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Original Article

Effects of non-paretic arm movements during bridge exercises on trunk muscle activity in stroke patients

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Abstract. [Purpose] The purpose of this study was to determine the effects of non-paretic arm movement during the bridge exercise on trunk muscle activity in stroke patients. [Participants and Methods] In total, 18 stroke patients were recruited. Surface EMG electrodes were attached over the trunk muscles (rectus abdominis, RA; internal oblique, IO; erector spinae, ES), and three kinds of bridge exercises were performed: 1) 'standard' bridge, 2) bridge with unilateral isometric arm flexion, and 3) bridge with unilateral isometric arm horizontal abduction. [Results] According to the activity of the trunk muscles measured during bridge exercises, only the IO and ES showed significantly greater muscle activity during bridges with isometric arm horizontal abduction and flexion than during the standard bridge. Additionally, comparison of the paretic and non-paretic sides showed that muscle activity was higher on the paretic side. [Conclusion] This study showed that, as an exercise to heighten the activity of the trunk muscles in stroke patients, bridge exercises with accompanying non-paretic arm flexion and horizontal abduction were more effective clinically than a standard bridge.

Key words: Bridge exercise, Non-paretic arm movement, Trunk muscle

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INTRODUCTION

Stroke has become a major reason for prolonged medical disorders[1)]. One of the most important impairments after stroke is muscle weakness on the ipsilateral side of the body, including in the trunk region[2)]. Weakness of the trunk muscles can lead to postural instability, resulting in difficulties with balance control and functional activity in stroke patients[3)]. Thus, therapeutic exercises to improve trunk muscle strength in stroke patients are important in allowing patients to accomplish functional tasks independently[2, 3)].

The bridge exercise is one of the most clinically useful exercises for trunk stability and muscle strengthening as part of a rehabilitation program[4)]. It is also an appropriate exercise to increase trunk stability through coordinating both global muscles, such as the rectus abdominis (RA) and erector spinae (ES), and local muscles, such as the internal oblique (IO)[5)].

Recently, some researchers have emphasized rehabilitative exercises combining the extremities to improve trunk muscle activity. Hodges et al.[6)] reported that trunk muscle activity and trunk stability could be increased effectively by including movement of the upper and lower extremities during exercises. Aruin and Latash[7)] reported that the activity pattern of the trunk muscles was related to the direction of limb movement. Also, Lee et al.[8)] in a study using Thera-band in hemiplegia patients with stroke, reported that the external oblique, which is a trunk rotator, on the paretic side showed significantly higher activity in non-paretic arm extension and abduction than did that on the non-paretic side. These studies suggest methods that use the non-paretic side to increases trunk muscle strength on the paretic side in therapeutic exercises with

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Table 1. Demographic characteristics of the stroke participants (n=18)

Gender (M/F)	Height (cm)	Weight (kg)	Age (years)	Affected limb (R/L)	MMSE-K	K-MBI	MAS	Time post stroke (months)
18/0	169.10 ± 5.06	68.67 ± 8.63	53.07 ± 8.99	9/9	28.06 ± 2.22	90.44 ± 6.16	0.56 ± 0.50	8.69 ± 2.59

F: female; K-MBI: Korean-Modified Barthel Index; L: left; MAS: Modified Ashworth Scale; MMSE-K: Mini Mental State Examination-Korea version; M: male; R: right.

hemiplegic patients.

However, although additional arm movement increased abdominal muscle strength in patients with stroke, few studies have investigated the combined effects of additional arm movements during bridge exercises. Also, few studies have investigated the effects of bridge exercise on trunk muscle activity in stroke patients. Thus, the purpose of this study was to assess the effects of non-paretic arm movement during the bridge exercise on trunk muscle activity in stroke patients.

PARTICIPANTS AND METHODS

The participants were 18 adult hemiplegic patients diagnosed with stroke using computed tomography and magnetic resonance imaging at Pusan National University Yangsan Hospital, Korea. The criteria for inclusion were: 1) K-MBI scores of 70 points or higher; 2) MAS scores of 0–2, and physical ability to perform the required exercise; 3) MMSE-K of 24 points or higher; 4) diagnosis of hemiplegia resulting from a stroke at least 6 months previously. Criteria for exclusion were: 1) unable to perform the required exercises due to limited range of motion in the upper and lower extremities, spasticity or associated reaction; and 2) a neurological or orthopedic disease resulting in other motor disabilities. All participants sufficiently understood the purpose and method of this study and voluntarily signed an informed consent form approved by Pusan National University Yangsan Hospital's Ethics Committee for Human Investigations prior to participation. This study was approved by the Pusan National University Yangsan Hospital Institutional Review Board (05-2016-023). The general characteristics of the participants are provided in Table 1.

The position of the bridging exercise was as follows: The participants lay in a supine position with the knees flexed at 90° and legs spread shoulder-width apart with the soles in a neutral position. During bridge exercises, the pelvis was raised from the floor until the hip joint extension became 0°, and a bar was installed at the height of the thigh between the greater trochanter and femoral condyle to confirm the correct trunk position. The standard bridge exercise was conducted with both hands spread to at the sides at 30°, with the palms facing downward and the hands evenly spread on the floor. The bridges with unilateral isometric arm horizontal abduction and flexion were conducted with the non-paretic upper extremity flexed at 90° using a red Thera-band (The Hygenic Corp., Akron, OH, USA). The elasticity of the red Thera-band was moderate, and its length was set at 80 cm, with the non-paretic shoulder joint as the axis. The intensity of the band was determined so that the patient would not have any spasticity or associated reaction through the pilot test. Additionally, a goniometer was used to determine the upper extremity range of motion (shoulder joint flexion: 60°, horizontal abduction: 60°), and a target bar was installed to precisely control upper extremity movement. The bridge exercise was held for 5 s under isometric contraction; it was repeated three times. Participants had a 30-s rest between trials and 3-min rest between positions to prevent muscle fatigue.

A surface electromyography system (TELEMYO 2400R-G2, Noraxon, Inc., USA) was used to measure activity in the RA, IO, and ES muscles bilaterally. The sampling rate was set to 1,000 Hz. A band-pass filter between 20 and 450 Hz was used. Raw data for the six muscles were processed into the root mean square (RMS) data. Normalization of the EMG data collected from each muscle was performed by calculating the RMS of a 5-s reference voluntary contraction (RVC). The RVC values of the RA and IO were measured during a 5-s supine isometric trunk curl-up and bilateral twist. The RVC value of the ES was measured during 5-s prone isometric trunk extension. Three different muscle tests were performed with no added resistance. All of the surface EMG measurements were done three times for 5 s each. The average value for the middle 3 s, excluding the first and last seconds, was standardized to %RVC for comparative analysis.

Data are expressed as means ± standard deviations. Significant differences among the three kinds of exercises and between the two sides (paretic vs. non-paretic) were measured with 3 × 2 repeated-measures analysis of variance. If there was significant interaction between exercise type and side, a *post hoc* analysis using Bonferroni correction and paired t-tests were conducted to identify differences in pair comparisons. The data were analyzed using the SPSS software (ver. 18.0; Chicago, IL, USA). The significance level was set at $p<0.05$.

RESULTS

Table 2 shows the means and standard deviations of voluntary contraction value percentages related to each exercise type and side. A significant type-by-side interaction was observed for activity in the IO and the ES muscle. According to the *post*

Table 2. Activation of the trunk muscles during three different types of bridging exercises (n=18)

Muscles	Non-paretic side			Paretic side		
	Bridge	Flexion	Abduction	Bridge	Flexion	Abduction
RA	0.89 ± 0.91	0.88 ± 0.70	0.96 ± 0.78	0.82 ± 0.76	0.90 ± 0.79	0.92 ± 0.77
IO	1.85 ± 1.20	2.23 ± 1.59*	2.41 ± 1.55*	2.79 ± 1.24§	3.83 ± 1.87*, §	3.83 ± 1.75*, §
ES	12.37 ± 8.96	13.79 ± 10.04*	14.22 ± 10.21*	23.61 ± 13.41§	29.01 ± 16.57*, §	29.65 ± 16.79*, §

Values are means ± SD.
*There is significantly greater muscle activity compared with bridge (p<0.05).
§ There is significantly greater muscle activity compared with non-paretic side (p<0.05).
RA: rectus abdominis; IO: internal oblique; ES: erector spinae.

hoc analysis, bridges with unilateral isometric arm horizontal abduction and flexion showed significantly greater activation than did the standard bridge (p<0.05). The muscle activation was significantly greater on the paretic than on the non-paretic side (p<0.05). The RA showed no significant difference in main effect or a significant interaction for exercise type × side.

DISCUSSION

We investigated the effect of non-paretic arm movements during bridge exercises on trunk muscle activity in stroke patients. According to the measurements of trunk muscle activity during the three kinds of bridge exercises, there was significant difference among exercise types only for the IO and ES (p<0.05).

In the present study, EMG activity of the trunk muscles, namely the IO and ES, showed greater muscle activity during bridge exercises with isometric arm horizontal abduction and flexion than during the standard bridge exercise. The IO is known as a trunk stabilizer muscle in diverse movements, similar to the transverse abdominis muscle[9)]. The IO maintains spinal curvature and plays an important role in maintaining the stability of the front, back, and side of the trunk[10)]. The trunk muscle that plays a leading role in bridge exercises is the ES. Research evaluating the functions of the ES in stroke patients has not been reported before, but research performed with healthy adults as participants has confirmed that the ES acts in postural maintenance against gravity, regardless of postural changes, and ES activity increases when balance is maintained in an unstable posture[11)]. Movements of the upper and lower extremities during bridge exercises create internal perturbations in trunk stability, resulting in increased trunk-stabilizing exertion in response to increased proprioceptive demand[12)]. It is thought that when non-paretic arm movement accompanies bridge exercises, internal perturbation of the trunk increases instability, and the activity of the IO and ES significantly increases to maintain a given posture. Thus, our results suggest that non-paretic upper limb movement may be beneficial to increase IO and ES muscle activity during bridge exercises.

In our findings, IO and ES activity was significantly higher on the paretic than the non-paretic side during movements of the upper extremities (flexion, horizontal abduction). Trunk muscle activity responds in the direction opposite and with the same force as movements of the upper and lower limbs. Aruin and Latash[7)] reported that shoulder flexion induced back muscle activity to control induced trunk flexion by reactive forces. Also, Lee et al.[8)] reported that abdominal muscles activity was increased significantly on the paretic versus the non-paretic side during non-paretic arm extension and horizontal abduction in a seated position. Thus, it seems that contralateral trunk muscle activity increased significantly during unilateral arm movement in reaction to postural demands in the present study. Additionally, unilateral limb movements cause torque, and the trunk muscles must counteract this instability[13)]. Behm et al.[13)] suggested that the imbalanced movement caused by the resistance of the unilateral arm outer base of support would result in a destabilizing torque that would be countered by activation of the contralateral trunk muscles. Thus, contralateral trunk muscle activity would be expected to increase significantly during unilateral arm movement in reaction to postural demands in the present study. Indeed, our results suggest that non-paretic upper limb movements may be beneficial to increase paretic trunk muscle activity during bridge exercises.

The RA showed no significant difference in main effect and no significant interaction during the exercises. During upper extremity movement with bridge exercises, the instability of the base of support increases, and such instability may increase the burden on spinal rotation. Left and right rotation of the trunk are controlled by the IO and external oblique or by the transverse abdominis moving diagonally or horizontally, rather than by muscles arranged in the vertical direction, such as the RA[14)]. The RA, which composes the front of the abdominal wall, acts largely in trunk flexion and makes little contribution to trunk stability. Thus, RA muscle activity did not differ among the exercises used in this study.

This study has some limitations. First, the number of participants was small at 18 patients. Second, we did not measure trunk movements, although we did instruct participants to maintain a particular posture during the non-paretic arm exercise. Finally, this study used a crossover design. There was no long-term follow-up observation, making it difficult to judge the long-term effects of bridge exercises with accompanying non-paretic side upper extremity movements.

In conclusion, the IO and the ES were activated more during bridge exercises with isometric arm horizontal abduction and flexion than during a standard bridge exercise. Additionally, muscle activation on the paretic side was significantly higher than that on the non-paretic side. Thus, this study showed that bridge exercises with accompanying non-paretic-side upper limb horizontal abduction and flexion were more effective clinically than was the standard bridge exercise as a way to increase stroke patients trunk muscle activity, particularly paretic-side trunk muscle activity.

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Conflicts of interest

None.

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