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Different hip rotations influence hip abductor muscles activity during isometric side-lying hip abduction in subjects with gluteus medius weakness

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ABSTRACT

The purpose of this study was to establish the effects of different hip rotations during isometric side-lying hip abduction (SHA) in subjects with gluteus medius (Gmed) weakness by investigating the electromyographic (EMG) amplitude of the Gmed, tensor fasciae latae (TFL) activity, and gluteus maximus (Gmax), and the activity ratio of the Gmed/TFL, Gmax/TFL, and Gmed/Gmax. Nineteen subjects with Gmed weakness were recruited for this study. Subjects performed three isometric hip abductions: frontal SHA with neutral hips (SHA-N), frontal SHA with hip medial rotation (SHA-MR), and frontal SHA with hip lateral rotation (SHA-LR). Surface EMG amplitude was measured to collect the EMG data from the Gmed, TFL, and Gmax. A one-way repeated-measures analysis of variance was used to determine the statistical significance of the Gmed, TFL, and Gmax EMG activity and the Gmed/TFL, Gmax/TFL, and Gmed/Gmax EMG activity ratios. Gmed EMG activity was significantly greater in SHA-MR than in SHA-N. TFL EMG activity was significantly greater in SHA-LR than in SHA-N. The Gmed/TFL and Gmed/Gmax EMG activity ratios were also significantly greater in SHA-MR than in SHA-N or SHA-LR. The results of this study suggest that SHA-MR can be used as an effective method to increase Gmed activation and to decrease TFL activity during SHA exercises.

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1. Introduction

The gluteus medius (Gmed) is the primary muscle that acts as a hip abductor (Standring et al., 2005), a pelvis stabilizer in a unilateral stance against gravity (Al-Hayani, 2009; Gottschalk et al., 1989), and a controller hip adduction and internal rotation eccentrically (Moore and Dalley, 1999). Accordingly, Gmed weakness can lead to lateral hip pain (Strauss et al., 2010), iliotibial-band friction syndrome (Fredericson et al., 2002; Lee et al., 2012), patellofemoral pain syndrome (Cichanowski et al., 2007; Robinson and Nee, 2007; Magalhães et al., 2010; Nakagawa et al., 2012), and osteoarthritis of the knee (Hinman et al., 2010). Therefore, many therapeutic exercise protocols have focused on Gmed activity for prevention and rehabilitation in clinical and athletic training settings.

Many previous studies have examined the effectiveness of various exercises to increase Gmed activity including a single-leg stance, hip clams, side steps, bridging, sideways hop exercises, and side-lying hip abduction (SHA) (Bolgla and Uhl, 2005; Distefano et al., 2009; McBeth et al., 2012; Selkowitz et al., 2013). Of these various exercise, SHA exercise is frequently used in rehabilitation sessions because it can be performed early in a rehabilitation program to generate proper neuromuscular control and strength since it is a less demanding exercise as an open kinematic chain exercise. Additionally, SHA is effective in targeting Gmed muscle activity. Previous study reported that Gmed activity was greater than almost 16% of maximal voluntary isometric contraction (MVIC) than single-limb squat, band walk, single-limb

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deadlift, and side-way hop exercise (Distefano et al., 2009). Bolgla and Uhl (2005) also reported that SHA induced greater electromyographic (EMG) amplitude of Gmed than the non-weight bearing standing hip abduction exercises used in their study. Thus, SHA exercise has been recommended for inducing Gmed activation.

When prescribing exercise for Gmed activation, one should consider the relative activation of all synergist muscles. Synergist muscles act together and affect each other during movement (Chance-Larsen et al., 2010; Page et al., 2009). Accordingly, previous investigators have examined the Gmed, tensor fasciae latae (TFL), and gluteus maximus (Gmax) as hip abductors during hip rehabilitation (Cambridge et al., 2012; Homan et al., 2013; Distefano et al., 2009; McBeth et al., 2012; Selkowitz et al., 2013). TFL is an abductor and medial rotator at the hip (Gottschalk et al., 1989; Neumann, 2010). However, when a person's gait exhibits a movement pattern with excessive medial rotation, the TFL may be dominant or over-active as a hip abductor compared to the Gmed (Sahrmann, 2003). An over-active TFL can also put lateral force on the patella through connections to the iliotibial band (Kwak et al., 2000; Merican and Amis, 2008, 2009). This movement pattern has been associated with patellofemoral pain (Powers, 2003, 2010; Souza and Powers, 2009). The upper portion of the Gmax also acts as hip abductor and lateral rotator during gait (Blandine, 1993; Lyons et al., 1983; Neumann, 2010). Thus, the Gmed and Gmax control excessive hip medial rotation and adduction in ambulation (Delp et al., 1999; Lyons et al., 1983). However, the TFL is an abductor and medial rotator of the hip. Additionally, less activation of the Gmax muscle compared to the TFL can be observed in degenerative hip joint pathology (Grimaldi et al., 2009). Abnormal hip kinematics and impaired hip muscle performance have been associated with these various musculoskeletal disorders. For this reason, this study decided to investigate Gmed, TFL, and Gmax activity during SHA exercises.

In a previous study, McBeth et al. (2012) reported the TFL was more active than the Gmed and Gmax during SHA when subjects' hips were laterally rotated. The theoretical rationale was that hip lateral rotation (LR) activated the Gmed as a hip lateral rotator. However, a hip lateral rotator cannot act against gravity during SHA-LR compared SHA-medial rotation (MR). It is possible that SHA-MR can facilitate the Gmed and Gmax as hip lateral rotators with regard to gravity. Thus, SHA-MR can be used to increase Gmed and Gmax activity relative to TFL activity. However, a limitation of previous studies was that they evaluated Gmed, TFL, and Gmax muscle activity during SHA in healthy subjects; they did not investigate these muscle activities during SHA with different hip rotations in subjects with Gmed weakness. Therefore, an examination of Gmed, TFL, and Gmax activation with different hip rotations during SHA in subjects with Gmed weakness will provide new, valuable information.

The purpose of this research was to establish the effects of SHA with different hip rotations in the frontal plane (frontal SHA with neutral hip, SHA-N; SHA with hip MR, SHA-MR; and SHA with hip LR, SHA-LR) on Gmed, TFL, and Gmax EMG activity, and the EMG activity ratios of Gmed/TFL, Gmax/TFL, and Gmed/Gmax during isometric SHA in subjects with Gmed weakness. The hypothesis was that Gmed and Gmax EMG activity and the EMG activity ratios of the Gmed/TFL, Gmax/TFL, and Gmed/Gmax would increase and that TFL activity would decrease in SHA-MR, compared with the other SHA exercises in subjects with Gmed weakness.

2. Methods

2.1. Subjects

G-power software provided power analyses. The necessary sample size of seven subjects was calculated from data obtained from a pilot study of seven subjects to achieve a power of 0.80 and an effect size of 0.40 (calculated by the partial η^2 of 0.14 from the pilot study), with an α level of 0.05. We recruited 27 participants in the beginning of the study. Nineteen subjects (eight males, 11 females) with weak Gmed participated in current study through the manual muscle testing (Table 1). Subjects were between 18 and 30 years of age. Inclusion criteria included being free from past or current inflammatory arthritis and lower-extremity or back dysfunction, and being able to maintain five seconds of isometric hip abduction in the side-lying position (Kim et al., 2011). All exercise was performed on the dominant leg for each subject, defined as the leg preferred for kicking a soccer ball (Bolgla and Uhl, 2005; McBeth et al., 2012). Then, Gmed weakness was confirmed by performing manual muscle testing. To confirm Gmed weakness, subjects assumed a side-lying position on the treatment table. Each subject's bottom leg was flexed for comfort and stability, and the test leg was aligned with the rest of the trunk. The hip of the test limb was abducted to 50% of the hip abduction total ROM, and the investigator's hand was placed 10 cm proximal to the lateral femoral epicondyle (Khayambashi et al., 2012). An isometric hold was performed for five seconds against resistance. The principal investigator (JHL) provided verbal encouragement to facilitate maximal performance and gave instructions to avoid any medial rotation or flexion of the hip through recruitment of the TFL or any hip hiking through use of the quadratus lumborum (Fredericson et al., 2002). Subjects took a three-minute rest between the two trials (Friel et al., 2006). Muscle grading was based on the method described by Kendall et al. (2005). Strength was graded as 0, 1, 2, 3, 4, or 5/5, then grouped as either 'weak' (3/5 or less) or 'strong' (4 or 5/5) (Bewyer et al., 2009). The reliability for individual muscle groups ranged from 0.63 to 0.93 (Kendall et al., 1993, 2005). Cohen's Kappa was 0.89 for the two investigators in this study.

The study excluded subjects with past or present musculoskeletal, neurological, or cardiopulmonary diseases that could interfere with SHA. Additionally, using Craig's test, those with excessive femoral anteversion above 42° were excluded because the mean peak Gmed was decreased in subjects with femoral anteversion above 42° (Nyland et al., 2004). Overweight or obese subjects were also excluded, as fatty tissue, acting as a low-pass filter, could interfere with EMG signals (Wong, 1999). Subjects were identified as 'overweight' and 'obese' if they had a body mass index (BMI) > 25 (Flegal et al., 1998). BMI is defined as a subject's weight divided by the square of his or her height, in units of kg/m^2. Prior to the study, subjects signed a written consent form to participate. The University Institutional Review Board approved the protocol for this study, and each volunteer gave informed consent prior to participation.

Table 1
Characteristic of participants (mean ± sd).

Characteristics	Participants (n = 19)
Age (years)	21.00 ± 1.73
Height (cm)	166.00 ± 0.07
Weight (kg)	59.79 ± 9.61
BMI (kg/m^2)	21.54 ± 2.56
Modified Ober test (°)	−0.20 ± 5.97
Hip abduction total ROM (°)	46.11 ± 15.17
Hip medial rotation total ROM (°)	49.66 ± 7.21
Hip lateral rotation total ROM (°)	49.31 ± 11.11

Abbreviation: BMI: body mass index, ROM: range of motion.
Hip adduction (below horizontal plane) was recorded as a negative number and abduction was recorded as a positive number.