J Int Acad Phys Ther Res 2019; 10(4): 1873~1878
ISSN 2092-8475
www.iaptr.org
https://doi.org/10.20540/JIAPTR.2019.10.4.1873

Effect of Deep Lumbar Muscle Stabilization Exercise on the Spatiotemporal Walking Ability of Stroke Patients

Background: Walking is a complex activity. The main components of walking include balance, coordination, and symmetrical posture. The characteristics of walking patterns of stroke patients include slow walking, measured by gait cycle and walking speed. This is an important factor that reflects post-stroke quality of life and walking ability.
Objective: This study aimed to examine the effect of deep lumbar muscle stabilization exercise on the spatiotemporal walking ability of stroke patients.
Design: Quasi-experial study
Methods: The experiment was conducted 5 times per week for 4 weeks, with 30 minutes per session, on 10 subjects in the experimental group who performed the deep lumbar muscle stabilization exercise and 10 subjects in the control group who performed a regular exercise. Variables that represent the spatiotemporal walking ability (step length, stride length, step rate, and walking speed) were measured using GAITRrite before and after the experiment and were analyzed.
Results: There was a significant difference in the pre- and post-exercise spatiotemporal walking ability between the two groups ($p<.05$). Furthermore, there was a significant difference in the step rate and walking speed between the two groups ($p<.05$).
Conclusions: Deep lumbar muscle stabilization exercise is effective in improving the walking ability of stroke patients. Therefore, its application will help improve the spatiotemporal walking ability of stroke patients.

Key words: *Stroke; Walking speed; Stride length; Step length; Step rate*

Jongchan Ahn, PT, MS[a]
Wonho Choi, PT, PhD, Prof.[b]

[a]Department of Physical Therapy, With Me Hospital, Inchon, Republic of Korea
[b]Department of Physical Therapy, Gachon University, Inchon, Republic of Korea

Received : 02 October 2019
Revised : 18 November 2019
Accepted : 20 November 2019

Address for correspondence
Wonho Choi, PT, PhD
Department of Physical Therapy, Gachon University, 191, Hambakmoero, Yeonsu-ku, Inchon, Republic of Korea
Tel: 82-32-820-4423
E-mail: whchoi@gachon.ac.kr

INTRODUCTION

Stroke is a cerebrovascular disease caused by an abnormal blood supply to the brain. Stroke causes physical disabilities and social disadvantages. The enhancement and recovery of walking is closely related to a stroke patient's return to society and work.[1] The most common symptom of stroke is the weakening of the muscles on the paralyzed side, and this muscle weakness also shows on the trunk strength on the paralyzed side.[2] For trunk stability, co-contraction must occur to obtain stability in the momentary posture and speed and under various loads on the spine.[3] Therefore, appropriate strength and endurance of the trunk muscle are very important, and it has been suggested that the abdomen and trunk muscles that link the motor control of the core muscles and spinal stability are important for moving and controlling the posture of the trunk.[4] The function of the musculus transversus abdominis and multifidus muscles enhance co-contraction to promote the function and motion of the limbs.[5] Exercises that simultaneously train the musculus transversus abdominis and multifidus muscles are effective at enhancing the ability to correct unstable posture and may improve posture control.[3] The characteristics of walking of stroke patients include asymmetry, reduced stride length and walking, wide proximal surface, and longer swing phase.[6] In detail, the characteristics of walking patterns are as follows: slow walking as determined by gait cycle and walking speed, differences in the stride length between the affected side and the normal side, a short stance phase of the affected side and a long swing phase of the unaffected side. Walking is a complex activity. The main components of walking include balance, coordination, and symmetrical posture. Therefore, walking factors must be considered an important component in the rehabilitation of stroke patients.[7]

Deep lumbar muscle stabilization exercise program for the enhancement of walking abilities in stroke patients increase the stability of the lower trunk, and requires balance, motor control, appropriate strength, and endurance. The common problem of reduced control due to hemiplegia such as the paralysis and reduced co-contraction of the trunk muscle, as well as the tendency to fall toward the paralyzed side further worsen the left-right asymmetry. This results in many problems including reduced quality of balance and walking, thereby contributing to the extreme frustration that patients experience after a stroke.[8]

In conclusion, deep lumbar muscle stabilization exercise controls unstable posture and improves the ability to maintain posture in daily life, which leads to recovery of the ability to control muscles and motion, and further minimize the stress mechanically exerted on the spine while performing the optimal function. However, there is insufficient research regarding the effect of applying this to stroke patients. Therefore, the objective of this study was to identify the effects of deep lumbar muscle stabilization exercise on the spatiotemporal walking ability of stroke patients.

SUBJECTS AND METHODS

Subjects

This research was approved by the Institutional Review Board (IRB) of Gachon University (1044396-201902-HR-012-01).

A total of 20 patients diagnosed with stroke more than 6 months ago and currently hospitalized at the W Rehabilitation Hospital in Incheon between March and April of 2019 were recruited. They sufficiently understood the contents of this study and completed the research consent form. The selection criteria were as follows: patients who could independently perform the motion of standing up; those who could move a distance of 10 m without help from others; those without orthopedic conditions or cardiovascular diseases; those without visual or audio disorder or vision loss that could affect the research; those who could understand the instructions of the therapist and scored 24 points or above on the Mimi Mental State Examination Korean; and those whose grade on the Modified Ashworth Scale was 1+ or below. The exclusion criteria were as follows: amblyopia, vertigo, those with vestibular dysfunction; those with orthopedic problems in the lower extremities. The general characteristics of the subjects who participated in this research are shown in Table 1. For this study, researchers explained the purpose of this study to all subjects and obtained consent. The study was conducted after sufficient explanation about the research procedures. To ensure an objective evaluation, one independent examiner who did not participate in the research planning process conducted the measurements.

Table 1. General characteristics of the subjects

Group		Experimental (n = 10)	Control (n = 10)
Age (years)		52.50 ± 10.16	53.00 ± 6.85
Weight (kg)		64.80 ± 10.09	64.40 ± 9.58
Height (cm)		164.20 ± 9.94	166.10 ± 6.77
Gender	Male	6	8
	Female	4	2
Stroke classification	Infarction	10	7
	Hemorrhage	0	3
Hemiplegia	Right	4	6
	Left	6	4
MAS	grade 0	3	2
	grade 1	6	5
	grade 1+	1	3

MAS: modified ashworth scale

All subjects were measured before and 4 weeks after the exercises using identical methods.

Intervention Methods

Twenty patients who satisfied the research subject selection criteria were selected. To minimize selection bias, they were randomly assigned. In order to randomly assign the subjects, cards with "1" or "2" written on them were placed in an enclosed envelope. Each subject picked one card from the envelope with their eyes covered. Subjects with "1" cards were assigned to the experimental group performing the deep lumbar muscle stabilization exercise and subjects with "2" cards were assigned to the control group performing regular exercises. Both groups performed exercises for five 30-minute sessions per week for a total of 4 weeks. The difficulty level and duration of exercise were controlled according to the patient's ability for all exercises.

Exercise Methods

Stabilizer Pressure Biofeedback Unit (PBU, Chattanooga Group, Australia) enables continuous resistance exercise with identical residence from the beginning to the end of the exercise by uniformly regulating the resistance by controlling the air pressure. For the deep lumbar muscle stabilization exercise, Stabilizer PBU was placed underneath the lumbar. When the subject contracts the lower abdomen, the pressure control was manipulated so the pressure was set to 40 mmHg. The subject was instructed to maintain this and was trained until he or she can maintain the contracted lower abdomen for 10 seconds or more before starting the exercise.[9] Each exercise comprised of 3 sets of 10 repetitions[10] (Table 2).

Measurement Methods

1) Measuring walking ability

In this study, GAITRite (CIR System Inc. USA) was used to measure the walking ability of the research subjects. GAITRite system is an equipment for which the reliability and validity of analyzing the spatial and temporal factors of walking have been tested. To measure the walking, each subject performed one practice walking following the examiner before performing one test. For the walking ability, the spatiotemporal factors including step length, stride length, step rate, and walking speed were comparatively analyzed. The rater reliability of this test was r=.90. The correlation coefficient among all walking measurements made in a comfortable walking speed was 0.96 or higher.[11]

Statistical Analysis

Data for this study was processed using SPSS version 20.0. Means and standard deviations of the general characteristics of the research subjects were calculated using descriptive statistics. The homogeneity was tested using independent-sample t-test, and the normality of the pre-intervention dependent variables of the two groups were tested using Kolmogorov-Smirnov test and Shapiro-Wilk test. Because a normal distribution was not followed, non-parametric statistical methods were used. Using Wilcoxon signed-rank test, the differences in the pre- and post-intervention dependent variables were analyzed by the intervention method within group. Using Mann-Whitney U test, the changes in the dependent variables by the intervention method between groups were analyzed. The statistical significance level was set at $p<.05$.

Table 2. Treatment protocol in the deep lumbar muscle stabilization exercise

Exercise	Session	Time
Exercise for the TrA in 4 point kneeling	10sec * 10rep * 3set	5 min
Exercise for the TrA in dorsal decubitus with flexed knees	10sec * 10rep * 3set	5 min
Exercise for the LM in ventral decubitus	10sec * 10rep * 3set	5 min
Co-contraction of the TrA and LM in upright position	10sec * 10rep * 3set	5 min
Co-contraction for the TrA and LM in 4 point kneeling	10sec * 10rep * 3set	5 min
Co-contraction for the TrA and LM in standing with balance pad		5 min

TrA: Transverse abdominis, LM: Lumbar multifidus
sec: second, rep: repetition min: minute

RESULTS

1. Changes in the spatiotemporal walking ability

1) Changes in the step length

Patients undergoing deep lumbar muscle stabilization exercise had statistically significant differences in step length during pre- and post-exercise, with the pre and post-exercise step length being 35.78 ± 11.37 cm and 43.93 ± 11.45 cm, respectively ($p<.05$). Regular exercise also had statistically significant differences in step length during pre- and post-exercise with the pre- and post-exercise step length being 37.29 ± 17.29 cm and 44.44 ± 17.12 cm, respectively ($p<.05$). However, no statistically significant differences were observed between the two groups ($p>.05$) (Table 3).

2) Change in stride length

Deep lumbar muscle stabilization exercise had statistically significant differences in stride length during pre- and post-exercise, with the pre- and post-exercise stride length being 74.15 ± 25.56 cm and 89.36 ± 26.19 cm, respectively ($p<.05$). Regular exercise also had statistically significant differences in stride length during pre- and post-exercise with the pre- and post-exercise stride length being 76.44 ± 32.01 cm and 85.89 ± 32.42 cm, respectively ($p<.05$). However, no statistically significant differences were observed between the two groups ($p>.05$) (Table 4).

3) Change in step rate

Deep lumbar muscle stabilization exercise had statistically significant differences in step rate during pre- and post-exercise, with the pre- and post-exercise step rate being 73.97 ± 19.75 step/min and 97.14 ± 14.41 step/min, respectively ($p<.05$). Regular exercise also had statistically significant differences in step rate during pre- and post-exercise, with the pre- and post-exercise step rate being 73.18 ± 21.93 step/min and 83.75 ± 27.67 step/min, respectively ($p<.05$). In particular, the differences between groups were more significant for step rate ($p<.05$) (Table 5).

4) Change in walking speed

Deep lumbar muscle stabilization exercise had statistically significant differences in walking speed during pre- and post-exercise with the pre- and post-exercise walking speed being 47.96 ± 27.65 cm/sec and 72.72 ± 26.73 cm/sec, respectively ($p<.05$). Regular exercise also had statistically significant differences in walking speed during pre- and post-exercise, with the pre- and post-exercise walking speed being 49.55 ± 33.31 cm/sec and 62.34 ± 40.30 cm/sec, respectively ($p<.05$). In addition, there was significant difference in walking speed between groups ($p<.05$) (Table 6).

Table 3. Difference between the groups and between pre- and post-exercise in step length of the subjects

Group	pre	post	p	Between group p-value
Experimental (n = 10)	35.78 ± 11.37	43.93 ± 11.45	.005*	.450
Control (n = 10)	37.29 ± 17.29	44.44 ± 17.12	.022*	

Values are means ± SD (cm), $p<.05$*

Table 4. Difference between the groups and between pre- and post-exercise stride length of the subjects

Group	pre	post	p	Between group p-value
Experimental (n = 10)	74.15 ± 25.56	89.36 ± 26.19	.005*	.151
Control (n = 10)	77.56 ± 31.25	85.69 ± 32.39	.028*	

Values are means ± SD (cm), $p<.05$*

Table 5. Difference between the groups and between pre- and post-exercise in step rate of the subjects

Group	pre	post	p	Between group p-value
Experimental (n = 10)	73.97 ± 19.75	97.14 ± 14.41	.005*	.041*
Control (n = 10)	73.18 ± 21.93	83.75 ± 27.67	.005*	

Values are means ± SD (step/min), $p<.05$*

Table 6. Difference between the groups and between pre– and post–exercise in walking speed of the subjects

Group	pre	post	p	Between group p–value
Experimental (n = 10)	47.96 ± 27.65	72.72 ± 26.73	.005*	.028*
Control (n = 10)	49.55 ± 33.31	62.34 ± 40.30	.007*	

Values are means ± SD (cm/sec), p<.05*

DISCUSSION

This study was conducted to identify the effect of deep lumbar muscle stabilization exercise on the spatiotemporal walking ability of stroke patients. The walking speed of stroke patients is an important factor that reflects the post–stroke quality of life and walking ability, and the walking speed of stroke patients greatly affect the motions in their daily lives.[12] Trunk muscles play the role of maintaining body balance, enhancing exercise performance in the anti–gravity position as well as providing the stability of the proximal muscles while moving the limbs. Thus, the strengthening of the trunk muscles can be considered a very important factor in the rehabilitation of hemiplegic patients.[13] These muscles provide stability of the trunk with respect to the movement of the limbs and prevent lumbar rotation, thereby being effective at maintaining the stability of the trunk and pelvis. Therefore, many muscles must cooperate for the stability of the trunk.[14] Based on these observations from prior studies, the current study investigated the effects of deep lumbar muscle stabilization exercise and regular exercise in stroke–induced hemiplegic patients under the assumption that they will need deep lumbar muscle stabilization exercise.

Deep lumbar muscle stabilization exercise used stabilizer PBU to dynamically simultaneously apply stability and motility to enable the selective activity of muscles and enhance strength and endurance as well as the sensory–motor control. According to Caty et al. the maintenance of appropriate strength and endurance of the trunk muscles was very important; they reported that increased the left–right asymmetry and decreased balance resulted in a reduction of walking speed.[15] In this study, deep lumbar muscle stabilization exercise was performed for 8 weeks by stroke–induced hemiplegic patients, and the changes in the walking ability with time were examined. The results of this study showed that the step rate and walking speed greatly improved after deep lumbar muscle stabilization exercise. Jang showed that 4 weeks of trunk stability training using sling board had a substantially improved the activity of trunk muscles.[16] Kim also found that there were statistically significant changes in the muscle activity of the rectus abdominis muscle, internal oblique abdominal muscle, external oblique abdominal muscle, erector spinae muscle, and transversus abdominis after trunk stability training exercise,[17] whereas Yu reported statistically significant changes in the muscle activity of the rectus abdominis muscle, external oblique abdominal muscle, internal oblique abdominal muscle, and erector spinae muscle after the trunk stability strengthening exercise.[18] The characteristics of walking among stroke patients include asymmetry, reduced stride length and walking, wide proximal surface, longer swing phase, and large amount of energy expended when the foot on the paralyzed side is moved while walking.[19] Walking controls unstable balance.[20] This study also reported improved walking ability through deep lumbar muscle stabilization exercise. Deep lumbar muscle stabilization exercise is thought to maintain the normal cervical, thoracic, and lumbar curves to protect the spine and reduce mechanical stress, thereby enhancing the walking ability. Therefore, based on the results of this study, if deep lumbar muscle stabilization exercise is applied to hemiplegic patients, enhancement in the spinal stabilization, balance, and walking ability can be anticipated.

However, because this study was conducted only on selected patients who satisfied the conditions of this study, there are limitations in generalizing the results of this study to all adult hemiplegic patients.

CONCLUSION

Deep lumbar muscle stabilization exercise is effective at improving the walking ability of stroke patients. Therefore, its application will clinically help to improve the spatiotemporal walking ability of stroke patients.

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