



Original Article

Trunk exercises performed on an unstable surface improve trunk muscle activation, postural control, and gait speed in patients with stroke

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Abstract. [Purpose] This study examined the effects of trunk exercises performed on an unstable surface on trunk muscle activation, postural control, and gait speed in stroke patients. [Subjects] Twenty-four participants with stroke were recruited in this study and randomly distributed into experimental (n = 12) and control groups (n = 12). [Methods] Subjects in the experimental group participated in trunk exercises on the balance pad for 30 min, five times a week for 4 weeks; those in the control group performed trunk exercises on a stable surface for 30 min, five times a week for 4 weeks. Trunk muscle activation was measured by using surface electromyography, and trunk control was evaluated with the Trunk Impairment Scale (TIS). Gait speed was measured with the 10-Meter Walk Test. [Results] Activity of the external and internal oblique muscles in the experimental group was significantly higher than that in the control group. The TIS score of the experimental group showed significantly greater improvement than did that of the control group. The 10-Meter Walk Test (10MWT) score also significantly improved in the experimental group. [Conclusion] Trunk exercises on an unstable surface improve trunk muscle activation, postural control, and gait speed in patients with hemiparetic stroke.

Key words: Stroke, Trunk exercise, Unstable surface

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INTRODUCTION

Trunk plays an important role in stabilizing the pelvis and spinal column^{1, 2}. However, stroke patients are less capable of balance³⁻⁶ and postural control⁷ due to trunk muscle weakness and damaged proprioception. In addition, postural sway increases in the sitting position⁸, whereas weight-shifting ability diminishes⁹.

Sitting balance is a predictor of functional recovery, and the role of the trunk muscles in maintaining balance is important because the center of mass becomes lower than that in the standing position¹⁰. Kim et al.¹¹ reported that trunk muscle activation during a reaching task in stroke patients is highly correlated not only with trunk control but also with balance.

To improve balance in the sitting position, pelvic tilt or bridging, weight-shifting, and trunk stabilization exercises using the arms and legs may be used as training methods¹². The trunk muscles contract to counteract postural sway during shoulder or hip flexion exercise in the sitting position¹³, and the ability to regulate the alignment of the trunk is required to counteract the center of mass change during weight-shifting exercises¹⁴.

In addition, exercising on an unstable surface increases postural sway, further promoting trunk muscle activation¹⁵. In studies that conducted trunk stabilization exercises on an unstable surface, with stroke patients as subjects, the thickness of

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the trunk muscle increased, and the balancing ability improved^{16, 17}); however, there was no significant difference in trunk muscle activation between groups in a study that conducted trunk stabilization exercises using a sling¹⁸).

Studies in stroke patients on the effects of trunk exercises on trunk muscle activation are lacking, and studies on how the support surface affects trunk muscle activation in stroke patients are also needed. Therefore, we investigated the effects of trunk exercise on an unstable surface on trunk muscle activation, postural control, and gait speed in stroke patients.

SUBJECTS AND METHODS

A total of 24 patients with hemiparetic stroke were recruited for this study from K Hospital. Subjects who were diagnosed with the first onset of unilateral hemispheric stroke, had no neglect of paretic limbs, could sit independently for 30 s on a stable surface, were medically stable, had no peripheral neuritis, had no musculoskeletal problems such as low back pain or arthritis affecting motor performance, and could understand and follow simple verbal instructions were included in the study¹⁵. Table 1 lists the general characteristics of the subjects. After the subjects were informed about the study, they agreed to participate and signed consent forms. The study was approved by the Institutional Review Board of Gachon University.

Trunk exercises included weight-shifting and arm flexion in the sitting position. During the weight shifting exercise, the subjects were instructed to sit with their arms folded and to shift their weights from midline to the right and left, as far as they could, and touch a bar placed on both sides. During the arm flexion exercise, the subjects were instructed to flex both their arms as high as they could. The experimental group performed the exercises on the balance pad, and the control group, on a stable surface, for 30 min, 5 times a week for 4 weeks.

A surface electromyogram (EMG) (Telemetry 2400 G2, Telemetry EMG System; Noraxon, Scottsdale, AZ, USA) was used for measuring the muscle activity. Before the electrodes were attached, the skin over three muscles was swabbed with alcohol to minimize skin resistance. Surface electrodes were placed over the three muscles of the affected side: on the erector spinae, 2 cm laterally from L3; on the external oblique, just above the anterior superior iliac spine (ASIS); and on the internal oblique, 2 cm inferior and medial to the ASIS¹⁹. The EMG recordings were taken while the subject performed maximum isometric contractions for 5 s. The sampling rate was set at 1,500 Hz, and the bandstop of the EMG recordings was set at 60 Hz. The EMG signals were full-wave rectified and integrated over 3 s of a 5-s maximum contraction period. All participants repeated the contraction three times with a 1-min rest between the trials for preventing muscle fatigue. The integrated EMG (I-EMG) before training was defined as 100%.

The Trunk Impairment Scale (TIS), which requires observing the quality of trunk movement, serves as a guide for trunk treatment in stroke patients. The test consists of three subscales: static sitting balance, dynamic sitting balance, and coordination. The TIS is an excellent and reliable tool for measurement, with intraclass correlation coefficients for test-retest reliability of $r = 0.96$ and inter-rater reliability of $r = 0.99$ ²⁰.

The 10MWT measured the time that each subject took for walking. The inter- and intra-rater reliability was high ($r = 0.89-1.00$)²¹.

The normality of variables was assessed by using the Shapiro-Wilk test. Independent t-test (for continuous variables) and χ^2 test (for categorical variables) were used for comparing the baseline characteristics of the subjects in the experimental and control groups. The paired t-test was used for within-group comparisons, and the independent t-test, for between-group comparisons. The level of statistical significance was set at 0.05. SPSS 12.0 (SPSS, Chicago, IL, USA) was used for the statistical analysis.

Table 1. Common and clinical characteristics of the subjects (N = 24)

Variable	Experimental group (n = 12)	Control group (n = 12)
Gender		
Male	8	6
Female	4	6
Age (yrs)	58.9 ± 11.0	60.7 ± 7.8
Weight (kg)	64.3 ± 10.0	63.6 ± 9.6
Height (cm)	166.1 ± 9.1	162.9 ± 7.8
Stroke type		
Ischemic	8	7
Hemorrhagic	4	5
Affected side		
Left	7	6
Right	5	6
Post-stroke duration (months)	8.0 ± 3.2	8.4 ± 2.4
MMSE	25.7 ± 1.9	25.5 ± 1.6

MMSE: Mini Mental State Examination

RESULTS

No significant difference was found in the general characteristics and pretest scores between the experimental and control groups at baseline (Table 1). After training, the activity of the external and internal oblique muscles in the experimental group (mean change, $84.54 \pm 74.34\%$ and $62.24 \pm 55.91\%$, respectively) was significantly higher than that in the control group (mean change, $26.80 \pm 59.46\%$ and $12.51 \pm 35.67\%$, respectively). However, the results showed that there were no significant differences in the activity of the erector spinae between the experimental and control groups. The change in the TIS score in the experimental group (mean score change, 4.83 ± 2.17) was significantly higher than that in the control group (mean score change, 2.42 ± 2.35). The change of in the 10MWT time in the experimental group (mean time change, 5.4 ± 3.5) showed a significant decrease compared to that in the control group (mean time change, 1.6 ± 2.6) (Table 2).

DISCUSSION

This investigation of the effects of trunk exercises performed on an unstable surface on trunk muscle activation in stroke patients showed that the activation of the external and internal oblique muscles, excluding the erector spinae, significantly increased, compared to that in the control group. When the arm is lifted in the sitting position, the moment of the trunk acts backward to maintain stability as the center of mass moves forward²², and postural sway occurs because of this shift in the center of mass and the reaction force²³. In addition, to maintain trunk stability during weight-shifting in order to counteract the change in the center of mass, a properly coordinated action of muscles regulated by the nervous system is needed¹⁴. When trunk exercise was performed on a balance ball in this study, trunk muscle activation might have been further promoted because of the reaction force acting against the shaking of the surface.

However, the reason why the activation of the erector spinae in the experimental group was not significantly different from that in the control group may be because the erector spinae, as the axial trunk muscle, was relatively less affected by the support surface during weight-shifting than was the lateral trunk muscles, such as the external oblique muscle, displaying the unilateral preponderance of the internal oblique muscle^{24, 25}. According to Marshall and Murphy²⁶, the activity of muscles related to postural sway and task execution increases as the center of mass moves away from the midline on an unstable surface. Therefore, in this study, the maximum weight-shifting distance and shoulder flexion angle, which can be measured in the sitting position, were measured to reach the target point.

In addition, we investigated the effects of the exercise on the postural control of the trunk. The results showed that dynamic postural control and coordination of the postural control of the trunk in the experimental group were significantly improved compared to those in the control group. Postural control refers to the ability of the trunk muscle to maintain the upright position during shifting of weight or the center of mass on the base of a support surface²⁷. In this study, trunk exercises on an unstable surface may have improved the control ability because activation of the trunk muscles was increased.

Trunk control ability is reportedly significantly correlated with balance, gait, and functional ability²⁸. In a study that analyzed trunk kinematics during walking in stroke patients, pelvic movement was reportedly unstable and asymmetrical²⁹. Karthikbabu et al.³⁰ reported that gait speed and symmetry were improved by trunk exercises, which can be attributed to the

Table 2. Comparison of the experimental and control groups (N = 24)

Scale	Experimental group (n = 12)			Control group (n = 12)		
	Pre-test	Post-test	Change	Pre-test	Post-test	Change
EMG (%)						
ES	100	127.9 ± 15.6	$27.9 \pm 15.6^*$	100	117.8 ± 26.9	$17.8 \pm 26.9^*$
EO	100	184.5 ± 74.3	$84.5 \pm 74.3^{*#}$	100	126.8 ± 59.5	26.8 ± 59.5
IO	100	162.2 ± 55.9	$62.2 \pm 55.9^{*#}$	100	112.5 ± 35.7	12.5 ± 35.7
TIS (score)						
Static	5.83 ± 0.72	6.42 ± 0.67	$0.58 \pm 0.79^*$	5.50 ± 1.09	6.17 ± 1.11	0.67 ± 1.07
Dynamic	5.33 ± 1.92	7.75 ± 1.54	$2.42 \pm 1.24^{*#}$	5.33 ± 2.15	6.25 ± 1.29	0.92 ± 1.56
Coordination	2.58 ± 1.24	4.42 ± 0.79	$1.83 \pm 1.03^{*#}$	2.67 ± 1.15	3.50 ± 1.38	0.83 ± 1.19
Total	13.75 ± 3.08	18.58 ± 1.98	$4.83 \pm 2.17^{*#}$	13.50 ± 3.32	15.92 ± 2.84	2.42 ± 2.35
10MWT (s)	24.5 ± 7.5	19.1 ± 7.7	$5.4 \pm 3.5^{*#}$	26.9 ± 5.3	25.2 ± 5.0	1.6 ± 2.6

Values are presented as mean \pm SD.

*Significant differences between pre- and post-tests ($p < 0.05$).

#Significant differences between the experimental and the control groups ($p < 0.05$).

EMG: electromyography; ES: erector spinae; EO: external oblique; IO: internal oblique; TIS: Trunk Impairment Scale; 10MWT: 10-Meter Walk Test

increase in weight shifting toward the diseased leg during walking as the symmetrical pelvic movement improved. In this study, as selective movement and symmetrical postural control of the trunk were improved by weight shifting and shoulder flexion exercise on an unstable surface, the carryover effect may also have appeared in walking.

The trunk exercises performed on an unstable surface in this study significantly improved trunk muscle activation, postural control, and the gait speed of stroke patients. However, it is difficult to generalize because of the limited number of subjects, and we could not verify whether postural sway and weight distribution in the sitting position were improved. Therefore, in future studies, it is necessary to develop various protocols depending on patient condition to verify the effects of trunk exercise on postural sway on an unstable surface.

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