Effect of Hip Joint Position on Hip Abductor Muscle Activity during Lateral Step-up Exercises

KYUNG-HEE NOH, PT, MSc, MIN-HYEOK KANG, PT, MSc, SUN-JOUNG AN, OTD, MI-HYUN KIM, PT, PhD, WON-GYU YOO, PT, PhD, JAE-SEOP OH, PT, PhD

1) Department of Rehabilitation Science, Graduate School, Inje University
2) Department of Occupational Therapy, College of Biomedical Science and Engineering, Inje University
3) Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University:

607 Obang-dong, Gimhae-si, Gyeongsangnam-do 621-749, South Korea. E-mail: ysr rehab@inje.ac.kr

Abstract. [Purpose] This study examined the influences of different hip positions on electromyographic (EMG) activity of the hip abductor and the quadratus lumborum muscles during lateral step-up exercises. [Subjects] Fifteen healthy subjects (ten men and five women) participated in this study. [Methods] The subjects performed lateral step-up exercises in hip-neutral, internal rotation, and external rotation positions. EMG activity of the gluteus medius, tensor fascia latae, and the quadratus lumborum muscles was measured using surface electromyography during the exercises. EMG activity of each muscle in the three hip positions during lateral step-up exercises was analyzed using one-way repeated-measures analysis of variance. [Results] EMG activity of the gluteus medius muscle was significantly increased in the hip-neutral and internal rotation positions compared with the external rotation position during lateral step-up exercises (p<0.05). Significantly increased EMG activity of the tensor fascia latae muscle was observed in the hip internal rotation position compared with other hip positions. There was no significant difference in the activity of the quadratus lumborum among the three hip positions during lateral step-up exercises (p>0.05). [Conclusion] These findings indicate that maintaining the hip-neutral position could be used as an effective method to increase the activity of the gluteus medius during lateral step-up exercise.

Key words: Gluteus medius, Hip position, Lateral set-up

INTRODUCTION

Over the past decade in the field of physical therapy, strengthening exercises for the gluteus medius have been used to prevent lower extremity musculoskeletal injuries, to rehabilitate, and to improve performance in the clinical setting4–5. Weakness of the gluteus medius muscle is associated with many musculoskeletal disorders of the lower extremities such as patellofemoral pain syndrome1, anterior cruciate ligament sprain3, and ankle instability9.

To increase the strength of the gluteus medius, many clinicians have emphasized unilateral weight-bearing exercises during therapeutic exercise programs. Unilateral weight-bearing exercises in the standing position are often performed in the rehabilitation of individuals with back and hip pathologies6. Hip abductors, especially the gluteus medius, produce a force twice that of the person’s body weight to provide stability to the hip joint on the frontal plane during single-limb support7. It is believed that unilateral weight-bearing exercises are useful for strengthening the gluteus medius, as these exercises generate greater demand on the gluteus medius to control pelvic movement compared with non-weight-bearing exercises6, 9.

According to Janda, hip abduction has failed if hip flexion, hip internal rotation, or lateral pelvic tilt is observed during the hip abduction movement10. To strengthen the gluteus medius effectively, compensatory movement of the hip and pelvis using the tensor fascia latae and quadratus lumborum should be considered11, 12. Overactivation of the tensor fascia latae induces hip internal rotation10, 12, and lateral pelvic tilt can occur when the quadratus lumborum substitutes for a weakened gluteus medius13, 14. Substitution by the tensor fascia latae and quadratus lumborum leads to hip internal rotation and lateral pelvic tilt, and the lumbar spine undergoes lateral flexion, resulting in lateral instability and impaired movement of the lower extremity during unilateral weight-bearing exercises10.

A number of researchers have reported that, among many unilateral weight-bearing exercises, step-up exercises could reinforce gluteus medius activity and improve balance control13–15. Because the movement patterns of the step-up exercises are similar to daily life activities such as climbing stairs, they are easy and safe to perform and can be readily modified for different levels of exercise by changes in the step height16. Step-up exercises can be performed in the forward or lateral direction. Recently, many physical therapists have chosen to use lateral step-up exercises to increase the activation of the gluteus medius because they are more effective than forward step-up exercise17. Bolgla and Uh18 compared the EMG activity of the gluteus medius among...
six different exercises. They reported significantly greater maximum voluntary contraction of the gluteus medius in the stance leg during lateral step-up exercises compared with other hip abduction exercises.

A recent tendency in the therapeutic exercise program has been to focus on selective muscle strengthening\(^\text{[11]}\). Although many studies assessing step-up exercises have been conducted with subjects performing the forward step up, few studies reported in the literature have investigated the lateral direction\(^\text{[15, 16]}\). Additionally, we were unable to identify any study demonstrating the effect of hip position and investigating the selective recruitment of the gluteus medius and the inhibition of the tensor fascia latae and quadratus lumborum muscles during lateral step-up exercises. Therefore, the purpose of this study was to investigate the effect of hip position on EMG activity of the gluteus medius, the tensor fascia latae, and the quadratus lumborum during lateral step-up exercises. Investigating the effects of hip position during lateral step up exercises will provide beneficial information to the clinician for designing and implementing protocols.

Based on published reports and clinical experience, we hypothesized that lateral step-up exercises in the hip-neutral position increases the gluteus medius activity selectively.

**SUBJECTS AND METHODS**

Fifteen healthy adults (ten males, five females) were enrolled in this study. The mean age of the subjects was 25.07 ± 3.59 years, the mean weight was 65.93 ± 6.31 kg, and the mean height was 172.07 ± 5.03 cm. Subjects were excluded if they had orthopedic damage, serious neurological disease, lower-extremity pain, or a lower-extremity injury during the last 6 months. The Inje University Faculty of Health Science Human Ethics Committee approved this study, and all subjects provided written informed consent before participation.

EMG activity of the gluteus medius, the tensor fascia latae, and the quadratus lumborum on the dominant side was measured using a DelSYS-Transform Wireless EMG system (Delsys Inc., Boston, MA, USA). The skin impedance was minimized by rubbing the skin 3-4 times with sandpaper, followed by cleaning the skin with 70% isopropyl alcohol prior to placing the electrodes. The electrodes were placed parallel to the muscle fibers over the proximal one-third of the distance between the iliac crest and the greater trochanter for the gluteus medius, 2 cm inferior to the anterior superior iliac spine for the tensor fascia latae, 4 cm lateral from the belly of the erector spinae, and at a slightly oblique angle and half the distance between the 12th rib and the iliac crest for the quadratus lumborum\(^\text{[17]}\). The sampling rate of the EMG signal was 1,000 Hz using a bandwidth of 20-450 Hz. The raw data from individual muscles during the lateral step-up exercises were processed using root mean squares (RMS) for analysis. To normalize the EMG signals, maximal voluntary isometric contractions (MVIC) of each muscle were measured using the manual muscle test as described by Kendall et al.\(^\text{[18]}\). Each MVIC maneuver was performed twice for 5 s. The average muscle activity for the middle 3 s of two trials was used for normalization.

The subjects performed lateral step-up exercises in the hip-neutral position (HNP), 20° hip internal rotation position (HIRP), and 20° hip external rotation position (HERP). Subjects stood next to a 21.5-cm-high step and placed their dominant-side foot onto the step with their feet shoulder-width apart\(^\text{[15]}\). Foot placements for the three different hip positions were marked with white tape on the step. The subjects placed the big toe in line with the calcaneus on the white tape and aligned the knee over their ankle, while the pelvis and trunk were maintained in a neutral position. To control the load applied to the dominant-side lower extremity, a scale was placed under the foot of the non-dominant side. Subjects were instructed to hold 50 ± 4% of their weight on the scale in the starting position and to keep their nondominant foot dorsiflexed during lateral step-up exercises\(^\text{[19]}\). The 50 ± 4% of their body weight on the nondominant side was the mean value during comfortable lateral step-up exercises in our pilot study. After preparation for the exercises, the lateral step-up exercises were performed for 2 s. A metronome was used to measure the 2-s period for each lateral step up. The order of the exercises was randomized, and each exercise was repeated three times, with rest periods of 1 min between trials and 5 min between exercises. The mean value of the three trials for each exercise was used for data analysis.

One-way repeated-measures analysis of variance (ANOVA) was used to determine the main effects of the hip position and muscle. A post hoc comparative analysis of the three different hip positions was performed with Bonferroni’s correction. The statistical significance level was set at \(p<0.05\), and the collected data were analyzed using SPSS ver. 18.0 (SPSS, Inc., Chicago, IL, USA).

**RESULTS**

The results of statistical analyses of each muscle activity are shown in Table 1. The activity of the gluteus medius was significantly different among the three hip positions \((p<0.05)\). Post hoc analysis revealed that the EMG activity of the gluteus medius was significantly more increased in HNP and HIRP compared with HERP, but there was no significant difference between HNP and HIRP. The activity of the tensor fascia latae also differed significantly among the three conditions \((p<0.05)\). The post hoc analysis revealed significantly greater EMG activity of the tensor fascia latae in HIRP compared with HNP and HERP. No significant difference in the tensor fascia latae activity was observed between HNP and HERP. The EMG activity of the quadratus lumborum did not differ significantly with the changes in hip positions during lateral step-up exercises \((p>0.05)\).

**DISCUSSION**

Lateral step-up exercises have been commonly used to strengthen the gluteus medius in the clinical setting\(^\text{[15, 20]}\). However, previous studies overlooked the importance of hip position, which could induce overactivation of the tensor fascia latae and the quadratus lumborum. The present study was performed to demonstrate the effect of hip position on...
the EMG activity of the hip abductors and the quadratus lumborum.

Our results showed that the EMG activity of the gluteus medius was significantly more increased in HNP and HIRP compared with HERP (p<0.05). Exercises for strengthening the gluteus medius are often performed in a unilateral weight-bearing position, as the gluteus medius undergoes greater external torque in this position compared with a non-weight-bearing position. Functionally, the gluteus medius has been described as an important stabilizer of the pelvis in the frontal plane. Due to the role of the gluteus medius, its activity increases when movement of contralateral lower extremity is performed laterally compared with forward exercise. During lateral step-up exercises, HNP may be the best position to facilitate the role of the gluteus medius as a stabilizer in the frontal plane. However, when subjects perform the lateral step-up exercises in HERP, the force needed for pelvic and hip stability might be provided not only by the gluteus medius but also by the hip external rotator muscles such as the gluteus maximus. It is postulated that participation of other hip external rotator muscles in pelvis and hip stability may decrease the demand for the gluteus medius during lateral step-up exercises in HERP. In the present study, there was no significant difference in the EMG activity of the gluteus medius between HNP and HIRP (p>0.05). Interestingly, previous studies showed that gluteus medius activity was increased during hip internal rotation as well as hip abduction. Researchers have shown that the gluteus medius has a role during hip internal rotation, although its main function is controlling hip movements in the frontal plane. O’Dwyer et al. investigated the effects of the direction of the hip isometric contraction on the activation of the gluteus medius and reported that the EMG activity of the gluteus medius was not significantly different during hip internal rotation and abduction due to the function of the gluteus medius in hip internal rotation. These previous studies help to explain why no significant differences were observed in gluteus medius activity between HNP and HIRP in our study.

An altered movement pattern of the hip joint during weight-bearing tasks is generally enhanced by the predominance of the tensor fascia latae. The tensor fascia latae produces movement with hip abduction, flexion, and internal rotation because it originates from the anterior part of the external lip of the iliac crest and the outer surface of the anterosuperior iliac spine and inserts into the iliobibial tract of the fascia latae. Janda also commented that internal rotation of the femur during a one-leg standing task occurred if the tensor fascia latae activated dominantly. In the present study, it was concluded that the tensor fascia latae was more active in HIRP than in HNP and HERP because of its anatomic orientation acting on internal hip rotation. However, these increases in EMG activity in the tensor fascia latae can possibly lead to lower extremity disorders among healthy people during lateral step-up exercises. Therefore, physical therapists should consider the hip joint position during lateral step-up exercises.

EMG activity of the quadratus lumborum was not significantly different in the three hip positions during the lateral step-up exercises in the present study. The quadratus lumborum is activated when the trunk bends laterally or the pelvis tilts laterally. In our study, we minimized the compensatory trunk lateral bending generated by the plantar flexion of the non-dominant foot or changes in the performance speed using the scale and metronome during all lateral step-up exercises. Reduced deviations of the trunk lateral bending may explain the absence of significant differences in quadratus lumborum activity among HNP, HIRP, and HERP during the lateral step-up exercises in the present study.

In the clinical setting, it is considered that selective strengthening of the gluteus medius while minimizing activity of the tensor fascia latae is an important factor for the prevention or rehabilitation of lower-extremity disorders. Although the tensor fascia latae contributes to hip abduction, as does the gluteus medius, the hip internal rotation induced by the predominance of the tensor fascia latae and weakness of the gluteus medius may increase the valgus angle, subsequently leading to iliobibial band syndrome or patellofemoral pain syndrome. The findings of the present study showed that the lateral step-up exercises performed in HNP were effective for producing greater EMG activity of the gluteus medius and reducing the activity of the tensor fascia latae.

The research presented in this study has several limitations. First, it was difficult to normalize the results, as the sample size was small and the participants were healthy young people. Second, we did not measure kinematic and kinetic data of the lower extremity during lateral step-up exercises. To assess changes in hip and knee joints in response to different hip positions during lateral step-up exercises, kinematic and kinetic data will be measured in

Table 1. EMG activation expressed as a percentage of maximal voluntary isometric contractions (%MVIC) for each muscle in the three hip positions during lateral step-up exercises

<table>
<thead>
<tr>
<th>Muscles</th>
<th>HNP</th>
<th>HIRP</th>
<th>HERP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gluteus medius</td>
<td>38.81 ± 13.01</td>
<td>41.27 ± 13.16</td>
<td>30.17 ± 9.81*</td>
</tr>
<tr>
<td>Tensor fascia latae</td>
<td>15.09 ± 10.22</td>
<td>18.83 ± 11.12</td>
<td>14.50 ± 10.87*</td>
</tr>
<tr>
<td>Quadratus lumborum</td>
<td>19.42 ± 16.82</td>
<td>21.76 ± 20.49</td>
<td>17.31 ± 11.63</td>
</tr>
</tbody>
</table>

Abbreviations: HNP, hip-neutral position; HIRP, hip internal rotation position; HERP, hip external rotation position. *p<0.05
future studies. Finally, we did not measure the EMG activity of the subdivisions of the gluteus medius. The gluteus medius can be divided into three components based on functional differences. The role of each subdivision during lateral step-up exercises should be investigated in future studies.

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