Effects of Core Stability Exercises on Energy Expenditure During Gait in Subacute Stroke Patients

Kyeoung-Man Jung
Dept. of Physical Therapy, Won-Kwang University Hospital

Purpose This study aimed to evaluate the effect of core stability exercises on energy expenditure during gait in subacute stroke patients. ***Methods*** The study included 24 subacute stroke patients randomly allocated to the experimental group (n=12) and control group (n=12). Patients in the experimental group performed the core stability exercises (20 min) and conventional physical treatment (20 min), while those in the control group performed conventional physical treatment (40 min) only. Both groups performed training five times a week for 4 weeks. Outcome assessments evaluated energy cost, physiological cost index, and walking speeds. The patients were assessed before and after intervention. The Shapiro-Wilk test was used to assess normalization. Within-group differences were analyzed using the paired t-test, while between-group differences were analyzed using an independent t-test. ***Results*** After 4 weeks of exercise, both the groups showed significant increased walking speed and significant decreased energy cost, physiological cost index ($p < .05$). However, the experimental group was more effective than control group was increasing in walking speed ($p < .05$) and decreasing in energy cost (EC), physiological cost index (PCI) ($p < .05$). ***Conclustion*** We suggest that core stability exercises effectively improve walking speed and energy efficiency during gait in subacute stroke patients.

Key words Core stability exercise, Energy cost, Physiological Cost Index, Stroke, Walking speed

Corresponding author Kyeoung-Man Jung (future1347@naver.com)

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I. Introduction

Stroke results from occlusion or hemorrhage of a major artery in the brain and is a major cause of severe disability.[1] After a stroke, survivors experience impaired balance and gait because of asymmetric posture, insufficient strength, sensorimotor deficits, changes in trunk muscle tension, body imbalance, and deficient weight transfer ability.[2,3] Trunk muscle weakness and impaired proprioception of the affected side may interfere with balance, stability, trunk control ability, and gait and may decrease one's ability to control posture.[4] Therefore, stroke patients usually lose function of the trunk muscles, leading to weak trunk muscle strength, decreased trunk control ability, and decreased trunk balance ability.[5]

The core can be described as a muscular box with the abdominals in the front, paraspinals and gluteals in the back, diaphragm as the roof, and pelvic floor and hip girdle musculature as the bottom.[6] Core stability exercises strengthen the transversus abdominis muscles, multifidus muscles, erector spinae muscles, rectus abdominis, pelvic floor muscles, and diaphragm as well as coordinate contractions.[7] Deep muscles play an important role in maintaining trunk stability and balance control during whole-body movements using the postural muscles.[8] Core stability is defined as the ability of the lumbopelvic-hip complex to prevent buckling of the vertebral column and return it to equilibrium following perturbation.[9] Core stability exercises have recently been rediscovered in stroke rehabilitation programs.

The goal of human walking is progression of the body in the desired direction using the least possible physiological energy expenditure. However, stroke patients have higher energy demands compared to

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healthy individuals because of spasticity, asymmetrical posture, abnormal muscle activation patterns, and reduced oxygen uptake capacity.[10,11] Studied gait cycles in stroke patients indicated that 33% of the step cycle of the affected side leg is spent in the swing phase, while 80% of the step cycle of the unaffected leg is spent in stance compared to a healthy person swing to stance ratio.[12] Because of the remarkable reduction in walking speed, the rate of energy consumption while walking for stroke patients is less than that for healthy subjects, despite the inefficient gait pattern and high energy consumption.[13,14] The core stability exercises improved reaction time, an important factor in optimal balance.[15] Kim et al. (2009) reported that walking ability in stroke patients significantly increased after the use of core stability exercises and that walking ability improved as balance improved.[16] Ijmker et al. (2013) reported that gait energy consumption decreased when an elastic belt was attached to the subject's waist and external stability was provided.[17] Houdijk et al. (2010) measured and compared the amount of energy consumed in maintaining four standing positions against stroke patients and normal people, and found that an average of 125% more energy was used in stroke patients. Thus, the degree of balance capability can have a direct impact on energy consumption, and restoring balance capability is an important factor in reducing energy consumption.[18] The measurement of physiological energy expenditure is the most objective method for quantitatively evaluating gait disturbance and functional performance abnormalities and can be used to measure the effects of various exercise intervention.[11]

However, no previous studies have investigated the effect of core stability exercises on energy expenditure during gait in subacute stroke patients. Therefore, the purpose of this study was to determine the effect of core stability exercises on energy expenditure during gait in subacute stroke patients to provide basic helpful information about energy efficiency during gait in subacute stroke patients.

II. Materials and Methods

1. Participants

A total of 24 patients at Won-Kwang University Hospital were enrolled in this study. A total of 24 patients were enrolled in this study at Won-Kwang University Hospital from February 1 to June 30, 2014. The inclusion criterion was age 30-75 years. All patients experienced a single stroke in any area of the brain except the pons or cerebellum, were ambulatory with a residual gait deficit, and had the ability to walk continuously for 10 minutes on a treadmill at a comfortable speed. Subjects were excluded if they had angina, dizziness, a resting heart rate outside the range of 40-100 beats per minute, or orthopedic problems in the lower limbs or spine. Our study followed the principles of the Declaration of Helsinki and all the recruits provided informed consent. Patient demographic information is summarized in Table 1. There were no statistically significant intergroup differences in any variables.

2. Study design

These 24 study subjects were randomly assigned to the experimental group or control group (n = 12

Table 1. General and medical characteristics of the study subjects

Variables (units)	Experimental group (n=12)	Control group (n=12)
Gender male(%) female(%)	7(58.3)/5(41.6)	6(50.0)/6(50.0)
Age(year)a	61.67±8.54	60.42±7.25
Affected side Left(%) Right(%)	5(41.6)/7(58.3)	6(50.0)/6(50.0)
Onset duration (week)	9.58±1.82	10.58±1.38
MMSE-K(score)	26.17±2.75	27.50±1.45

each). Patients in the experimental group completed the core stability exercises, while those in the control group performed conventional treatment 20 minutes each day five times a week for 4 weeks. The conventional treatment program consisted mainly of stretching, strengthening, range of motion exercises, and balance and gait training for 20 minutes of day five times a week for 4 weeks. The core stability exercise program was modified and supplemented to the method used in the previous study.[19] The core stability exercises programs were as follows: 1) Bridging exercise: Bend both knees while lying on a mat and perform selective movements of the pelvis and extension of the hip joint. 2) Unilateral pelvic bridging exercise: rest one foot on the mat and use one leg to lift the pelvis horizontally. 3) Abdominal drawing-in maneuver with leg lifts: move from the supine position to the hook-lying position and place the hip joint at 40 degrees and knee joint at 80 degrees using a cushion below the knee joint and pull the navel deeply toward the lumbar region. Alternate the legs to lift. 4) Curl-up: bend both knees to 90 degrees of flexion while on an exercise ball and put the hand on the chest region. Pull the head, both shoulders, thoracic spine, and lumbar spine slowly off the floor and complete a successful curl-up. The four exercises were performed for 5 minutes each, and the difficulty level was adjusted by increasing the speed and frequency.

3. Measurements

1) Energy cost

Measures of energy cost were collected with Quinton Q-stress (Quinton Q-stress; CARDIAC SCIENCE, USA) cardiac stress testing system. Subjects wore a nose clip and breathed through a mouthpiece that collected expired air. Expired air was sampled continuously from a mixing chamber, passed through a drying tube, and analyzed for O2 and CO2 concentrations while the participants walked at a comfortable speed on the treadmill for 5 minutes. The measures of the last 2 minutes (steady state condition) were recorded and stored for analysis. Oxygen cost was calculated by dividing the oxygen expenditure values by the distance covered in meters and reported as mL/kg/m.[20]

2) Physiological Cost Index

All study participants performed a treadmill walking test at their own suspected walking speed for the entire 5-minute period. During all tests, the participants wore a portable Quinton Q-stress breath gas analyzer (CARDIAC SCIENCE) to assess heart rate. Each walk session lasted at least 5 minutes to allow reaching and maintaining a cardiac steady status. The PCI was calculated as follows:[21]

$$\text{PCI} = \frac{\text{SSHR (beats/min)} - \text{resting HR (beats/min)}}{\text{walking speed (m/min)}}$$

3) Walking speed test

A 10-m walking test was performed by each participant, during which gait speed was measured while the patient walked 10 m. The walkway was 14 m long, including a 2-m section for acceleration and 2-m section for deceleration. The participants were asked to walk at a self-selected speed as safely as possible. Gait speed was measured with a stop watch based on the passage of the first and last foot. The participants were asked to walk three times and the mean walk speed was calculated as (m/second) = distance (m)/ time (seconds).[22]

4. Data analysis

The data were analyzed using Statistical Package for the Social Sciences v.19.0. The subjects were assessed before and after treatment. The subjects' characteristics were described using frequencies for the categorical data and mean ± standard deviation for the continuous data for the control and experimental groups. The Shapiro-Wilk test was used to assess normalization. Within-group differences were analyzed using the paired t-test, while between-group differences were analyzed using an independent t-test. The level of significance was established at $p < .05$.

III. Results

The baseline characteristics of both groups are shown in Table 1. No differences were found between the two groups for the collected demographic variables.

Table 2. Changes in energy cost, physiological cost index, and walking speed

		Experimental group(n=12)	Control group(n=12)	(t) p
ECa(ml/kg/m)	Pre	0.45±0.01b	0.45±0.01	(−0.77) 0.45
	Post	0.40±0.02	0.44±0.01	(−5.38) 0.00*
	Change	0.04±0.01	0.01±0.00	(6.38) 0.00*
	(t)p	(10.45) 0.00*	(7.34) 0.00*	
PCIc (beat/meter)	Pre	0.84±0.03	0.84±0.03	(−0.38) 0.70
	Post	0.76±0.04	0.82±0.03	(−4.09) 0.00*
	Change	0.07±0.03	0.01±0.00	(6.06) 0.00*
	(t)p	(8.63) 0.00*	(6.28) 0.00*	
Walking speed(m/s)	Pre	0.38±0.03	0.38±0.02	(−0.33) 0.74
	Post	0.42±0.02	0.41±0.02	(0.88) 0.38
	Change	0.04±0.02	0.02±0.01	(1.96) 0.63
	(t)p	(−6.25) 0.00*	(−7.68) 0.00*	

[a]Energy cost, [b]mean ± standard deviation, [c]Physiological cost index; *p < .05.

Intergroup comparisons at baseline also showed no difference in any of the outcome measures. Pre- to post-intervention results for all variables were significantly different in both groups (p<.05). Significant intergroup differences were observed for walking speed, energy cost, and PCI indices post-intervention (p<.05). However, all variables in the experimental group were significantly greater than those in the control group (p<.05).

The values of the patients in the experimental group were significantly improved compared to those in the control group in all outcome measures.

IV. Discussion

Core stability exercises involve the active cooperation of the trunk muscles and pelvis to create stability and enable effective gait.[23,24] Adjusting the muscles in the process of maintaining balance and integrating human walking involves the central and peripheral nervous system.[25] Stroke patients while walking in the normal energy consumption compared to two times greater.[26] Approximately 39-72% of stroke patients report feeling fatigue while walking, which impedes successful rehabilitation and negatively influences quality of life.[27] Thus, appropriately reducing energy expenditure during walking is an important factor in stroke rehabilitation.[25] Therefore, this study attempted to determine the effect of core stability exercise on reducing energy consumption during walking in stroke patients by measuring the oxygen consumption ratio and PCI using the linear proportion between heart rate and oxygen intake. Our results showed that, after walking treatment, walking speed, energy cost, and PCI were significantly improved in both groups. However, a comparison of the changes between before and after treatment showed greater improvement in the experimental group. Jung and Jung (2016) reported that walking speed and energy consumption improved after trunk stabilization exercise in a single case study.[28] After applying core stability exercises in 16 patients, Chung et al. (2013) reported that walking speed significantly improved in the experimental group versus the control group.[29] VanSwearingen et al. (2009) reported that energy efficiency during walking improved after the application of a therapeutic intervention to improve movement timing and coordination in 47 elderly people.[30] The walking speed of patients with hemiplegia is slower than that of normal subjects, while the consumption of oxygen consumed by walking is always higher in stroke patients at the same walking speed.[14] A strengthening exercise program can improve walking ability and efficiency of stroke patients.[11] In stroke patients, trunk muscle strengthening exercises for stabilizing the trunk are very effective for improving postural control and gait ability.[16] Reisman et al. (2009) compared energy efficiency during walking in 16 patients with chronic stroke and a self-selected walking speed < 1.2 ms and reported that energy efficiency improves at a faster walking speed versus that at a self-selected walking speed; thus, to improve efficiency, therapeutic intervention is needed to improve walking speed.[21] In addition, Houdijk et al. (2010) reported that stroke patients with decreased balance ability require more energy than normal subjects to conserve balance. Therefore, appropriate intervention methods are needed to improve balance and walking efficiency.[18] Lee and Shin (2010) reported a computer virtual reality exercise program that reduced symmetrical movement, reduced unnecessary compensation, and increased walking efficiency.[31] The results of that previous study were similar to those of this study. These results suggest that the improved balance ability of the pelvis and the muscle control around the lumbar region through the core stability exercise improve walking speed. In addition, trunk stability is a prerequisite for symmetrical lower limb movement. The core stability exercises performed in this study strengthened the trunk muscles and improved symmetrical movements during walking through correct posture alignment, resulting in reduced energy expenditure. Compared to normal people, stroke patients consume excessive energy in order to maintain balance during walking. The present study has some limitations that required consideration. First, the small sample size may have influenced the results; thus, our results cannot be generalized to all stroke patients. Second, there was a lack of long-term follow-up of the patients to determine whether the observed short-term improvement was maintained over time. Third, there are clear limitations to its application to walking on the ground since our study involved subjects walking on a treadmill. In the future, it will be necessary to study intervention methods that improve walking efficiency by minimizing the energy consumption during walking for many patients with stroke-induced walking disorder. Improvement of balance ability through core stability exercise can provide energy efficient walking by reducing walking energy consumption, and furthermore, it can improve the quality of life by reducing fatigue.

V. Conclusion

The purpose of this study was to evaluate the effect of core stability exercises on energy expenditure during gait in subacute stroke patients. The study included 24 subacute stroke patients randomly allocated to the experimental group (EG) and control group (CG) (n = 12 each). Patients in the EG performed the core stability exercises (20 min) and conventional treatment (20 min), while those in the CG performed conventional treatment (40 min) only. Both groups completed training five times a week for 4 weeks. Both groups showed significant improvements ($p < .05$). However, the experimental group demonstrated a greater increase in walking speed ($p < .05$) and decrease in energy expenditure ($p < .05$). Thus, our findings suggest that the core stability exercise effectively improves walking speed and energy efficiency during gait in subacute stroke patients. Improvement of balance ability through core stability exercise can provide energy efficient walking by reducing walking energy consumption, and furthermore, it can improve the quality of life by reducing fatigue.

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