



Original Article

The correlation between muscle activity of the quadriceps and balance and gait in stroke patients

DAE JUNG YANG, PhD, PT¹⁾, SEUNG KYU PARK, PhD, PT¹⁾, YO HAN UHM, PT¹⁾,
SAM HEON PARK, PT¹⁾, DONG WHAN CHUN, PT¹⁾, JE HO KIM, PhD, PT¹⁾*

¹⁾ Department of Physical Therapy, Graduate School of Physical Therapy, Sehan University:
1113 Noksaek-ro, Samho-eup, Yeongam-gun, Jeollanam-do, Republic of Korea

Abstract. [Purpose] The purpose of this study was to examine the correlation between quadriceps muscle activity and balance and gait in stroke patients. [Subjects and Methods] Fifty-five stroke patients (30 males 25 females; mean age 58.7 years; stroke duration 4.82 months; Korean mini-mental state examination score 26.4) participated in this study. MP100 surface electromyography, BioRescue, and LUKOtronic were used to measure the quadriceps muscle activity, balance, and gait, respectively. [Results] There was a significant correlation between quadriceps muscle activity (vastus lateralis % reference voluntary contraction, vastus medialis % reference voluntary contraction) and balance (limits of stability) and gait (gait velocity) but there was none between vastus lateralis % reference voluntary contraction, vastus medialis % reference voluntary contraction. [Conclusion] An increase in quadriceps muscle activity will improve balance and gait ability. To improve function in stroke patients, training is needed to strengthen the quadriceps muscles.

Key words: Muscle activity, Balance, Gait

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INTRODUCTION

Stroke damages the sensory-motor system, leading to limitations in daily activity, increased risk of falling, and decreased functional independence^{1, 2)}. Stroke causes muscle weakening in patients due to a decrease in the rate of motor unit recruitment and weakness of selective type II fibers²⁾, with decreased extension torque in knee joints on the non-paralyzed and paralyzed side when compared to that of healthy individuals of the same age³⁾. Among the lower extremity muscles, the quadriceps provides stability during stance phase in the gait cycle and supports normal posture alignment on the knee joint. Coordination between the vastus lateralis and vastus medialis is necessary for the normal function of the knee joint. Quadriceps muscle strength is a very important factor in the functional recovery of stroke patients⁴⁾. Balance refers to the ability to maintain upright posture when dynamic gravitational change occurs. Stroke patients show difficulty in functional performance such as gait due to decreased limits of stability (LOS) and an increase in postural sway while maintaining upright postures⁵⁾.

Gait is controlled through interactions of many systems, such as the nervous and musculoskeletal systems, and a continuous, repeating posture that moves the body forward⁶⁾. Stroke patients face limitations in daily activities due to slow, unstable gait. Thus, the main objective in rehabilitation of stroke patients is a fast, effective gait. This is an important index in judging the prognosis⁷⁾.

This study aims to provide basic data for the rehabilitation of stroke patients by analyzing correlations between quadriceps muscle activity and balance and gait velocity in stroke patients.

*Corresponding author. Je Ho Kim (E-mail: albam20@naver.com)

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SUBJECTS AND METHODS

This study was approved by the bioethics Committee of Sehan University Center (institutional review board approval number: 2015-04) on July 28, 2015. This study selected 55 patients who received inpatient treatment after the diagnosis of stroke. Patients read and signed an informed consent form before the start of the study. The selection criteria were hemiplegia on the right side, ability to communicate, a score higher than 24 points in the Korean Mini-mental State Examination, ability to walk more than 10 m independently, and without muscular or skeletal system diseases that could affect the experiment. MP100 (Biopac system Inc., USA) surface EMG was used to measure the quadriceps muscle activity; muscle activity was measured for the vastus lateralis and vastus medialis. The sampling rate was 1,024 Hz, a notch filter was used at 60 Hz, a band pass filter was used at 30–450 Hz, and collected signals were managed with root mean squares. To normalize the muscle activity, % reference voluntary contraction (%RVC) was used⁸⁾. BioRescue (RM Ingenierie, France) was used to measure balance ability. Moving distance and moving area of the center of pressure were measured, as well as LOS⁹⁾. LUKOtronic (Lutz-Kovacs Electronic, Austria) motion analysis system was used to analyze gait velocity as the temporal and spatial variance of gait, and collected data were analyzed using GaitLab (Lutz-Kovacs Electronic, Austria)¹⁰⁾.

SPSS (IBM Co., Armonk, NY, USA) ver. 18.0 statistical software was used to analyze the results. Characteristics of subjects used descriptive statistics. Correlations between quadriceps muscle activity and balance and gait velocity were assessed using Pearson's correlation coefficient. Statistical significance level was set as $\alpha=0.05$.

RESULT

Table 1 summarizes the data for gait velocity, limits of stability, and muscle activity of the vastus lateralis (VL) and vastus medialis (VM), along with the general characteristics of the subjects. Table 2 summarizes the correlation between quadriceps muscle activity and balance and gait velocity. A significant correlation was found between VL %RVC and LOS ($r=0.75$, $p<0.01$) and gait velocity ($r=0.74$, $p<0.01$); however, no significant correlation was observed for VM %RVC. There was a significant correlation between VM %RVC and LOS ($r=0.85$, $p<0.01$) and gait velocity ($r=0.86$, $p<0.01$), and also between LOS and gait velocity ($r=0.85$, $p<0.01$).

DISCUSSION

This study confirmed that significant correlations exist between quadriceps muscle activity and stability limits and gait velocity in stroke patients.

Quadriceps muscle activity controls vertical moving velocity of the center of mass and buffers the impact from load on the joints by adjusting the amount of knee flexion^{11, 12)}. Quadriceps muscle strengthening should initially be considered to improve functional performance in stroke patients^{13, 14)}.

Table 1. General subject characteristics and dependent variables (N=55)

Variable	Mean \pm SD (%)
Gender	30/25
Male/Female (%)	(54.5/45.6)
Etiology	35/20
Infarction/Hemorrhage (%)	(63.6/36.4)
Age (years)	58.7 \pm 3.8
Height (cm)	165.5 \pm 8.9
Mass (kg)	65.1 \pm 5.9
Post-stroke duration (month)	4.8 \pm 1.1
MMSE-K (score)	26.4 \pm 2.8
VL %RVC (%)	31.9 \pm 4.6
VM %RVC (%)	27.2 \pm 5.2
LOS (cm ²)	90.5 \pm 9.1
GV (m/s)	0.4 \pm 0.1

MMSE-K: Korean version of the mini-mental state examination; VL %RVC: vastus lateralis % reference voluntary contraction; VM %RVC: vastus medialis % reference voluntary contraction; LOS: limits of stability; GV: gait velocity

Table 2. Correlation between quadriceps muscle activation and LOS and gait velocity (N=55)

	VM %RVC (%)	LOS (cm ²)	GV (m/s)
VL %RVC (%)	0.32	0.75**	0.74**
VM %RVC (%)		0.85**	0.86**
LOS (cm ²)			0.85**

VL %RVC: vastus lateralis % reference voluntary contraction; VM %RVC: vastus medialis % reference voluntary contraction; LOS: limits of stability; GV: gait velocity.
** $p<0.01$

In the knee joint, 80% of total extension torque is produced by the vastus medialis and vastus lateralis of the quadriceps, and the muscle activity ratio for each of these in a normal individual is about 1:1¹⁵⁾. Compared to a normal person, a patient with knee joint malfunction presents a difference in the muscle activity ratio¹⁶⁾. This study did not find significant correlations between the vastus medialis and vastus lateralis muscle activity. This may be due to the effect of muscle imbalance caused by differences in the muscle activity ratio in stroke patients who also have malfunctioning knee joints, according to pilot studies.

When et al.¹⁷⁾ compared and measured muscle activity in 15 stroke patients and 10 normal subjects of similar ages during balance maintenance in various environments, and the muscle activity of the vastus medialis and vastus lateralis showed a significant difference. Furthermore, this study revealed a significant correlation between muscle activity of the vastus medialis and vastus lateralis and balance. Quadriceps activity is thought to show a correlation with balance ability after a decrease in asymmetrical weight-bearing. This study also confirmed a significantly higher correlation between the vastus medialis and balance, which is considered necessary for selective muscle strengthening of the vastus medialis to improve balance.

Boudarham et al.¹⁸⁾ analyzed the length of a single step and gait velocity causing fatigue in the quadriceps, hamstring, and gastrocnemius in 13 stroke patients. The result showed that fatigue of the quadriceps significantly decreased walking ability, while improvement of quadriceps activity showed a high correlation with gait velocity, stride, and weight-bearing ratio^{19, 20)}. This study also revealed significant correlations between gait velocity and muscle activity of the vastus medialis and vastus lateralis. Quadriceps muscle activity was found to show a correlation with gait velocity due to improvement in the stance phase of the gait cycle by providing stability to the knee joints.

This study confirmed that a significant correlation exists between quadriceps muscle activity and balance and gait. However, the study has limitations. It is difficult to generalize the results for all stroke patients because of the small number of subjects and regional limits. A study of the effect of quadriceps strength training on balance and quality of life in stroke patients is therefore necessary.

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