

Original Article

Activity of the Femoral Muscles during Toe-gripping Action

MASAYUKI SOMA, RPT, MS¹*, SHIN MURATA, RPT, PhD², YOSHIHIRO KAI, RPT, PhD²,
HIDEYUKI NAKAE, RPT, MS¹, YOUSUKE SATOU, RPT¹

¹) Course of Rehabilitation, Department of Health Sciences, Tohoku Fukushi University: 1-8-1 Kunimi,
Aoba-ku, Sendai-city 981-8522, Japan

²) Course of Physical Therapy, Department of Health Sciences, Kyoto Tachibana University, Japan

Abstract. [Purpose] In the present study, we investigated femoral muscle activity during toe-gripping, and the role of the femoral muscles in toe-gripping strength. [Subjects] Fourteen healthy young women were selected. [Methods] We measured the maximum voluntary contraction of the rectus femoris and long head of the biceps femoris muscles. We then calculated the percent integrated EMG (%IEMG) during the toe-gripping action. [Results] We found that the %IEMG of the biceps femoris was significantly higher than that of the rectus femoris. Moreover, a significant positive correlation was found between the %IEMG of the rectus femoris and that of the biceps femoris. [Conclusion] These results suggest that femoral muscles co-contract during the toe-gripping action, and thus possibly contribute to knee joint stability.

Key words: Toe-gripping strength, Activity of muscle, Healthy females

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INTRODUCTION

Toe-gripping is a complex motion involving several muscles. In the toe, these include the intrinsic flexor pollicis brevis, flexor pollicis longus, lumbricalis, flexor brevis, and flexor longus muscles¹). Toe-gripping strength is measured in the sitting position with the trunk vertical, the hip and knee joints at 90°, and the ankle joint in the neutral position¹⁻³). Low toe-gripping strength is a risk factor of falls for the elderly, and several studies have reported that toe-gripping strength is lower in subjects with a history of falls than in those with no history of falls¹⁻⁴). Furthermore, toe-gripping strength can be increased by training⁵), which can decrease the risk of falls¹). Therefore, interventions targeting toe-gripping strength are effective for fall prevention. However, the mechanism by which toe-gripping strength is produced remains unclear.

Souma et al.⁶) studied the %IEMG of several crural muscles (the soleus muscle, medial head of the gastrocnemius muscle, and tibialis anterior) during toe-gripping in 3 different ankle joint positions—10° of plantar flexion and 0° and 10° of dorsiflexion—and reported that the crural muscles help the ankle joint by co-contracting during toe-gripping. In another study, Nakae et al.⁷) calculated the %IEMG of the same muscles during toe-gripping with sub-

jects seated on the edge of a seat or standing, and reported that the %IEMG of the medial gastrocnemius muscle was significantly lower when subjects were seated than when they were standing. However, as both studies focused on the activity of the crural muscles, the activity of the femoral muscles during toe-gripping remains unclear. We believe it is important to elucidate the contribution of femoral muscles to toe-gripping strength.

In the present study, we investigated femoral muscle activity during toe-gripping to examine the role of the femoral muscles in toe-gripping strength.

SUBJECTS AND METHODS

Fourteen healthy young women with no known orthopedic impairments were selected. Their average (mean ± SD) age, height, and body weight were 20.6 ± 1.0 years, 159.4 ± 6.3 cm, and 51.8 ± 5.8 kg, respectively. This study was approved by the ethics committee for human research of Tohoku Fukushi University, and written informed consent was received from all of the subjects after the purpose of the study had been explained to them.

Toe-gripping strength of the dominant toe and EMG activity of the ipsilateral thigh were synchronously recorded to assess the activity of the rectus femoris and biceps femoris muscles. Toe-gripping strength was measured using a toe-gripping dynamometer (T.K.K.3360; Takei Co, Ltd, Niigata, Japan). As described by Uritani⁸), the subjects were instructed to sit with their trunk in the vertical position, hip and knee joints at 90°, and ankle joints in the neutral position. The handle of the force meter was set on the first metatarsophalangeal joint. After a sufficient number of training trials and adequate rest, toe-gripping strength was mea-

*Corresponding author. Masayuki Soma (E-mail: soma@tfu-mail.tfu.ac.jp)

sured twice and the maximal force was used in the analysis. For all subjects, the right toe was dominant (defined as the toe used to kick a ball).

To measure the maximum voluntary contraction (MVC) activity of the rectus femoris muscles, as described by Kai⁹⁾, each subject was instructed to sit on a chair with the hip and knee joints at 90°, and to exert maximal isometric force of knee extension while resisting an opposing force applied by the examiner. The EMG was recorded for 3 seconds while each subject exerted maximal force of knee extension. To measure the MVC of the biceps femoris muscle, each subject was instructed to generate maximal isometric force of knee flexion while resisting an opposing force applied by the examiner. The EMG was recorded for 3 seconds while each subject exerted maximal force of knee flexion. After confirmation of adequate skin preparation (skin resistance of less than 5 k Ω), three bipolar lead electrodes (DE-2.1, Delsys, Inc., Boston, USA) were attached to the skin over the rectus femoris and the long head of the biceps femoris, as described by Peroto¹⁰⁾. For measurement of the rectus femoris muscle, the electrode was attached at the midpoint between the superior edge of the patella and the anterior superior iliac spine. For measurement of the long head of the biceps femoris, the electrode was attached at the midpoint between the head of the fibula and ischial tuberosity.

The EMG signal was collected using ML846 Power Lab 4/26 (sample: 1,000 Hz; AD Instruments Co., Ltd.) and transferred to a personal computer. The bandwidth was 20–500 Hz. The EMG signal segment selected and integrated (integrated electromyogram: IEMG) for analysis was the middle 1 s of the entire 3-s duration of continuous maximal toe-gripping strength.

The IEMG was analyzed using Lab Chart Pro v7.3.5 (AD Instruments Co., Ltd.) and normalized to the IEMG of each muscle's MVC.

SPSS software (version 12.0 for Windows, SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Repeated Mann-Whitney U tests were used to compare the %IEMG of the rectus and biceps femoris muscles. Relationships between the %IEMG of the rectus and biceps femoris muscles were statistically analyzed using Spearman's correlation coefficient. The level of significance was chosen as 5%.

RESULTS

The average (mean \pm SD) toe-gripping strength was 20.9 \pm 3.6 kg. The average (mean \pm SD) %IEMG values of the rectus and biceps femoris muscles were 7.0% \pm 6.2% and 25.6% \pm 15.9%, respectively. The %IEMG of the biceps femoris was significantly higher than that of the rectus femoris ($p < 0.01$, Table 1).

Using Spearman's correlation coefficient analysis, a significant positive correlation was found between the %IEMG of the rectus femoris and that of the biceps femoris ($r = 0.548$, $p < 0.05$).

Table 1. Comparison of the %IEMG values of the rectus femoris and biceps femoris muscles during toe-gripping action

	Rectus femoris median (range: min–max)	Biceps femoris median (range: min–max)
%IEMG	4.8* (1.5–21.1)	27.2 (3.0–68.1)

Mann-Whitney U test*: $p < 0.05$

DISCUSSION

In the present study, we found that the %IEMG of the biceps femoris was significantly higher than that of the rectus femoris. Moreover, a significant positive correlation was found between the %IEMG of these two muscles. These results suggest that femoral muscles co-contract during toe-gripping action, and thus possibly contribute to knee joint stability.

We found that toe-gripping action stimulates femoral muscle activity and that the %IEMG of the biceps femoris was significantly higher than that of the rectus femoris. Sato et al.¹¹⁾ reported that during toe-gripping, the tibialis anterior and soleus muscles are activated first, followed by the gradual activation of the medial head of the gastrocnemius muscle. The biceps femoris initiates knee flexion, and the medial head of the gastrocnemius is a synergist for knee flexion. Additionally, active tension of the biceps femoris decreases during toe-gripping in knee flexion. This may be because the length of the biceps femoris is shorter during active tension than during resting tension. We think that the activation of the biceps femoris during toe-gripping was caused by increasing motor unit recruitment and synchronization of the impulse to compensate for decreasing activity of the biceps femoris.

In the present study, we found a significant positive correlation between the %IEMG of the rectus femoris and that of the biceps femoris. This suggests that the %IEMG of the rectus femoris increases with increases in the %IEMG of the biceps femoris. In other words, these muscles co-contract during toe-gripping.

Toe-gripping strength was measured using a closed kinetic chain movement, and therefore, the likelihood of movement in the directions of flexion or extension of the knee joint is less. However, because the gastrocnemius also acts on knee joint flexion during exertion of toe-gripping strength, the knee joint is readily displaced in the direction of flexion. To prevent this, it is thought that the knee joint is immobilized by contraction of the rectus femoris, that is, we think the rectus femoris during exertion of toe-gripping strength acts in order to control the action of knee joint flexion by the gastrocnemius.

Our study had certain limitations. First, we were unable to avoid the common problems that negatively affect surface EMG recording, such as skin resistance, artifacts, and the effects of proximal muscles. Second, as only healthy young women participated in this study, it is difficult to extend our findings to the general population. In future studies, we need to consider this aspect, and involve healthy young men and individuals of different age groups.

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