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Original Article

Effects of trunk stabilization exercises on balance, functionality and abdominal muscle thickness in hemiplegic patients

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ABSTRACT

Objectives: This study aims to investigate the effects of trunk stabilization exercises (TSEs) in addition to conventional exercises in patients with stroke on balance, functionality and abdominal muscle thickness as measured by ultrasonography (USG) and to compare the patients' non-paretic side abdominal muscle thickness with healthy population.

Patients and methods: Between April 2019 and June 2019, a total of 26 hemiparesis/hemiplegic patients with stroke (15 males, 11 females; mean age: 62.3±7.8 years; range, 52 to 71 years) confirmed by neurological examination or computed tomography (CT) / magnetic resonance imaging (MRI) and 20 age-matched healthy volunteers (12 males, 8 females; mean age: 62.3±7.2 years; range, 53 to 70 years) were included in the study. The patients were randomized into two groups. In the first group (n=13), TSE were performed in addition to conventional neurorehabilitation program, five times/week for a total of four weeks. The second group (n=13) was given conventional neurorehabilitation program, five times/week for a total of four weeks. Also, healthy volunteers as the third group were compared with the patient population. The evaluations were made at the beginning and end of the treatment. The Berg Balance Scale (BBS), Barthel Index (BI), Postural Assessment Scale for Stroke Patients (PASS), and Functional Reach Test (FRT) were used. Abdominal muscle thickness at rest and contraction were evaluated using USG.

Results: Ten patients in Group 1 and 10 patients in Group 2 completed study. A significant improvement was observed in all abdominal muscles in both groups ($p<0.05$), indicating no significant difference between the groups ($p>0.05$). There was a statistically significant improvement for BBS and FRT in both groups. The PASS and BI scores showed a significant improvement only in TSE group.

Conclusion: Both the TSE and conventional neurorehabilitation program provided significant improvements in abdominal muscle thickness, balance and trunk control. For postural control and functionality, additional TSE seems to be more effective.

Keywords: Abdominal muscle, hemiplegia, trunk stabilization, ultrasonography.

Cerebrovascular accident (CVA) is the most common neurological disease in the world. In addition, it is ranked third among the causes of death after coronary artery disease and cancer all over the world and second among the causes of disability.[1] The most common finding in stroke is hemiplegia or hemiparesis depending on the severity of cellular damage caused by ischemia or hemorrhage.[2]

The main goal of rehabilitation programs after CVA is to facilitate daily living activities, improve functions, prevent complications, and improve the quality of life of the individual. Balance is a complex situation involving the planning of the movement by detecting external stimuli in order to protect the perpendicular posture of the individual. It is the basis of all functional activities performed during the day. Sitting balance has been reported as an indicator of post-stroke motor and functional improvement.[3] Trunk balance is also an early predictor of the post-stroke daily activities.[4] A decrease in balance, stability, and postural control ability may be observed in stroke patients as a result of weakness in trunk muscles and loss of proprioception.[5] It has been shown in many studies that exercises increasing trunk balance increase functionality, balance, and mobility. It has also been

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shown that trunk stabilization exercises (TSEs) can also provide benefit by stimulating proprioceptors in muscles and joints responsible for maintaining posture.[6]

Recently, with the widespread use of ultrasonographic (USG) imaging, it has become quite easy to identify changes in muscle thickness and morphology. This imaging method allows us to compare the effectiveness of different exercise methods in the field of rehabilitation.

Although there are studies in the literature examining the effect of TSEs on abdominal muscle thickness and balance, functionality, and postural control in stroke rehabilitation, there are few studies in which all these evaluations are performed together. In the present study, we aimed to evaluate the effect of TSEs on abdominal muscle thickness evaluated as balance, functionality, and USG in stroke patients.

PATIENTS AND METHODS

This double-blind, randomized-controlled study was conducted at the Physical Medicine and Rehabilitation (PMR) outpatient of University of Health Sciences, Haydarpaşa Numune Training and Research Hospital, between April 2019 and June 2019. A total of 26 hemiparesis/hemiplegic patients with stroke (15 males, 11 females; mean age: 62.3±7.8 years; range, 52 to 71 years) confirmed by neurological examination or computed tomography (CT) / magnetic resonance imaging (MRI) and 20 age-matched healthy volunteers (12 males, 8 females; mean age: 62.3±7.2 years; range, 53 to 70 years) were included in the study.

Inclusion criteria were as follows: the confirmation of the first stroke attack by neurological examination and CT/MRI, having ≥3 months passed after the stroke, being at an age between 18 and 75 years, being able to take verbal instructions, having no cognitive deficit (Mini Mental Status Scale score ≥25), having Modified Ashworth Scale in upper and lower extremity muscles between 0-3, Brunnstrom Stage ≥3 for upper and lower extremities, and having stable medical condition. Exclusion criteria were acute or chronic low back pain, history of lumbar and/or abdominal operation, history of previously known brain lesion, known neurological disease other than stroke, and body mass index (BMI) of ≥30 kg/m^2. In addition, participants were excluded, if patients disrupted the exercise program or if any of the conditions shown among the exclusion criteria emerged during the study.

Power analysis was performed to determine the minimum number of patients to be included in the study. As a result of the power analysis performed with the G*Power version 3.1.9.2 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) by basing on the statistical comparison results given in the reference publication, when the effect size (d) for the percentage change in the transversus abdominis (TrA) parameter was taken as 1.589 and standard deviation (SD) was taken as 11.6, the number of samples determined for power=0.80 and α=0.05 was as a minimum n=8 for each subgroup. Considering dropouts, 13 patients were planned to be included in each group. Furthermore, 20 healthy individuals that were matched by age and sex were included in the study to compare abdominal muscle thickness within the patient population.

The patients were randomly divided into two groups. Randomization was performed by the closed envelope method. In addition to conventional neurophysiological exercises, trunk stabilization exercises were applied to the first group and conventional neurophysiological exercises were applied to the second group.

Prior to treatment, all patients were informed in detail on the treatments. The patients who participated in the study were asked to continue their normal daily lives without any changes or arrangements regarding medication use and activities of daily living. In addition to demographic data such as age, sex, profession, educational status, BMI, hemiplegic side, dominant side, stroke type, time since stroke, spasticity stages according to the Modified Ashworth Scale, Brunnstrom Motor Recovery Stage values and additional diseases were recorded.

Three patients from each group were excluded from the study. One patient in the first group experienced intracranial hemorrhage and two patients discontinued treatment; three patients in the second group did not participate in their post-treatment evaluations. No treatment-related side effects were observed in any patients. The study flowchart is shown in Figure 1.

Procedure

Group 1: In addition to conventional neurophysiological exercises, TSEs were applied for five days/week for a total of four weeks, 5 repetitions/sets for a total of 3 sets. These exercises were performed under the guidance of a

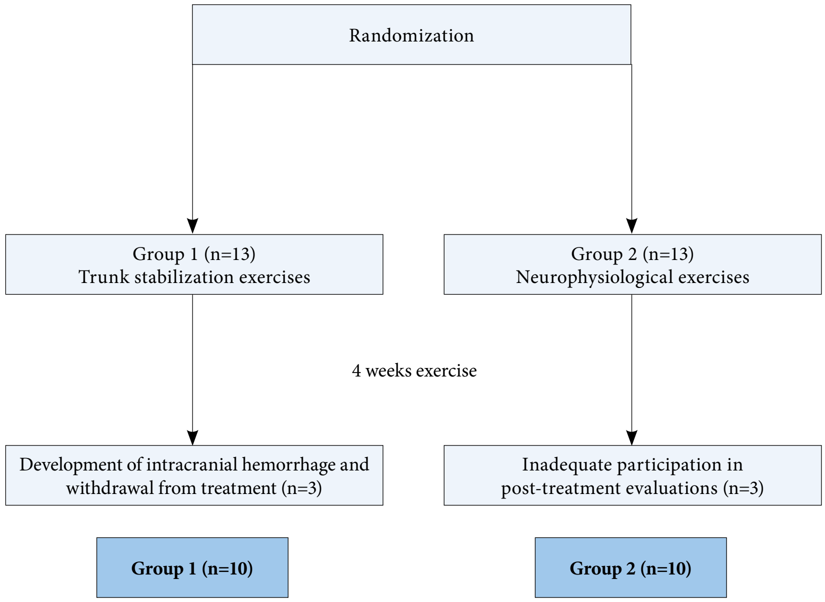

Figure 1. Study flowchart.

physiotherapist in the form of flexor trunk exercises in the supine position, extensor trunk exercises in the sitting position, anterior and posterior pelvic tilt exercises while sitting on the Bobath ball.

Group 2: As conventional exercises, neurophysiological exercises such as stretching/passive mobilization and range of motion exercises for the hemiparetic side, posture control training, walking training, strengthening exercises, functional exercises to facilitate the activities of daily living, occupational therapy were applied under the guidance of a physiotherapist for a total of four weeks with a frequency of five days a week.

Methods of evaluation

The first measurements were made on the first day of the study and the second measurements were made at the end of four weeks of treatment.

1. Evaluation of muscle thickness by USG: The USG measurements were performed by a PMR specialist experienced in musculoskeletal USG before and at the end of treatment by using Mindray DC-T6 USG device (China) 5-10 MHz linear probe. The PMR specialist who performed the evaluation was blind to the groups.

During the evaluation, two pillows were placed under the knees of the participants and the hips were at 45° flexion and the knees were at 20° flexion in the supine position. At rest, measurements to minimize the effect of breathing on lateral abdominal muscle thickness were recorded at the end of a challenging expiration following a deep inspiration. In this way, at rest muscle thickness of rectus abdominis (RA), externus obliquus (EO), internus obliquus (IO), and TrA were evaluated on both sides. For RA, the probe was placed longitudinally 3 cm above the umbilicus and 3 cm away from the midline. For EO, IO, and TrA, the image was taken from the midpoint of the line connecting the inferior angle of the last rib with the iliac crystal, and the probe was positioned perpendicular to these muscles. The same measurements were repeated, while the patient was performing the abdominal retraction maneuver for contracted measurements. This maneuver pulls the patient's abdomen towards their spine, allowing the lower abdominal wall to move in. It has been shown to be the most effective maneuver in activating abdominal muscles.[7]

This distance was recorded by drawing a perpendicular calliper between the hyperechogenic fascia lines during the measurement (Figure 2a, b). Each measurement was repeated twice and the mean of these values was taken.

2. Evaluation of balance: Berg Balance Scale (BDS) was used to evaluate the balance skills of the participants. In this scale, where 14 items including tasks requiring balance such as sitting, standing, leaning, stepping are evaluated, the scoring is made over five points according to whether the individual can do the task independently or against time. The score of 0 is rated as inability to perform the task, the score of 4 is rated as safe, independent performance,

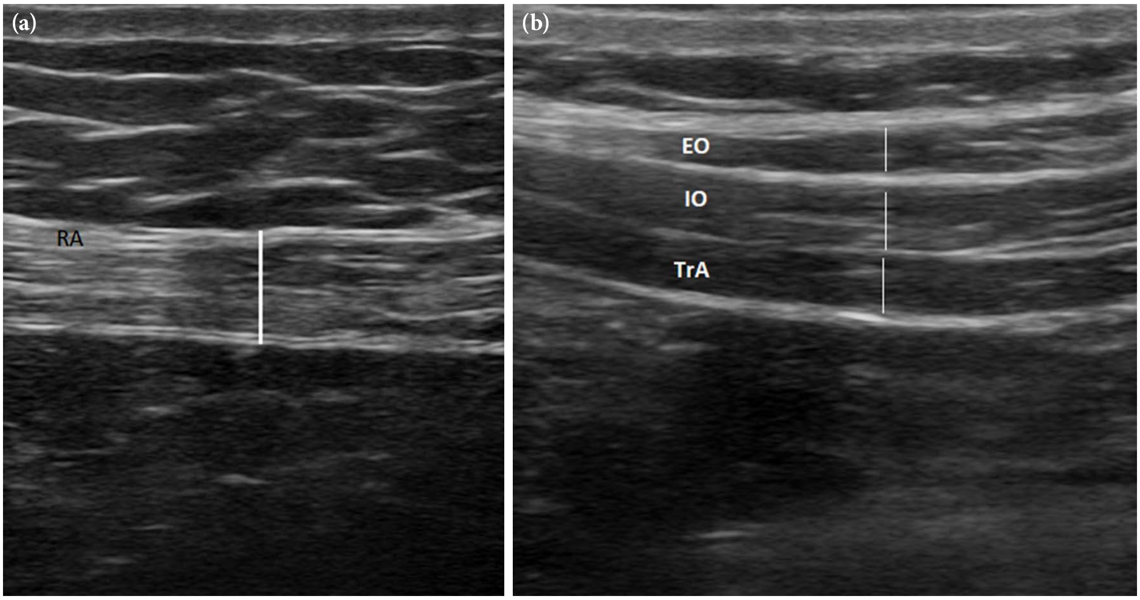

Figure 2. **(a, b)** Ultrasonographic image of abdominal muscles. The vertical distance between hyperechogenic fascia lines was recorded for muscle thickness.

RA: Rectus abdominis; EO: Externus obliquus; IO: Internus obliquus; TrA: Transversus abdominis.

and the total score is calculated between 0 and 56. The Turkish validity and reliability study of the Berg balance scale was conducted.[8]

3. *Functional level measurement:* Barthel Index (BI) was used to evaluate the functional level. The BI mainly contains 10 sections evaluating mobility and self-care activities. It evaluates nutrition, transfer, self-care, toilet use, bathroom, movement, wheelchair use (if applicable), stair climbing, dressing, bowel and bladder control. The total score is between 0-100. The validity and reliability study was conducted in the Turkish population.[9]

4. *Evaluation of postural control:* Postural Assessment Scale for Stroke Patients (PASS) was used. The PASS is a special scale that can be used to measure balance even in stroke patients with very low physical performance. Verification and standardization were performed by Benaim et al.[10] It contains 12 items that measure the individual's balance performance when the degree of difficulty is different; i.e., while lying down, sitting, standing, or changing position while standing. The scale is applied under two main headings: maintaining the posture and changing the posture. The feasibility of movement between 0-3 is tested; "0" is the lowest value; "3" is the highest value. The scale is evaluated between 0-36.

5. *Evaluation of trunk control:* Modified Functional Resting Test (FRT) was used.[11] In this test, while the patient is sitting upright, they hold their arm on the unaffected side close to the wall but not touching the wall by making a fist with their shoulder at 90° flexion and elbow fully extended. In this position, the patient is asked to reach the farthest point where they can reach without taking a step. At the beginning and end of the test, the difference between the measurements made at the level of the third metacarpals is recorded. After three attempts, the two best results are averaged. All evaluations were performed before and after treatment.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). The suitability of the parameters for normal distribution was evaluated with the Shapiro-Wilk test. Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. One-way analysis of variance (ANOVA) was used to compare the normally distributed parameters between the groups and the Tukey's honest significant difference (HDS) test was used to determine the group causing the difference. The Student t-test was used for the comparison of normally distributed parameters between the two groups, and Mann Whitney U test was used for the comparison of non-normally distributed parameters between the two groups. Paired sample test was used for intra-group comparisons of normally distributed quantitative data and Wilcoxon signed-rank test was used for intra-group comparisons of non-normally distributed parameters. The chi-square test, Fisher exact test, Fisher-Freeman-Halton test, and Yates continuity correction were used to compare qualitative data. A *p* value of <0.05 was considered statistically significant.

RESULTS

The patients were examined under three groups: 10 patients (25%) in Group 1, 10 patients (25%) in Group 2, and 20 healthy individuals (50%) in Group 3. There were no statistically significant differences among all three groups in terms of age, sex, BMI, profession, educational status, and dominant side (p>0.05). There was no statistically significant difference between Group 1 and Group 2 in terms of time since stroke, hemiplegic side, and stroke types (p>0.05) (Table 1).

Comparison of pre-treatment hemiplegic and intact side USG muscle measurements in Group 1 and Group 2

In both groups, at rest and contraction USG measurement values of intact side RA, TrA, OI, and EO muscles were found to be statistically significantly higher than hemiplegic side values (p<0.05).

Comparison of post-treatment hemiplegic and intact side USG muscle measurements in Group 1 and Group 2.

In Group 1, only the intact side was found to be statistically significantly higher than the hemiplegic side in the contracted thickness of EO (p=0.002; p<0.05). There was no statistically significant difference between intact and hemiplegic sides in at rest and contraction measurement values of all muscle groups evaluated in Group 2 (p>0.05).

Comparison of pre-treatment and post-treatment intra-group and inter-group USG data

The RA, TrA, IO and EO at rest and contraction muscle thicknesses of Group 1 and Group 2 increased

TABLE 1
Baseline demographic and clinical characteristics of participants

	Group 1			Group 2			Group 3			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			61.9±7.4			62.7±8.2			61±7.2	0.837[1]
Body mass index (kg/m^2)			25.5±3.4			26.6±2.0			26.1±2.2	0.624[1]
Stroke duration (days)			343±285.8			342.5±297.1			-	0.997[2]
Sex										1.000[3]
Female	4	40		4	40		8	40		
Male	6	60		6	60		12	60		
Profession										0.721[4]
Housewife	3	30		4	40		6	30		
Retired	3	30		4	40		10	50		
Working	4	40		2	20		4	20		
Education status										0.589[4]
Primary education	7	70		6	60		9	45		
Secondary education	3	30		3	30		10	50		
University	0	0		1	10		1	5		
Hemiplegic side										1.000[5]
Right	4	40		5	50		-	-		
Left	6	60		5	50		-	-		
Dominant side										0.274[3]
Right	10	100		9	90		15	75		
Left	0	0		1	10		5	25		
Stroke type										1.000[5]
Ischemic	10	100		9	90		-	-		
Hemorrhagic	0	0		1	10		-	-		

SD: Standard deviation; [1] One-way ANOVA test; [2] Student t test; [3] Fisher Freeman Halton test; [4] Chi-square test; [5] Fisher exact test.

TABLE 2
Evaluation of pre-treatment and post-treatment at rest muscle thickness of inter- and intra-group

		Group 1			Group 2			Group 3	
		Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	*p*
RA muscle	Non-hemiplegic side								
	Pre-treatment	8.11±1.42			9.1±1.44			10.03±1.83	**0.016*[1a]**
	Post-treatment	9.54±1.89			10.06±1.57				**0.5[1b]**
	PRE-POST *p*[2]		**<0.001***			**0.002***			
	Pre-post difference		1.55	0.5-2.5		0.95	0.2-2.2	-	0.37[3]
	Hemiplegic side								
	Pre-treatment	7.23±1.38			7.72±1.61			9.73±1.58	**<0.001*[1a]**
	Post-treatment	8.53±1.35			8.75±1.39				**0.723[1b]**
	PRE-POST *p*[2]		**<0.001***			**0.005***			
	Pre-post difference		1.15	0.4-2.3		0.6	0.1-2.6	-	0.824[3]
TrA muscle	Non-hemiplegic side								
	Pre-treatment	5.28±1.08			5.21±1.16			5.68±0.99	**0.430[1a]**
	Post-treatment	6.49±0.96			6.07±1.3				**0.422[1b]**
	PRE-POST *p*[2]		**<0.001***			**0.002***			
	Pre-post difference		1.25	0.7-1.9		0.75	0.1-1.9	-	0.503[3]
	Hemiplegic side								
	Pre-treatment	4.24±1.01			4.43±1.23			5.42±0.9	**0.007*[1a]**
	Post-treatment	5.71±1.2			5.23±1.19				**0.381[1b]**
	PRE-POST *p*[2]		**<0.001***			**<0.001***			
	Pre-post difference		1.15	0.9-2.9		0.7	0.5-1.2	-	**0.016*[3]**
IO muscle	Non-hemiplegic side								
	Pre-treatment	5.72±0.88			6.08±1.34			6.41±0.97	**0.244[1a]**
	Post-treatment	6.78±0.88			7±1.58				**0.705[1b]**
	PRE-POST *p*[2]		<0.001*			<0.001*			
	Pre-post difference		1.05	0.6-1.8		0.85	0.4-1.9	-	0.882[3]
	Hemiplegic side								
	Pre-treatment	4.74±0.76			5.35±1.24			6.11±0.91	**0.003*[1a]**
	Post-treatment	5.63±0.99			6.03±1.46				**0.483[1b]**
	PRE-POST *p*[2]		**<0.001***			**0.001***			
	Pre-post difference		0.85	0.3-1.8		0.55	0.3-1.6	-	0.23[3]
EO muscle	Non-hemiplegic side								
	Pre-treatment	6.11±0.94			6.73±1.23			6.54±1.34	**0.513[1a]**
	Post-treatment	7.15±1.1			7.66±1.44				**0.385[1b]**
	PRE-POST *p*[2]		**<0.001***			**0.001***			
	Pre-post difference		1.1	0.3-1.7		0.85	0.1-2.3	-	0.370[3]
	Hemiplegic side								
	Pre-treatment	5.28±1.06			5.67±1.32			6.14±1.14	**0.168[1a]**
	Post-treatment	6.28±1.13			6.58±1.35				**0.596[1b]**
	PRE-POST *p*[2]		**0.001***			**<0.001***			
	Pre-post difference		1.05	0.1-2		0.75	0.3-2	-	0.824[3]

SD: Standard deviation; PRE: Pre-treatment; POST: Post-treatment; RA: Rectus abdominis; TrA: Transversus abdominis; IO:Internus obliquus; EO: Externus obliquus; [1a] One way ANOVA test; [1b] Student t test; [2] Paired samples t test; * p<0.05; [3]Mann-Whitney U test (Group 1 & 2)

TABLE 3
Evaluation of pre-treatment and post-treatment contraction muscle thickness of inter- and intra-groups

		Group 1			Group 2			Group 3	
		Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	*p*
RA muscle	Non-hemiplegic side								
	Pre-treatment	8.65±1.6			9.79±1.32			10.75±1.84	**0.009*[1a]**
	Post-treatment	10.26±1.98			11.07±1.38				**0.302[1b]**
	Pre-Post *p*[2]		**<0.001***			**0.001***			
	Pre-post difference		1.4	0.6-2.7		1.2	0.2-2.7	-	0.824[3]
	Hemiplegic side								
	Pre-treatment	7.72±1.44			8.21±1.34			10.28±1.62	**<0.001*[1a]**
	Post-treatment	9.55±1.7			9.47±1.05				**0.901[1b]**
	Pre-Post *p*[2]		**<0.001***			**<0.001***			
	Pre-post difference		2.05	1.1-2.3		1.2	0.5-2.2	-	0.046*[3]
TrA muscle	Non-hemiplegic side								
	Pre-treatment	6.28±1			6.17±1.33			6.57±0.88	**0.563[1a]**
	Post-treatment	7.46±1.62			6.72±1.36				**0.282[1b]**
	Pre-Post *p*[2]		**0.005***			**0.043***			
	Pre-post difference		0.7	0.4-3.5		0.65	0.2-1.5	-	0.201[3]
	Hemiplegic side								
	Pre-treatment	5.23±1.1			4.9±1.31			6.24±0.91	**0.004*[1a]**
	Post-treatment	6.69±1.8			5.84±1.25				**0.236[1b]**
	Pre-Post *p*[2]		**0.003***			**<0.001***			
	Pre-post difference		1.3	0.1-3.3		0.85	0.4-1.6	-	**0.331[3]**
IO muscle	Non-hemiplegic side								
	Pre-treatment	6.48±1.01			6.85±1.44			6.98±1.03	**0.532[1a]**
	Post-treatment	7.85±1.01			7.76±1.47				**0.875[1b]**
	Pre-Post *p*[2]		<0.001*			0.002*			
	Pre-post difference		1.4	0.3-2.6		0.8	0.3-2.5	-	0.201[3]
	Hemiplegic side								
	Pre-treatment	5.35±0.82			5.86±1.36			6.77±0.92	**0.003*[1a]**
	Post-treatment	6.54±1.13			6.6±1.72				**0.927[1b]**
	Pre-Post *p*[2]		**<0.001***			**0.016***			
	Pre-post difference		1.05	0.2-2.4		0.7	0.1-2.5	-	0.8[3]
EO muscle	Non-hemiplegic side								
	Pre-treatment	6.69±0.77			7.48±1.4			7.41±1.37	**0.280[1a]**
	Post-treatment	7.99±1.29			8.35±1.45				**0.566[1b]**
	Pre-Post *p*[2]		**0.002***			**0.001***			
	Pre-post difference		1.35	0-2.5		0.85	0.2-1.8	-	0.152[3]
	Hemiplegic side								
	Pre-treatment	5.8±1.14			6.28±1.25			6.91±1.09	**0.047*[1a]**
	Post-treatment	7.09±1.22			7.43±1.56				**0.594[1b]**
	Pre-Post *p*[2]		**0.001***			**0.001***			
	Pre-post difference		1.2	0.4-2.7		0.85	0.5-2.7	-	0.824[3]

SD: Standard deviation; PRE: Pre-treatment; POST: Post-treatment; RA: Rectus abdominis; TrA: Transversus abdominis; IO:Internus obliquus; EO: Externus obliquus; [1a] One way ANOVA test; [1b] Student t test; [2] Paired samples t test; * $p<0.05$; [3] Mann-Whitney U test (Group 1 & 2).

significantly both on the hemiplegic side and on the intact side after the treatment (p<0.05).

When the pre-treatment intact sides of Group 1 and Group 2 and the measurements of healthy individuals were compared, no significant difference was found in terms of at rest and contraction muscle thickness of TrA, IO, EO muscles. In Group 1 and Group 2, intact side RA muscle at rest and contraction thickness was found to be statistically significantly lower compared to healthy individuals (p<0.05). However, there were no statistically significant differences between Group 1 and Group 2 (p>0.05).

When the post-treatment intact side of Group 1 and Group 2 and TrA, IO, EO, and RA thicknesses of healthy individuals were compared, no significant difference was found at rest and contraction muscle thickness (p>0.05).

When the pre-treatment hemiplegic side of Group 1 and Group 2 and at rest and contraction RA, TrA, IO muscle thicknesses of healthy individuals were, significantly higher values were found in healthy individuals (p<0.05). There were no statistically significant differences between Group 1 and Group 2 (p>0.05). There were no statistically significant differences among the three groups in terms of these values after treatment (p>0.05).

When the pre-treatment hemiplegic side of Group 1 and Group 2 and healthy group EO contraction muscle thickness values were compared, healthy group were found to be statistically significantly higher (p=0.047). There were no statistically significant differences between Group 1 and Group 2 (p>0.05). There were no statistically significant differences between the hemiplegic sides of Group 1 and Group 2 and the healthy group after treatment in terms of EO contraction muscle thickness (p>0.05) (Table 2, 3).

When the pre-post treatment difference between Group 1 and Group 2 was compared, thickness of

TABLE 4
Comparison of pre-treatment and post-treatment balance, posture and functionality of inter- and intra-groups

	Group 1			Group 2			Group 3	
Tests	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	*p*
Berg test								
Pre-treatment	41.2±9.8			35.6±11.79				**0.263[1a]**
Post-treatment	48.1±8.25			41.6±9.85				**0.127[1a]**
PRE-POST *p*[2a]		**<0.001***			**0.004***			
Pre-post difference								
Barthel test								
Pre-treatment	88±16.7	92.5	40-100	78.5±24.39	95	40-100		**0.461[1b]**
Post-treatment	94.5±13.01	100	40-100	80±25.5	100	35-100		**0.143[1b]**
PRE-POST *p*[2b]		**0.026***			**0.257**			
Pre-post difference		5	0-25		0	0-10		0.247[1c]
FRT								
Pre-treatment	16.1±5.61			9.9±4.25				**0.012*[1a]**
Post-treatment	19.5±6.69			13.6±7.49				**0.080[1a]**
PRE-POST *p*[2a]		**0.001***			**0.036***			
Pre-post difference		3	1-7		2	1-17		0.436[1c]
PASS								
Pre-treatment	28.6±4.9			27.3±6.2				**0.609[1a]**
Post-treatment	31.9±3.78			28.5±6.62				**0.176[1a]**
PRE-POST *p*[2a]		**0.001***			**0.154**			
Pre-post difference		3	0-7		1.5	0-5		**0.165[1c]**

SD: Standard deviation;PRE: Pre-treatment; POST: Post-treatment; FRT: Functional reach test; PASS: Postural assessment scale for stroke patients; [1a] Student t test; [1b] Mann-Whitney U test; [1c] Mann-Whitney U test; [2a] Paired samples t-test; [2b] Wilcoxon sign test; * p<0.05.

hemiplegic side contracted RA muscle and hemiplegic side TrA muscle thickness at rest were significantly higher in Group 1 than Group 2.

Intra-rater correlation coefficient was used to evaluate intra-observer reliability between USG measurements and classified according to Shrout recommendations (≤0.10=almost none, 0.11-0.40=mild, 0.41-0.60=reasonable, 0.61-0.80=moderate, 0.81 1.0=substantially higher). Since the intraclass correlation coefficients (ICC) of USG abdominal muscle thickness measurements were all >0.9, the intra-observer reliability rate was evaluated to be significantly high.[12]

Balance, posture, and functional parameters

There were no statistically significant differences between Group 1 and Group 2 in terms of pre- and post-treatment BDS values (p>0.05). In both groups, the increase in post-treatment values was statistically significant compared to pre-treatment BDS values (p<0.05).

There were no statistically significant differences between Group 1 and Group 2 in terms of pre- and post-treatment BI values (p>0.05). In Group 1, the increase in post-treatment values was statistically significant compared to the pre-treatment BMI values (p=0.026; p<0.05). In Group 2, there were no statistically significant changes in post-treatment values compared to pre-treatment BMI values (p>0.05).

The pre-treatment FRT values of Group 1 were found to be statistically significantly higher than Group 2 (p=0.012; p<0.05). There were no statistically significant differences between the two groups in terms of post-treatment FRT values (p=0.080; p>0.05). In both groups, the increase observed after the treatment was statistically significant compared to the pre-treatment FRT values (p<0.05).

There were no statistically significant differences between Group 1 and Group 2 in terms of pre- and post-treatment PASS test values (p>0.05). In Group 1, the increase in post-treatment values was statistically significant compared to the pre-treatment PASS test values (p=0.001; p<0.05). In Group 2, there were no statistically significant changes in post-treatment values compared to pre-treatment PASS test values (p=0.154; p>0.05) (Table 4).

DISCUSSION

In the present study, hemiplegic side abdominal muscle thickness significantly decreased in stroke compared to both the healthy age group and intact side; conventional neurophysiological exercises alone or combined with TSEs significantly increased abdominal muscle thicknesses; while they improved balance and trunk control, there was also a significant improvement in postural control and functionality in the group where TSEs were combined.

In addition, comparison between pre-treatment intact and hemiplegic side muscle thickness, abdominal muscle thickness was significantly lower on the hemiplegic side. In post-treatment measurements, this difference between the intact and hemiplegic side disappeared, except for EO muscle. In line with this result, if conventional neurophysiological exercises are applied alone or in combination with TSEs, it can be said that asymmetry between the paretic and non-paretic sides of the trunk can be improved.

When the pre-treatment hemiplegic sides of hemiplegic patients and healthy group on the same side muscle thicknesses were compared, except for EO muscle at rest thickness, muscle thickness on hemiplegic side were found to be lower than the healthy group in terms of muscle thickness on the same side. This result shows that not only the upper and lower extremities, but also the trunk is affected on the hemiplegic side in stroke.

The RA, TrA, IO, and EO muscles play a major role in trunk stabilization, as well as in posture control. Particularly, the TrA muscle is of utmost importance in terms of lumbar stabilization.[13] In case of any loss of trunk balance, initially TrA is activated and increases the abdominal internal pressure and followed by RA, IO, and EO contraction.[14] The fact that EO is the last activated muscle in case of loss of trunk balance can be interpreted as having less role in trunk stabilization than other muscles. In this study, the fact that the contraction thickness of the hemiplegic side EO muscle could not capture the intact side in the first group after treatment may be related to this.

When the pre-treatment at rest and contraction abdominal muscle thickness of the intact healthy group of stroke patients on the same side of the healthy group were compared, no significant difference was observed in all muscles, except for RA muscle.

In one study, RA was the thickest among the superficial and deep abdominal muscle thicknesses measured by USG in healthy adults, followed by IO muscle, EO muscle, and TrA muscle, respectively. While asymmetry was not detected between the right and left sides, a negative correlation was shown between RA, IO, and EO muscles and age, and no correlation was observed between TrA and age.[15] Since RA is both a superficial muscle and the thickest among the abdominal muscles, it is expected to be affected by atrophy in the earlier period. In this study, the fact that the intact side RA muscle thickness of stroke patients was found to be lower than that of healthy individuals can be attributed to this situation.

Kim et al.[16] investigated the asymmetry between the right and left sides in their study where they evaluated abdominal muscle thickness of subacute stroke patients and healthy individuals with USG at rest and in case of contraction. While there was no significant difference between the right and left side in the control and stroke groups in the measurements during rest, a significant difference was found in favor of the intact side in the contraction muscle thickness measurements in the hemiplegia group. In this study, both at rest and contraction thickness of all muscles were found to be significantly higher on the intact side. The difference can be explained by the fact that the patients included in this study were mostly in the chronic period. As the duration of the disease progresses, non-use atrophy becomes evident; asymmetry in abdominal muscles is inevitable. Seo et al.[17] found significant asymmetry between the paretic-nonparetic abdominal muscles at rest in chronic hemiplegia patients; they observed lower contraction rates on the paretic side. Seo et al.[18] investigated the effect of neurophysiological exercises and trunk stabilization exercises combined with neurophysiological exercises on balance and thickness of deep abdominal muscles in 17 patients with chronic stroke and found an increase in at rest and contraction muscle thickness on both hemiplegic and intact sides of the combined exercise group, while an increase in at rest muscle thickness was found in the control group. In this study, there was a significant increase in both at rest and contraction thickness of the muscles measured in both groups. This can be explained by an average disease duration of 28 months in the Seo et al.'s[18] study and 11.4 months in our study. As the duration of the disease progresses, the benefit of rehabilitation is expected to decrease. Both the results of these studies indicate the importance of early rehabilitation.

Yoo et al.[19] investigated the effects of TSEs on abdominal muscle thickness and balance in 24 chronic stroke patients and found no significant improvement in IO and TrA muscle thickness on hemiplegic and non-hemiplegic sides in the group performing exercises on unstable surfaces while no significant improvement was observed in the group performing on mat. We included TSEs performed on both stable and unstable surfaces in rehabilitation program. Unlike Yoo et al.,[19] we found no significant improvement in all muscles in the TSE group compared to pre-treatment, it can be associated with the more comprehensive exercise program.

Major disorders in trunk muscle activity in hemiparetic patients can be listed as decreased activity in lateral trunk muscles, delayed onset of contraction and loss of synchronization between activation of related muscle pairs.[20] Since these problems may cause motor and functional losses, it is critical to include exercises that provide co-activation of trunk flexor and extensor muscles in the post-stroke rehabilitation of hemiparetic patients.[21]

In studies examining the effectiveness of TSEs in stroke rehabilitation, they concluded that conventional exercises and combined exercises were also effective on balance and functionality, but the combined group was more effective.[16,22,23]

The results of our study were similar to the above two studies. Kim et al.[16] compared the TSE program and traditional rehabilitation program in terms of their effects on daily living activities and balance in patients with chronic stroke and observed a significant improvement in all scores in both groups and found a higher recovery rate in the group included in TSEs.

Trunk stabilization exercises increase the dynamic stabilization of the trunk by providing coordinated contraction of deep stabilizing muscles such as multifidus and TrA and superficial stabilizing muscles such as erector spina and RA.[24]

Rapid improvement in trunk functions allows the patient to start complex walking and balance exercises earlier in rehabilitation. Furthermore, trunk stability helps coordinated extremity movements required for daily activities and higher-level motor tasks.[25]

In a systematic review of Cabanas-Valdés et al.,[26] 10 randomized-controlled studies comparing trunk strengthening exercises and conventional therapy in stroke patients were evaluated and an improvement in FRT and BDS was observed in favor of the trunk strengthening exercise group. In the studies within the scope of the review, subacute and chronic stroke patients were examined and trunk strengthening exercises were shown to have a positive effect on both patient groups.[26]

In our study, the fact that there was no significant difference between the two groups in BDS can be explained by the fact that rehabilitation time was insufficient to create a significant difference and the time elapsed from stroke was longer in our study. It is expected that the positive effect of TSEs on balance would be more pronounced in acute patients.

The limitations to this study are having relatively low duration of treatment and the time after stroke in a wide range of patients. These may have affected the results of the study. Furthermore, it was not possible to observe the long-term effects of exercise programs applied, since our study included only pre- and post-treatment evaluations and did not include post- treatment follow-up evaluations. In future studies, long-term effects of exercises should be observed with post-treatment follow-up evaluations.

In conclusion, neurophysiological exercises alone or in combination with TSEs is effective in improving balance and dynamic trunk control by increasing abdominal muscle thickness. It is more beneficial to include TSEs in the rehabilitation program to be applied for postural control and increased functionality.

Ethics Committee Approval: The study protocol was approved by the University of Health Sciences, Haydarpaşa Numune Training and Research Hospital Ethics Committee (date: 11.02.2019, no: HNEAH-KAEK 2019/9). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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