

The effect of foot position on erector spinae and gluteus maximus muscle activation during sit-to-stand performed by chronic stroke patients

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Abstract. [Purpose] The aim of this study was to use surface electromyography (EMG) to investigate the effects of different foot positioning on bilateral erector spinae (ES) and gluteus maximus (GM) activation during sit-to-stand performed by individuals with stroke. [Subjects] Fifteen randomly selected participants with stroke were enrolled in this study. [Methods] All the participants were asked to perform sit-to-stand (STS) using three different strategies: (1) symmetric foot position, (2) unaffected foot placed behind the affected foot position (asymmetric-1), (3) affected foot placed behind the unaffected foot position (asymmetric-2). An EMG system was used to measure ES and GM muscle activities. The strategies were performed in a random order, and the mean values of five measurements were used in the analysis. One-way repeated measure ANOVA was used to determine the statistical significance of differences between the conditions. [Results] The affected ES muscle activity was significantly greater in asymmetric-2 (180.7 ± 73.4) than in symmetrical foot placement (149.8 ± 54.2). In addition, the affected ES, unaffected ES, and affected GM muscle activity were significantly greater in asymmetric-2 (180.7 ± 73.4 , 173.5 ± 83.1 , 98.3 ± 90.3 respectively) than in asymmetric-1 foot placement (147.3 ± 53.8 , 151.2 ± 76.5 , 84.9 ± 73.8 respectively). [Conclusion] Our results suggest that it may be more desirable for persons with stroke to place the affected foot behind the unaffected foot when performing STS to increase affected ES and GM muscle activation.

Key words: Electromyography, Sit-to-stand, Stroke

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INTRODUCTION

Persons with stroke have increased instability, and 61–85% of their body weight is loaded onto the unaffected limb, resulting in asymmetrical movement compared with healthy persons¹⁾.

Sit-to-stand (STS) begins in a safe sitting position and progresses to an unstable standing position, and it requires the lower extremity and trunk muscles to work together in harmony²⁾. However, persons with stroke have the tendency to put more weight on the unaffected lower extremity, the time to complete STS is prolonged, and they show large amounts of mediolateral excursion of the center of pressure (COP)³⁾. Persons with stroke perform an inadequate STS and the majority of their weight is placed on the unaffected side, or the unaffected lower extremity is placed posterior to the affected lower extremity when they perform STS.

The ideal goal in the rehabilitation of individuals with

stroke is to decrease asymmetrical patterns during movement, and to reduce gait asymmetries by achieving more symmetrical weight-bearing⁴⁾. Camargos et al.⁵⁾ reported that more weight-bearing on the affected lower extremity could lead to fall prevention and accelerate the functional ability of the affected lower extremity. Brunt et al.⁶⁾ stated that when persons with stroke placed their affected lower extremity posterior to the unaffected lower extremity during STS training, an increase in the muscle activation of the quadriceps was observed, compared to symmetrical lower extremity placement, or placement of the affected lower extremity anterior to the unaffected lower extremity.

Millington et al.⁷⁾ reported that at 14.6% of the STS action, erector spinae muscle activation was initiated, the center of mass (COM) traveled from posterior to anterior and superior, and maximal erector spinae muscle activation was observed. Ashford and De Souza⁸⁾ reported that when normal healthy adults perform STS, although the muscle activation of the lower extremity is important, the erector spinae and the gluteus maximus muscles have an important role in maintaining posture, and also play a role in limiting the amount of trunk sway during STS.

Previous studies have examined persons with stroke performing STS by measuring lower extremity muscle activities, however, there are few studies that have examined erector spinae and the gluteus maximus muscle activation.

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Also, depending on the position of the lower extremity during STS, there is a difference in trunk muscle activation as well. Therefore, the aim of this study was to investigate the effects of performing STS in different foot positions on the erector spinae and gluteus maximus muscle activities.

SUBJECTS AND METHODS

Fifteen subjects with stroke admitted to D and M Hospitals who provided their informed consent and met the inclusion criteria were enrolled in this study. The inclusion criteria included a diagnosis of hemiplegia more than 6 months earlier, ability to understand the researcher's instruction and training, a MMSE score of greater than 24, a Trunk Impairment Scale (TIS) sitting score of greater than 8 points, and an assessment of higher than stage 4 on the Brunnstrom stages of recovery for the lower extremity. Subjects with one or more of the following conditions were excluded from the study: a significant orthopedic condition or chronic pain condition affecting standing ability, symptoms of cardiac failure, uncontrolled hypertension, or a neurologic disease other than the initial stroke event (Table 1). All subjects signed a consent form approved by the Sahmyook University Institutional Review Board.

The subjects were asked to perform STS using three different strategies: symmetric foot position, unaffected foot placed behind the affected foot position (asymmetric-1), and affected foot placed behind the unaffected foot position (asymmetric-2). The researcher instructed each subject to perform 5 sit-to-stands for each of the foot positions. After the command "start", the subject leaned forward and rose to the standing position. After achieving the standing position, the subjects were asked to remain standing for 3 seconds while the erector spinae and gluteus maximus muscle activities were measured using surface electromyography (EMG). Then, they were instructed to sit down again at a comfortable speed⁹. Subjects performed STS while facing a mirror, so that they could visually see themselves performing the STS. In addition, in order to prevent them from leaning towards the unaffected side, each subject's hip joint was marked 5 cm away from a line on the mirror while sitting, and they were asked "please do not cross this line when you stand" prior to the test. The subjects sat on a chair, which did not have a back or armrest¹⁰. The height of the chair was adjusted so that each subject's knee joint was at a 90-degree angle with one-third of the thigh length resting on the seat¹¹. For the symmetrical foot placement, the feet were positioned shoulder-width apart with the toes aligned in the coronal plane. There were 2 asymmetrical foot positions, asymmetric-1 and asymmetric-2. For asymmetric-1, the affected knee angle was set at 90 degrees, and the toes of the unaffected foot were placed one half of the foot length behind the toes of the affected foot. For asymmetric-2, the unaffected knee angle was set at 90 degrees, and the toes of the affected foot were placed one half of the foot length behind the toes of the unaffected foot⁵.

During STS, EMG Telemetry 2400 G2 Telemetry EMB System (Noraxon, USA, 2007) was used to measure erector spinae and gluteus maximus muscle activities. Prior to applying the electrodes, hair was removed, and the skin was sterilized with alcohol after rubbing with fine sandpaper to

Table 1. General characteristics of the subjects (N=15)

	Subject
Gender (Male/Female)	7/8
Age (yr)	53.3 ± 10.9*
Height (cm)	164.9 ± 7.3
Weight (kg)	63.5 ± 8.9
Etiology (Infarction/Hemorrhage)	12/3
Paretic side (Left/Right)	10/5
Post-Stroke duration (months)	14.0 ± 10.5
MMSE (scores)	26.3 ± 1.7
Brunnstrom's Stages (3/4/5)	6/ 5/ 4
FMA (scores)	16.5 ± 5.5
TIS (scores)	11.5 ± 2.7

*Mean±SD

MMSE: Mini-Mental State Examination, FMA: Fugl-Meyer Assessment, TIS: Trunk Impairment Scale

reduce skin resistance. Adhesive electrodes were placed at the level of L2, 5 cm apart, lateral to the vertebrae for the erector spinae, and for the gluteus maximus, they were placed between the posterior iliac spine and the ischial tuberosity⁸.

The EMG signals were collected using a pair of pre-amplified Ag-AgCl surface electrodes with a diameter of 2 cm. The collected data were saved and analyzed using the MyoResearch Master Edition 1.06 XP. EMG signals were collected at a sampling rate of 1,500 Hz, and were bandpass-filtered between 20–450 Hz. Data were full-wave rectified, the RMS (root mean square) values were calculated, and the average values of 250 ms were computed.

Statistical analyses were performed using SPSS ver. 18.0 and the general characteristics of the subjects are presented as descriptive statistics. In order to determine the significance of differences in the erector spinae and gluteus maximus muscle activities among the three different foot positions, one-way repeated measure ANOVA was used. Significance was accepted for values of $p < 0.05$.

RESULTS

The affected erector spinae muscle activation was significantly greater with asymmetric-2 than symmetrical foot placement ($p < 0.05$). In addition, there was a more significant increase when the affected foot was placed behind the unaffected foot (asymmetric-2) than placement of the unaffected foot behind the affected foot (asymmetric-1) ($p < 0.05$) (Table 2).

The unaffected erector spinae muscle activation was significantly greater when the affected foot was placed behind the unaffected foot (asymmetric-2) than when the unaffected foot was placed behind the affected foot (asymmetric-1) ($p < 0.05$).

The affected gluteus maximus muscle activation showed a more significant increase when the affected foot was placed behind the unaffected foot (asymmetric-2) than when the unaffected foot was placed behind the affected foot (asymmetric-1) ($p < 0.05$).

Table 2. Muscle activities of the erector spinae and gluteus maximus during STS in the different foot positions (N=15)

Muscle (μ V)		Symmetric	Asymmetric-1	Asymmetric-2
ES	Affected	149.8 \pm 54.2*	147.3 \pm 53.8	180.7 \pm 73.4 ^{ab}
	Unaffected	156.9 \pm 75.8	151.2 \pm 76.5	173.5 \pm 83.1 ^b
GM	Affected	84.1 \pm 56.0	84.9 \pm 73.8	98.3 \pm 90.3 ^b
	Unaffected	71.5 \pm 41.1	87.9 \pm 69.9	82.5 \pm 51.4

Symmetric: with the toe aligned, asymmetric-1: unaffected foot placed behind the affected foot, asymmetric-2: affected foot placed behind the unaffected foot, ES: erector spinae, GM: gluteus maximus

*Mean \pm SD.

^aStatistically significant increase compared with symmetric ($p < 0.05$)

^bStatistically significant increase compared with asymmetric-1 ($p < 0.05$)

DISCUSSION

This study examined the differences in erector spinae and gluteus maximus muscle activities during STS with different foot placements. Mun et al. examined the effect of different support surfaces on the functional movement ability of stroke patients during STS¹²). Stephen et al.⁸) reported that after STS and maintaining stance, the erector spinae and gluteus maximus muscles were activated continuously, and that during STS, when the COM travels forward and then upward, maximal erector spinae muscle activation was seen. Since weakening of muscular strength occurs in the trunk muscles on the affected side of persons with stroke, the trunk muscles and extremity muscles need to be strengthened to improve this condition¹³). Camargos et al.⁵) reported that greater muscle activation and motor unit recruitment of the lower extremity was seen when the affected foot was placed behind the unaffected foot.

The present study examined the effects of foot position on erector spinae and gluteus maximus muscle activities during STS performed by stroke patients, and significant differences in the activation of the affected side erector spinae were observed among the positions. When the affected foot was placed behind the unaffected foot during STS, compared to the other two conditions, the affected erector spinae muscle activation was higher. Individuals with stroke tend to voluntarily avoid weight-bearing on the affected lower extremity and have difficulty achieving a symmetrical standing posture. To avoid this, Kim and Roh¹⁴) suggested placing the affected foot behind the unaffected foot during STS as it provides a more equal amount of weight-bearing and prevents overuse of the unaffected side. Chen et al.¹⁵) reported that when the affected lower extremity is placed behind the unaffected foot, in contrast to symmetrical foot placement during STS, a greater load is placed on the affected lower extremity, resulting in more equal weight-bearing by the lower extremities. Therefore, placing the affected foot

behind the unaffected foot should produce an increase in muscle activity of the affected lower extremity and promote weight-bearing on the affected side during STS.

This was a cross-sectional study that examined the erector spinae and gluteus maximus muscle activities, not the lower extremity muscle activities, so it was not possible to compare lower extremity and trunk muscle activities. Therefore, further studies are needed with larger sample sizes, which examine the erector spinae and gluteus maximus muscle activities as well as trunk and lower extremity muscle activities during STS. All the subjects demonstrated a significant increase in muscle activation of the affected erector spinae muscles during STS when the affected foot was placed behind the unaffected foot. Our results suggest that it may be better for persons with stroke to place the affected foot behind the unaffected foot when performing STS as it increases the affected side erector spinae and gluteus maximus muscle activities.

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