

# Hip Muscle Activity during Isometric Contraction of Hip Abduction

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**Abstract.** [Purpose] This study aimed to determine the effect of varying hip flexion angle on hip muscle activity during isometric contraction in abduction. [Subjects] Twenty-seven healthy men (mean age=21.5 years, SD=1.2) participated in this study. [Methods] Surface electromyography (EMG) was recorded of the upper portion of the gluteus maximus (UGM), lower portion of the gluteus maximus (LGM), tensor fasciae latae (TFL), and gluteus medius (GMed) during isometric contraction under two measurement conditions: hip flexion angle (0, 20, 40, 60, and 80 degrees) and abduction of the hip joint at 20, 40, 60, and 80% maximum strength. Integrated EMG (IEMG) were calculated and normalized to the value of maximum voluntary contraction (MVC). [Results] Results indicated that the IEMG of both the UGM and LGM increased significantly with increases in hip flexion angle, whereas the IEMG of the TFL decreased significantly. The maximum activities of the UGM and the LGM were  $85.7 \pm 80.8\%$ MVC and  $38.2 \pm 32.9\%$ MVC at 80 degrees of hip flexion, respectively, and that of the TFL was  $71.0 \pm 39.0\%$ MVC at 40 degrees of hip flexion. [Conclusion] The IEMG of the GMed did not change with increases in hip flexion angle. Hip flexion angle affected the activity of the GM and TFL during isometric contraction in abduction.

**Key words:** Hip abductor, Electromyography, Muscle activity

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## INTRODUCTION

The activity of the gluteus maximus (GM) in standing movements is very important. In particular, it seems that the activity of the GM increases during one foot standing with the trunk tilted anteriorly because the GM acts in both abduction and extension of the hip joint. However, most studies that use the moment arm vector concept have reported that the abductor function of the GM is weak<sup>1, 2)</sup>. A straight-line model study of the GM with the hip in the anatomical zero position found that the GM was unimportant for abduction of the hip joint. We question this finding based solely on anatomical neutral position, because the hip joint, which is a ball and socket joint, can adopt various positions. Although GM is known as an extensor of the hip joint in humans, it acts as an abductor in tetrapods<sup>3)</sup>; therefore GM has the possibility of acting as a hip abductor in flexion of the hip joint. Basmajian and DeLuca<sup>4)</sup> reported that the GM was active during extension of the thigh at the hip joint, lateral rotation, abduction against heavy resistance with the thigh flexed to 90°, and adduction against resistance that holds the thigh abducted. Although some studies<sup>5, 6)</sup> have

reported results agreeing with those of Basmajian and DeLuca<sup>4)</sup>, they did not describe the details of electromyography data.

Several studies<sup>7-9)</sup> have reported that the GM is functionally divided into upper (UGM) and lower segments (LGM). Both the UGM and sartorius muscles might assist hip abduction against strong muscle resistance<sup>8)</sup>. However, little attention has been given to GM activity during abduction in flexion of the hip joint. We postulated that the human GM would play the same important abductor function in flexion of the hip joint as it does in tetrapods. We, therefore, hypothesized that GM activity is directly proportional to the resistance provided against adduction in flexion of the hip joint.

Hislop and Montgomery<sup>10)</sup> reported an increase in the activity of the tensor fasciae latae (TFL) during abduction in flexion of the hip joint; however, other studies report that the activity of the TFL decreases in the same condition<sup>11, 12)</sup>. We postulated that TFL activity would decrease with increasing hip joint flexion, because the TFL force vector passes through the forward hip joint in hip flexion; therefore, the TFL would act as an abductor, or as a flexor. Moreover, because the gluteus medius (GMed), together with the gluteus minimus, both abduct and stabilize the hip joint<sup>13, 14)</sup>, the effect of hip flexion angle on GMed activity is not known well. The purpose of this study was to determine the effect of hip flexion angle on the activities of the GM, TFL, and GMed during isometric contraction in abduction.

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## SUBJECTS AND METHODS

Twenty-seven healthy males (age  $21.5 \pm 1.2$  years; height  $172.8 \pm 5.0$  cm; body mass  $64.6 \pm 2.3$  kg (mean  $\pm$  SD)) with no history of hip joint problems participated in this study. All subjects provided their written informed consent prior to participation, and approval was granted by the Tohoku Bunka Gakuen University's Human Subjects Ethics Committee.

We measured the maximum abduction strength (MAS) of the right hip joint and surface electromyography (EMG). EMG data were collected from four segments of three muscles: the right UGM, LGM, GMed, and TFL. Measurement conditions were hip flexion angles of 0, 20, 40, 60, and 80 degree, and strength of right hip abduction of 20, 40, 60, and 80%MAS.

With subjects lying prone on a table, the gluteus region was cleaned using fine sand paper and alcohol before disposable electrodes were placed on the skin superficial to the belly of the muscles. UGM electrodes were placed two finger's width above the line just under the spina iliaca posterior superior and the trochanter major; LGM electrodes were set below the same line; TFL electrodes were placed between the spina iliaca anterior superior and the trochanter major; and GMed electrodes were set between the UGM and TFL. The distance between electrodes was 2.5 cm. After we had confirmed the belly of the muscles via an ultrasound scan (Viewbox, TANITA, Tokyo, Japan), proper electrode placement was determined. EMG were amplified by bipolar leads (MT-11, GEHC-J, Tokyo, Japan). EMG were measured during maximum voluntary isometric contraction (MVC) in the two positions as described by Hislop and Montgomery (2007): the TFL and GMed were measured during side-lying abduction at 0 degrees flexion of the hip joint, and the UGM and LGM were measured during prone-lying extension with knee flexion. Subjects were instructed to maintain their maximum voluntary contraction for 3 seconds and EMG measurements were taken once.

After taking EMG measurements of MVC, subjects lay supine on the table with a slippery sheet spread under around the lower extremity, and the pelvis fixed to the bed with a belt. We measured MAS at 0 degrees flexion of the hip joint with a strain gauge sensor ( $\mu$ -TAS MT1, ANIMA, Tokyo, Japan), which was placed between the resistance belt and the epicondylus lateralis. The knee joints were maintained in the neutral position, and the ankle joint was fixed in the neutral position with a plastic shoehorn brace.

The table was manipulated to achieve the different hip angles for each measurement. Subjects were instructed to control abduction strength to the indicated value for 3 seconds, and EMG measurements were taken as described above. Biofeedback of abduction strength was given to subjects via a display. The analog EMG signal passed through a 16 bit A/D board (PowerLab, ADInstruments, Nagoya, Japan), and all signals were sampled at 1 kHz.

EMG data were filtered with a 10 Hz high-pass, FIR digital filter. After the signal was full-wave rectified, the integrated EMG (IEMG) was calculated using the steady data of 2 seconds within the 3 seconds of data. Data of each

trial were normalized to the IEMG of MVC. We used the normalized IEMG (%MVC) to express the muscle activity.

A two-factor,  $5 \times 4$ , within-subjects analysis of variance (ANOVA) was used to analyze differences in activities of the hip muscles. Independent variables were the factors of hip flexion angle and %MAS, and the dependent variable was hip muscle activity. Significant individual differences were evaluated using the Scheffe test. Differences were assessed with two-sided tests, with an alpha level of 0.05.

## RESULTS

MAS were  $130.5 \pm 16.9$  Nm at 0 degrees flexion of the hip joint. For the UGM, the ANOVA showed significant main effects of both hip flexion angle ( $p < 0.001$ ) and %MAS ( $p < 0.001$ ). The IEMG increased with each increment of hip flexion angle and %MAS. There was a significant interaction effect between hip flexion angle and %MAS ( $p < 0.001$ ). Also, the change in the IEMG between the hip flexion angles increased with each increment of %MAS (Table 1).

For the LGM, there were significant main effects of both hip flexion angle ( $p < 0.001$ ) and hip abduction strength ( $p < 0.001$ ). The IEMG increased with each increment of hip flexion angle and %MAS. Although there was a significant interaction effect between the two conditions ( $p < 0.001$ ), the simple main effect was not significant for hip flexion angles at 20% MAS (Table 1).

The results for the GMed differed from those of the UGM and LGM. Although there were significant main effects of both hip flexion angle ( $p < 0.05$ ) and %MAS ( $p < 0.001$ ), there was no significant interaction effect between hip flexion angle and %MAS. The Scheffe tests also showed no significant the differences among the hip flexion angles (Table 1).

Finally, for the TFL, there were significant main effects of both hip flexion angle ( $p < 0.001$ ) and hip abduction strength ( $p < 0.001$ ). The IEMG, however, decreased as hip flexion angle increased. TFL activity increased though with each increment of MAS, just as for the other muscles, but there was no significant interaction effect between hip flexion angle and %MAS (Table 1).

## DISCUSSION

This study confirmed our hypothesis that GM activity is directly proportional to resistance against adduction in flexion of the hip joint. The GM in the anatomical neutral position of the hip has an action line that is nearly perpendicular to the femoral shaft, whereas its action line becomes parallel to the femoral shaft in flexion of the hip joint. More specifically, mean UGM activity reaches 80% MVC, because the UGM shifts to a position nearly parallel to the femoral shaft. In contrast, the moment arm of the GM in hip extension decreases as the hip flexion angle increases<sup>15</sup>. Therefore, an abductor function in flexion of the hip joint might be an important function of the GM.

Human walking is characterized by erect bipedalism, and it is thought that the UGM evolved alongside erect bipedalism, because daily activities performed while standing require the muscle forces of abduction and extension of the hip joint. During walking, GM activity increases syn-

**Table 1.** Hip muscles activities during isometric contraction of abduction with increases in hip flexion angle

	0 degrees	20 degrees	40 degrees	60 degrees	80 degrees
<b>Gluteus Maximus (upper)</b>					
20%MAS	4.6± 3.2	7.1± 6.5	7.7± 7.8	8.4± 9.0 †	9.7± 8.4 ‡
40%MAS	7.9± 7.7	11.1±14.1 †	15.4±18.7 †	19.5±20.8 ‡	25.5±24.4 ‡
60%AS	12.9±13.2	20.1±22.3 †	28.2±29.3 †	37.1±35.9 ‡	48.8±41.3 ‡
80%MAS	29.5±20.9	33.9±25.1	51.9±53.5 †	59.8±54.3 ‡	85.7±80.8 ‡
<b>Gluteus Maximus (lower)</b>					
20%MAS	3.9± 1.7	5.4± 4.2	6.1± 7.6	5.1± 4.2	5.0± 2.1
40%MAS	5.3± 2.3	5.4± 2.6	8.3±10.1	9.0±11.0	11.5±15.0
60%MAS	8.3± 4.2	9.8± 7.4	12.7±11.0	17.2±23.0	20.8±21.3 †
80%MAS	20.2±15.2	19.4±11.8	25.5±21.3	30.8±27.6	38.2±32.9 †
<b>Gluteus Medius</b>					
20%MAS	5.2± 3.9	6.2± 4.3	7.0± 5.3	8.0± 6.1	9.1± 7.3
40%MAS	13.1± 9.0	12.6± 8.0	14.5± 9.9	18.3±13.8	21.9±18.7
60%MAS	32.2±18.0	29.1±19.1	32.6±20.9	35.4±24.2	40.3±33.0
80%MAS	58.6±29.7	52.6±31.3	53.8±43.2	54.9±43.0	66.1±53.0
<b>Tensor fasciae latae</b>					
20%MAS	14.1± 7.9	13.3± 7.8	11.1± 5.7	9.7± 6.8 †	6.9± 4.5 ‡
40%MAS	28.0±12.3	23.2± 9.4 †	22.4±11.1 †	20.2±10.5 †	15.1± 9.9 ‡
60%MAS	49.4±17.5	41.2±16.8 †	44.5±31.5	34.9±17.8 ‡	27.1±15.0 ‡
80%MAS	69.8±29.4	71.0±39.0	55.3±32.7	49.3±27.5 ‡	45.1±23.9 ‡

Significant difference from 0 degrees at each %MAS. †:  $p<0.05$ . ‡:  $p<0.01$ .

MAS=maximum abduction strength, Unit:%MVC (maximum voluntary isometric contraction)

chronously with the GMed from the terminal swing to mid-stance<sup>7, 9</sup>. The UGM acts as an abductor and hip abductor muscle activity increases rapidly in the loading response (20%MVC); an external force acts on flexion and adduction of the hip joint when it is flexed at approximately 30 degrees in the loading response phase<sup>16</sup>.

GMed activity showed no significant differences with change of hip flexion angle in this study. The GMed is a fan-shaped muscle composed of three distinct parts<sup>13, 14</sup>. In this study, electrodes were placed over the middle part, which runs forward to the femoral neck in the anatomical neutral position and attaches to the ridge on the great trochanter, which is located near the center of the hip joint in the sagittal plane. Although the moment arm vector of abduction for the GMed anterior segment decreases in flexion of the hip joint<sup>17</sup>, it is not obvious for the middle and posterior segments. Moreover, the GMed, together with the gluteus minimus, are known stabilizers of the hip joint. For example, a single-leg bridge exercise in the supine position activated the GMed to 72.5% MVC<sup>18</sup>. Therefore, there is a possibility that the GMed middle segment acts through a wide range of hip joint motion.

TFL activity decreased with increasing hip flexion in contrast to the UGM and LGM. This result was same as that reported by Matsuki et al.<sup>12</sup>, who reported that TFL activity measured by EMG with fine-wire electrodes decreased in flexion of the hip joint. Although the TFL is separated into two parts, anteromedial and posterolateral<sup>19</sup>, it is difficult to measure each part using EMG. For this reason, we placed the electrodes on the center of the belly. The TFL attaches

from the spina iliaca anterior superior to the fascia lata and inserts upon the tractus iliotibialis. The TFL shifts to a position nearly perpendicular to the femoral shaft with each increment of hip flexion. Thus the TFL is a hip flexor rather than an abductor when the hip is flexed, which explains why TFL activity decreased with increasing hip flexion.

The results of this study suggest two important points for physical therapy. First, it is possible that the UGM plays an important role in posture maintenance in flexion of the hip joint, for instance, in walking with anterior tilt of trunk in a passage where the ceiling is low, or when ascending stairs. The strength training of the UGM, therefore, is important for improvement of the function. Second, there is suitable posture for each muscle in the strength training of the hip abductors. For strengthening the TFL, abduction movement in hip extension is desirable. In contrast, abduction movement in hip flexion is desirable for strengthening the UGM.

Limitations on this study were cross-talk from nearby muscles and changes in electrode location with hip joint flexion. Cross-talk was cannot be entirely excluded from surface electromyography data. In addition, we should pay attention to the spatial relation between the innervation zone and the electrodes because it affects EMG amplitude.

In conclusion, UGM and LGM activities increased significantly as a function of incremental increases in hip flexion angle. In comparison, TFL activity decreased significantly with incremental increases in hip flexion angle. On the other hand, GMed activity did not change as a function of hip flexion angle.

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