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Four-Week Comparative Effects of Abdominal Drawing-In and Diaphragmatic Breathing Maneuvers on Abdominal Muscle Thickness, Trunk Control, and Balance in Patients With Chronic Stroke

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Abstract

Background: Patients with chronic stroke often shows decreased trunk muscle activity and trunk performance. To resolve these problems, many trunk stabilizing techniques including the abdominal drawing-in maneuver (ADIM) and the diaphragmatic breathing maneuver (DBM) are used to improve trunk muscle strength.

Objects: To compare the effects of the ADIM and the DBM on abdominal muscle thickness, trunk control, and balance in patients with chronic stroke.

Methods: This was a randomized controlled trial. Nineteen patients were randomly allocated to the ADIM (n_1=10) and DBM (n_2=9) groups. The ADIM and DBM techniques were performed three times per week for 4 weeks. The thicknesses of the transversus abdominis (TrA), internal oblique muscle, and external oblique muscles on the paretic and non-paretic sides, Trunk Impairment Scale (TIS) score, and Berg Balance Scale (BBS) score were used to assess changes in motor development after 4 weeks of training.

Results: After the training periods, the TrA thickness on the paretic side, TIS score, and BBS score improved significantly in both groups compared to baseline ($p<.05$). TIS score was significantly greater in the DBM group than in the ADIM group ($p<.05$).

Conclusion: This study demonstrated that ADIM and DBM are beneficial for improving TrA muscle thickness in the paretic side, trunk control, and balance ability. Intergroup comparison revealed that TIS score was significantly improved in the DBM group versus the ADIM group. Thus, DBM may be an effective treatment for low trunk muscle activity and performance in patients with chronic stroke.

Key Words: Abdominal drawing-in maneuver; Diaphragmatic breathing maneuver; Stroke.

Introduction

Patients with stroke experience difficulties with recognition, communication, mobility, gait, and activities of daily living (Bohannon et al, 1988; Peterson, 2004). In particular, hemiplegic patients present with reduced motor unit firing rates, muscle fiber thickness, and muscle fiber numbers due to transsynaptic degeneration of the spinal motorneurons and corticospinal fibers (Weightman, 1994). Thus, their trunk muscle function is commonly reduced (Hsieh et al, 2002). Previous studies reported that the peak torque of the trunk flexor and extensor muscles is lower in patients with stroke compared with those of healthy subjects. The weakness was in the paretic side, compared to the non-paretic side, and delayed contraction was observed (Karatas et al, 2004). Moreover, abdominal muscle thickness was decreased in patients

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with stroke compared to healthy subjects, particularly that of the transversus abdominis (TrA) muscle (Seo et al, 2015). Trunk muscle weakness affects trunk performance and balance in patients with stroke (Karatas et al, 2004), making them unable to maintain bilateral weight shifting due to trunk muscle weakness and impaired trunk motor control ability. Trunk muscle strength has been positively correlated with balance and functional performance in patients with stroke (Chan et al, 2015).

To improve trunk muscle function, various studies were related to postural core stabilization exercises aiming to identify methods to improve muscular strength and endurance in the lumbar region (Chung et al, 2014; Jung et al, 2016; Karatas et al, 2004; Liao et al, 2015; Yu and Park, 2013). In a recent postural core stabilization technique, the abdominal drawing-in maneuver (ADIM) and diaphragmatic breathing maneuver (DBM) have been used to improve postural sway area, sway path length, sway max velocity (Haruyama et al, 2016; Lim et al, 2012), grip strength, and pulmonary function (Yoon et al, 2015) as well as improve unsupported sitting balance ability in patients with stroke (Choi et al, 2016).

The ADIM is a core stabilization exercise in which the TrA muscle is selectively contracted earlier than other abdominal muscles such as the rectus abdominis, external oblique (EO) muscle, and internal oblique (IO). The ADIM has been widely used to improve lumbopelvic region instability through neuromuscular rehabilitation of the TrA and IO muscles (Henry and Westervelt, 2005; Hides et al, 2006; Hodges et al, 2002; O'Sullivan et al, 1998). Previous studies reported the effect of ADIM training in patients with chronic stroke (Haruyama et al, 2017; Lim et al, 2012). Haruyama et al. (2017) compared core stabilization exercises with ADIM and only conventional exercise to estimate trunk function, and showed that the use of core stabilization exercise with ADIM group resulted in a mean Trunk Impairment Scale (TIS) score that was 2.92 points greater than that in the control group. Lim et al. (2012) reported the effect of bridging exercise with ADIM on dynamic standing balance and showed that a bridging exercise with ADIM was more effective than a conventional bridging exercise at decreasing postural sway length, area, and velocity. The DBM involves the integrated spinal stabilizing system, which is comprised of balanced co-activation of the diaphragm, pelvic floor, all sections of the abdominals and spinal extensors in the lower thoracic and lumbar region, and the deep cervical flexors and spinal extensors in the cervical and upper thoracic region (Frank et al, 2013). Due to its caudal descent or concentric contraction during inspiration, the diaphragm creates intra-abdominal pressure within the integrated spinal stabilizing system. This increased intra-abdominal pressure simultaneously activates deep pelvic floor muscles to provide inferior stability and eccentrically contracts abdominal wall muscles to provide anterolateral and posterior spinal stability, thereby improving overall postural stability (Kolar et al, 2014). Two previous studies compared the effects of the ADIM and DBM techniques related to balance performance in patients with stroke (Choi et al, 2016; Yoon et al, 2015). Yoon et al. (2015) demonstrated that the ADIM group showed significant improvement on the modified functional reaching test compared to the DBM group. In another study, the ADIM and DBM groups showed significant improvement in sitting balance ability compared to the control group. However, there was no significant difference between the ADIM and DBM groups (Choi et al, 2016).

Although the ADIM and DBM techniques effectively improved the associated balance performance, no previous studies have compared their effects on selective trunk muscle activation and trunk control ability in patients with chronic stroke. Therefore, the aim of this study was to compare the 4-week training effect of ADIM versus DBM on abdominal muscle (TrA, IO, EO) thickness, trunk control, and balance ability in patients with chronic stroke. We hypothesized that there would be a difference in abdominal muscle thickness, trunk control ability, and balance performance between ADIM and DBM treatment in patients with chronic stroke.

Methods

Subjects

Before patient recruitment, a power analysis was performed using G*power software (version 3.1.2; Franz Faul, University of Kiel, Kiel, Germany). Based on a pilot study of six participants (two patients in the ADIM group and four in the DBM group), a power analysis was conducted to achieve a significant α level of .05, power of .80, and effect size of 1.78. The results of the power analysis showed that seven patients were required per group. As a result, we recruited 20 patients with stroke (10 in the ADIM group and 10 in the DBM group) from BEST Rehabilitation Hospital, Yeoju city. However, one patient in the DBM group dropped out because of being discharged from the hospital during the study period. Consequently, we recruited 19 patients with stroke (10 in the ADIM group and nine in the DBM group). The inclusion criteria were as follows: (1) a diagnosis of hemiplegia due to hemorrhagic or ischemic stroke; >6 months post-stroke to minimize the effects of natural recovery; (2) ability stand independently; (3) ability to follow instruction as determined by a score of at least 24 of 30 on the Korean version of the Mini-Mental State Examination (K-MMSE) (Jung et al, 2016); and (4) the ability to understand and follow simple verbal instructions (Chung et al, 2014). The exclusion criteria included a history or current diagnosis of other neurological or musculoskeletal diseases, hemi-neglect, visual lesions, or pain (Chung et al, 2014). Baseline data were collected for each subject, including gender, age, weight, height, time from stroke onset, stroke type, hemiplegic side, and K-MMSE score. Table 1 summarizes the general characteristics of the 19 patients with stroke included in this study. All patients provided written informed consent prior to participating, and the Yonsei University Wonju Institutional Review Board approved the study (approval number: 1041849-201704-BM-032-02).

Abdominal muscle thickness using ultrasonography imaging

An ultrasound (US) device (ECUBE 9, Alpion Medical Systems Co., Ltd., Korea) was used to measure TrA, IO, and EO thicknesses on the paretic and non-paretic side in both groups. Patients in both groups were positioned in the crook lying position with 70° of hip flexion. Measurements were made at the end of expiration to reduce the impact of respiration. A 12-㎒ linear transducer head was

Table 1. Patients' baseline characteristics (N=19)

Characteristic	ADIM[a] (n_1=10)	DBM[b] (n_2=9)	p
Age (year)	59.3±10.5[c]	59.1±13.7	.973
Height (㎝)	164.1±5.2	165.0±6.0	.728
Weight (㎏)	61.5±9.3	65.2±10.5	.423
Sex (M[d]/F[e])	6/4	7/2	.405
Hemiplegic side (L[f]/R[g])	5/5	5/4	.809
Type of stroke (ischemia/hemorrhage)	8/2	6/3	.510
Disease duration (months)	19.3±9.5	16.8±8.6	.554
K-MMSE[h]	26.3±1.6	26.7±2.5	.703

[a]abdominal drawing-in maneuver, [b]diaphragmatic breathing maneuver, [c]mean±standard deviation, [d]male, [e]female, [f]left, [g]right, [h]Korean Mini-Mental State.

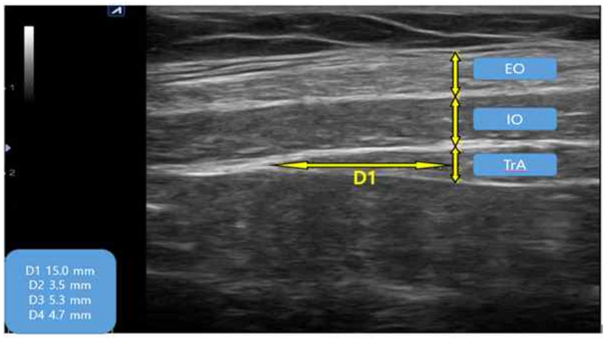

Figure 1. Measurements of abdominal muscles thickness (external oblique; EO, internal oblique; IO, transversus abdominis; TrA, reference line from the muscle-fascia junction of the TrA; D1, TrA muscle thickness; D2, IO thickness; D3, EO thickness; D4).

placed 2.5 ㎝ inside the space between the 12th thoracic vertebra and the iliac crest. After the ultrasound imaging measurements were taken, a horizontal line was drawn in the area 1.5 ㎝ away from the muscle-fascia junction of the TrA muscle on the ultrasound image. A vertical line was then drawn from the horizontal line upward to sequentially measure the TrA, IO, and EO muscle thicknesses on the paretic and non-paretic sides (Hodges et al, 2003; Lee et al, 2011). The measurement was repeated three times, and the mean value was used in the statistical analysis (Figure 1).

Trunk control test using Trunk Impairment Scale

The TIS is clinical test that is used to measure motor impairment of the trunk after stroke and measure static and dynamic sitting balance and trunk coordination. The maximum scores for static sitting balance, dynamic sitting balance, and coordination were 7, 10, and 6 points, respectively. The total score was 0～23 points, with higher scores indicating better trunk performance. The intraclass correlation coefficients (ICC) of this measurement tool were .96～.99 (Verheyden et al, 2004). The measurement was repeated three times, and the highest value was used in the analysis (Verheyden et al, 2004; Verheyden et al, 2006).

Balance test using Berg Balance Scale

The BBS is clinical test that is used to measure the balance ability of patients or elderly individuals. This tool comprises 14 items related to functional tasks related to activities of daily living and involves static and dynamic balance abilities. Points are assigned for sitting, standing, and changing posture and range from a minimum of 0 to a maximum of 4 with a maximum score of 56 points. Higher scores indicate better balance. The ICC of this measurement tool was .95～.98 (Blum and Korner-Bitensky, 2008). The measurement was repeated three times, and the lowest value was used in the analysis (Berg et al, 1995; Downs et al, 2013).

Procedure

This was a randomized controlled trial. Patients were allocated to the ADIM (n_1=10) or DBM (n_2=9) group using an online algorithm (http://www.randomization.com). Patient characteristics and outcome measures were assessed by a physical therapist with 7 years of experience (Yoon et al, 2013) who was blinded to the study. The outcome measures were the TrA, IO, and EO muscle thicknesses on the paretic and non-paretic sides, TIS score for trunk control ability, and BBS score for balance ability. The patients had not changed their physical exercise programs or medical treatments within a month before the study started. All patients performed conventional rehabilitation (60 minutes) according to the daily inpatient treatment program during the study period. Before the intervention, the patients were familiarized with the ADIM and the DBM. The familiarization period ended when the participant could successfully perform the ADIM and the DBM for 5 seconds each.

Both core stabilization techniques were standardized and the patient was instructed to perform and maintain them for 5 seconds with normal breathing, followed by a 3 second rest. One session consisted of 10 times of each technique, and the patient performed three sessions. Between sessions, the subject

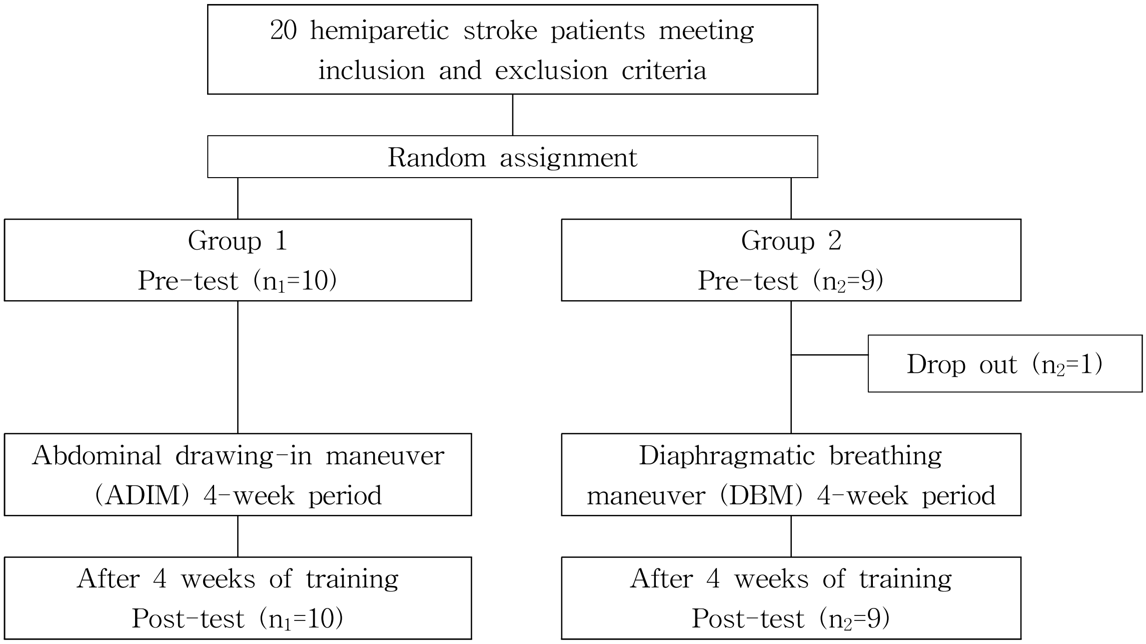

Figure 2. Experimental procedures.

rested for 60 seconds (Marshall and Murphy, 2005; O'sullivan, 2000). The ADIM and DBM were performed three times a week for 4 weeks at the same place under the guidance of another experienced but blinded physical therapist (Figure 2). During ADIM training, the patients were positioned in the crook lying position with 70° of hip flexion. The subjects were instructed to breathe in and out and pull the navel up and toward the spine. The principal investigator visually monitored for pelvic movement. When the patients performed this exercise, a real-time US device was used to provide visual feedback to monitor the changes in paretic TrA and IO muscle thicknesses and confirm successful ADIM performance (Lee et al, 2011). During the DBM training, the patients were positioned in the crook lying position with 70° of hip flexion. Successful or corrective steps for DBM included: (1) The patient was instructed to exhale and neutralize the thorax and rib cage in a caudal position; (2) The patient was then asked to inhale to make his or her diaphragm descend and co-activate the TrA and pelvic floor muscles while maintaining this neutral caudal alignment; (3) The therapist anteriorly palpated the xiphoid process, laterally the 10th to 12th ribs, and posteriorly the angulus costae to ensure symmetrical activation against the therapist's fingers while expanding the lower ribs (10th to 12th ribs) in a lateral direction; and (4) The corrective movement involves caudal movement, widening of the intercostal spaces, and relatively stable rib motion (no cranial motion) in a transverse plane (Kolar et al, 2014). The principal investigator visually confirmed these corrective movements without the therapist's manipulation during the familiarization periods. When the patients performed this exercise without the therapist's palpation, a real-time US device was used to provide visual feedback of the caudal movement of the diaphragm during inspiration to ensure successful DBM.

Real-time ultrasound for monitoring diaphragm movement and abdominal muscle contraction

Real-time US was used to provide the visual feedback for TrA and IO contraction during ADIM training and the patients' diaphragm movements during DBM training (Figure 3). To ensure accurate ADIM, a 12-㎒ linear transducer was

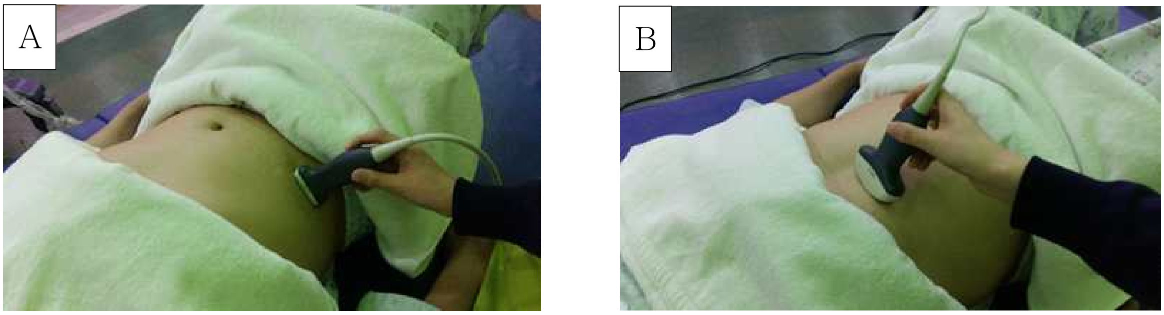

Figure 3. Abdominal drawing-in (A) and diaphragmatic breathing maneuver (B) using real-time ultrasonography.

placed where the muscle thickness was measured (Hodges et al, 2003; Lee et al, 2011). To monitor diaphragm movement, a real-time US with a 5-㎒ curved transducer was placed on the midpoint between the mid-clavicular and anterior axillary lines in the subcostal area and directed medially, cranially, and dorsally (Boussuges et al, 2009).

Statistical analysis

PASW Statistics 18 software (SPSS, Chicago, IL, USA) was used to perform all of the statistical analyses. The data are presented as mean and standard deviation (SD). The one-sample Kolmogorov-Smirnov test was used to test for a normal distribution. Independent t tests and Chi-squared tests were used for homogeneity testing. Paired t tests were used to compare the abdominal muscle thicknesses on the paretic and non-paretic side, TIS scores, and BBS scores between post- and pre-test in the respective ADIM and DBM groups. Independent t tests were used to evaluate the difference between the mean post-test values of the ADIM and DBM groups. Effect size (ES) is generally considered more appropriate for determining whether a meaningful change occurred because it considers group variability. The ES is calculated to determine meaningful intergroup changes in pre- and post-test values (differences in mean values post- and pre-test/differences in mean standard deviation values between post- and pre-test) (Lee et al, 2015; Portney and Watkins, 2000). The level of significance was set at $p<.05$.

Results

Outcome measures are presented in Table 2. No significant differences were found in the baseline values of any dependent variables between the ADIM and DBM groups (Table 1; $p>.05$). In the ADIM group, TrA thickness on the paretic side ($p<.05$, ES=.34), TIS score ($p<.05$, ES=.20), and BBS score ($p<.05$, ES=.19) significantly improved compared with the pre-test values. In the DBM group, TrA thickness on the paretic side ($p<.05$, ES=1.00), TIS score ($p<.05$, ES=1.21), and BBS score ($p<.05$, ES=.41) significantly improved compared with the pre-test values. In both groups, post- and pre-test IO and EO thicknesses on the paretic side as well as TrA, IO, and EO thicknesses on the non-paretic side did not differ significantly ($p>.05$). TIS score improved significantly in the DBM group than in the ADIM group ($p<.05$, ES=1.63).

Discussion

The present study compared the training effects of 4-week ADIM versus DBM programs using real-time US imaging on TrA, IO, and EO thicknesses on the paretic and non-paretic side, TIS score, and BBS score in patients with chronic stroke. Both groups showed significantly increased post- versus pre-test TrA thicknesses on the paretic side, TIS score, and BBS score. The mean post-test TIS scores were significantly improved in the DBM group compared to the ADIM group. The findings of this study indicated that the use of DBM improved trunk control ability in patients with chronic stroke compared to the use of ADIM. Our outcomes partially supported our hypothesis.

TrA muscle thickness increased significantly in both groups (by 29.2 % and 14.8 % in the ADIM and DBM groups, respectively) after intervention compared to the baseline values. These results are consistent with those of previous studies. Seo et al. (2012) examined the effects of trunk stabilization exercise using ADIM on deep abdominal muscle thicknesses in patients with chronic stroke. The experimental groups (EG) received trunk stabilization with visual feedback using US imaging for 30 minutes five times a week for 5 weeks. Mean TrA muscle thickness on the paretic side increased by 18.13 % and 6.6 % in the EG and control group (CG), respectively. Bunn (2007) also demonstrated that real-time US feedback is more effective than biofeedback using a manometer in re-educating the muscles. They explained that using visual feedback can be a more efficient approach to teaching muscle contraction. In this study, real-time US was used to provide visual feedback for abdominal muscle contraction during ADIM training and diaphragm descending movements during DBM training. In the DBM group, we supposed that TrA thickness increased through synergistic co-activation of the diaphragm and TrA. In the ADIM group, TrA thickness increased through selective muscle contraction. Frank et al. (2013) explained that the TrA regulates internal abdominal pressure together with the diaphragm and pelvic floor muscles and provides anterior lumbopelvic postural stability. These intrinsic muscles provide spinal stiffness in coordination with intra-abdominal pressure, which serves to provide dynamic spinal stability (Frank et al, 2013). As a result, we believed that the trunk stabilization improved due to increased TrA thicknesses in both groups.

The TIS was used in the examination of trunk control ability in patients with chronic stroke. The TIS score increased significantly in both groups (by .60 points and 2.11 points in the ADIM and DBM groups, respectively) after intervention compared to baseline. In a between-group comparison, the DBM group showed a significantly increased TIS score compared to the ADIM group ($p<.05$). Verheyden et al. (2009) conducted traditional exercises on the CG and instructed the EG to participate in traditional exercise therapy as well as individual core exercises for 30 minutes four times a week over a period of 5 weeks. They found that the dynamic sitting balance

Table 2. Intervention changes by group (N=19)

Parameter		ADIM[a] (n_1=10)			DBM[b] (n_2=9)		
		Pre-test	Post-test	ES[c]	Pre-test	Post-test	ES
TrA[d] (㎜)	paretic	2.90±1.30[e]	3.33±1.24*	.34	2.02±.48	2.61±.69**	1.00
	non-paretic	3.08±.96	3.15±1.03	.07	2.27±.58	2.38±.46	.21
IO[f] (㎜)	paretic	5.79±1.66	5.93±1.52	.09	5.36±1.50	5.82±1.84	.28
	non-paretic	6.72±3.08	6.84±3.05	.04	6.41±1.72	5.63±1.87	.43
EO[g] (㎜)	paretic	3.55±1.17	3.42±.86	.13	2.86±1.13	3.03±.95	.16
	non-paretic	3.87±1.03	3.99±.87	.13	3.53±1.02	3.18±.65	.42
TIS[h] (score)		13.60±2.91	14.20±2.94*	.20	12.11±2.37	14.22±2.33**†	1.21
BBS[i] (score)		30.80±10.03	32.80±10.55**	.19	31.67±9.42	35.44±9.19*	.41

[a]abdominal drawing-in maneuver, [b]diaphragmatic breathing maneuver, [c]effect size, [d]transversus abdominis, [e]mean±standard deviation, [f]internal oblique muscle, [g]external oblique muscle, [h]trunk impairment scale, [i]Berg balance scale, *$p<.05$ and **$p<.01$ indicate a significant intragroup pre- versus post-test differences, † $p<.05$ indicates a significant intergroup difference in post-test means.

subscale of the TIS significantly increased in the EG ($p<.05$). Moreover, Yu and Park (2013) examined the effects of individual core exercises on muscle activity and TIS in patients with chronic stroke. The EG performed core strength exercises for 30 minutes five times a week for 4 weeks. The TIS score increased by 4.00 points and .50 point, respectively, in the EG and CG. They demonstrated that trunk control ability increased via activation of the core muscles such as the TrA, IO, and EO. Moreover, Hodges and Gandevia (2000) confirmed that diaphragm contraction is related to trunk control. They evaluated diaphragm activation during a repetitive postural task and demonstrated that its electromyographic activity increases with increasing task difficulty. Saunders et al. (2004) explained that a combination of tonic and phasic activities between the diaphragm and the TrA should be used when trunk stability is required. Thus, in this study, we supposed that the mean TIS score in the DBM group significantly increased compared to that in the ADIM group due to the increased contractions of the diaphragm.

The BBS was used to examine the balance ability of patients with chronic stroke (Blum and Korner-Bitensky, 2008). The BBS score increased significantly in both groups (by 3.78 points and 2.00 points in the DBM and ADIM groups, respectively) after intervention compared to the baseline values. Various studies suggested that trunk exercises for trunk stability help improve the balance ability required for standing and walking in patients with chronic stroke (Jijimol et al, 2013; Jung et al, 2014; Saeys et al, 2012). Saeys et al. (2012) reported that trunk stability was essential for coordinated limb movements and that trunk control training improved dynamic balance. Jung et al. (2014) demonstrated that improvements in trunk control affected dynamic balance, walking speed, and symmetrical trunk movement during gait in patients with chronic stroke. Accordingly, in this study, the balance ability significantly increased through a synchronous contraction between the diaphragm and the TrA and a selective contraction of the TrA muscle in the DBM and ADIM groups, respectively.

This study has several limitations. First, our findings may not be generalizable to all patients with stroke. Because the patients in our study had chronic stroke and mild to moderate physical impairment, they are not representative of all stroke patients. Second, no follow-up was performed, so the carry-over effect of ADIM and DBM could not be studied. Follow-up studies are needed to explain these effects. Third, in this study, we examined only three outcome measurements (muscle thickness, trunk control ability, and balance ability). It is insufficient to evaluate the functional improvements of patients with chronic stroke. Thus, future studies that include many patients and a follow-up period should compare the effectiveness of many conditions and exercises for improving various outcome measurements.

Conclusion

This study compared the 4-week training effects of ADIM versus DBM on TrA, IO, and EO thicknesses on the paretic and non-paretic side, TIS score, and BBS score in patients with chronic stroke. Our findings suggest that both ADIM and DBM training improve TrA thickness on the paretic side, TIS score, and BBS score. In conclusion, both ADIM and DBM training are necessary interventions for increasing TrA activation on the paretic side, trunk control ability, and balance ability in patients with chronic stroke. Additionally, DBM training would be more effective on trunk control ability than ADIM training in patients with chronic stroke.

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