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Activity of Posterior Oblique Sling Muscles during Quadruped Hip Extension with Different Shoulder Positions

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Abstract While various studies have been conducted on trunk muscle activation in the quadruped position, no research has been conducted on posterior oblique sling (POS) muscle activation in the quadruped position despite its clinical importance. It has been demonstrated that the movement of the upper extremity affects the muscle activity of the contralateral lower extremity through the POS. The purpose of this study was to compare the EMG of the POS muscles during quadruped hip extension (QHE) with different shoulder positions. The participants performed hip extension in the quadruped position without shoulder movement (quadruped hip extension; QHE), QHE with shoulder extension and internal rotation (QHE with SEI), and QHE with shoulder flexion and external rotation (QHE with SFE). EMG of the POS muscles was measured during three different positions. During the QHE with SFE position, the lower trapezius has the highest EMG among all the POS muscles. Additionally, the contralateral erector spinae, ipsilateral erector spinae, and gluteus maximus presented higher EMG activity during QHE with SFE than during QHE and QHE with SEI. Therefore, QHE with SFE position may be clinically recommended as an effective exercise to improve EMG activity of POS muscles and increase lumbopelvic stability.

Keywords Electromyography, Posterior Oblique Sling, Quadruped Position, Shoulder Position, Thoracolumbar Fascia

1. Introduction

Muscles generate an internal force to facilitate the active motion of a body segment, while the myofascia creates a passive motion by facilitating the transfer of the internal force to the distal segment [1]. The myofascia not only connects the proximal extremity to the distal extremity, but also the upper extremity to the lower extremity. The myofascia is divided into the anterior oblique sling (AOS), posterior oblique sling (POS), and longitudinal sling. The AOS consists of the pectoralis major, external oblique, transverse abdominis, and internal oblique muscles on the anterior side of the body, while the POS consists of the latissimus dorsi, erector spinae, gluteus maximus, and biceps femoris muscles on the posterior side of the body [2]. This myofascial sling system connects anatomically disconnected muscles via passive structures and can thus facilitate the transfer of forces between the lower and upper extremities with the trunk as a mediator [3]. Additionally, thoracolumbar fascia, which is located at the center of POS, is known to facilitate reciprocal gait patterns by providing contralateral upper trunk stability during the swing phase of gait [4].

The muscles of the POS are located on the posterior side of the body; for this reason, electromyographic (EMG) activity has been commonly measured in the prone position. Kang and Hwang [5] measured the EMG of the POS muscles during prone hip extension (PHE) with contralateral arm extension and internal rotation to examine the effect of upper extremity movements on lower extremity muscle activity. The contralateral upper extremity muscles (latissimus dorsi, erector spinae, multifidus) are activated during both PHE and PHE with contralateral arm extension. All the POS muscles are more activated during PHE with contralateral arm extension than during PHE alone [5]. Jeon et al.[6] investigated the EMG of the POS muscles during PHE with and without contralateral arm flexion and observed a greater increase in the EMG of the contralateral multifidus and gluteus maximus during PHE with arm flexion than PHE without arm flexion. These results demonstrate that the movement of the upper extremity affects the muscle activity of the contralateral lower extremity through the POS. Thus, PHE effectively strengthens the POS muscles and increases the stability of the lumbopelvic region.

Lower extremity exercises in the quadruped position (also known as the 4-point kneeling exercise) are often recommended as a way to increase trunk muscle activity and stability [7]. Beith et al. [8] reported that while the internal abdominal oblique and rectus abdominal muscles are activated during the abdominal hollowing maneuver in both the quadruped and prone positions, the external abdominal oblique muscle is barely activated during the same exercise in the prone position. This result indicates that the quadruped position may be more effective than the prone position at activating the trunk muscles. Stevens et al. [9] reported that raising one arm or leg while in the quadruped position may be more effective at increasing trunk muscle activity. Various studies have been conducted on trunk muscle activation in the quadruped position. However, no research has been conducted on POS muscle activation in the quadruped position despite its clinical importance. Therefore, this study aimed at the measurement of POS muscle activities in the quadruped position. To increase POS muscle activities, hip extension was applied in the quadruped position. Additionally, POS muscles activities were compared between different shoulder positions during quadruped hip extension (QHE).

The upper extremity position may affect the POS muscle activities of the trunk and lower extremity. In previous studies, POS muscle activities were measured according to different shoulder positions during PHE. As a result, it was reported that shoulder position affects POS muscle activities during PHE, with an impact on lumbopelvic stabilization [5, 10]. However, no studies have been conducted before to evaluate the impact of varying shoulder positions on POS muscle activities in the quadruped position. In this study, the EMG of the POS muscles during quadruped hip extension (QHE) with different shoulder positions were compared to investigate the effect of the upper extremity on the lower extremity via the POS in the quadruped position.

2. Materials and Methods

2.1. Participants

Twenty-four healthy young adults volunteered for this study. Three volunteers who did not satisfy the requirements were excluded, and the remaining 21 participated in the study (male: 12, female: 9, mean age: 21.15 ± 1.78 years, mean height: 167.55 ± 8.24 cm, mean weight: 63.95 ± 11.55 kg). Only participants with right leg dominance were included. Those with any of the following symptoms were excluded: 1) limited movement of the hip and knee joints, 2) pain when in the quadruped or QHE positions, 3) shoulder muscle weakness in the quadruped position, and 4) low back pain or lower extremity dysfunction in the last 12 months [6]. Participants were informed about the purpose and methods of the study and provided written consents before the start of the study. This study was approved by the Institutional Review Board.

2.2. Measurement

EMG of the POS muscles was measured using the Delsys-Trigno Wireless EMG system (Delsys Inc., Boston, MA, USA). EMG data were analyzed using the Delsys EMG Work analysis. The root mean square (RMS) was computed from the raw EMG data. EMG signals were standardized using reference voluntary contractions (% RVCs) [10]. EMG was measured before muscle contraction. Before measuring EMG, one of three positions (QHE without shoulder movement [QHE], QHE with shoulder extension and internal rotation [SEI], and QHE with shoulder flexion and external rotation [SFE]) was randomly assigned to each subject. Each position was maintained for 5 s, though only the EMG values recorded during the middle 3 s (excluding the first and last second) were used. Each movement was repeated 3 times, and the mean of the three measurements was used for the analysis. To reduce errors in EMG signals, the skin was wiped clean with an alcohol swab and shaven before the electrodes were attached to the target region. Electrodes were attached to all the POS muscles of the leg that was to be used for performing QHE, from the ipsilateral biceps femoris to the contralateral lower trapezius (i.e., contralateral lower trapezius, contralateral latissimus dorsi, contralateral and ipsilateral erector spinae, ipsilateral gluteus maximus, and ipsilateral biceps femoris). The exact locations of the electrodes on the muscles are as follows: lower trapezius: lateral side of seventh thoracic spinous process, latissimus dorsi: 4 cm below the inferior border of scapula, erector spinae: 4 cm lateral at the L3-L4 spinous process, gluteus maximus: halfway between the sacrum and greater trochanter, and biceps femoris: halfway between the ischial tuberosity and lateral epicondyle of the tibia [11].

2.3. Experimental Procedure

The participants performed hip extension by raising their dominant leg until it was parallel with their trunk in the quadruped position. For the first position, the participants performed hip extension in the quadruped position without shoulder movement (quadruped hip extension without shoulder movement; QHE) (Figure 1). For the second position, the participants performed QHE with shoulder extension and internal rotation (SEI) while lifting a 1 kg dumbbell with the upper extremity contralateral to the extended lower extremity (QHE with SEI). During this position, the shoulder was extended until it was parallel with the trunk (shoulder at 180° extension) (Figure 2). For the third position, the participants performed QHE with SFE while lifting a 1 kg dumbbell with the upper extremity contralateral to the extended lower extremity (QHE with SFE). During this position, the shoulder was flexed until it was parallel with the trunk (shoulder at 180° extension) (Figure 3). Once the EMG of the POS muscles was measured during the first QHE position, the participants were assigned to perform the QHE with SEI and the QHE with SFE positions in a random order. The participants maintained isometric contraction for 5 s for each exercise. Each position was performed 3 times, and the mean of the three measurements was used. To prevent muscle fatigue, the participants were given a 3-min break between positions.

Figure 1. Quadruped hip extension (QHE) position

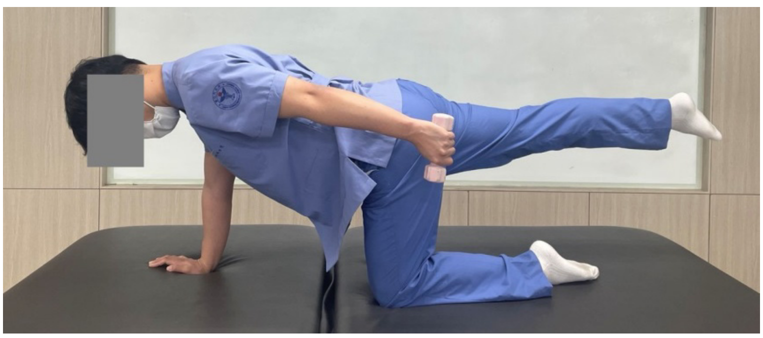


Figure 2. Quadruped hip extension with shoulder extension and internal rotation (QHE with SEI) position

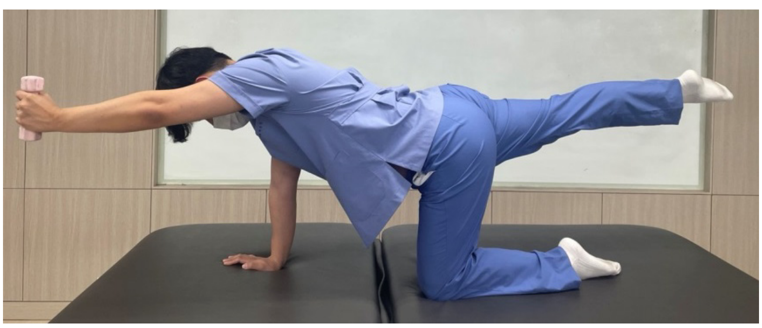


Figure 3. Quadruped hip extension with shoulder flexion and external rotation (QHE with SFE) position

2.4. Data Analysis

Data were analyzed using SPSS version 25.0 for window (IBP Corp., Armonk, NY, USA). A significance level of α=.05 was used for all statistical analyses. The general characteristics of the participants were analyzed using descriptive statistics. One-way repeated measure analysis of variance (ANOVA) was used to compare the EMG of the POS muscles during QHE with the different shoulder positions. Bonferroni correction was used for post-hoc testing.

3. Results

This study examined the EMG of the POS muscles during QHE, QHE with SEI, and QHE with SFE positions (Table 1). The ipsilateral biceps femoris had the highest EMG (50.56% RVC) during QHE; however, there was no significant difference compared to QHE with SEI and QHE with SFE. The contralateral latissimus dorsi showed the highest EMG (53.38% RVC) during the QHE with SEI, which was significantly higher than both QHE and QHE with SFE ($p < 0.001$). The contralateral lower trapezius had the highest EMG (61.75% RVC) during QHE with SFE, which was significantly higher than both QHE and QHE with SEI ($p < 0.001$). In addition, EMG of the contralateral erector spinae was 37.95% RVC during the QHE with SFE, which was significantly higher than the QHE position.

No significant difference in POS EMG was found between the QHE with SEI and the QHE with SFE. However, the EMG of the contralateral latissimus dorsi was higher during QHE with SEI than both QHE and QHE with SFE. And, the EMG of the contralateral lower trapezius during QHE with SFE was significantly during QHE with SFE than QHE or QHE with SEI.

Table 1. EMG (% RVC) of the POS muscles during QHE with different shoulder positions

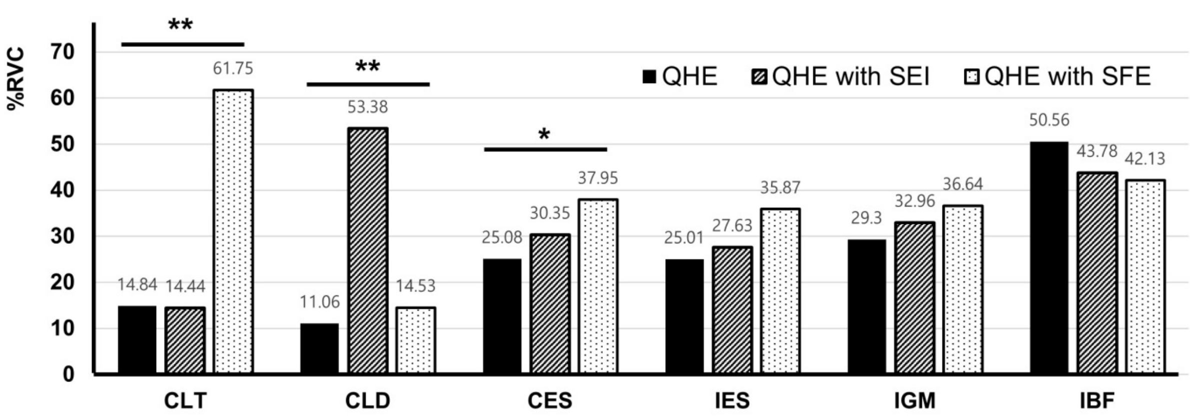
Position	Contralateral lower trapezius	Contralateral latissimus dorsi	Contralateral erector spinae	Ipsilateral erector spinae	Ipsilateral gluteus maximus	Ipsilateral biceps femoris
QHE	14.84±8.42	11.06±7.91	25.08±13.50	25.01±15.31	29.30±16.27	50.56±45.46
QHE with SEI	14.44±9.72	53.38±23.80[a,c]	30.35±17.49	27.63±15.91	32.96±18.19	43.78±40.26
QHE with SFE	61.75±49.95[b,c]	14.53±8.84	37.95±13.92[b]	35.87±22.81	36.64±24.62	42.13±32.71
F	17.512	49.152	3.861	2.007	0.707	0.264
P	0.000**	0.000**	0.026*	0.143	0.497	0.769

QHE: quadruped hip extension; QHE with SEI: quadruped hip extension with shoulder extension and internal rotation; QHE with SFE: quadruped hip extension with shoulder flexion and external rotation

[a]significant difference between QHE and QHE with SEI

[b]significant difference between QHE and QHE with SFE

[c]significant difference between QHE with SEI and QHE with SFE



CLT: contralateral lower trapezius; CLD: contralateral latissimus dorsi; CES: contralateral erector spinae; IES: ipsilateral erector spinae; IGM: ipsilateral gluteus maximus; IBF: ipsilateral biceps femoris

Figure 4. EMG of the POS muscles during QHE with different shoulder positions

4. Discussion

The POS muscles are involved in dynamic lumbo-pelvic stability, and the thoracolumbar fascia, latissimus dorsi, erector spinae, gluteus maximus, and biceps femoris connect the upper extremities to the lower extremities by crossing the posterior side of the body in an 'X' shape [5, 12]. Previous studies have mostly measured the EMG of the POS muscles in the prone position [6, 10]. However, Kim et al. [13] reported that contralateral arm and leg lifts in the quadruped position are more effective in selectively increasing the EMG of the lumbar muscles compared with trunk extension in the prone position. So far, no study has examined the EMG of the POS muscles during hip extension or shoulder movements in the quadruped position. In this study, the EMG of the POS muscles was measured during QHE (quadruped hip extension) with three different shoulder positions.

First, during the QHE position, EMG of the ipsilateral biceps femoris (50.56% RVC) was the highest among the POS muscles, followed by the ipsilateral gluteus maximus (29.30% RVC). However, there was no significant difference compared to other positions (QHE with SEI and SFE). Kim et al. [3] measured the EMG of the POS muscles during prone hip extension (PHE) position, and reported that maximum voluntary isometric contraction (MVIC) of the ipsilateral biceps femoris of 39.12% during PHE. This result is lower than the value obtained for ipsilateral biceps femoris activity in this study (during QHE). Comparing the results of both studies, it can be suggested that EMG activity of the ipsilateral biceps femoris is higher in QHE than in PHE. Moreover, ipsilateral erector spinae was 32.23 % MVIC and contralateral erector spinae MVIC was 40.23% MVIC during PHE in the mentioned study. These values are higher than ipsilateral and contralateral erector spinae EMG activities in the present study (during QHE). Thus, it is considered that the back muscles, which constitute the connecting part of POS, present a higher activity during PHE than during QHE. This difference is considered as difference of the hip extension angle in QHE and PHE postures. In this study, EMG was measured at a hip extension angle of 0° during QHE (hip extension was parallel with the trunk), whereas, in the previous study, EMG was measured at a hip extension angle of 10° during PHE [14]. The ROM of hip extension is 10 ~ 20°, it is thought that the EMG of POS muscles was affected in PHE position. The activity of the erector spinae in the lumbar region was found to increase as the angle of the anterior pelvic tilt increased in PHE position [15]. Whereas, hip extension was performed up to being parallel with the trunk, the anterior tilt angle in the QHE position was smaller than in PHE position. Consequently, it may induce less POS activity of the ipsilateral and contralateral erector spinae.

Second, during QHE with SEI, EMG of the contralateral latissimus dorsi (53.38% RVC) was the highest among the POS muscles, and was significantly higher than QHE and QHE with SFE positions. Whereas, EMG of the contralateral lower trapezius (14.44% RVC) had the lowest among the POS muscles during QHE with SEI. The latissimus dorsi acts as a moment arm for shoulder extension, adduction, and internal rotation and facilitates the extension and lateral flexion of the lumbar spine [16]. The latissimus dorsi and gluteus maximus are functionally connected to one another via the thoracolumbar fascia, controlling the gait patterns of the upper and lower extremities and playing an important role in trunk stability during rotation [4]. These extensive connections between latissimus dorsi and gluteus maximus make a possible pathway for myofascial force transmission. The gluteus maximus is interconnected with the contralateral latissimus dorsi and ipsilateral biceps femoris via the thoracolumbar fascia [6].

Kang and Hwang [5] examined the EMG of the POS muscles during PHE (prone hip extension) with or without SEI (shoulder extension and internal rotation), and reported significantly higher EMG of the latissimus dorsi, and gluteus maximus during PHE with SEI than PHE without SEI. However, in the present study, latissimus dorsi EMG activity was significantly higher during QHE with SEI than during QHE with SFE and QHE, and the gluteus maximus did not present a significant difference in EMG activity among the three positions. This indicates that SEI movement during PHE is a more effective method to increase EMG activity of both latissimus dorsi and gluteus maximus muscles than during QHE.

Additionally, the previously mentioned study reported significantly higher EMG activity of the contralateral erector spinae during PHE with SEI than PHE without SEI [5]. However, in the present study, there was no significant difference in the EMG activity of the contralateral and ipsilateral erector spinae between QHE and QHE with SEI. Thus, in this study, considering that performing SEI movement during QHE increased only the latissimus activity, but not other POS muscles activities, it seems to be more effective to apply SEI movement during PHE than QHE.

Third, during QHE with SFE, EMG of the contralateral lower trapezius (61.75% RVC) was the highest among the POS muscles and was significantly higher than the activities for that muscle during QHE and QHE with SEI. The middle and lower trapezius muscles are located at the superficial back line of POS and play important roles in controlling the rotation of the trunk and pelvis [12]. The lower trapezius facilitates torque generation during shoulder abduction and external rotation through a longer moment arm [17]. The lower trapezius is essential for optimal movement and stabilization of the scapulothoracic joint. Tsuruike et al. [18] reported that the lower trapezius, which is a major muscle controlling the serratus anterior and scapula-humeral rhythms, showed the highest EMG in the quadruped position with shoulder flexion. Oyama et al. [19] reported that the lower trapezius has an EMG of

72% MVIC during scapular retraction with shoulder abduction (120°) and external rotation in the prone position. These results indicate that the EMG of the lower trapezius increases considerably when the quadruped or prone position is accompanied by shoulder flexion, abduction, and external rotation.

In addition, EMG of the contralateral erector spinae was 37.95% RVC during the QHE with SFE, which was significantly higher than QHE. The erector spinae in the lumbar region contributes to trunk stability, and activating this muscle can reduce lower back pain [20]. The contralateral erector spinae, ipsilateral erector spinae, and gluteus maximus (connecting part of POS muscles) presented a higher EMG activity during QHE with SFE than during both QHE and QHE with SEI. This indicates that SFE is a more effective movement than SEI for the overall muscle activity of POS during QHE; the difference in the lever arm length is considered the reason for that. The lever arm length is longer when applying shoulder flexion than shoulder extension during QHE, leading to an increase in POS muscle activities during QHE with SFE. Therefore, QHE with SFE may be clinically recommended as an effective practice to improve overall muscle activity of POS.

This study has a few limitations. First, we did not compare directly POS muscle activities between PHE and QHE positions. Second, the results of this study cannot be generalized to the elderly or patients with back pain because only young healthy participants were included. Therefore, we will examine in further studies POS muscle activities according to shoulder movement during prone and quadruped positions in different ages and disease groups such as low back pain.

5. Conclusions

This study aimed to compare the EMG of the POS muscles between different shoulder positions during QHE positions (QHE, QHE with SEI, and QHE with SFE). First, during QHE, EMG activity of the ipsilateral biceps femoris was the highest among the POS muscles, followed by that of the ipsilateral gluteus maximus. However, there was no significant difference when comparing these EMG values to those of the other positions (QHE with SEI and SFE). Second, during QHE with SEI, EMG activity of the contralateral latissimus dorsi was the highest among POS muscles and was significantly higher than the activities for that muscle in QHE and QHE with SFE positions. Third, during QHE with SFE, EMG activity of the contralateral lower trapezius was the highest among POS muscles and was significantly higher than during QHE and QHE with SEI. Additionally, the contralateral erector spinae, ipsilateral erector spinae, and gluteus maximus (connecting part of POS muscles) presented a higher EMG activity during QHE with SFE than during QHE and QHE with SEI Therefore, QHE with SFE may be clinically recommended as an effective practice to improve the overall EMG activity of POS muscles, and it is also expected to increase lumbopelvic stability.

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