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Original Article

Piriformis electromyography activity during prone and side-lying hip joint movement

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Abstract. [Purpose] To measure electromyographic activity of the piriformis using fine-wire electrodes during 7 hip movements. [Subjects and Methods] Eleven healthy men, without severe low back pain or lower limb injury, participated in this study. Fine-wire electrodes were inserted into the piriformis and surface electrodes were attached to the muscles in the hip region and the trunk muscles on the dominant arm side. Electromyographic signal amplitude was measured during 7 hip movements: side-lying external rotation in hip neutral position, side-lying abduction in hip neutral position, side-lying abduction in hip external rotation, side-lying abduction in hip internal rotation, prone extension in hip neutral position, prone extension in hip external rotation, and prone extension in hip internal rotation. Repeated-measures one-way analysis of variance was used to examine electromyographic activity in each of the 7 hip movements. [Results] Piriformis electromyographic activity was highest during prone hip extension in external rotation. Both the superior and inferior portions of the gluteus maximus were also highly activated during prone hip extension in external rotation. [Conclusion] Prone hip extension in external rotation induced high electromyographic activity in the piriformis and superior and inferior gluteus maximus muscles.
Key words: Electromyography, Piriformis, Hip external rotator

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INTRODUCTION

Extensors produce the greatest torque among all the hip muscle groups[1)]. The gluteus maximus (GMax), adductor magnus, hamstrings, and gluteus medius (GMed) are mobilizing muscles for hip extension[2–4)]. In contrast with the extension mobilizers, the short external rotators of the hip supply mechanical stability[5)]. The piriformis is an important hip stabilizer[6)], and should act as a functional stabilizer during hip extension. A study by Gilphart et al.[7)] speculated that the piriformis may have a role in stabilizing the hip joint during dynamic movement such as walking. Bennell et al.[8)] stated that improved strength in the hip external rotator muscles is essential to rehabilitation after hip arthroscopy. These previous studies emphasize the importance of the piriformis for normal function.

To evaluate piriformis function, two recent studies used EMG measurements with bipolar fine-wire electrodes. Gilphart et al.[7)] reported highest piriformis EMG activity during movement involving hip extension and also observed higher activity during hip abduction. Hodges et al.[9)] reported that piriformis activation was significantly higher during hip extension, external rotation, and abduction than in hip flexion, internal rotation, and adduction. Both studies found high piriformis activation during hip extension, external rotation, and abduction.

However, neither study investigated piriformis EMG characteristics from an anatomical perspective. Although Gilphart et al.[7)] and Hodges et al.[9)] noted the characteristics of piriformis EMG activity during 13 hip rehabilitation exercises and 6

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Table 1. Details of each hip movement

Trials	Positions	Movement	Hip positions
1) SL-ER	Side-lying	External rotation	Neutral
2) SL-Abd	Side-lying	Abduction	Neutral
3) SL-Abd-ER	Side-lying	Abduction	External rotation
4) SL-Abd-IR	Side-lying	Abduction	Internal rotation
5) PR-Ext	Prone	Extension	Neutral
6) PR-Ext-ER	Prone	Extension	External rotation
7) PR-Ext-IR	Prone	Extension	Internal rotation

SL-ER: side-lying external rotation; SL-Abd: side-lying abduction; SL-Abd-ER: side-lying abduction in external rotation; SL-Abd-IR: side-lying abduction in internal rotation; PR-Ext: prone extension; PR-Ext-ER: prone extension in external rotation; PR-Ext-IR: prone extension in internal rotation.

simple hip movements, respectively, neither study examined the effects of different hip joint positions (external rotation or internal rotation) on EMG activity. The deep hip external rotators are often referred to as the rotator cuff of the hip[5, 6], as their role and morphology are analogous to the rotator cuff muscles of the shoulder, especially the infraspinatus and teres minor. Kurokawa et al.[10] clarified their functions in different glenohumeral joint positions and proposed that the infraspinatus was activated more in shoulder adduction whereas the teres minor was activated more in abduction. Hamada et al.[11] reported that teres minor EMG activity was higher during external rotation at 90° of glenohumeral joint abduction than at 0° of abduction. In contrast to the proposed functions of the rotator cuff muscles, little is known about the external hip rotators. Furthermore, analysis of monoarticular muscles surrounding the hip joint, as typified by the external rotators, has not been sufficient to achieve consensus on their functions. Therefore, this study aimed to investigate the response of the piriformis to changes in hip joint position.

SUBJECTS AND METHODS

Eleven healthy volunteers (average height: 174.0 ± 7.5 cm, body mass: 71.7 ± 13.5 kg, age: 22 ± 2 years) participated in this study. Participants were excluded if they had lower limb injuries or low back pain in the prior three months. As an invasive protocol with bipolar fine-wire insertion was involved, the examiner fully explained the experiment, the safety of the method, and treatment in an emergency before commencement of the study. An ultrasound device (LOGIQ e, GE, USA) was used to verify needle tip, tissue, and piriformis locations. Subjects gave written informed consent if they agreed to participate. This study was approved by the ethics committee of Waseda University (2016-093).

Bipolar, fine-wire, intramuscular, Teflon-coated, stainless steel electrodes with uninsulated tips bent at 3 mm and 5 mm to create hooks, were attached to 23-G sterilized Cattelan needles (Unique Medical, Japan) and used for measurement of piriformis EMG activity. Insertion into the piriformis was accomplished by an experienced orthopedic surgeon[12]. The participants were placed in side-lying position with their dominant hand side up, and with knees flexed at 90° and hips flexed at 45°. After identification of the piriformis muscle on the monitor, a Cattelan needle, with an attached bipolar fine-wire electrode was inserted into the piriformis under ultrasound guidance.

In addition to piriformis EMG measurement with implanted electrodes, measurement with surface electrodes (BlueSensor N-00-S, METS Co., Japan) was also performed. The target muscles were the inferior portion of the gluteus maximus (i-GMax), superior portion of the gluteus maximus (s-GMax), gluteus medius (GMed), biceps femoris, rectus femoris, semitendinosus, adductor magnus, internal oblique, external oblique, rectus abdominis, erector spinae, and multifidus. As the inferior and superior portions of the gluteus maximus have distinct functions[13], measurement of gluteus maximus activity was divided into two categories. The surface electrodes were placed perpendicular to muscle fibers.

This study examined 7 different hip movements. The effects of different hip joint positions on 3 hip movements that reportedly induce high piriformis EMG activity were evaluated[7, 9]: hip side-lying external rotation, hip side-lying abduction, and hip prone extension. The specific trials are shown in Table 1 and Fig. 1. All trials were performed with the knee extended. Subjects were directed to position their hips in maximum external and internal rotation without compensatory upper limb movement.

Before the trials, the examiner attached reflective markers (QPM190, Qualysis AB, Sweden) to the lateral femoral epicondyle, lateral malleolus, and greater trochanter on the dominant arm side. Every seventh trial was photographed using 6 3D motion-capture cameras (OQUS, Qualysis AB, Sweden) at a sampling rate of 200 Hz; the cameras were synchronized with a versatile telemetry EMG system and wireless EMG sensors (BioLog DL-5000, S&ME Co., Ltd., Japan). To identify a start point, a 1-s rest time was set prior to each trial. Using the average and standard deviation of the Z-coordinate for the middle 500 ms during the rest time, we defined the start point at the Z-coordinate beyond "average + 2 SD." Immediately after the rest time, the subjects were instructed to perform each trial for 3 s. This study analyzed EMG activity for each muscle during each trial, from the start point to the finish point, where the markers on the lateral femoral epicondyle reached the highest level.

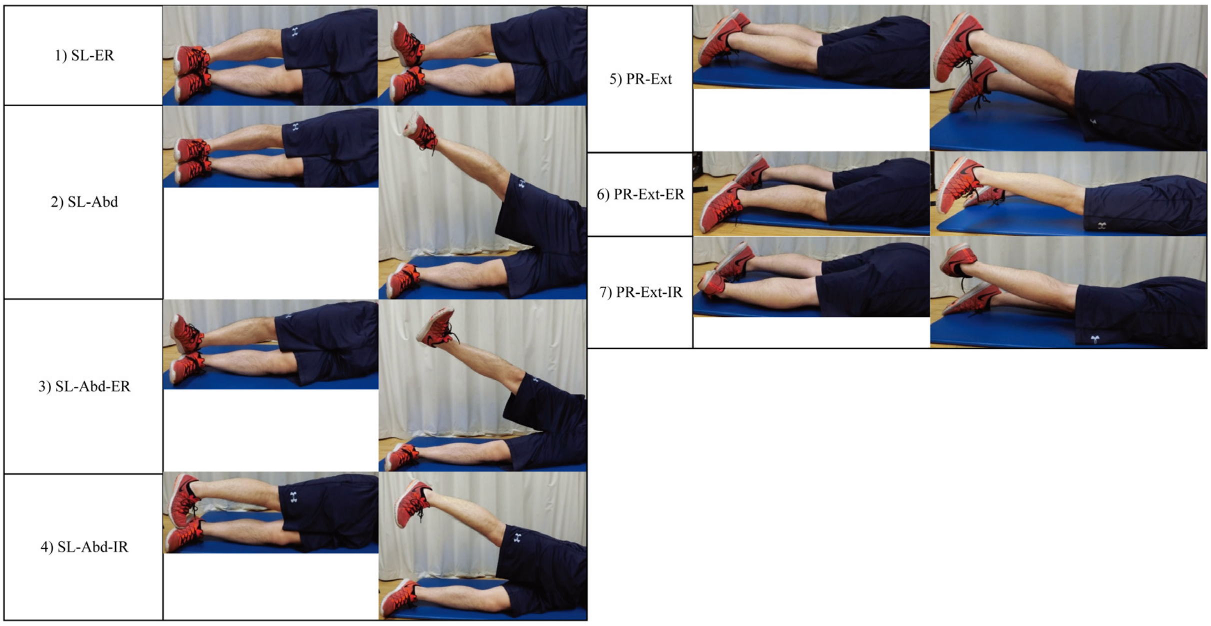

Fig. 1. Details of each hip movement.
Left picture: starting joint positions, right picture: highest joint positions.
SL-ER: side-lying external rotation; SL-Abd: side-lying abduction; SL-Abd-ER: side-lying abduction in external rotation; SL-Abd-IR: side-lying abduction in internal rotation; PR-Ext: prone extension; PR-Ext-ER: prone extension in external rotation; PR-Ext-IR: prone extension in internal rotation.

EMG activity was examined using biological information analysis software (BIMUTAS-Video, Kissei Comtec Co., Ltd., Japan). EMG activity was sampled at 1,000 Hz. The bandpass filter for the fine-wire electrodes was processed between 10 and 1,000 Hz, whereas that for the surface electrodes was between 20 and 500 Hz. EMG activity was represented as percent maximum voluntary contraction (%MVC), which was calculated from the root mean square (RMS) amplitude and normalized by the RMS of the MVC. Piriformis MVC was obtained with maximum hip external rotation against resistance from the examiner, with the subject in side-lying position with the dominant arm side up, the knee flexed at 90°, and the hip slightly flexed. Prior to the study, we determined this position as the most suitable for independent measurement of piriformis EMG activity with minimal GMax and GMed activity. MVC for GMax and GMed was also obtained with maximum prone hip extension and side-lying hip abduction against resistance from the examiner.

Repeated-measures one-way analysis of variance was used to determine which trials increased EMG activity in each hip region muscle.

RESULTS

EMG activity of each muscle is shown in Table 2. Piriformis EMG activity with prone extension in hip external rotation (PR-Ext-ER) showed the highest activation among all trials ($p<0.05$, excluding that for side-lying abduction in hip external rotation [SL-Abd-ER], $p<0.1$). More specifically, in a comparison of 3 extension trials, piriformis EMG activity with PR-Ext-ER was higher than that in 2 other trials: prone extension in hip neutral position (PR-Ext) and prone extension in hip internal rotation (PR-Ext-IR). On the other hand, piriformis EMG activities during all 3 abduction trials, i.e., side-lying abduction in hip neutral position (SL-Abd), SL-Abd-ER, and side-lying abduction in hip internal rotation (SL-Abd-IR) were not significantly different. Furthermore, in a comparison of hip abduction and extension in different hip positions, piriformis EMG activity with PR-Ext-ER tended to be higher than that with SL-Abd-ER, whereas activity with PR-Ext-IR and PR-Ext was not significantly different from that with SL-Abd-IR and SL-Abd.

With respect to i-GMax EMG activity, PR-Ext-ER showed highest activation compared with other trials except PR-Ext ($p<0.05$). More specifically, in a comparison of 3 extension trials, i-GMax EMG activity with PR-Ext-ER was higher than that with PR-Ext-IR. With regard to s-GMax EMG activity, PR-Ext-ER showed highest activation among all trials. More specifically, in a comparison of 3 extension trials, s-GMax EMG activity with PR-Ext-ER was higher than that with PR-Ext and PR-Ext-IR.

Table 2. Mean amplitude of all 13 muscle EMG activities during the seven trials (%MVC)

Trials	Piriformis (n=10)	i-GMax (n=10)	s-GMax (n=10)	GMed (n=10)	BF (n=10)	ST (n=9)	RF (n=10)	RA (n=7)	EO (n=9)	IO (n=9)	ES (n=8)	MF (n=10)	Add (n=9)
1) SL-ER	$7.0 \pm 5.9^{*}$	$5.2 \pm 3.2^{*}$	$5.8 \pm 2.6^{*}$	$6.6 \pm 5.0^{*}$	$2.0 \pm 1.6^{*+-}$	$1.3 \pm 0.8^{**}$	5.5 ± 5.9	9.9 ± 18.6	10.7 ± 9.4	3.8 ± 2.9	2.3 ± 1.1	2.9 ± 2.8*	9.3 ± 6.6
2) SL-Abd	$18.6 \pm 9.1^{*}$	$5.6 \pm 2.4^{*}$	$17.7 \pm 12.1^{*}$	$38.0 \pm 14.2^{*}$	$1.9 \pm 1.9^{*+-}$	2.8 ± 4.0	9.6 ± 17.0	3.5 ± 2.8	20.8 ± 24.3	9.6 ± 7.3	10.1 ± 7.5	13.8 ± 17.4	32.7 ± 40.1
3) SL-Abd-ER	$15.3 \pm 9.7^{**}$	$6.4 \pm 3.0^{*}$	$19.7 \pm 15.2^{*}$	$40.5 \pm 16.9^{*}$	$1.8 \pm 1.8^{*+-}$	$2.1 \pm 3.2^{**}$	16.7 ± 15.7	3.5 ± 2.5	44.0 ± 72.6	8.7 ± 7.0	6.5 ± 5.3	11.7 ± 15.0	25.5 ± 29.2
4) SL-Abd-IR	$18.4 \pm 18.6^{*}$	$5.7 \pm 2.5^{*}$	$15.1 \pm 8.8^{*}$	$36.3 \pm 16.7^{*‡}$	$2.7 \pm 3.7^{*+-}$	$3.3 \pm 2.8^{**}$	4.7 ± 6.0	4.1 ± 2.7	17.1 ± 13.4	13.1 ± 8.3	10.1 ± 5.9	13.3 ± 13.0	15.8 ± 16.6
5) PR-Ext	$30.5 \pm 26.3^{*}$	23.5 ± 18.7	$22.2 \pm 15.2^{*}$	$16.7 \pm 11.1^{†}$	$32.3 \pm 13.3^{*}$	35.2 ± 25.5	11.0 ± 18.7	7.2 ± 9.6	19.5 ± 15.2	12.1 ± 22.6	28.2 ± 17.6	$33.7 \pm 23.6^{*}$	17.1 ± 12.1
6) PR-Ext-ER	$69.6 \pm 40.6^{*}$	$33.1 \pm 9.5^{*}$	$56.8 \pm 19.8^{*}$	$42.0 \pm 21.6^{*†}$	$38.8 \pm 17.1^{+}$	16.5 ± 11.2	3.7 ± 3.2	4.9 ± 3.2	32.3 ± 36.8	12.7 ± 11.1	26.7 ± 18.7	38.2 ± 22.8*	10.4 ± 4.9
7) PR-Ext-IR	$9.8 \pm 7.4^{*}$	$15.1 \pm 12.6^{*}$	$11.2 \pm 9.7^{*}$	$12.5 \pm 10.0^{†‡}$	$29.0 \pm 11.2^{-}$	$41.3 \pm 26.1^{*}$	10.8 ± 10.0	4.7 ± 3.9	13.9 ± 6.8	20.3 ± 27.0	29.1 ± 16.3	67.0 ± 103.9	27.9 ± 26.1

Values are shown as mean ± SD.
Bold is used to reveal the significant EMG activity. *, †, ‡, $p<0.05$, **,††, ‡ ‡ $p<0.1$.
SL-ER: side-lying external rotation; SL-Abd: side-lying abduction; SL-Abd-ER: side-lying abduction in external rotation; SL-Abd-IR: side-lying abduction in internal rotation; PR-Ext: prone extension; PR-Ext-ER: prone extension in external rotation; PR-Ext-IR: prone extension in internal rotation.

DISCUSSION

Piriformis EMG activity during prone hip extension was significantly higher with the hip joint in external rotation. All extension trials in this study were movements in the sagittal plane, and did not generate differences in the required modalities of movement. However, there was a clear distinction before the start of trials. As each hip extension had to start from a different hip joint position, piriformis conditions varied. The piriformis runs nearly parallel to the femur in hip external rotation, but is not parallel to the femur in hip internal rotation. Considering that positioning of the hip joint in external rotation led to increased EMG activity of the piriformis during hip extension, it may be necessary to position piriformis fibers parallel to the femur to increase EMG activity. This theory is also analogous to teres minor activity[11]. Hamada et al.[11] reported high teres minor EMG activity during external rotation at 90° of glenohumeral joint abduction compared to the activity at 0° of abduction. This suggested that positioning the glenohumeral joint at 90° of abduction to place the teres minor fibers parallel to the humerus results in high EMG activity. Therefore, this study suggests that a strategy to increase EMG activity would be similar for both the hip and glenohumeral joints.

In a comparison with SL-Abd-ER, piriformis EMG activity in PR-Ext-ER tended to be higher. There was no difference in hip joint position before the start of trials since both required hip external rotation. However, SL-Abd-ER and PR-Ext-ER move the hip in different directions. PR-Ext-ER moves the hip in the sagittal plane, allowing piriformis fibers to remain parallel to the femur, whereas SL-Abd-ER moves the hip in the frontal plane, preventing piriformis fibers from remaining parallel to the femur. Therefore, it may be useful to adopt movements in the sagittal plane for higher piriformis EMG activity.

This study suggests that positioning the hip joint in external rotation and keeping the piriformis fibers parallel to the femur during hip extension are necessary for high piriformis EMG activity. However, since this study only focused on EMG activity in a lying position, further studies may need to evaluate piriformis EMG activities in other positions, such as standing.

Both i-GMax and s-GMax were highly activated with PR-Ext-ER. The i-GMax EMG activity with PR-Ext-ER was significantly higher than that with PR-Ext-IR. On the other hand, s-GMax EMG activity with PR-Ext-ER was significantly higher than that with PR-Ext and PR-Ext-IR. This finding is the same as in a previous study[14], which observed increased GMax activity during extension in external rotation in comparison with that during extension in a neutral hip joint position. In other words, shortening GMax by externally rotating the hip joint is a means of increasing activity. Considering piriformis EMG activity was also high with PR-Ext-ER, indicating that piriformis function may be similar to that of GMax function, this study implies that the piriformis has a role in inducing high EMG activity in the GMax.

In conclusion, this study investigated piriformis EMG activity during several hip movements and concluded that activation was high with prone hip extension in external rotation. Therefore, it may be necessary to keep the piriformis fibers parallel to the femur during hip movement for high EMG activity.

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