

Difference of Muscle Activity by Pelvic Tilt in Side-Lying Hip Abduction

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| Abstract |

PURPOSE: This study was to evaluate the muscle activity of gluteus medius, tensor fascia latae, and quadratus lumborum during side-lying abduction exercise in various pelvic tilting positions.

METHODS: We measured the activity of three muscles in three pelvic tilt positions for 17 normal subjects with performing the side-lying hip abduction. Three pelvic tilt positions were posterior tilt, neutral tilt and anterior tilt. We used the mean value after participants performed the hip abduction three times each position.

RESULTS: The activity of gluteus medius within three pelvic positions showed the highest activity in pelvic posterior tilt position and the lowest in pelvic neutral tilt position ($p = .04$). The activity of tensor fascia latae showed the lowest in pelvic posterior tilt position and the highest in pelvic posterior tilt position ($p = .00$). The activity of quadratus lumborum revealed the lowest activity in pelvic neutral tilt position and the highest in pelvic anterior tilt

position ($p = .00$). The activity of selective gluteus medius activation according to pelvic displacement showed the highest activity in pelvic neutral tilt position and lowest in pelvic anterior tilt position ($p = .00$).

CONCLUSION: Hip abduction with Pelvic posterior tilt position may be effective in increasing gluteus medius and may be effective in strengthening exercise program for the gluteus medius. In addition, Hip abduction with pelvic neutral position may have an effect on the selective gluteus medius, which is considered to be effective in the exercise program for muscle reeducation training of the gluteus medius.

Key Words: Gluteus medius, Quadratus lumborum, Surface EMG, Tensor fascia latae

I. Introduction

Abnormal interactions of hip muscle can cause hip dysfunction and lead to musculoskeletal disorders of the hip and knee (Ferber et al., 2010; Hewett et al., 2005; Willson and Davis, 2008; Leinonen et al., 2000). Especially, low activity and weakening of the gluteus medius (GM) can causes compensation by the synergist tensor fascia latae (TFL) and quadratus lumborum (QL) (Lee et al., 2013; Clark and Lucett, 2011). Excessive compensatory activity

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of the TFL pulls the retinaculum of the knee. This moves the patella to the lateral side and causes patellofemoral pain syndrome (Merican and Amis, 2008). Early contraction of the QL occurs when the angle of side-lying abduction is less than 20 degrees. This causes hip elevation and in turn, mobilization and not stabilization of the QL (Page et al., 2010).

Excessive activation of the QL causes the pelvis to move outward, resulting in lateral bending and instability of the lumbar region (Cynn et al., 2006). Therefore, strengthening of the gluteus muscles can affect prevention diseases that may occur in the lumbar region and the knee.

Side-lying hip abduction is commonly used as a GM exercise (Distefano and Blackburn, 2009; Gwon and Kim, 2016) or GM strength test of hip abductor in clinic (Kendall et al., 2005). In addition, Macadam (2015) and Selkowitz and Beneck (2013) reported that GM activity was higher during side-lying hip abduction exercise than clam exercise. However, Selkowitz and Beneck (2013) suggested that Side-lying abduction was non-adequate because activity of the TFL was higher during clam exercise. Resistance exercises using elastic bands in various postures such as a standing posture, side-lying bridge posture, and side-lying posture can be used as a way to increase activity of the GM (Macadam et al., 2015).

Selective activation of the GM and lowering compensation of hip surrounding muscles is very useful when planning a clinical exercise program for lower limb dysfunction (Selkowitz et al., 2013). Selective activation of the GM using side-lying hip abduction exercise is still controversial among researchers (Lee and Cynn, 2014; Macadam et al., 2015; Joseph and Jennifer, 2012; Kim et al., 2016).

In the study by Cynn and Oh (2006), activity of the QL was lowered in the side-lying hip abduction while maintaining lumbar stability using biofeedback pressure. On the contrary, activity of the GM was increased. Lumbar pelvic instability was observed with increased activity of the QL and inhibited activation of GM.

Park and Kim (2010) and Lee et al. (2011) reported if stability of the pelvis is increased through the pelvic compression belt, activity of the QL is lowered and activity of the GM and multifidus muscles is increased during side-lying hip abduction.

In Vezina et al. (2000) study, the inferior rectus abdominis, superior rectus abdominis, external oblique, erector spinae, and multifidus muscles were highly active in supporting posterior tilt isometric exercise of the pelvis. Queiroz and Cagliari (2010) reported that activation of the core muscles, gluteus maximus, external oblique, and internal oblique muscles were increased in pelvis posterior position rather than pelvic-neutral position or anterior tilt position.

According to previous studies, side-lying hip abduction has been used to compare the correlation between the GM and TFL or between the GM and QL. However, there are few studies on the correlation of muscular activation of the three muscles (QL, GM, TFL) in pelvic posterior tilt position. Therefore, it is necessary to compare activities of the three muscles among different pelvic positions including posterior pelvic tilt position for finding proper pelvic position to activate the GM.

Thereby, this study was aiming to evaluate activity of the GM, TFL, and QL during side-lying abduction exercise in various pelvic tilt positions. Moreover, we would like to suggest the effective pelvic position to selectively activate the GM.

II. Methods

1. Subject

The subjects of this study were 17 male students in their 20s who attended E university in Seongnam city. The inclusion criteria of the subject include Grade 4 (good) in the muscle manual testing for hip abduction and no pain or limitation in hip abduction. The mean age of the subjects was $23.06 \pm .90$ years, mean height was 173.18 ± 5.40 cm, mean weight

Table 1. Subjects of general characteristics (mean±SD)

Characteristics	Subjects (n=17)
Height (cm)	173.18 ± 5.40
Weight (kg)	67.18 ± 5.63
BMI (%)	22.31 ± 1.34
Hip Abduction ROM (°)	43.71 ± 3.91
Age (Year)	23.06 ± .90

* Abbreviation; BMI: body mass index, ROM: range of motion. SD: standard deviation

was 67.18 ± 5.63 kg, mean BMI was 22.31 ± 1.34 and mean hip abduction ROM 43.71 ± 3.91 as shown in Table 1. The exclusion criteria for this study were excluded if the movement was restricted due to pain in the hip or knee, there is a history of hip and knee anterior cruciate ligament surgery within the last 3 months, Neurological impairment, Those with hip and knee fractures and osteoporosis arthritis, Malignant neoplasm, Vascular diseases, Patients with psychiatric problems that do not understand the content of the study agreement are excluded. All subjects agreed to voluntarily participate in the study and explained the method and purpose of the study. This paper was reviewed and approved by the Institutional Review Board (IRB) of Eulji University (IRB Approval number: EU16-29).

2. EMG data collection

EMG signals are collected at a sampling rate of 1,000 Hz using MR-XP 1.08 Master Edition software (Noraxon MyoResearch system, Noraxon Inc, USA). To eliminate noise, a band pass filter of 20 to 250 Hz and noise filtering (60 Hz), and the collected EMG signal is processed in 200 ms using a root mean square method. Normalizing to the measurements uses the Maximal Voluntary Isometric Contraction (MVIC) value.

3. Normalization of data (MVIC: Maximal Voluntary Isometric Contraction)

MVIC measures GM, TFL and QL using standard manual muscle-test position (Kendall et al., 2005). The

subject performed MVIC for 5 seconds. Each muscle contraction is rested for 10 seconds, and when it is changed to another muscle, it rests for about 3 minutes (Lee et al., 2013). During the measurement of the GM, the subject performs a side-lying position while the measuring leg is lifted up and bends the hip joint and knee of the opposite leg to improve the stability of the floor support. The measuring leg performs approximately 50% of the side-lying abduction angle, and additionally performs a slight extension and external rotation. Resistance is applied downward from the ankle and the other hand stabilizes the pelvis. In MVIC measurement of TFL, the subject is supine lying, internal rotation of the hip joint as much as possible, and flexion of the hip joint and extension of the knee. Resistance forces in the direction of the hip joint extension. During the MVIC measurement of the QL, the subject performs a slight extension and abduction of the hip joint in a prone-lying state, performing elevation of the pelvis. Resistance pulls the lower limb in the muscle direction of the QL. Measurements are performed twice for each muscle of the MVIC and the average of the two measurements is used as the data. The EMG data measured in this experiment are later normalized to % MVIC.

4. Experimental methods

All subjects used only dominant legs. Based on past research, leg that kicks the passing ball is defined to dominant leg (Distefano et al., 2009). Before the experiment, all participants were able to reduce the discomfort and pain during side-lying hip abduction by running a submaximal speed run for 5 minutes (Willcox and Burden, 2013; Hunter et al., 2003). The selected 17 subjects were performed to pelvic neutral tilt position hip side-lying abduction (PNPSA), pelvic posterior tilt position hip side-lying abduction (PPPSA), and pelvic anterior tilt position hip side-lying abduction (PAPSA) and maintained isometric contraction for 5 seconds. The side lying posture keeps the scapula and hips in contact with the wall. The

angle of the side-lying abduction is 50% of the maximum range of motion. The posterior tilt of the pelvis is performed until the waist touches the wall and the anterior tilt of the pelvis is performed until the trunk is not collapsed (Lee et al., 2013). Muscle activity of GM, TFL, and QL is measured by electromyography (EMG) in each exercise. For electromyography, Ag/AgCl (Ag/AgCl surface electrode, Noraxon Inc, USA) is used as a disposable adhesive electrode. In order to solve the problem caused by the difference in the distance between the electrodes when the electrode area is 4×2.2 cm, the whole diameter is 1 cm and the distance between the electrodes is 2 cm, when two single electrodes are used, the electrodes are arranged side by side.

To minimize skin resistance before electrode attachment, shave the attachment area and wipe the skin with alcohol swab. After the electrode attachment area is completely dried, the electrode is attached to the skin. The location of the EMG electrode is located at the standardized location dominated by the GM, the TFL, and the QL (Jeffrey et al., 1998; Eleanor, 2011; Arokoski et al., 2001). The GM palpate the iliac crest and place two active electrodes parallel to the direction of the muscle fiber at a distance of 2 cm from the proximal 1/3 point between the iliac crest and the greater trochanter. Caution should be exercised for signal cross-talk between Gluteus maximus and Gluteus minimus when electrodes are attached (Jeffrey et al., 1998; Eleanor, 2011). TFL palpates the ASIS in the knee extension posture and places the active electrode parallel to the muscle fibers approximately 2 cm below it (Jeffrey et al., 1998; Eleanor, 2011). The QL locates the electrode at a slight oblique angle to the halfway between the 12th rib and the iliac crest at about 4 cm lateral to the vertebral transverse process (Arokoski et al., 2001). The EMG data are calculated by analyzing only the data of the middle 3 seconds to reduce the influence of the beginning and the end of the exercise among the measurement values when the side-lying abduction

is maintained for 5 seconds. The subjects perform the exercise three times each. Between each run, rest is given 3 minutes. The mean value of the analyzed data is used as the experimental value.

5. Data analysis and statistical methods

Comparisons of muscle activity differences between gluteus medius activation %MVIC (GMA), tensor fascia latae activation %MVIC (TFLA), quadratus lumborum activation %MVIC (QLA), and selective gluteus medius activation %MVIC (SGMA) in PNPSA, PPPSA, and PAPSA behaviors are performed using the parametric repeated measures ANOVA (Friedman test). All statistical data were processed using SPSS 21.0 software (SPSS Inc, Chicago, IL) with a significance level of .05. (SGMA = $GMA / (TFLA + QLA) \times 100$).

III. Results

1. GMA analysis according to pelvic tilt

The GMA analysis according to the pelvic tilt is shown in Table 2 and the results are as follows. GMA data were $49.62 \pm 24.63\%$ in PNPSA, $62.43 \pm 18.97\%$ in PPPSA and $50.15 \pm 26.01\%$ in PAPSA. Compared with PNPSA, PPPSA and PAPSA showed increased activity and PPPSA showed higher activity than PAPSA. This analysis was statistically significant ($p = .04$).

2. TFLA analysis according to pelvic tilt

The TFLA analysis according to the pelvic tilt is shown in Table 2 and the results are as follows. TFLA data were $54.84 \pm 15.14\%$ for PNPSA, $76.73 \pm 17.60\%$ for PPPSA and $49.70 \pm 19.12\%$ for PAPSA. The activity of PPPSA was higher than that of PNPSA, and the activity of PPPSA was higher than that of PAPSA, and PAPSA was lower than that of PNPSA. This analysis was statistically significant ($p = .00$).

Table 2. The comparing of muscle activity among different pelvic tilt position

	Exercise	Mean	SD	P value
GMA	PNPSA	49.62	24.63	.04*
	PPPSA	62.43	18.97	
	PAPSA	50.15	26.01	
TFLA	PNPSA	54.84	15.14	.00*
	PPPSA	76.73	17.60	
	PAPSA	49.70	19.12	
QLA	PNPSA	30.01	21.62	.00*
	PPPSA	44.74	19.09	
	PAPSA	60.42	29.16	
SGMA	PNPSA	57.79	25.95	.00*
	PPPSA	55.14	17.87	
	PAPSA	43.89	20.63	

* ($P < .05$)

* Abbreviation; GMA: Gluteus medius activation %MVIC, TFLA: Tensor fascia latae activation %MVIC, QLA: Quadratus lumborum activation %MVIC, SGMA: Selective Gluteus medius activation %MVIC, PNPSA: Pelvic Neutral tilt position hip side-lying abduction, PPPSA: Pelvic Posterior tilt position hip side-lying abduction, PAPSA: Pelvic Anterior tilt position hip side-lying abduction, SD: standard deviation

3. QLA analysis according to pelvic tilt

The QLA analysis according to the pelvic tilt is shown in Table 2 and the results are as follows. QLA data were $30.01 \pm 21.62\%$ in PNPSA, $44.74 \pm 19.07\%$ in PPPSA and $60.42 \pm 29.16\%$ in PAPSA. Compared with PNPSA, PPPSA and PAPSA increased activity and PPPSA was lower than PAPSA. This analysis was statistically significant ($p = .00$).

4. SGMA analysis according to pelvic tilt

The SGMA analysis according to pelvic displacement is shown in Table 3 and the results are as follows. SGMA data showed $57.79 \pm 25.95\%$ in PNPSA, $55.14 \pm 17.87\%$ in PPPSA and $43.89 \pm 20.63\%$ in PAPSA. The activity of PPPSA and PAPSA was lower than that of PNPSA. Also, the activity of PAPSA was lower than that of PPPSA. This analysis was statistically significant ($p = .00$).

IV. Discussion

In this study, activity of the GM, TFL and QL was measured (MVIC %) during side-lying hip abduction in pelvic neutral tilt, pelvic posterior tilt, and pelvic anterior tilt. The purpose of this study was to determine the effective posture for SGMA by comparing the measured muscle activity. As a result of the study, the GMA differed in different pelvic tilt positions, and the highest activity was observed in pelvic posterior tilt.

Kendall et al. (2005) used a side-lying hip abduction motion in a hip abductor isometric contraction test, and Distefano et al. (2009) used side-lying hip abduction as an optimal therapeutic exercise to strengthen the GM. Therefore, we selected the side-lying position for hip abduction exercise.

In Drysdale et al. (2004) research, pelvic posterior tilt showed high activity of the rectus abdominis, external

oblique and transverse abdominis muscles, which act as the core muscles of the abdomen among various pelvic postures.

Cynn et al. (2006) study showed that when side-lying hip abduction with lumbar stability was performed using biofeedback, activity of the QL was decreased and activity of the GM was increased. Park et al. (2010) study used a compression belt to improve stability of the lumbar spine, reduce compensation by the QL, and increase activity of the GM.

According to Cynn et al. (2006) and Park et al. (2010), proper lumbar stability control increases activity of the GM and decreases activity of the compensatory muscles such as QL and TFL.

Similar to the results of previous studies, we found that the GMA was the highest during the PPPSA, which may be related to the increase in lumbar stability by activating core muscles of the abdomen through the posterior tilt of the pelvic. The results of this study can be interpreted that pelvic posterior tilt increased abdominal muscle activation and led to lumbar stability. Therefore, increased lumbar stability may improve activity of the GM during side-lying abduction. Thereby, PPPSA may be helpful in GMA.

However, activity of the TFL and QL was the lowest in the pelvic neutral tilt and anterior tilt positions, respectively. Additionally, SGMA was the highest among all the muscles examined.

This research results showed that pelvic tilt, which is the most SGMA, is the neutral tilt of the pelvic. Therefore, we can conclude that the PNPSA is the most attentive exercise that reduces compensation by the TFL and the QL and increases the SGMA.

In summary, the most effective pelvic tilt for increasing GMA was the PPPSA. Therefore, we suggest using the posterior tilt position of the pelvis during an exercise if the purpose of the exercise is training of the GM. However, if the subject shows excessive activation of the TFL and QL, we recommend the pelvic neutral position to diminish

excessive muscle activation.

This study has some limitations. The first limitation was that the subjects were 17 men in their 20s. Therefore, the results were inadequate to generalize to women and wider ages. The second technical limitation is that there was some data error in the measurement of the EMG data due to differences in the thickness of the fat layer that could possibly influence the experimental result of this study. In order to overcome limitations of the present study, it is better to select various age groups and genders in the future.

V. Conclusion

In this study, activity of the GM, TFL, and QL was measured during side-lying hip abduction with pelvic neutral tilt, pelvic posterior tilt, and pelvic anterior tilt positions. PPPSA may be effective in increasing GMA and may be effective in strengthening exercise program for the GM. In addition, PNPSA may have an effect on the SGMA, which is considered to be effective in the exercise program for muscle reeducation training of the GM.

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