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Comparison of EMG Activity of the Posterior Oblique Sling Muscles and Pelvic Rotation During Prone Hip Extension With and Without Lower Trapezius Pre-Activation

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Abstract

Background: Prone hip extension (PHE) can be performed to measure the lumbopelvic motor patterns and motions. Imbalances in lumbopelvic muscle activity and muscle weakness can result in instability including pain in lumbopelvic region. The posterior oblique sling (POS) muscles contribute to dynamic lumbopelvic stability. In addition, POS are anatomically aligned with the trapezius muscle group according to shoulder positions.

Objects: This study compared the electromyography (EMG) activity of POS and pelvic compensations during PHE with and without pre-activation of lower trapezius muscle (lowT).

Methods: Sixteen healthy males were recruited. PHE was performed in randomized order: PHE with and without lowT pre-activation. Surface EMG signals were recorded for biceps femoris (BF), gluteus maximus (GM) (ipsilateral), lumbar multifidus (MF) (bilateral), and the lowT (contralateral). An electromagnetic tracking motion analysis was used to measure the angle of pelvic rotation and anterior tilting.

Results: The ipsilateral GM and bilateral MF EMG amplitudes were greater during PHE with lowT pre-activation compared to PHE without lowT pre-activation ($p<.05$). The BF amplitude during PHE without lowT pre-activation was significantly greater than that during PHE with lowT pre-activation ($p<.05$). The angles of pelvic rotation and anterior tilting during PHE with lowT pre-activation were significantly smaller compared to PHE without lowT pre-activation ($p<.05$).

Conclusion: PHE with lowT pre-activation, which is aligned with the POS, showed more increased MF and GM muscular activity with smaller lumbopelvic compensations in rotation and anterior tilting compared to PHE without lowT pre-activation.

Key Words: Gluteus maximus; Lumbopelvic instability; Posterior oblique sling; Prone hip extension.

Introduction

Prone hip extension (PHE) can be performed for the measurement of the lumbopelvic motor patterns (Tateuchi et al, 2012). The lumbopelvic region during PHE ideally remains neutral without lumbopelvic compensations in extension or rotation (Comerford and Mottram, 2012). Lumbopelvic instability during PHE leads to limitations of controlling excessive compensations in lumbar extension and rotation and pelvic anterior tilt and rotation (Sahrmann, 2002).

Imbalances in lumbopelvic muscle activity and muscle weakness can result in lumbopelvic instability (Hodges and Moseley, 2003). Although the local and global muscles can contribute to lumbopelvic stability (Bergmark, 1989), the global muscles

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are primarily involved with the spinal control and transfer loads directly from the spine to the legs during PHE (Danneels et al, 2001). Therefore, global muscle training can contribute to prevention and treatment of low-back pain (Comerford and Mottram, 2012).

A myofascial sling can contribute to the facilitation of the force transfer through the trunk from the leg to the arm because these muscles are interconnected anatomically (Kendall et al, 2005). The gluteus maximus (GM) is interconnected with the ipsilateral bicep femoris (BF) and the contralateral latissimus dorsi (LD) via the thoracolumbar fascia (Vleeming et al, 1995). Therefore, The GM acts as a load transfer through the hip. These muscles consist of the posterior oblique sling muscles contributing to dynamic lumbopelvic stability (Vleeming et al, 1995). Similarly, Myers (2009) described that three different major lines including superficial back line, superficial front line, and lateral line. In the superficial back line, according to shoulder positions, the posterior oblique sling muscles are anatomically aligned with the trapezius muscles (Myers, 2009). The middle trapezius and lower trapezius (lowT) are especially important in the scapulothoracic joint as stabilizers (Myers, 2009).

The various studies have focused the LD, multifidus (MF), and GM muscle activation patterns during PHE exercise (Kim et al, 2013; Kim and Kim, 2015). However, to our knowledge, no study has assessed the posterior oblique sling muscles and pelvic compensations between PHE and PHE with and without lowT pre-activation. Therefore, this study compared the electromyography (EMG) activity of the posterior oblique myofascial sling and the angle of lumbopelvic rotation and anterior tilting between PHE with and without lowT pre-activation. We hypothesized that PHE with lowT pre-activation would increase MF and GM muscular activity and decrease the angles of lumbopelvic rotation and anterior tilting compared to PHE without lowT pre-activation.

Methods

Subjects

Sixteen healthy male participants were recruited in this study (dominant leg: 16 right side). Their mean age (years) was 27.3±2.2 (mean±standard deviation), their mean body mass (㎏) was 75.1±4.1, and their mean height (㎝) was 175.1±3.8. The exclusion criteria were as follows: 1) limited range of motion of the bilateral hip joint; 2) a history of lower back pain in the past 12 months; 3) lower extremity dysfunctions such as patellofemoral pain syndrome or anterior cruciate ligament sprains in the past 12 months; 4) pain in any joint of the body during PHE; 5) shoulder muscle weakness during all the PHE exercises. The experimental protocols were explained in detail to all of the participants, and an informed written consent was gathered. This study was approved by the Yonsei University Wonju Institutional Review Board (approval number: 1041849-201510-BM-075-01).

Experimental procedure

Sixteen participants were randomly performed PHE with and without lowT pre-activation. We used the metronome set at 60 beats per minute for subjects to perform each exercise in a standard manner (Nyland et al, 2004). Each participant was instructed to perform PHE performance until hip extension angle (10°) reached the target bar. EMG data were collected for 5 sec during the isometric phase of exercise. The participants were instructed to maintain the initial position for 5 sec before they raise the dominant leg. Next, the hip extension was maintained for 5 sec with the target bar. Each PHE performance was repetitive for three consecutive times with 5 min resting time between performances to minimize muscle fatigue (Sykes and Wong, 2003).

PHE without lowT pre-activation

The participant assumed a prone position on the table with the upper trunk, pelvis, and lower extremity in a straight line. Both arms were comfortably placed beside the trunk without pushing the ground with their hands. The hip joint was extended at 10° with knee extension touching the target bar (Figure 1A). This position was maintained for 5 sec, and then the participants slowly returned to the starting position. The electromagnetic motion sensor in sacral spine (S2) centrally located at the sacrum can monitor pelvic anterior tilting and rotation measurement during the exercises (Hungerford et al, 2007).

PHE with lowT pre-activation

The participant assumed a prone position on the table with the upper trunk, pelvis, and lower extremity in a straight line. Both arms were comfortably placed beside the trunk without pushing the ground with their hands. The participants were asked to perform contralateral shoulder abduction at 125° angle and external rotation with 1 ㎏ load to activate lowT before PHE was performed until their ipsilateral leg touched the target bar (Kendall et al, 2005; Oyama et al, 2010) (Figure 1B). Also, the participants without limitation of motion were asked to perform the lowT activating motion by touching the target bar to avoid compensations such as trunk extension and rotation. The hip joint was extended at 10° with knee extension touching the target bar. The position was maintained for 5 sec, and then the participant slowly returned to the starting position. The electromagnetic motion sensor in S2 can monitor for pelvic anterior tilting and rotation measurement during the exercises.

Electromyography recording and data analysis

The surface EMG-feedback with a wireless telemetry system (TeleMyo 2400T, Noraxon, Scottsdale, AZ, USA) was used with the analyzing software. Filtered movement artifacts were eliminated by a 20-450 ㎐ digital band-pass filter (Lancosh FIR). The sample rate was set to 1024 ㎐. Root mean square was used to process the EMG signals with a moving window of 50 ㎳. EMG signals were recorded for 5 sec (2 sec to 4 sec used for data analysis) while the dominant leg was maintained at the target bar during the isometric phase (Ayotte et al, 2007). The target regions were cleaned by cotton with isopropyl alcohol before electrodes were attached to minimize skin resistance. Disposable Ag/AgCl surface electrodes were attached on the target regions. Two electrodes were attached parallel to the proper muscle fiber along with the muscle fibers each on contralateral lowT (the inferior medial border of the scapula for the muscle mass and on an oblique angle, approximately 5 ㎝ down from the scapular spine at least a 90° shoulder angle), bilateral MF (at a 2 finger-width distance lateral from the spinous process of L5), right GM (50% on the line extending between the sacrum and greater trochanter), right BF (70% on the line extending between the ischial tuberosity and lateral epicondyle) (Cram et al, 1998). MF, GM, BF,

Figure 1. Prone hip extension without lower trapezius pre-activation (A) and Prone hip extension with lower trapezius pre-activation (B).

and lowT muscles were performed for the manual muscle testing positions with the guideline recommended by Kendall et al (2005) to measure maximal voluntary isometric contraction normalization.

Kinematics measurements

The Polhemus LibertyTM (Polhemus, Colchester, VT, USA) was used to calculate pelvic rotation and anterior tilting at 120 ㎐. This electromagnetic tracking device was accurate at .08 ㎝ for position and .15° for orientation (Mills et al, 2007). The electromagnetic motion sensor was firmly attached to the skin on S2 with adhesive tape to diminish sensor to motion artifacts. The transmitter remained in the same position for all measurements during PHE performances. The orientation of the electromagnetic tracker system was defined with +X parallel line to both anterior superior iliac crest, +Y parallel line to anterior-posterior axis, and +Z vertically upward line during PHE. In this study, S2 sensor in +X and +Y line was used to measure pelvic anterior tilting and rotation angle (in degrees). For kinematic angles, the differences between initial and final positions in the sagittal plane for pelvic anterior tilting and the transverse plane for pelvic rotation were measured during the performances.

Statistical analysis

The data are expressed as means±standard deviations. One-sample Kolmogorov-Smirnov test was employed to ensure the normal distribution of the data. The significant difference in EMG muscular activities and pelvic compensations between the two conditions (PHE without lowT pre-activation vs. PHE with lowT pre-activation) was assessed using paired t-test with the significance level set to .05. The SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

Results

EMG amplitude

The ipsilateral BF, GM, and bilateral MF EMG amplitudes were significantly different between PHE with and without lowT pre-activation ($p<.05$). Bilateral MF and ipsilateral GM EMG amplitude were greatest in the PHE with lowT pre-activation compared to PHE without lowT pre-activation (Table 1). On the other hand, the BF amplitude in PHE with lowT pre-activation was significantly smaller than PHE without lowT pre-activation (Table 1).

Lumbopelvic kinematics

The angles of pelvic rotation and anterior tilting during PHE with lowT pre-activation were significantly smaller compared to PHE without lowT pre-activation ($p<.05$) as shown in Table 2.

Discussion

In this study, the EMG activities of the posterior oblique sling muscles and the angles of rotation and

Table 1. EMG amplitude of the various muscles

Muscles	PHE[a] without lowT[b] pre-activation (%MVIC[c])	PHE with lowT pre-activation (%MVIC)	t value	p value
lowT (contralateral)	5.25±2.37[d]	69.96±21.37 (7.50%)	26.16	<.001[*]
MF[e] (ipsilateral)	25.25±11.37	49.28±13.49 (51.24%)	11.48	<.05[*]
MF (contralateral)	31.48±10.24	47.68±11.40 (66.02%)	8.55	<.05[*]
GM[f] (ipsilateral)	20.34±14.21	43.79±16.42 (46.45%)	10.21	<.05[*]
BF[g] (ipsilateral)	46.54±14.62	28.44±17.56 (-61.11%)	-9.96	<.05[*]

[a]prone hip extension, [b]lower trapezius, [c]maximal voluntary isometric contraction, [d]mean±standard deviation, [e]multifidus, [f]gluteus maximus, [g]biceps femoris, [*]significant difference between two conditions ($p<.05$).

Table 2. Lumbopelvic kinematics during two different exercises (Unit: °)

Lumbopelvic kinematics	PHE[a] without lowT[b] pre-activation	PHE with lowT pre-activation	t value	p value
Rotation	5.41±.75[c]	1.99±.64	4.70	<.05*
Anterior tilting	8.75±.22	2.56±.52	6.70	<.05*

[a]prone hip extension, [b]lower trapezius, [c]mean±standard deviation, *significant difference between two conditions ($p<.05$).

anterior tilting were assessed during PHE with and without lowT pre-activation. Our findings showed that the activity of the bilateral MF and ipsilateral GM was facilitated and the BF was inhibited during PHE with lowT pre-activation compared to PHE without lowT pre-activation. In the PHE with lowT pre-activation, the relative differences in right and left MF, ipsilateral GM, and BF muscle activities were 51.24%, 66.02%, 46.45%, and 61.11% compared to PHE without lowT pre-activation.

There are some possible mechanisms. First, shoulder abduction at 125° and external rotation with 1 ㎏ load was performed before hip extension at 10° for the performance of PHE with lowT pre-activation. This can contribute to increase the counterbalance forces compared to PHE without lowT pre-activation. This counterbalance force would contribute to greater improvement of the bilateral MF and ipsilateral GM activity (Kim et al, 2013). In a previous study, during unilateral single-legged hold exercise on a round foam roll, the counterbalance force contributed to bilateral transverse abdominis and internal oblique muscle contractions to improve lumbar stability by enhancing the intra-abdominal pressure (Kim et al, 2011). In this study, the bilateral MF and ipsilateral GM activity contributed to this counterbalance force to stabilize the lumbopelvic region. In addition, ipsilateral GM was activated to perform hip extension with lumbopelvic stability. The BF muscle can be inhibited by the facilitated MF and GM as a muscle synergist during PHE with lowT pre-activation compared to without lowT pre-activation. Therefore, the relatively decreased GM muscular activity levels during PHE without lowT pre-activation may affect increased BF muscle activity to compensate for weak counterbalance force.

Second, the myofascial sling was anatomically interconnected muscles as a chain (Myers, 2009). Muscle slings are considered for the facilitation of the load transfer from the lower to the upper body through the trunk (Page et al, 2010). The lowT muscle aligned with the elements of the posterior oblique sling can be also the muscle in the superficial back line (Myers, 2009). The lowT can act as a stabilizing muscle of the scapulothoracic joint. Therefore, the lowT pre-activation during PHE may improve greater myofascial sling co-activation stabilizing the thoracic and lumbar spine compared to PHE without lowT pre-activation because greater shoulder abduction and external rotation angle were needed to activate the lowT (Kim et al, 2015).

In a previous study, the angle of anterior pelvic tilt was significantly increased during PHE without an abdominal drawing-in maneuver (ADIM) compared to PHE with ADIM (Oh et al, 2007). An ADIM with a pressure biofeedback unit during PHE was an effective method for lumbopelvic stability (Oh et al, 2007). This was consistent with the findings of our study. We showed that pelvic rotation and anterior tilting during PHE without lowT pre-activation were significantly greater compared to PHE with lowT pre-activation ($p<.05$). These results imply that the different stabilizing strategies which were contributed from the facilitation of MF and GM and inhibition of BF muscles during PHE with lowT pre-activation might provide the counterbalance force. Accordingly, the different muscular activation strategies with this counterbalance force can improve lumbopelvic stabilization during PHE. In our study, PHE with lowT pre-activation can be recommended for individuals with GM weakness to effectively strengthen GM muscle without lumbopelvic compensations.

This study has several limitations. First, our result cannot be generalized to participants with chronic low back pain. Group differences in EMG amplitudes of posterior oblique sling muscles during exercises were needed for further study. Second, cross-talk between the lowT/MF and the BF/GM may be possible because of surface EMG. Third, this study investigated only posterior oblique sling muscle activities during PHE exercises. A future study should investigate EMG onset time difference during different PHE exercises.

Conclusion

In this study, the purpose was to compare the EMG activity of the posterior oblique myofascial sling muscles and the angle of lumbopelvic rotation and anterior tilting between PHE with and without lowT pre-activation. Our findings suggest that PHE with lowT pre-activation contributes to increased MF and GM muscular activity, decreased BF muscular activity, and decreased angles in lumbopelvic rotation and anterior tilting compared to PHE without lowT pre-activation. Therefore, the lowT pre-activation can be applied as a lumbopelvic stabilization technique during PHE to strengthen MF and GM muscles for minimizing lumbopelvic compensated motions.

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