

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INTRODUCTION

Balance is an importance for daily activities and gait and influenced by factors such as abnormal proprioception and limb and trunk muscle paralysis^{1, 2)}. The balance function of post-stroke patients has been studied in terms of postural disorders, postural malalignment, and asymmetry of weight distribution, which play important roles in safe and independent performance in the ordinary life of movements and walking²⁾. Conventional neurodevelopmental therapy for post-stroke patients has been focused on stimulating and inhibiting exercises to normalize muscle tone based on goal-oriented performances³⁾. Given the importance of balance function in post-stroke patients, additive treatment strategy to improve balance performance should be considered, and to improve the balance of post-stroke hemiplegic patients, isokinetic strengthening and the training of trunk and limb muscles to prevent muscle atrophy have been applied⁴⁻⁶⁾.

Systems and factors associated with balance function are visual system, vestibular system, proprioceptive system, musculoskeletal system, and cognitive ability⁷⁾. In addition, trunk and limb muscle strengths may be related to balance and functional disabilities^{8, 9)}, which may be the target of sling exercise (SE). The mechanism of the SE in improving balance is the coordination and regulation of automatic postural responses in the muscle around the abdominal, lumbar, pelvic, and lower limb regions, which have important roles in maintaining balance^{10, 11)}.

SE has been known as an additional rehabilitation exercise protocol that can improve balance and gait¹²⁾. In terms of the

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influence of both trunk and limb strengths on balance, SE focused on both strengthening the trunk and limb muscles should be considered. Moreover, instead of the conventional balance test such as the Berg Balance Scale (BBS), quantitative balance measurement may scientifically show the effect of SE, outweighing the effects of accompanied conventional exercise.

The hypotheses of this study were that (1) the SE for trunk and limb stabilization may improve balance ability and gait, and that (2) quantitative balance measurement may successfully show these improvements in a randomized controlled study. The purpose of this study was to examine the effects of SE on the quantitative balance function of post-stroke hemiplegic patients. The standardized SE program for the trunk and limb for post-stroke patients in this study was constructed based on these concepts. Thus, this study aimed to prove the effects of SE and suggest the application of SE as an additive treatment strategy in post-stroke patients.

SUBJECTS AND METHODS

Post-stroke hemiplegic patients (post-onset duration between 6 months and 1 year) were recruited if they met the following criteria for functional level: patients who can maintain the standing posture; patients with muscle strength greater than grade 2 in the Medical Research Council scale; patients with spasticity of <1 in the Modified Ashworth scale; patients with a minimum score of 24 points in the Korean version of the Mini-Mental State Examination (MMSE-K). The exclusion criteria were (1) aphasia or cognitive impairment, (2) other neurological deficits besides stroke, (3) unilateral neglect or visual field defect, (4) severe medical or neurological disease, and (5) vestibular or orthopedic problems that affect balance ability. The study protocol was approved by the institutional review board of Seoul Medical Center (IRB No. 2013-030), and all the patients provided written informed consent.

The patients were assigned into SE and control exercise (CE) groups. The SE group performed 30 minutes of the standardized SE program (two graded exercise of back, back and adductor, back and hip extensor, back and hip extensor and abductor, and hamstring in supine position; hip adduction and abduction in side-lying position, and trunk in prone on elbow position) for the trunk and limb three times a week for 6 weeks, focusing on strengthening and neural control. All procedure of SE was performed with the sling equipment on the patient-tolerable intensity, and physical therapists, who shared the SE protocol before this study, instructed and guided the SE procedure. Meanwhile, the CE group performed conventional exercise program such as cycling or gait training by themselves in addition to the daily multidisciplinary rehabilitation programs.

Postural sway was measured in standing posture before and after training by using the Good Balance System (Metitur Ltd., Jyväskylä, Finland; www.Metitur.com), which consisted with 800 mm-equilateral triangle shaped force plate, sided hand-rail for the safety, and monitor system for the visual feedback. Patients instructed to stand in comfortable upright position on the force plate while looking the monitor ahead. The point where the total sum of a pressure field acts on a body was defined as center of pressure (COP), and it used in postural sway measurement. The postural sway parameters were mean velocity (mm/s) in anteroposterior (VAP) and mediolateral (VML) direction, mean velocity moment (VM, mm²/s) of the movement of COP, and mean distance (mm) in anteroposterior (DAP) and mediolateral (DML) direction between the COP and the center point of force plate of Good Balance System. In addition, the Korean version of the Modified Barthel Index (K-MBI), Korean version of the Berg balance scale (K-BBS), and 10-m gait speed test were administered.

The baseline characteristics of the categorical data were analyzed by using the χ^2 test, and the paired t-test was used in the analysis of intergroup differences in baseline continuous data and intragroup changes in pre- and post-measurements. A p-value<0.05 was considered significant.

RESULTS

For this study, 18 post-stroke patients (13 men; mean age, 55.3 years; post-onset duration, 273 days) were recruited. They were randomly assigned into SE (n=10) and CE (n=8) groups. Table 1 shows the baseline characteristics of the recruited post-stroke patients. The number of affected sides of paralysis were right (4 in SE and 6 in CE) and left (6 in SE and 2 in CE), and type of stroke were infarction (5 in SE and 3 in CE) and hemorrhage (5 in SE and 5 in CE) respectively. The baseline characteristics of the patients in both groups did not show significant differences in age, gender, affected side, and stroke type. Mean MMSE-K did not show significant differences between SE and CE (28.2 ± 1.6 vs. 26.8 ± 2.0 , $p=0.12$).

There was a significant improvement in both SE and CE groups from pre to post treatment in K-MBI, which was greater in the SE group. All postural sway measurements of the Good Balance System significantly improved in SE group from pre to post treatment while none of the postural measurements changed in CE group. Additionally, all parameters of postural sway in SE group except for DML showed more significant improvement than those in CE group (Table 2).

DISCUSSION

Stroke causes long-term disabilities, and previous studies have been conducted to improve the balance in post-stroke recovery using the several techniques such as motor imagery¹³⁾, functional electrical stimulation¹⁴⁾, whole body vibration,¹⁵⁾ and virtual reality¹⁶⁾. SE is also known as a treatment strategy to improve balance adjustment and functional outcome in various clinical quantities^{17, 18)}. This study was able to demonstrate the effects of SE on the balance of post-stroke patients

Table 1. Baseline characteristics of the recruited post-stroke patients

Variables	SE (n=10)	CE (n=8)
Age (years), mean \pm SD	56.4 \pm 9.6	53.9 \pm 12.7
Post-onset duration (days), mean \pm SD	296.9 \pm 144.6	227.1 \pm 88.5
Gender (male/female), n	9/1	4/4
Affected side (right/left), n	4/6	6/2
Type of stroke (infarction/hemorrhage), n	5/5	3/5
MMSE-K (0–30)	28.2 \pm 1.6	26.8 \pm 2.0

Values are expressed as mean \pm SD and analyzed by using the paired t-test, except gender, affected side, and type of stroke, which are expressed as number and analyzed by using the χ^2 test.

SE: sling exercise group; CE: control exercise group; MMSE-K: Korean version of Mini-Mental State Examination; K-MBI: Korean version of the Modified Barthel Index; K-BBS: Korean version of Berg Balance Scale; VAP: anteroposterior velocity; VML: mediolateral velocity; VM: velocity moment; DAP: anteroposterior distance; DML: mediolateral anteroposterior

Table 2. Comparison of performance measurements between the two groups of sling and control exercises

Variables	SE		CE		Δ	
	Pre	Post	Pre	Post	SE	CE
K-MBI (0–100)	75.5 \pm 15.0	79.0 \pm 15.5 *	62.6 \pm 20.4	70.6 \pm 22.5 *	3.5 \pm 4.1	8.0 \pm 7.9
K-BBS (0–56)	37.3 \pm 11.2	43.6 \pm 7.8 **	31.1 \pm 13.9	31.1 \pm 13.9	6.3 \pm 5.9	2.1 \pm 5.3
10m walking speed (m/s)	0.39 \pm 0.16	0.54 \pm 0.2 *	0.35 \pm 0.28	0.38 \pm 0.26	0.14 \pm 0.10	0.03 \pm 0.02 *
Analysis of Good Balance System measurements						
VAP (mm/s)	12.4 \pm 4.8	10.2 \pm 3.0 *	10.3 \pm 2.4	10.9 \pm 2.9	-2.3 \pm 2.6	0.6 \pm 1.0 *
VML (mm/s)	8.3 \pm 4.1	6.3 \pm 2.6 *	8.1 \pm 5.1	8.0 \pm 3.6	-2.0 \pm 2.3	-0.02 \pm 2.4
VM (mm ² /s)	45.3 \pm 33.4	27.1 \pm 20.2 *	37.2 \pm 45.7	37.7 \pm 42.0	-18.1 \pm 18.2	0.5 \pm 6.0 *
DAP (mm)	372.8 \pm 143.5	305.3 \pm 88.4 *	308.6 \pm 71.0	325.3 \pm 86.0	-67.5 \pm 79.2	16.7 \pm 28.7 *
DML (mm)	244.7 \pm 126.4	192.1 \pm 86.3 *	241.7 \pm 153.2	245.7 \pm 112.6	-52.5 \pm 70.0	4.0 \pm 65.3

Values are expressed as mean \pm SD and analyzed by using the paired t-test.

*p<0.05, **p<0.01

SE: sling exercise group; CE: control exercise group; Δ : the changes of each scales between pre- and post-evaluation; K-MBI: Korean version of the Modified Barthel Index; K-BBS: Korean version of Berg Balance Scale; VAP: anteroposterior velocity; VML: mediolateral velocity; VM: velocity moment; DAP: anteroposterior distance; DML: mediolateral distance

All baseline performance measurements did not show significant differences between SE and CE, which did not described in the Table 2.

and the effects of SE on various functional measurements, especially quantitative balance performance.

Because balance function is controlled by not only muscle components but also neural components, both muscle weakness and neural control impairment in post-stroke patients are the main target of SE¹³. SE can activate and strengthen the trunk and limb muscles with help of sling equipment¹⁹, and also can stimulate proprioceptors and nerve roots, and motor organs of the cerebrum¹². Therefore, SE may be the effective adjuvant treatment strategy in post-stroke patients with muscle weakness and neural impairment.

This study used a quantitative measurement for balance performance which provides more distinct data than qualitative measurements used in previous studies such as K-BBS^{20, 21}, which show the psychometric properties in measuring the balance²². Moreover, the Good balance system used in this study can show the precise scaling in measuring the balance function with reflecting the good sensitivity of balance functional recovery.

Both SE and CE showed improvements in K-MBI and did not show differences in changes of K-MBI, which is a common outcome measurement used in conventional rehabilitation²³. Regarding the baseline setting for daily multidisciplinary rehabilitation programs, both SE and CE could expect the natural recovery after stroke²⁴. Moreover, K-MBI is focused on functional recovery of activities of daily livings, the main effects of SE has been obscured by the comprehensive K-MBI.

There are some limitations in the current study. The total amount of exercise was not controlled thoroughly between SE and CE with possibility of additional exercise effects of SE. However, the improvements and no differences of K-MBI in both groups might reflect the additive effects of SE in post-stroke patients. Additionally, this study only focused on balance, suggesting the need for further studies for comprehensive assessments. Moreover, because this study recruited post-stroke patients with a relatively good performance, the results of this study cannot be regarded in general post-stroke patients. Thus, other feasible balance measurements may be considered for post-stroke patients with relatively poor performance. Moreover,

a long-term follow-up study should be considered to prove the long-term effects of SE.

The effects of SE on balance performance were identified in this study and suggest the need for an additive treatment strategy in post-stroke patients. Moreover, this study is meaningful in terms of providing a quantitative data for the effect of SE on balance in stroke patients, which may be applicable in rehabilitative therapeutic strategy in the future.

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