Gluteus Medius Muscle Activities during Standing Hip Abduction Exercises in the Transverse Plane at Different Angles

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Objective: *To examine gluteus medius (GMed) muscle activity while performing standing hip abduction exercise in the transverse plane at different angles*
Material and Method: *Muscle activity of both sides of the GMed was measured by electromyography (EMG) with a sampling frequency of 1,500 Hz. Participants were asked to perform standing hip abduction exercise in the transverse plane at different angles including 0°, 15°, 30°, 45°, 60°, 75°, and 90°. Percent maximum voluntary isometric contraction (MVIC) of average EMG of GMed muscles was reported from three trials for each limb. Repeated-measure ANOVA was used to analyze the data.*
Results: *Nine healthy volunteers were included in the present study. The finding indicated that angle of hip motion in the transverse plane significantly ($p<0.05$) affects GMed muscle activity of swing and stance limbs. Standing hip abduction exercise at 30° in the transverse plane was observed to produce the highest EMG of swing limb (64.68% MVIC) than other angles. In stance limb, a decreasing trend of GMed muscle activity while performing standing hip abduction exercise was noted from 0° to 90° in the transverse plane, respectively.*
Conclusion: *GMed muscle activities of swing and stance limbs during hip abduction exercise exhibited the highest EMG at 30° and 0° in the transverse plane, respectively. Therefore, these exercises of GMed muscle could be suggested for early rehabilitation. Standing exercises with 0° and 30° hip abductions might be suitable for weight bearing and non-weight bearing purposes.*

Keywords: *Gluteus medius, Muscle activity, Standing hip abduction exercise*

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Hip abductor muscle weakness relates to the risk of lower extremity injuries such as patellofemoral pain syndrome (PFPS), anterior cruciate ligament (ACL) sprain, and knee osteoarthritis[1-4]. Increasing knee valgus loading was reported in cases of hip abductor muscle weakness[1, 2]. In 2005, Chang et al[3] proposed the mechanism of high loading medial knee in people with osteoarthritis for abductor muscle weakness can potentially lead to poor control of the body's center of mass in the frontal plane and contralateral pelvic drop. Then the lever arm of the varus torque and knee adduction moment increase. These contribute to increased medial knee loading and the risk of developing knee pain. Hip abductor muscle exercise was suggested to reduce the medial loading of a symptomatic knee, external knee adduction moment during gait cycle, and knee pain scores[5]. Gaining strength and improving activation of the hip abductor muscle may be the critical point for rehabilitation and injury prevention.

Various therapeutic exercises can help to increase GMed muscle activation and strength such as lateral step-up exercise, single-limb squat exercise, side-lying hip abduction exercise, lateral band walk, single-limb deadlift, and standing hip abduction exercise[6-9]. The most effective exercise for the GMed muscle has yet to be determined. Distefano et al reported that the GMed muscle exhibited the highest activation in side-lying hip abduction exercise[6]. Several studies have suggested that not only hip abductor activated during side-lying hip abduction exercise but also tensor fascia latae and quadratus lumborum might be more activated as compensation[10,11]. The present study was based on the notion that side-lying hip abduction exercise is

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difficult for people with weak GMed muscles. Therefore, standing hip abduction exercise might be appropriate in early rehabilitation before turning to anti-gravitational exercise or more the functional exercise of GMed. Taking the aforementioned assumption, the present study aimed to examine GMed activity while performing hip exercise in the transverse plane at different angles.

Material and Method

The present study was an observational design and collected data in the laboratory, Faculty of Physical Therapy, Mahidol University. All participants repeatedly measured GMed muscles activity while performing hip abduction exercise in the transverse plane at different angles. Each participant read and signed an informed consent form, approved by the Mahidol University Institutional Review Board (MU-IRB COA. NO. 2014/001.0301).

Participants

Nine healthy males volunteered in the present study. Criteria included BMI range between 18.5 and 23.0 kg/m^2, right leg dominance, and age from 18 to 25 years. The dominant right leg is preferred leg for kicking a ball[12]. Exclusion criteria included: a) having neurological or musculoskeletal problems such as back pain, lower extremity pain, lower extremity discrepancy, and scoliosis and b) participating in sports training at least three times weekly.

Instrument

Dynamic muscle activity of both GMed sides was measured by electromyography (EMG), Noraxon Myosystem, with a sampling frequency of 1500 Hz. Side-lying was the starting posture for EMG electrode placement. Shaving, abrading, and cleaning the skin with alcohol occurred before electrode application was performed over the muscle belly. Electrodes were placed at 50% of the straight line from the iliac crest to the trochanter. Inter-electrode spacing was 2 cm from center to center. Inter-electrode impedance was less than 10 kiloohm. The cables were tightly attached using adhesive tape to minimize the noise. The procedure of surface electrode placement followed recommendations of the European Recommendations for Surface Electromyography (SENIAM)[13]. To determine appropriate location of electrodes, the electrical signal of GMed was observed on the software window during three warm-up practices with submaximal voluntary isometric contraction. After EMG electrode placement, participants performed three maximum voluntary isometric contractions (MVICs). The MVIC was used to normalize the EMG purpose. The starting position of MVIC testing was the side-lying with hip neutral position. Side-lying was preferred to produce a maximum contraction according to the starting position of the manual muscle test of hip abduction. The order of side testing was selected randomly. Pillows were used to support the neutral position during MVIC testing. The straps were applied over the lateral femoral condyle and pelvic brim. Before MVIC testing, each participant was allowed to perform three trials of submaximal contractions to be familiar with the test. Then participants were allowed to rest 120 sec before actual three MVIC testing. Each MVIC trial was collected in 3 sec. Subjects were allowed to rest 90 sec between trials to prevent fatigue effect. MVIC of left and right GMed muscles was examined.

Second order recursive Butterworth filter was used for filtering the EMG data. Low pass frequency 450 Hz and high pass frequency 20 Hz were preferred[14]. Then full-wave rectification was processed. EMG data in each trial was selected in the period of 1,000 ms before and 1,000 ms after heel contacted the object.

Procedure

All participants were asked to perform standing hip exercise in the transverse plane at different angles including 0°, 15°, 30°, 45°, 60°, 75°, and 90°. The research setting is shown in Fig. 1. The right side was the swing limb and the left side was the stance limb. The waist level height of a table was placed in the front of subjects. They were allowed to hold it to prevent loss of balance while testing. During hip abduction,

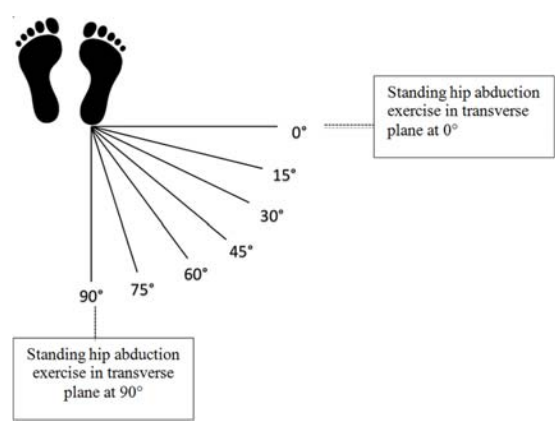

Fig. 1 The figure illustrates the starting position, various angles of standing hip abduction exercise in transverse plane, and research setting in the laboratory.

they were asked to keep the trunk in vertical alignment, to keep neutral position of hip rotation, and to keep full knee extension. All participants were instructed to perform right hip abduction and touch the circular marker by the heel. The marker was attached to a pole. The height of the circular marker setting was 30% leg length that was determined in the pilot study. This height was a suitable level for keeping the trunk in vertical alignment. The order of angle testing was selected randomly. Before testing, the distance between the pole and standing position was determined in the first angle testing for each subject and then used for the other angle tests as well. The pole was placed at a distance from which the subject could touch the marker with vertical trunk alignment. Complete data on three trials of standing hip abduction testing were collected in this study. Resting between trials and angle testing was 30 and 120 sec, respectively.

Statistical analysis

Percent MVIC of average EMG of the GMed muscle from three trials for each limb was reported in the present study. The statistical comparisons were analyzed by SPSS package version 18. The data showed normal distribution. One-way repeated measures ANOVA was used to compare the main effect of angle in the transverse plane. Pairwise comparisons were performed with Bonferroni correction. The level of statistical significance was set as a p-value less than 0.05.

Results

The results of the current study exhibited that hip abduction angle significantly influenced average GMed muscle activity of the swing limb ($F(6, 48) = 13.8$, $p<0.001$) and stance limb ($F(1, 48) = 13.7$, $p = 0.006$). Average GMed muscle activity of the swing limb was higher than stance limb at all angles in the transverse plane except for 90°. Pairwise comparisons between angles are shown in Table 1.

Discussion

The main purpose of the present study was to investigate GMed muscle activity during standing hip abduction exercise in the transverse plane at various angles. The results found that angle significantly ($p<0.05$) affected GMed muscle activity of swing and stance limbs (Table 1).

Concerning the swing limb, standing hip abduction exercise at 30 in the transverse plane was observed to produce a higher EMG (64.68%) than 0° (63.59%), 15° (59.47% MVIC), and 45° (53.69%). The GMed muscle plays two major roles, namely, pelvic stabilization during one-leg stance activities and hip abduction with rotation movement[15,16]. The GMed muscle was divided in two compartments including anterior and posterior parts[17]. The direction and arrangement of the fascicle within the muscle belly influenced the line of muscle contraction[18]. When determining the sensor location, the GMed compartment in the present study may have been the anterior compartment, which presented dominant action in range of 0° to 45° in the transverse plane of standing hip abduction exercise, especially at 45°. A previous study investigated muscle activity of the lower limbs during weight-bearing exercises and suggested that MVIC greater than 50% to 60% was effective for gaining muscle strength[19]. The external moment to resist

Table 1. Comparison of average GMed muscle activity of the swing (right) limb and stance (left) limb during standing hip abduction exercise in the transverse plane at different angles (mean (SD))

Angle (°)	GMed muscle activity (% MVIC)	
	Swing limb (right leg)	Stance limb (left leg)
0	63.59 (41.16)[a]	43.71 (15.05)[a,b,c]
15	59.47 (28.30)[a,b]	42.21 (13.65)
30	64.68 (39.88)[a]	40.47 (12.76)
45	53.69 (26.11)[a]	40.21 (13.76)[a,c]
60	42.35 (21.44)[a]	34.35 (13.14)
75	43.93 (30.58)	30.31 (8.76)
90	21.25 (18.06)	27.30 (11.09)

[a] Statistically significant difference compared with 90° ($p<0.05$), [b] Statistically significant difference compared with 75° ($p<0.05$), [c] Statistically significant difference compared with 60° ($p<0.05$)

internal GMed contraction of the swing limb was 16% body mass, approximately[20,21]. The present study showed that greater than 50% MVIC of GMed muscle activity was found in the swing limb at 0°, 15°, 30°, and 45°. It was thought that standing hip exercise in 0° to 45° abduction angles could help to gain strength. Moreover, exercise at 30° might be suggested for early rehabilitation before turning to anti-gravitational exercise or the more functional exercises of the GMed. However, no significant difference was noted in 0° to 45°.

During standing hip abduction exercise, the GMed of the stance limb played the role of maintaining contralateral pelvic level[15]. Previous studies exhibited that single-leg stance activities needed more GMed muscle activity while adding load on the contralateral side while walking. The external moment to resist internal GMed contraction of the stance limb was 84% body mass, approximately[20,21]. A decreasing trend of GMed muscle activity of the stance limb was noted from 0° to 90° in the current study. It was possible that the highest external moment at 0° would be noted because of the maximum moment arm relative to the direction of muscle force. Bolgla et al[7] suggested that non-weight and weight bearing in standing hip abduction exercises may help to gain muscle strength. They reported that GMed muscle activity exhibited 33% and 46% MVIC during functioning in swing limb and stance limb, respectively. A lower GMed EMG of the stance limb in the present study was observed at 0° (43.71% MVIC) compared with Bolgla's study. However, Bolgla's study and the current study differed in the sensor location and the method for the standing hip abduction exercise. They placed EMG electrodes at one-third the distance between the iliac crest and greater trochanter. They asked subjects to perform standing hip abduction in the frontal plane with a cuff mass equal to 3% body mass at ankle of the swing limb. The range of motion during hip abduction was 25° in Bolgla's study. Adding a cuff mass at the ankle of the swing limb would increase the external moment for the GMed in stance limb. Then the GMed generated more muscle contraction. Increasing the weight cuff on the swing limb is suggested to enhance muscle activation of the GMed in the stance limb.

Limitations and future study

Moment arm change caused by the body's center of mass shifting could affect the GMed activity during trunk movement. We did not measure trunk movement while testing, a limitation of this study. However, the present study attempted to control this effect with the test instructing procedure to maintain the trunk in vertical alignment. Moreover, the present study observed every movement of the trunk while testing. Trunk position data should be collected in future studies. In addition, it would be interesting to examine other groups of subjects such as female, aging, and knee osteoarthritis groups.

Conclusion

Standing hip abduction exercise can help gain GMed muscle strength. The angle of hip abduction significantly influenced GMed muscle activity. GMed muscle activities exhibited the highest level at standing hip abduction exercise at 30° (64.68% MVIC) and 0° (63.59% MVIC) in the transverse plane of the swing limb and stance limb, respectively. Therefore, these exercises could be suggested for early rehabilitation of the GMed muscle. However, standing hip abduction exercises at 0° and 30° in the transverse plane might be suitable for weight bearing and non-weight bearing purposes, respectively.

What is already known on this topic?

Various therapeutic exercises can help to increase GMed muscle activation and strengthening such as lateral step-up exercise, single-limb squat exercise, side-lying hip abduction exercise, lateral band walk, single-limb deadlift, and standing hip abduction exercise.

What this study adds?

In standing hip abduction exercise, different angles of hip abduction significantly showed different muscle activity. GMed muscle activities exhibited the highest EMG at standing hip abduction exercise at 30° and 0° in the transverse plane of the swing limb and stance limb, respectively.

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Potential conflicts of interest

None.

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การทำงานของกล้ามเนื้อ Gluteus Medius ขณะยืนออกกำลังกายกางข้อสะโพกในแนวตามขวางที่หลายมุมองศา

คมศักดิ์ สินสุรินทร์, โสภิญญา ปลื้มใจ, ศรัณย์ ศรีสง่าบริบูรณ์, สุภัทร สวนจันทร์, รุ่งทิวา วัจฉละฐิติ

วัตถุประสงค์: *เพื่อทดสอบการทำงานของกล้ามเนื้อ Gluteus Medius ขณะยืนออกกำลังกายกางข้อสะโพกในแนวตามขวางที่หลายมุมองศา*

วัสดุและวิธีการ: *อาสาสมัครเพศชายที่มีสุขภาพแข็งแรง 9 คน ถูกคัดเข้าร่วมการศึกษา การทำงานของกล้ามเนื้อ Gluteus Medius ทั้งสองข้างถูกวัดโดยใช้เครื่องวัดสัญญาณไฟฟ้ากล้ามเนื้อที่ความถี่ 1,500 รอบ/วินาที โดยผู้เข้าร่วมงานวิจัย ถูกบอกให้ออกกำลังกายในท่ายืนกางข้อสะโพกในแนวตามขวางที่มุม 0°, 15°, 30°, 45°, 60°, 75°, และ 90° การศึกษาครั้งนี้รายงานเป็นค่าเฉลี่ยของสัญญาณไฟฟ้ากล้ามเนื้อ 3 ครั้งจากการกางข้อสะโพกเป็นเปอร์เซ็นต์ของการทำงานสูงสุดของกล้ามเนื้อ Gluteus Medius*

ผลการศึกษา: *ผลการศึกษาพบว่ามุมกางข้อสะโพกมีผลต่อการทำงานของกล้ามเนื้อ Gluteus Medius ของขาข้างที่กางและข้างที่ยืนรับน้ำหนักอย่างมีนัยสำคัญ การยืนออกกำลังกายกางข้อสะโพกมีการทำงานของกล้ามเนื้อข้างที่กางสะโพกมากที่สุดในแนวตามขวางที่มุม 30° (64.68%) ซึ่งมากกว่าที่มุม 0° (63.59%) 15° (59.47%) 45° (53.69%) ตามลำดับ ส่วนการทำงานของกล้ามเนื้อข้างที่ยืนรับน้ำหนักมีค่าลดลงตามลำดับจากมุม 0° ถึง 90°*

สรุป: *การยืนออกกำลังกายกางข้อสะโพกในแนวตามขวางที่มุม 30° มีการทำงานของกล้ามเนื้อ Gluteus Medius ของข้างที่กางมากที่สุด ส่วนการทำงานของกล้ามเนื้อ Gluteus Medius ของข้างที่รับน้ำหนักมีค่ามากสุดเมื่อกางข้อสะโพกในแนวตามขวางที่มุม 0° ดังนั้น การยืนออกกำลังกายกางข้อสะโพกในแนวตามขวางที่มุม 30° หรือ 0° สามารถเลือกใช้เพื่อฟื้นฟูการทำงานของกล้ามเนื้อ Gluteus Medius ในแต่ละข้างซึ่งการยืนออกกำลังกายกางข้อสะโพกในแนวตามขวางที่มุม 30° เหมาะกับ Gluteus Medius ของข้างที่ทำงานในรูปแบบที่ไม่ได้รับน้ำหนักส่วนการยืนออกกำลังกายกางข้อสะโพกในแนวตามขวางที่มุม 0° เหมาะกับ Gluteus Medius ของข้างที่ทำงานในรูปแบบรับน้ำหนัก*