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The Effects of a Bridging Exercise With Hip Adductor Contraction on the EMG Activities of Abdominal Muscles in Patients With Sub-Acute Stroke

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Abstract

Background: Muscle weakness and impaired trunk muscle control are common in stroke patients. The bridging exercise (BE) is generally used for trunk stabilization and improving the overall function of stroke patients. The effectiveness of the BE with hip adductor contraction (BEHA) in facilitating trunk muscle activation has been well studied in healthy adults. However, the impact of BEHA in sub-acute stroke patients has not yet been investigated.

Objects: The purpose of this study was to determine the effects of BEHA on the electromyography (EMG) activities and the asymmetry of the rectus abdominis (RA), external oblique (EO) and internal oblique (IO) abdominal muscles.

Methods: Twenty participants with sub-acute stroke (11 males and 9 females) were recruited. Each participant was asked to perform bridging exercises for five seconds under three different conditions: BE in a neutral position (BEN), BEHA with a large ball (BEHAL) and BEHA with a small ball (BEHAS). The EMG amplitudes of the bilateral RA, EO and IO and the asymmetry of the EMG activity between the sound and affected sides were compared among the conditions. The significance level was set at $\alpha=.05$.

Results: The EMG activities of RA, EO and IO were significantly greater during BEHAL and BEHAS than during BEN ($p<.05$); the asymmetry of the RA, EO and IO decreased significantly during BEHAL and BEHAS compared to BEN ($p<.05$). However, no measured variables showed any significant differences between BEHAL and BEHAS ($p>.05$).

Conclusion: This study compared the EMG activities of the RA, EO and IO on both sides and the asymmetry of the RA, EO and IO during BEN, BEHAL and BEHAS. Our findings suggest that BEHA was more effective for individuals with hemiplegic stroke at facilitating and normalizing abdominal muscle control than BEN.

Key Words: Asymmetry; Bridging exercise; Hip adduction; Stroke; Trunk.

Introduction

Trunk stability is essential to maintain an anti-gravity posture, such as when sitting and standing, and also to move the limbs smoothly (Hodes and Richardson, 1997). After stroke, problems in trunk control are common and have an effect on balance, gait and function (Ryeson et al, 2008; Verheyden et al, 2006). Trunk control is important to walk stably and reduce the falling risk in stroke patients (Neckel et al, 2008). Trunk control is an early predictor that may be used to anticipate activities of daily living in stroke

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patients six months after the onset of stroke (Hsieh et al, 2002); trunk strength is related with the Berg balance score at hospital discharge (Karata et al, 2004). Contrary to common perception that only the affected side of the trunk is impaired following a stroke, stroke patients experience effects on both the sound side and the affected side of the trunk (Tsuji et al, 2003).

The bridging exercise (BE) is commonly used therapeutically for trunk stabilization and has a positive effect on coordinated global and local muscle development (Stevens et al, 2006). Performing the BE on the floor lowers the center of gravity, reduces fear, increases the stability of weight-bearing during gait, and helps to stabilize posture (Schunk, 1982). A modified BE reportedly improved balance and weight bearing in a standing position in stroke patients (Song and Heo, 2015). Similarly, a core stability exercise involving BE improved stroke patients' dynamic balance and gait (Chung et al, 2013), while BE with abdominal drawing-in increased the balance ability in patients with stroke (Song and Heo, 2016).

Previous studies has reported the positive effects of various bridging exercises with hip adductor contraction (BEHA) in healthy adults. BEHA using a resistive Pilates device increased the electromyography (EMG) activity of the internal obliques (IO), adductor longus (AL) and gluteus maximus (GM) (Kim et al, 2007); BEHA with biofeedback using a stabilizer increased the EMG activity of the rectus abominis (RA), external obliques (EO), IO and GM (Jang et al, 2013), and BEHA with an exercise ball increased the EMG activity of the transversus abominis, adductor magnus (AM) and gluteus medius (Gmed) (Lee and Lee, 2012). Hip adductors could play a role in increasing contraction of abdominal muscles (Kibler et al, 1996) and different hip abduction angles during BE contributed to different muscle activities (Kang et al, 2016). Hip abduction or adduction angles could be controlled by using different sized balls. However, no previous study has examined the effects of a BEHA with using different sized balls in sub-acute stroke patients.

Therefore, the purpose of this study was to determine the effects of the BEHA on the EMG activities and asymmetry of the abdominal muscles (RA, EO and IO) in sub-acute stroke patients and to investigate whether there were any differences related to ball sizes for adduction. We hypothesized that BEHA would generate increased abdominal muscle EMG activity and produce more symmetrical EMG activities on both sides of the abdominal muscles to BE. Additionally, BEHA using a small ball (BEHAS) should be more effective than BEHA using a large ball (BEHAL).

Methods

Participants

Twenty sub-acute stroke inpatients who visited Kyunghee University Medical Center were included in this study. The selection criteria were: 1) after two weeks and within six months from stoke onset; 2) a Mini-Mental State Examination-Korean version score greater than 24/30 and the ability to comprehend simple commands; 3) modified Ashworth scale 0 or 1; 4) affected hip extensor strength F- or above on the manual muscle test; 5) affected lower extremity 3 or above on the Brunnstrum stage; 6) ability to perform the BEN, BEHAL and BEHAS independently; 7) ability to lift both shoulders from the mat in curling motion; and 8) above 20 years of age. Participants with any neurological disorder other than stroke were excluded. All of the protocols used in this study were approved by the Institutional Review Board at Kyunghee University Medical Center (approval num-

Table 1. Characteristics of the subjects (N=20)

Variable	Mean (SD[a])
Age (year)	57.7 (4.88)
Time post stroke (day)	31.8 (10.01)
MMES-K[b]	26.4 (1.27)

[a]standard deviation, [b]a mini-mental state examination-Korean version.

ber: KMC IRB 1621-01). Before their participation, the procedures, risks and benefits were explained to all the participants, who provided their informed consent. The characteristics of the participants are summarized in Table 1.

Instruments

Surface EMG data were collected using a DataLog MWX8 (DataLog MWX8, Biometrics Ltd., Newport, UK). The signal was full-wave rectified, and the root mean square value was calculated over 100 millisecond intervals. The EMG data were sampled at a frequency of 2,000 ㎐ and filtered using standard band-pass filtering techniques with cutoffs of 20 and 450 ㎐.

Procedures

The surface electrodes were placed over both sides (Pereira et al, 2011) of three muscle groups (Jang et al, 2013): 1) the RA centered on the muscle belly midway between the pubis and the umbilicus; 2) the EO located 5 ㎝ above the anterior superior iliac spine (ASIS); and 3) the IO located 2 ㎝ medial to the ASIS.

Before performing the BEs, all participants did three curl-ups for the reference voluntary contraction (RVC) (Pereira et al, 2011). Participants lied on the mat and maintained their hip joints at 45° and their knee joints at 90° of flexion with their foot and knees kept apart at shoulder width (Joo et al, 2012). For both sides of the RA, participants curled up, lifting both scapulae from the mat. For the right side of the EO and the left side of the IO, participants curled up with left rotation of the trunk, lifting the right side of the scapula from the mat. For the left side of the EO and the right side of the IO, participants curled up with right rotation of the trunk while lifting the left side of the scapula from the mat. All participants performed three sets of each curl-up. One set consisted of holding for five seconds and resting one minute. The RVC data of the first and last second of each contraction were discarded, and the middle three seconds were used instead (Jang et al, 2013).

The participants performed the BE in a neutral position (BEN) and the BEHA in the same supine position to allow for RVC. For the BEN, the participants lifted their buttocks as high as they could from the mat. The participants performed two BEHAs using different sized balls for controlling hip angles during BE. One was a BEHAL of a size similar to the width between both medial femoral epicondyles, and the other was a BEHAS of lesser width than that between medial femoral epicondyles in the same supine position to allow for RVC. When performing the BEHAL and BEHAS, the participants lifted their buttocks from the mat and then adducted their knees, pressing each ball as hard as they could. All participants performed three sets of the BEN, BEHAL and BEHAS. One set consisted of holding the position for five seconds and then resting for one minute. All data of the first and last second of each contraction were discarded, and the middle three seconds were used. The order of the BEN, BEHAL and BEHAS was performed randomly to reduce any order effects. Data for each muscle activation were normalized as percentages of the RVC.

Raw data were used to calculate the asymmetry of the RA, EO and IO using the following formula: (sound side-affected side)/(sound side+affected side)×100. When the score is close to zero, the asymmetry is decreased.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 12.0 (SPSS Inc., Chicago, IL, USA). A repeated-measure analysis of variance with Bonferroni corrections as post hoc was used to evaluate the differences in EMG activities and asymmetry among the BEN, BEHAL and BEHAS. All statistical tests were performed at the 5% level of significance.

Results

The activation values of each abdominal muscle during BEN, BEHAL and BEHAS before Bonferroni

Table 2. Comparison of the muscle activities among the different bridging exercise types

Muscle		Mean %RVC[a] (SD[b])			F-value	p-value
		BEN[c]	BEHAL[d]	BEHAS[e]		
Sound side	RA[f]	9.70 (2.32)	13.45 (2.90)	13.23 (2.93)	8.047	.003*
	EO[g]	11.34 (2.36)	15.16 (3.50)	15.39 (3.81)	6.484	.008*
	IO[h]	12.67 (2.59)	16.65 (4.11)	17.15 (4.13)	6.963	.006*
Affected side	RA	9.33 (2.46)	14.12 (4.03)	13.93 (4.18)	10.042	.001*
	EO	10.30 (2.07)	15.42 (4.06)	15.67 (4.29)	9.251	.002*
	IO	11.45 (2.20)	16.63 (4.31)	17.34 (4.86)	9.401	.002*

[a]reference voluntary contraction, [b]standard deviation, [c]bridging exercise in a neutral position, [d]bridging exercise with hip adductor contraction with a large ball, [e]bridging exercise with hip adductor contraction with a small ball, [f]rectus abdominis, [g]external olique, [h]internal oblique, *$p<.05$.

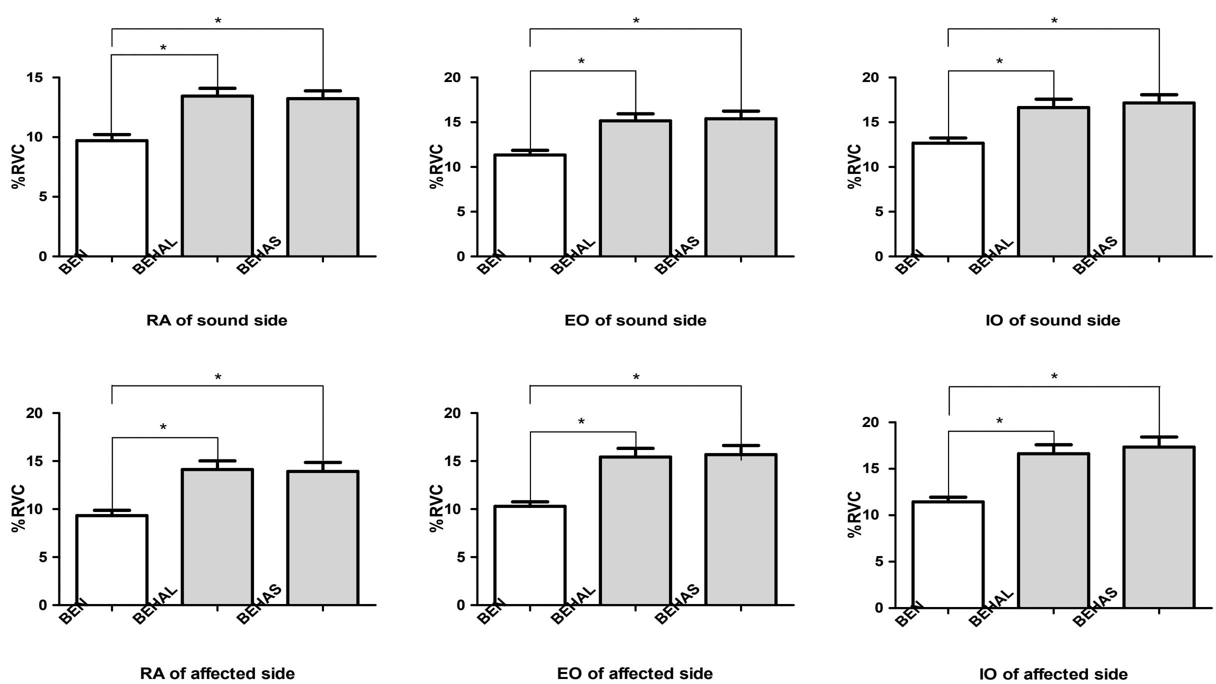

Figure 1. Comparison of the muscle activities among the different bridging exercise types. (RVC: reference voluntary contraction, BEN: bridging exercise in a neutral position, BEHAL: bridging exercise with hip adductor contraction with a large ball, BEHAS: bridging exercise with hip adductor contraction with a small ball, RA: rectus abdominis, EO: external oblique, IO: internal oblique, *$p<.05$).

corrections are summarized in Table 2, while Figure 1 shows those after the Bonferroni corrections. Significant differences can be seen among the BEN, BEHAL and BEHAS (Table 2): RA (F=8.047, p=.003), EO (F=6.484, p=.008) and IO (F=6.963, p=.006) of the sound side and RA (F=10.042, p=.001), EO (F=9.251, p=.002) and IO (F=9.401, p=.002), respectively. After the Bonferroni corrections (Figure 1), there were significant increases of muscle activity from BEN on both the sound side and the affected side during BEHAL. The increases on the sound side of the RA, EO and IO were 13.45 (p=.002), 15.16 (p=.006) and 16.65 (p=.006), respectively, while the increases on the affected side of the RA, EO and IO were 14.12

Table 3. Comparison of the asymmetry among the different types of bridging exercises

Muscle	Mean %unit[a] (SD[b])			F-value	p-value
	BEN[c]	BEHAL[d]	BEHAS[e]		
RA[f]	8.43 (5.78)	4.75 (4.58)	4.70 (4.55)	6.701	0.007*
EO[g]	9.43 (6.12)	4.29 (3.54)	4.20 (3.40)	7.442	0.004*
IO[h]	10.63 (4.94)	5.97 (4.16)	5.91 (5.14)	9.960	0.001*

[a](sound side-affected side)/(sound side+affected side)×100, [b]standard deviation, [c]bridging exercise in a neutral position, [d]bridging exercise with hip adductor contraction with a large ball, [e]bridging exercise with hip adductor contraction with a small ball, [f]rectus abdominis, [g]external oblique, [h]internal oblique, *p<.05.

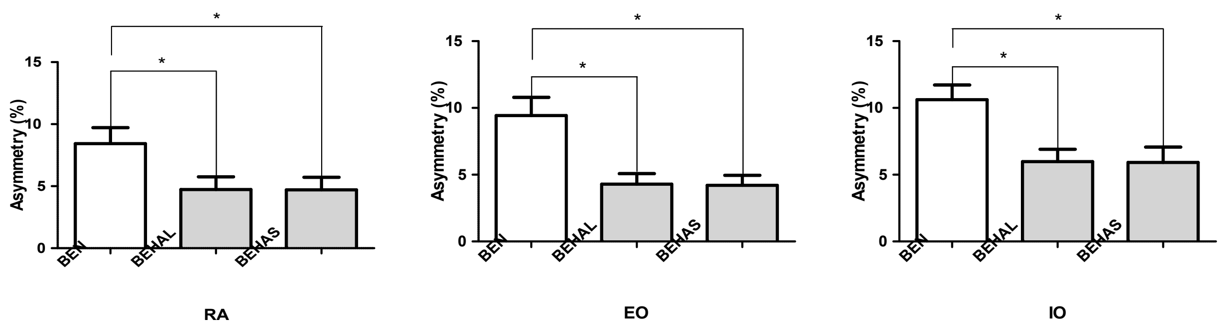

Figure 2. Comparison of the asymmetry among the different types of bridging exercises. (BEN: bridging exercise in a neutral position, BEHAL: bridging exercise with hip adductor contraction with a large ball, BEHAS: bridging exercise with hip adductor contraction with a small ball, RA: rectus abdominis, EO: external oblique, IO: internal oblique, *p<.05).

(p=.001), 15.42 (p=.001) and 16.63 (p=.001), respectively. In addition, during BEHAS, there were significant increases of muscle activity during BEN on both the sound side and the affected side. The increases on the sound side of the RA, EO and IO were 13.23 (p=.003), 15.39 (p=.005) and 17.15 (p=.004), respectively, and those on the affected side for the RA, EO and IO were 13.93 (p=.002), 15.67 (p=.001) and 17.34 (p=.001), respectively. However, there were no significant differences in the activation of the sound side RA (p=.496), EO (p=1.000) and IO (p=.08) and the affected side RA (p=.621), EO (p=.821) and IO (p=.05) between the BEHAL and BEHAS.

The asymmetry of each abdominal muscle during the BEN, BEHAL and BEHAS before the Bonferroni corrections is summarized in Table 3; Figure 2 shows the same values after Bonferroni corrections were made. There were significant differences among the BEN, BEHAL and BEHAS (Table 3): RA (F=6.701, p=.007), EO (F=7.442, p=.004) and IO (F=9.960, p=.001). After the Bonferroni corrections, there were significant decreases of muscle asymmetry from the BEN during BEHAL (Figure 2). The asymmetry values of RA, EO and IO were 4.74 (p=.04), 4.29 (p=.003) and 5.98 (p=.001), respectively, during the BEHAL, while those during BEHAS were 4.70 (p=.008) for RA, 4.20 (p=.004) for EO and 5.91 (p=.013) for IO. However, there were no significant differences in the asymmetry of RA (p=1.000), EO (p=1.000) and IO (p=1.000) between the BEHAL and BEHAS.

Discussion

This study evaluated the abdominal muscle activities of sub-acute stroke patients during BEN, BEHAL and BEHAS. Trunk muscles are responsible for stabilizing proximal body segments during voluntary limb movements (Verheyden et al, 2006); therefore, the proper activation of core muscles is essential for optimal functioning of the lumbopelvic-hip complex (McGill and Cholewichi, 2001). Trunk muscle strength is often impaired after stroke (Dickstein et al, 2004); contrary to common consideration, stroke patients are typically affected on both sides of the trunk instead of only on the affected side (Tsuji et al, 2003). In addition, stroke patients have trunk asymmetry, damaged trunk performance and problems in balance and gait (Ryerson et al, 2008; Verheyden et al, 2006). Although it has been acknowledged that impaired selective trunk muscle control is related to balance, gait and hand function following stroke (Davies, 1990), a majority of the post-stroke rehabilitation studies have focused only on the recovery of upper and lower extremity control (Moreland and Thomason, 1994; Moreland et al, 1998; van der Lee et al, 2001).

The BE is commonly used therapeutically for core muscle stabilization (Stevens et al, 2006). The BE increases abdominal pressure and induces muscle co-contraction to reduce hyperlordosis or anterior pelvic tilt (Kisner and Colby, 2007). Previous studies have reported positive effects of the BEHA on the EMG activities of trunk muscles in healthy adults (Jang et al, 2013; Joo et al, 2012; Kim et al, 2007; Lee and Lee, 2012). Our results showed that the EMG activities in both the sound and affected sides of the RA, EO and IO were increased during both BEHAL and BEHAS compared to during BEN and are similar the results of BEHA seen in healthy adults. Because both the sound and affected sides of the trunk are impaired in stroke patients (Tsuji et al, 2003), it is important to increase the muscle strength of the sound side as well as the affected side.

Our results could be explained as follows. First, increased EMG activities of the RA, EO and IO during the BEHA could be explained by the BEHA increased the activities of the abdominal muscles (Jang et al, 2013). Second, decreased asymmetry of the trunk during the BEHA could be explained by the hip adductor contraction increased the abdominal stability (Kibler et al, 1996) that may contribute to increasing contraction of the affected side of the trunk. Third, no significant differences in the activation and asymmetry of the trunk between the BEHAL and BEHAS could be explained by the torque-angle relationship on post-stroke was divergent from normal (Hedlund et al, 2012).

Our study is somewhat different than previous studies. First, we studied the effects of BEHA on the EMG activities of trunk muscles in sub-acute stroke patients. Previous studies have only reported the impact of BE without hip adduction in stroke patients or the effects of BEHA in healthy adults. Second, we assessed both the sound and the affected sides of the trunk muscles. Our findings that BEHA increased the EMG activity of both the sound and affected sides are meaningful because both sides of the trunk are impaired in stroke patients. Third, we measured the asymmetry of trunk muscles; it is important to decrease the asymmetry of muscle activity in stroke patients because this asymmetry produces asymmetrical movements. Fourth, although no measured variables showed any significant differences between the BEHAL and BEHAS, we attempted to compare the different conditions of the BEHA.

Our study had some limitations. First, we included a relatively small sample of participants. Second, because we only measured the EMG activity of the RA, EO and IO muscles, future studies will need to assess the EMG of the GM and trunk extensor muscles that contribute to bridging. Third, we only assessed adduction conditions during the BE. Therefore, longitudinal, randomized clinical studies to evaluate the long-term effects of the BEHA on more functional activity, such as balance and walking, will be needed in the future.

Conclusion

This study compared the EMG activities and asymmetry of both the affected and unaffected sides of the RA, EO and IO during BEN, BEHAL and BEHAS. We found that the BEHAL and BEHAS were more effective at increasing the activity of both sides of the RA, EO and IO and at decreasing the asymmetry of RA, EO and IO than the BEN. However, there were no significant differences in the activation of both sides of the RA, EO and IO or in the asymmetry of the RA, EO and IO between the BEHAL and BEHAS.

Our findings suggest that the BEHAL and BEHAS increase activities of RA, EO and IO and decrease the asymmetry of RA, EO and IO; therefore, they could be used clinically in sub-acute stroke patients. Further studies with a large sample size that involve other muscles and investigate the long-term effects of BEHA are recommended.

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