J. Phys. Ther. Sci.
24: 181–185, 2012

The Effect of Trunk Stabilization Exercise on the Thickness of the Deep Abdominal Muscles and Balance in Patients with Chronic Stroke

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Abstract. [Purpose] This study investigated the effect of trunk stabilization exercises on the thickness of deep abdominal muscles and balance in chronic stroke patients. [Subjects] Twelve patients with chronic stroke were divided into 2 groups, an experimental group (EG) of 6 people and a control group (CG) of 6 people. [Methods] The 2 groups received routine physical therapy for 30 min, 5 times a week for 5 weeks. In addition, EG performed trunk stabilization exercises with visual feedback, using ultrasonic imaging, for 30 min. For the thickness of the deep abdominal muscles, the muscle thickness gap was measured with ultrasonic imaging. The Postural Assessment Scale for Stroke Patients (PASS) and Functional Reach Test (FRT) were also performed to assess balance ability. Muscles thickness gap, PASS, and FRT were measured before and after the intervention. [Results] Significant differences between the pre- and post-intervention values were observed for all variables in EG. A post-intervention comparison of the 2 groups revealed significant differences in all variables. The improvement rate for all variables was significantly higher in EG than in CG. [Conclusion] According to our results, trunk stabilization exercises showed effects in chronic stroke patients on both the deep abdominal muscle thickness and balance. The results support the idea that simultaneous application of routine physical therapy and trunk stabilization exercises can promote the recovery of chronic stroke patients and be helpful in rehabilitating them and improving their functional outcome.
Key words: Trunk stabilization exercises, Deep abdominal muscle, Balance

(This article was submitted Aug. 26, 2011, and was accepted Oct. 19, 2011)

INTRODUCTION

After a stroke, patients present with many difficulties with mobility, activities of daily living, communication, recognition, and gait[1, 2)]. Hemiplegic patients, in particular, show a decrease in the thickness of muscle fibers and the rate of motor unit firing, as well as shrinkage of the muscle fibers that result in weakness of the muscle[3)]. Therefore, the function of the trunk muscle is generally reduced[4)]. This damage to the trunk muscle affects the control and stability of the trunk, coordination of movement, and balance, as the muscular strength of the trunk muscles decreases more than normal[5)]. The decrease in balance reduces the stability of the trunk, as the center of the bodyweight moves from the non-paralyzed side, and therefore, the strength of the muscles of the lower limbs become asymmetrical and lean towards one side[6)].

Clinical studies looking at the balance and walking disability of hemiplegic patients have been considered important for a long time[7)]. Many therapists concentrate on improving walking ability with their treatment and aim at recovery of the upper limbs in of rehabilitation after stroke[8, 9)]. However, they have little interest in the recovery of the ability of trunk control[8)]. If we keep emphasizing the importance of treatment for the functions of the upper limbs and walking, the stability of trunk may be unintentionally developed indirectly; so it makes it difficult to recover stability of the trunk[9)]. Therefore, trunk stabilization exercises are being increasingly implemented for the development of trunk control, development of muscular strength of the trunk muscles, and symmetric contraction.

Trunk stabilization exercises are exercises which reinforce the deep stabilizer muscles, namely, the multifidus muscles and transversus abdominis muscles, and the superficial stabilizer muscles, namely, the erector spinae muscles and rectus abdominis, as well as coordinate contraction[10)]. Deep muscles play an important role in maintaining the stability of the trunk and postural control while doing whole body exercise with tonicity or positional muscles[11)]. Stabilization exercises train the spine to locate at a central area and maintain its position, so that it develops muscle strength, flexibility, and coordination. The central area is the location that is the most stable and has the least resistance for patients when they perform exercises[12)].

Table 1. General characteristic of subjects

	Experimental (n=6)	Control(n=6)
Sex (Male/Female)	5/1	5/1
Age (years)	59.8(12.8)	57.83(10.7)
Height (cm)	162.1(7.9)	163.44(9.4)
Weight (Kg)	62.6(11.2)	62.55(9.2)
Paralysis Side (left/right)	3/3	5/1
Type (ischemic/hemorrhage)	3/3	3/3
Duration (months)	7.33(4.63)	16.50(15.44)
MMSE-K (points)	27.50(1.52)	27.16(1.33)
FAC (points)	3.17(0.98)	3.50(1.22)

NOTE. Values are frequency or mean (SD), Abbreviation: MMSE-K; Korean version of the mini-mental state examination, FAC; functional ambulation category

Many studies have shown that various methods such as isokinetic muscle testing, manual dynamometer, electromyogram (EMG) analysis, transcranial magnetic stimulation, computed tomography, and motion analysis can be used to evaluate trunk function ability after stroke[13]. Sonography analyzes the change in muscle by using a sonogram after exercise and is used as an objective tool[16, 17]. Visual feedback training using a few sonogram is effective for educating patients and visualzing the effects of exercise methods[14]. However, few sonographic studies have examined stroke patients.

Therefore, this study investigate the effect of trunk stabilization exercises on the thickness of deep abdominal muscles and the effectiveness of this change in the thickness of the deep abdominal muscles on balance.

SUBJECTS AND METHODS

The subjects of this study were 40 patients with chronic stroke admitted to H hospital, Daejeon City, Seventeen were selected using specific criteria. These patients were divided into an experimental group of 9 patients and a control group of 8 patients. The relevant inclusion criteria consisted of the following: agreement to participate in the study, within 6 months from the onset of stroke, no complaints of chronic back pain or current back pain, and the ability to follow directions given by therapists (MMSE-K over 24 points)[15]. Three patients in the experimental group and 1 patient in the control group did not complete the study, and 1 patient in the control group also failed to fully participate after sustaining an above-knee fracture during the study period. There were no significant differences in the age, height, weight, days since stroke onset, and MMSE-K between the experimental and control groups ($p>0.05$)(Table 1).

The sonograph used in this study was the Logiqsonography system (α-200; Samsung-GE Medical Systems Inc., Seongnam, Korea) which uses a 7.5-MHz linear transducer. It was used to measure the thicknesses of the transversus abdominis (TrA), internal oblique (IO), and external oblique (EO) muscles on the unaffected and affected sides during abdominal hollowing exercises (AHE). We explained about AHE for 5 min before the measurement, and patients were asked to remain in a position that decreases lumbar lordosis by bending the hip joint and the knee joint to 40–80 degrees while in the supine position[16]. During AHE, the lower abdomen was pulled up, and the coccyx pulled up and sustained for 5 s during expiration. The patients practiced AHE 3 times using the sonographic M-mode, and were allowed to rest for 1 min after 1 practice. After putting sonographic gel on the transducer head, it was placed about 25 mm inside the line between the 12th costal bone and the iliac crest, and measurements were taken[17]. Measurements were taken during contraction and repeated 3 times. We let the patients rest for 1 min after each measurement. The thickness of the muscles after sonographic measurement was measured in the following order, TrA, IO, and EO. A vertical line was drawn from a marked point after drawing a horizontal line 1.5 cm away from the end of the left/right side part (the muscle-fascia junction)[18]. The sonographic measurements of normal subjects are highly reliable[17].

One sonographer measured the TrA, IO, and EO of the 12 patients on both the unaffected and affected sides and this was done 3 times before and after intervention to ensure accuracy. The results exhibited very high repeatability with ICCs ranging from =0.92 to 0.99.

Balance abilities of static balance and dynamic balance were assessed. Static balance was evaluated with the Postural Assessment Scale for Stroke Patients (PASS). This assesses postural control ability and comprises 12 items concerned with posture maintenance and change. It assesses the static balance ability of stroke patients. Each item is given a score from 0–3 points, and the maximum score is 36 points. The inter-rater and intra-rater reliabilities of PASS have ICCs of $r=0.99$ and $r=0.98$[19], respectively.

Dynamic balance was assessed with the Functional Reach Test (FRT). This test assesses dynamic balance ability as the maximum possible distance that can be reached horizontally when reaching with the arm while keeping the basal area intact in a standing position. It is simple to measure. This test was developed to examine the change of balance function ability with time. The inter-rater and intra-rater reliabilities of FRT have ICCs of $r=0.99$ and $r=0.95$[20], respectively.

Subjects were randomly assigned to the experimental group (EG) and the control group (CG) in this study. Both experimental and control groups received conservative physiotherapy: and EG additionally performed trunk stabilization

Table 2. Change of muscle pre and post experiment in affected and sound side

Measures		Values				Rate of Change Values(%)	
		Experimental (n=6)		Control (n=6)		Experimental (n=6)	Control (n=6)
		Pretest	Posttest	Pretest	Posttest	Post-Pre	Post-Pre
TrA(P) (cm)	R	0.26(0.05)	0.34(0.05) *	0.30(0.11)	0.32(0.09)	32.67(17.10)	8.13(10.68) †
	C	0.39(0.10)	0.46(0.10) *	0.41(0.10)	0.43(0.11)	18.13(11.62)	4.08(4.62) †
TrA(NP) (cm)	R	0.29(0.06)	0.39(0.06) *	0.33(0.07)	0.36(0.06)	39.37(24.99)	8.13(10.68) †
	C	0.44(0.10)	0.51(0.10) *	0.46(0.08)	0.47(0.09)	15.26(9.63)	2.69(2.71) †
IO(P) (cm)	R	0.57(0.16)	0.71(0.05) *	0.56(0.25)	0.59(0.24) *	26.81(15.22)	5.27(4.30) †
	C	0.70(0.18)	0.83(0.16) *	0.71(0.22)	0.72(0.20)	22.24(25.98)	2.33(5.72) †
IO(NP) (cm)	R	0.66(0.20)	0.83(0.20) *	0.59(0.14)	0.64(0.15) *	28.63(11.56)	8.28(6.21) †
	C	0.70(0.10)	0.93(0.21) *	0.81(0.17)	0.82(0.17)	14.47(9.08)	0.36(0.73) †
EO(P) (cm)	R	0.38(0.99)	0.45(0.11) *	0.32(0.06)	0.35(0.08)	20.80(24.13)	7.69(8.16)
	C	0.39(0.10)	0.41(0.09)	0.39(0.09)	0.38(0.09)	5.91(10.40)	0.90(2.20)
EO(NP) (cm)	R	0.39(0.09)	0.45(0.10) *	0.37(0.09)	0.40(0.09)	18.10(19.99)	9.46(8.55)
	C	0.40(0.09)	0.44(0.09)	0.41(0.07)	0.42(0.08)	12.10(14.17)	1.76(3.95)

NOTE. Values are mean(SD). Abbreviation: TrA; transverse abdominal muscle, IO; internal oblique muscle, EO; external oblique muscle P; paretic side, NP; non-paretic side, R; rest, C; contracted, Post-Pre; post-intervention – pre-intervention. * Significant difference in within-group comparison. † Significant difference in between-group comparison.

exercises using sonographic visual feedback for 30 min. Conservative physiotherapy consisted of posture control training, walking training, and muscle strength exercises, and was conducted to maximize activities of daily living and to develop function[21]. The intervention was conducted 5 times a week, for 5 weeks for a total of 25 times. In the first week, we educated patients about trunk stabilization exercise methods, AHE, trunk side flexion (TIF), and resisted trunk rotation (RTR) methods using real-time ultrasound feedback; this was done 5 times in the week. These 3 exercises were conducted without real-time ultrasound feedback during the second to fifth week for 4 weeks.

We used real-time ultrasound feedback methods to re-educate muscles in the intervention in the first week. Education methods that use real-time ultrasound feedback are used to re-educate muscles by giving visual information about the change in the contraction of the muscles in real time to the patients through a monitor[14]. The sonographic M-mode can display changes of muscles on a monitor in real time, similar to an electromyogram signal, so it is easy to give patients visual information. Muscle re-education using real-time ultrasound feedback lasted 5–10 s for each exercise and was repeated for 3 sets, so that patients could learn the exact posture and paralyzed muscle contraction. Trunk stabilization exercises that are composed of AHE[22], TIF [25, 26], and RTR[23] were conducted 5 times a week, a total of 20 times.

The data that was collected in this study were analyzed statistically using SPSS version 12.0 for Windows. The Mann-Whitney U test was used to compare results between EG and CG. The intraclass correlation coefficient was used to investigate intra-rater reliability, and the Wilcoxon signed rank test was used to compare the effectiveness of the intervention in each group. The statistical level of significance was chosen as p=0.05.

RESULTS

The muscular thicknesses of the affected and unaffected sides before and after the experiment are shown in Table 2. TrA, IO, and EO thickness changes of the affected side were measured. There was a significant difference at both rest and contraction of TrA in EG between before and after the intervention (p<0.05). There was also a significant difference between the 2 groups in the change rate (p<0.05). There was a significant difference at both rest and contraction of IO in EG between before and after the intervention (p<0.05), but only at rest time in CG (p<0.05). There was also a significant difference between the 2 groups in change rate (p<0.05). There was a significant difference only at rest of the EO in EG between before and after the intervention (p<0.05).

TrA, IO, and EO thickness changes on the unaffected side were measured. There was a significant difference at both rest and contraction of TrA in EG between before and after the intervention (p<0.05). There was also a significant difference between the 2 groups in the change rate (p<0.05). There was intervention a significant difference at both rest and contraction of IO in EG between before and after the intervention (p<0.05), but only at rest time CG (p<0.05). There was also a significant difference between the 2 groups in the change rate (p<0.05). There was a significant difference only at rest of EO in EG between before and after the intervention (p<0.05).

The results for PASS and FRT before and after the experiment are shown in Table 3. There were statistically improvement after the intervention in both groups (p<0.05), and there were a statistically significant differences in the change rates of both groups (p<0.05).

Table 3. Compare of the PASS and FRT for stroke patients on experiment and control group

Measures	Values				Rate of Change Values(%)	
	Experimental (n=6)		Control (n=6)		Experimental (n=6)	Control (n=6)
	Pretest	Posttest	Pretest	Posttest	Post-Pre	Post-Pre
PASS (point)	27.50 (4.59)	32.67 (2.80)*	31.00 (2.28)	32.50 (1.87)*	20.32 (11.50)	4.95 (2.74) †
FRT (cm)	9.49 (3.66)	15.34 (4.63)*	8.63 (6.07)	10.44 (6.77)*	69.17 (26.69)	24.94 (16.77) †

NOTE. Values are mean(SD). Abbreviation: PASS; postural assessment scale for stroke patients , FRT; functional reach test, Post-Pre; post-intervention–pre-intervention. * Significant difference in within-group comparison. †Significant difference in between-group comparison.

DISCUSSION

Hemiplegic patients generally lose function of the trunk muscles leading to weakness of trunk muscle strength, so their trunk control ability decreases, and this affects trunk balance ability[9]. Therefore, the importance of trunk control in hemiplegic patients has been emphasized in recent studies[24].

Michael and Andre (2002)[25] reported that stabilization exercises using a Swiss ball can reinforce deep abdominal muscles of the trunk. Felipe et al. (2008)[26] reported that trunk stabilization exercises improved dynamic balance. Ryerson et al. (2008)[9] reported that trunk stabilization recovery exercises should also be a focus of rehabilitation also and can help quicken the return to social life. Dickstein et al.(1999)[27] reported that stroke patients could perform high steps when the trunk was symmetrically contracted.

This study focused on TrA, IO, and EO as they are trunk stabilization muscles. These muscles play an important role in trunk stabilization as well as postural control, and TrA has the biggest role in this system, being an important factor in lumbar stabilization[28]. TrA increase the abdominal internal pressure with the IO. TrA first contracts the lumbar region, followed by the IO and EO. Thus, TrA has an important role in promoting trunk stabilization when moving the extremities or trunk[29]. Accordingly, this study selected and used exercise methods that promote TrA.

Trunk stabilization exercises for stroke patients using biofeedback provided by manometer equipment have recently been reported[23]. However, exercise using biofeedback manometer equipment has been reported to be low on validity and reliability[30], whereas methods using ultrasound have been reported to be reliable[14]. Trunk stabilization exercises can be carried out using surface electromyogram biofeedback, but it is hard to exactly distinguish the signal, as the electrode placements for TrA and IO overlap in AHE. Therefore, it has limited use. Real-time ultrasound image, namely, measurement using the M-mode of sonography is effective at displaying the thickness changes of the muscles on a monitor in real time, like an EMG[18]. For this reason, Anderson et al. (2007)[14] reported that a real-time ultrasound feedback group better understood exercise methods than a biofeedback group. In other words, real-time ultrasound feedback is more effective than methods that used biofeedback provided by a manometer in re-education of the muscle. This study used real-time ultrasound feedback for the purpose of education in trunk stabilization exercises for this reason.

This study measured the thickness of muscles using sonography and balance in the EG and CG before and after the intervention. Concentrating on the results of measurement of thickness using sonography, there was a significant difference in TrA of EG at rest and contraction the affected and unaffected sides between before and after the intervention ($p<0.05$). The change rate of EG was significantly greater than that of CG ($p<0.05$). This shows that the thickness of the TrA can increase only after trunk stabilization exercises are conducted. There was a significant difference in IO of both EG and CG on the affected and unaffected sides at rest between before and after the intervention ($p<0.05$), but change rate of EG was significantly greater than that of CG ($p<0.05$). There was a significant difference IO of EG on the affected and unaffected sides the contraction between before and after the intervention ($p<0.05$), but not in CG ($p>0.05$). The change rate of EG was more significantly greater than that of CG ($p<0.05$). This shows that trunk stabilization exercises and general physical therapy are both effective for the enhancement of the thickness of IO, but trunk stabilization exercises are more effective.

Balance was assessed as static balance, PASS, and dynamic balance, FRT, in this study. There were significant improvements in the PASS results obtained for both the EG and CG after the intervention ($p<0.05$). However, the change rate of EG was significantly more than that of CG ($p<0.05$). This shows that trunk stabilization exercises are more effective for static balance recovery than general physical therapy. In addition, there were significant improvements in both EG and CG in dynamic balance (FRT) after the intervention ($p<0.05$). However, the change rate of EG was significantly more than that of CG ($p<0.05$). This shows that the trunk stabilization exercise is also more effective for dynamic balance recovery than general physical therapy. Sin (2009)[23] had 38 patients with stroke perform trunk stabilization exercises, 3 times a week for 7 weeks, and as a result, the trunk stabilization exercise group showed more significant improvements in dynamic balance ability as measured by the, Berg balance scale and TUG than the posture control training group ($p<0.05$). In this study we report broadly similar results, and this indicates that our intervention was effective for balance recovery. The intervention was based on the fact that deep abdominal muscles that are recovered by trunk stabilization exercise contract first before moving the extremities, and that this functions as a stabilization muscle so that trunk stabilization develops and helps balance development[22].

A limitation of this study is that only a small number of patients were studied, so it is hard to generalize the results. In addition, long-term effects were not studied as this study lasted only 5 weeks and further studies will be needed to address this. Long-term studies that include follow-up and involve many patients with comparative studies of trunk stabilization exercises and other exercises are needed.

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