Effects of fast and slow squat exercises on the muscle activity of the paretic lower extremity in patients with chronic stroke

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Abstract. [Purpose] The purpose of this study was to investigate the effects of the speed of squat exercises on paretic lower extremity muscle activity in patients with hemiplegia following a stroke. [Subjects and Methods] Ten stroke patients performed fast and slow squat exercises for 2 seconds and 8 seconds, respectively. The muscle activities of the paretic and non-paretic sides of the rectus femoris muscle, the biceps femoris muscle, and the tibialis anterior muscle were assessed and compared using surface electromyography. [Results] The paretic side of the rectus femoris muscle showed statistically significant differences in the fast squat exercise group, which demonstrated the highest muscle activity during the rapid return to the upright position. [Conclusion] The rectus femoris muscle showed the highest muscle activity during the return to the upright position during the fast squat exercise, which indicates that the rectus femoris muscle is highly active during the fast squat exercise.

Key words: Fast and slow squat exercise, Muscle activity, Chronic strokes

INTRODUCTION

A stroke is a central nervous system disorder caused by brain damage from a cerebrovascular hemorrhage, resulting in hemiparesis with sensory impairment and muscle weakness1). The resultant problems include asymmetric posture, body unbalance, decreased weight-shifting capacity2, 3), and difficulties in performing functional activities such as walking4). Generally, hemiparetic patients compensate for restricted movement and muscle weakness by shifting the center of gravity to the non-paretic side5). This compensation strategy makes weight shifting to the paretic side inefficient and perpetuates the muscle weakness on the paretic side5). Therefore, strength training exercises targeting activation of the paretic lower extremity muscles may improve functional movements of stroke patients6).

Numerous research studies have investigated various interventions to enhance muscle strength in stroke patients with hemiplegia. One study introduced squat exercises as a means to strengthen paretic lower extremity muscles of stroke patients7). Squat exercises as weight bearing exercises are known to be helpful in performing functional tasks such as walking and maintaining balance8); compared to non-weight-bearing exercises, weight-bearing exercises require more joint movements, which induces functional muscle recruitment patterns and stimulates proprioception9).

Clark10) reported that velocity has a greater influence on functional movement than the force of contraction. Gray11) noted that post-stroke balance rehabilitation interventions to improve muscle power should also address the components of power: velocity of movement and muscle strength. However, there are few research studies investigating squat exercise prescription for hemiparetic patients or the effects of squat velocity on muscle activation in stroke patients with hemiplegia.

The goal of this research is to report paretic and non-paretic lower extremity muscle activation patterns during squat exercises performed at different velocities.

SUBJECTS AND METHODS

The subjects of this research were 10 stroke patients hospitalized in a hospital located in C city, Korea. The selection criteria for the subjects were as follows: (1) those who were diagnosed with hemiparesis following a stroke, 6 months to 5 years ago, (2) those who did not have any (neurological, musculoskeletal, or cardiopulmonary) lesions apart from a stroke, (3) those who did not have limited range of motion in the hip or knee joints, (4) those who could stand for 30 seconds without support. Subjects indicated full understanding and consent to the experimental procedures prior to data collection. All procedures were approved by Institutional Review Board committee of Sunmoon University.

The order in which the subjects performed the squat exercises was determined randomly. The slow squat exercise was performed for 8 seconds, which is 200% of the time suggest-
ed by Kulas12), and the fast squat exercise was performed for 2 seconds, which is 50% of the time suggested by Kulas12). The form of the squat exercise used was adopted and applied from the study by Gray11), Kang13) and Lee14). Subjects were instructed to keep their heels on the floor, widen the stance to shoulder width apart, and maintain the trunk vertically. With a start signal, the subjects bent their knees to 120 degrees and returned to the upright position. There were assistants who were assigned to send a stop signal when the knee angle of the subjects reached 120 degrees. The subjects performed 3 rounds of the fast exercise and the slow exercise and were given a 1-minute break between rounds to minimize muscle fatigue. The mean value for the muscle activities during the 3 rounds were attained and analyzed. In order to assess the lower extremity muscle activity for the subjects, both sides of the rectus femoris (RF), biceps femoris (BF), and tibialis anterior (TA) were measured using surface electromyography (EMG) OQUS100 (Zero WIRE EMG, Italy). The collected data was analyzed with SPSS v18.0 for Windows Program (SPSS Inc., Chicago, IL, USA), and the frequency (percentage) and the mean (standard deviation) were calculated. Repeated measure ANOVA was used to compare the muscle activities of the paretic and non-paretic sides of the lower extremity and to compare the fast and slow squat exercises. When a significant difference was demonstrated, post hoc comparisons were performed using a Bonferroni correction. The level of significance for the statistics of the research was p<0.05.

Table 1. muscle activation of paretic, non-paretic rectus femoris, biceps femoris, tibialis anterior (µV)

| Muscle   | Paretic side | Non paretic side |
|----------|--------------|------------------|
|          | FSDa        | FSAb             | SSDc            | SSAd |
| RF*      | 15.37±8.46  | 22.69±9.26       | 18.7±8.63       | 19.34±9.17 |
| BF       | 4.38±1.65   | 6.0±2.11         | 4.29±2.20       | 5.38±3.38  |
| TA       | 26.17±30.72 | 24.32±27.93      | 29.40±44.33     | 34.49±50.04 |
| RF       | 13.98±9.80  | 21.32±10.94      | 17.61±8.16      | 19.65±10.98 |
| BF*      | 4.28±2.35   | 5.16±2.37        | 3.46±2.07       | 4.22±2.70  |
| TA       | 18.3±13.39  | 31.06±39.88      | 15.34±8.37      | 12.85±5.72  |

Values are mean ± SD
RF: rectus femoris, BF: biceps femoris, TA: tibialis anterior, FSD: fast squat descending, FSA: fast squat ascending, SSD: slow squat descending, SSA: slow squat ascending
*a<p<0.05

**RESULTS**

Among the 10 subjects, the number of male and female subjects was 8 (80%) and 2 (20%), respectively. The mean age, height, and weight were 49.8 years, 170.8 cm, and 63.9 kg, respectively.

The muscle activities of the RF, BF, and TA were measured for both the paretic and non-paretic sides, and the measurement was performed for both the fast squat exercise and the slow squat exercise (Table 1). As for the paretic RF during the fast squat exercise, the muscle activities in the descending motion and the ascending motion were 15.37±8.46 and 22.69±9.26, respectively, showing a significant difference (p<0.05). During the slow squat exercise, the muscle activities in the descending motion and the ascending motion were 18.7±8.63 and 19.34±9.17, respectively, showing a significant difference (p<0.05). According to post hoc results, the paretic RF in the fast ascending squat motion was significantly greater than in the fast descending motion and the slow descending motion (p<0.05). In addition, the non-paretic BF muscle activities during the fast and slow squat exercises showed a significant difference (p<0.05). Therefore, the paretic RF in the fast ascending motion was more effective. There were no significant differences in the activities of the non-paretic RF, paretic BF and TA, and non-paretic TA.

**DISCUSSION**

This research, with an intent to examine the effects of fast and slow squat exercises on the paretic lower extremity of stroke patients, measured the muscle activities of the RF, BF, and TA for both paretic and non-paretic sides using 6-channel surface EMG. The paretic RF showed significant differences in both the fast and slow squat exercises, and the muscle activity was the highest in the ascending motion of the fast squat exercise.

According to Cheng15), the hamstring muscles had greater activation in the non-paretic leg of stroke patients during sit-to-stand movements. Kim16) also reported elevated muscle activities of the non-paretic BF in stroke patients during obstacle crossing on the ground and underwater. In this study, the muscle activity of the non-paretic BF was significantly different in the fast and slow squat movements.

In the study by Kim17), the muscle activity of the paretic side was increased using progressive resistive exercises with elastic bands. Teixeira-Salmela18) also reported that the muscle strength of the paretic lower extremity increased with muscle strength exercises. In this research, the muscle activity of the paretic side was higher than that of the non-paretic side in both the fast and slow squat exercises. Therefore, the use of lower extremity muscles increased in both the fast and slow squat exercises. Carr19) reported that the tendency of stroke patients to use only the non-paretic side of the lower extremity can be corrected by proper training, subsequently leading to muscle activation of the paretic lower extremity. Thus, it seems that the squat form used in this research reduced the inappropriate compensation strategy, significantly enhancing the muscle activity of the paretic side.

According to Gray11), the muscle activity of the paretic RF showed significantly increased activity in the final form.
of the squat exercise. Khemlani et al. also demonstrated that in the standing-up motion from the squatting posture, the quadriceps femoris and tibialis anterior are activated almost simultaneously, contributing to the knee stability before unbending the knee. In this research, the parietic RF showed higher muscle activity in the ascending motion, and the effect was even greater in the fast squat exercise. This result can prove that RF controls the final motion of the squat exercise.

According to Farthing and Shepstone, many studies regarding the velocity of resistance training have revealed that training at fast speeds is more effective than training at slow speeds. Furthermore, Bottaro reported that the studies for the elderly showed muscle strengthening effects with training at fast speeds rather than slow speeds. In this research, the more significant difference in RF muscle activity was observed in the fast squat exercise rather than the slow squat exercise. Thus, we conclude that the strengthening of the RF can be more effectively achieved by the fast squat exercise.

This research investigated the effects of squat exercise velocity on the paretic lower extremity of 10 stroke patients. According to the results, hemiparetic patients with damaged postural reflex utilize the RF to provide stability to the ankle joint, which exerts a positive influence on the paretic lower extremity through the fast squat exercise. Accordingly, we believe that squat training programs for stroke patients need to be designed with the consideration of the speed of exercises. Further studies will include more detailed velocity data to illustrate the effects of squat exercise on the paretic lower extremity muscle activity in stroke patients.

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