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Muscle Activation During Common Hip Strengthening Exercises

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ABSTRACT

Purpose: The aim of this study was to analyze the gluteus medius (GM) and tensor fascia latae (TFL) activity with surface electromyography (EMG) during sidelying hip abduction (SHA) and hip abduction with knee flexion (HAF). **Methods:** Surface EMG data of the muscle activity of the GM and TFL was collected on the dominant lower extremity while performing two exercises commonly used in low back and hip rehabilitation. Fourteen healthy, active, pain-free adults (mean age ± SD, 28 ± 4.9, and range 21 to 38 years) participated in the study. Data were collected from the dominant lower extremity of all subjects (8 males, 6 females). All EMG data gathered during the exercises were normalized to a percent of the maximum voluntary isometric contraction (MVIC). Computerized voice activation commands were used to record and synchronize the data collection process. Mean activation levels and ratios of muscle activity were identified. **Results:** During the HAF exercise, the mean muscle activity values were 29.1% (GM) and 12.7% (TFL). The SHA exercise revealed mean muscle activity values of 40.6% (GM) and 31.5% (TFL). Both muscles displayed a significant increase in activation levels during the SHA exercise ($P \leq .016$). The TFL / GM muscle activation ratio was .49 and .81 for the HAF and SHA, respectively. The muscle activation ratio during the SHA exercise was significantly greater than the ratio identified during the HAF exercise ($P=.004$). **Conclusions:** The SHA exercise demonstrated the highest levels of muscle activity for both the GM and the TFL. The TFL / GM muscle activation ratio was highest during the SHA exercise, closer toward symmetry of activation between the 2 muscles. The HAF exercise was more effective in reducing the TFL activity in relation that of the GM. Since these muscles work agonistically to produce hip abduction, findings from this study provide the clinician with information about relative muscle activation and ratios to assist in selecting an exercise that would more effectively isolate the GM from the TFL.

Keywords: Electromyography, Hip, Strength

INTRODUCTION

The sidelying hip abduction (SHA) and hip abduction with knee flexion (HAF) movement tasks are commonly used to screen patients with hip and/or low back dysfunction (Davis, Bridge, Miller, & Nelson-Wong, 2011). Individuals with these dysfunctions seem to display altered movement patterns, making this type of screen appropriate. Neuromuscular inhibition, secondary to pain, has been shown to negatively impact maximal voluntary muscle activation and alter motor control patterns during volitional motion (Bruno & J., 2007; O'Sullivan, Phyty, Twomey, & Allison, 1997; Zedka, Prochazka, Knight, Gillard, & Gauthier, 1999). SHA is considered a novel screening tool and may be useful in predicting low back pain (LBP) development during prolonged standing tasks (Nelson-Wong, Flynn, & Callaghan, 2009). It is important to correctly identify muscle imbalances/altered movement patterns in order to develop effective treatment interventions.

Dysfunction of the gluteus medius (GM) has been linked to LBP and many rehabilitation programs focus on strengthening this muscle (Ekstrom, Donatelli, & Carp, 2007). One of the most important interventions utilized by rehabilitation professionals is therapeutic exercise. When selecting an exercise to target a specific muscle (GM), the clinician must consider both the effectiveness of the exercise to recruit the primary muscle and the relative activity levels of any secondary musculature, such as the tensor fascia latae (TFL). The secondary musculature (agonists) may already be working effectively or even in a state of over facilitation in order to compensate for the weakness in the primary muscle(s).

Electromyography is a commonly used technique to compare muscle activity between exercises/active movement tasks (Ayotte, Stetts, Keenan, & Greenway, 2007; Beutler, Cooper, Kirkendall, & Garrett, 2002; Bolgla & Uhl, 2005; Earl, Schmitz, & Arnold, 2001). Bolgla and Uhl (2005) found that SHA resulted in greater GM muscle activation than several other non-weight bearing upright exercises, secondary to the additional external torque applied to the muscle in this position. SHA was also significantly more effective in activating the GM muscle when compared to the HAF exercise. In addition, the GM displayed more activity during SHA than either the lunge or hop weight bearing exercises (Distefano, Blackburn, Marshall, & Padua, 2009).

When healthy controls performed SHA, the gluteus medius and tensor fascia latae were clinically observed to become active prior to the ipsilateral erector spinae, with the GM firing first (Greenman, 2003). In patients with LBP, abnormal firing patterns may lead to compensatory substitutions which reduce the ability of the stabilizing muscles to perform optimally (Danneels et al., 2002). Several authors agree that the most common pathologic substitution, during the SHA, seems to be the delay in firing of the GM (Bruno & J., 2007; Bullock-Saxton, Janda, & Bullock, 1994; Greenman, 2003). Hodges and Richardson (1998) concur and demonstrated that in patients with LBP, the normal proximal to distal muscle activation pattern was reversed.

There is a limited amount of literature regarding GM muscle activity during two of the most common rehabilitation exercises (SHA and HAF) for hip and/or low back dysfunctions. The available research has described the SHA to be more effective in recruiting the GM muscle than numerous other weight bearing and non-weight bearing exercises, including HAF. However, the research has not adequately considered the relative activity levels of and the ratio between the TFL and GM during these exercises. Therefore, the purpose of this study was to analyze the gluteus medius and tensor fascia latae activity with surface electromyography (EMG) during sidelying hip abduction and hip abduction with knee flexion and examine the TFL / GM muscle activation ratios during these exercises.

METHODS

Subjects

The data were obtained from a group of 14 healthy physically active volunteers (8 males, 6 females; mean ± SD age, 28 ± 4.9 years; height, 173.1 ± 8.9 cm; body mass, 76 ± 24.2 kg; body mass index, 25 ± 5.9 kg/m^2). Subjects were recruited from the student population and the local community. All were right leg dominant. The dominant lower extremity was tested in all subjects. Subjects were included if they were between 20 and 45 years of age, physically active, and able to perform the desired movement tasks. Subjects were excluded if they were pregnant or had given birth within the past 2 years, had a history of back or lower extremity surgery, had current symptoms related to the lumbar spine or current lower extremity pain. Subjects participating in competitive sports or high level strength training were also excluded. Inclusion and exclusion criteria were assessed with a questionnaire. All subjects gave their written, informed consent to participate in the study, which was approved by the University of Maryland Eastern Shore's Institutional Review Board.

Protocol

Subjects attended 1 test session. During this time demographic data was collected, questionnaires completed, subjects were assessed for adequate motor control/range of motion and oriented to the test protocol. All testing was performed on the dominant lower extremity. The testing procedure consisted of electrode placement, practice and familiarization, and movement task assessment.

General Practice Physical Activity Questionnaire

The GPPAQ provides a simple, four-level Physical Activity Index (PAI) reflecting an individual's current physical activity level. The instrument is intended for adults (16-74 years of age) and is a simple tool, requiring 30 seconds to complete. The GPPAQ has been shown to have good face and construct validity (Khaw et al., 2006).

Electrode Placement

After a brief walk to record height and weight, subjects were prepared for electrode placement. Alcohol was used to cleanse the skin and reduce tissue impedance. Bipolar surface electrodes (Noraxon USA, Inc; Scottsdale, AZ) were placed on the appropriate muscles based on the EMG manufacturer guidelines (Konrad, 2006) and a basic understanding of surface anatomy (Greenman, 2003; Kendall, 2005). Electrodes were Ag-AgCL pre-gelled with a diameter of 1cm and inter-electrode distance of 2 cm. The same examiner positioned the electrodes on all subjects. Each electrode was connected to a Noraxon Telemyo 2400T G2 transmitter (Noraxon USA, Inc; Scottsdale, AZ). The sampling rate was 1500 Hz. All raw myoelectric signals were pre-amplified (overall gain, 500). The common mode rejection ratio was >100 dB, the signal-to-noise ratio was <1 μV RMS baseline noise, and filtered to produce a bandwidth of 10-500 Hz.

For both movement exercises, the same hip muscles were analyzed. The TFL electrodes were placed at the mid-point of an imaginary line between the greater trochanter and the anterior superior iliac spine (ASIS). The GM electrodes were applied 2.5 cm posterior to the midpoint of the line bisecting the ASIS and greater trochanter. All electrodes were placed parallel to the fiber direction of the target muscle. Correct electrode placement was verified by EMG signal analysis (visual inspection) during the motion task under consideration. This information was also used to ensure that a true baseline was maintained at rest. A reference electrode was placed along the shaft of one of the ribs, right mid-axillary line.

For normalization of the EMG data, a maximal voluntary isometric contraction (MVIC) was performed for each muscle while recording the EMG signal amplitude. The test positions were consistent with those referenced in manual muscle test books commonly used by physical therapists (Kendall, 2005). The TFL was tested in supine with the knee extended, hip flexed and pressure in the direction of hip extension and adduction. The GM was tested in left sidelying with the test leg abducted with slight extension and slight external rotation and pressure in the direction of hip adduction and slight flexion. Manual pressure was gradually increased until maximal force was applied. This force was maintained for 5 seconds and each muscle tested 3 times with a 30-second rest in between each trial. The same examiners performed all manual muscle test procedures.

Exercises

During HAF, subjects were positioned on their side with their knees and hips flexed (60°) so the ankles were aligned with the trunk/pelvis **(FIGURE 1A)**. From this position, the subject performed maximal hip abduction. The second exercise under investigation was the SHA task. Subjects were positioned in left sidelying with the dominant leg in neutral, resting on a pillow, with the knee extended **(FIGURE 1B)**. Subjects performed maximal hip abduction with the knee extended. Before data collection, each motion was demonstrated by a member of the research team. After a period of familiarization and corrective feedback, subjects performed 3 trials of each motion task. A standardized set of computer generated voice commands were used to synchronize the data collection process. Upon command, subjects moved into the desired position and held that position for 3 seconds. Subjects rested for 1 minute between trials. Only the concentric phase of the task was analyzed.

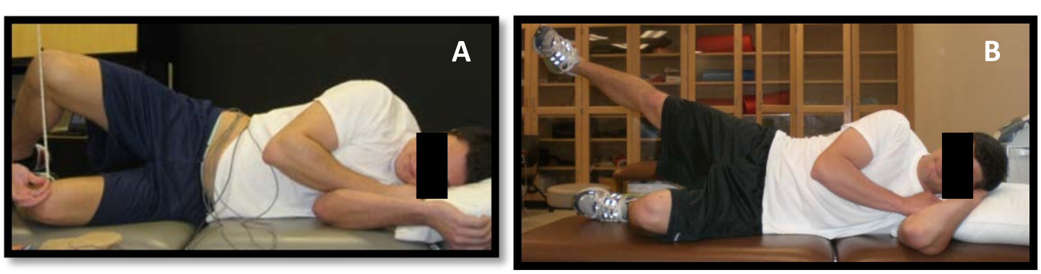

FIGURE 1. Exercises: (A) hip abduction with knee flexion and (B) sidelying hip abduction

Data Processing

Raw EMG data was converted from analog to digital at 1500 Hz. The raw signals were rectified, processed using a root-mean-square algorithm, and smoothed. Muscle activation was determined for each exercise. A muscle was considered to be activated when the signal surpassed the trigger level of 3 standard deviations beyond the baseline level at the beginning of the concentric phase of the motion. This method sets activation at a higher threshold and is considered to be a reliable technique (Bolgla, Malone, Umberger, & Uhl, 2010; Di Fabio, 1987). The point in time when each muscle reached this activity level was determined. The amplitude was calculated from a 3-second window when peak activity was most optimal for each muscle for each of the MVICs and exercises. The maximum EMG signal amplitude during the MVIC procedure was used to represent 100% muscle activity. The muscle activity identified during each exercise was expressed as a percentage of the MVIC.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences, version 17.0 (SPSS Inc, Chicago, IL). Descriptive statistics were computed for all variables. The data are presented in **Table 1** as a mean ± SD percent of MVIC with a 95% confidence interval (CI). Differences in muscle activation, expressed as a percentage of the MVIC, and muscle ratios between the exercises were investigated using paired-sample t tests. For all tests, significance was assessed at an alpha level of .05.

RESULTS

Muscle Activation

Normalized mean amplitudes, as well as standard deviations and confidence intervals for the gluteal medius and tensor fascia latae during the two exercises are displayed in **Table 1**. Muscle activity is expressed as a percent of MVIC during each exercise. The sidelying hip abduction exercise activated both muscles to higher levels than the hip abduction with knee flexion exercise. However, during both exercises, the GM displayed higher activity levels, as compared to the TFL.

TABLE 1. EMG Signal Amplitudes of the GM and the TFL During Hip Abduction with Knee Flexion and Sidelying Hip Abduction*

Exercise	Gluteal Medius	Tensor Fascia Latae
Hip Abduction with Knee Flexion	29.1 ± 13.7(21.2-37)	12.7 ± 10.5(6.6-18.8)
Sidelying Hip Abduction	40.6 ± 13.5(32.8-48.4)	31.5 ± 9.8(25.8-37.2)

* Values are expressed as mean ± SD percentage of MVIC and 95% CI in parentheses.

The GMed and TFL muscles displayed significantly greater amplitudes during the sidelying hip abduction exercise (**Table 2**). The sidelying hip abduction exercise produced not only higher but more similar TFL and GM mean signal amplitudes as compared to the hip abduction with knee flexion exercise.

TABLE 2. EMG Signal Amplitudes of the Gluteal Medius and the Tensor Fascia Latae*

Muscle	Hip Abduction with Knee Flexion	Sidelying Hip Abduction	P
Gluteal Medius	29.1 ± 13.7	40.6 ± 13.5	.016
Tensor Fascia Latae	12.7 ± 10.5	31.5 ± 9.8	<.001

* Values are expressed as mean ± SD percentage of MVIC.

Muscle Activation Ratio

Means and standard deviations for muscle amplitude activation TFL / GM ratios are found in **Table 3**. Data analysis indicated a significant difference in TFL / GM activation ratios (P=.004). The mean TFL/GM muscle activation ratio was highest during sidelying hip abduction exercise (81%), moving closer toward symmetry of activation between the two muscles. Conversely, during hip abduction with knee flexion the same muscle activation ratio was 49%, indicating a greater disparity between the two mean muscle activation amplitudes.

TABLE 3. EMG Signal Activation Ratio of the Tensor Fascia Latae / Gluteal Medius*

Exercise	**Hip Abduction with Knee Flexion**	**Sidelying Hip Abduction**	**P**
Gluteal Medius	29.1 ± 13.7	40.6 ± 13.5	
Tensor Fascia Latae	12.7 ± 10.5	31.5 ± 9.8	
Ratio	**0.49 ± 0.38**	**0.81 ± 0.21**	.004

* Values are expressed as mean ± SD percentage of MVIC.

DISCUSSION

The purpose of this study was to evaluate the gluteal medius and tensor fascia latae muscle activity during 2 commonly used exercises in physical rehabilitation and injury prevention programs. A significant difference in muscle activity was identified between the exercises. Both muscles displayed greater mean signal amplitudes during the sidelying hip abduction exercise. When considering the ratio of TFL to GM muscle activation, the hip abduction with knee flexion exercise was more effective in reducing the TFL activity in relation to that of the GM. In this study, the GM was better isolated from the TFL during the hip abduction with knee flexion exercise.

Ekstrom et al. (2007) assessed GM activation during the sidelying hip abduction exercise and found a mean ± SD EMG signal amplitude of 39% ± 17% MVIC. Distefano et al. (2009) examined GM activity during the hip abduction with knee flexion exercise and identified a mean ± SD EMG signal amplitude of 38% ± 29% MVIC. These values are similar to those found in our study. Previous literature suggests that EMG signal amplitudes greater than 45% MVIC may provide sufficient stimulus for strength gains (Ayotte et al., 2007; Ekstrom et al., 2007; Myers et al., 2005). Exercises producing EMG signal amplitudes less than 45% may be more beneficial for motor learning or endurance training purposes. Less trained individuals or those beginning physical rehabilitation programs may also benefit from the same type of exercise.

Sidelying hip abduction has been identified as a useful screening tool that performed moderately well in predicting those who are at risk for developing low back pain during prolonged standing (Nelson-Wong et al., 2009). This exercise has also been show to be effective in activating the gluteus medius (Bolgla & Uhl, 2005; Distefano et al., 2009; Ekstrom et al., 2007). In addition, Distefano et al. (2009) showed that sidelying hip abduction was more effective in activating the GM than the hip abduction with knee flexion exercise. Our results support this finding.

Gluteus medius weakness has been identified as a factor that contributes to lower extremity injury via altered joint loading patterns and reduced motor control (Fulkerson, 2002; Powers, 2003). When simply considering exercise effectiveness based on the highest mean EMG amplitude, SHA would be the better choice to strengthen the GM. However, exercise selection should consider other variables such as the general health and fitness level of the individual, the equipment needed, and other agonist muscles involved in the motion. Lower extremity physical rehabilitation may require the more facilitated muscle agonists, such as the TFL, to remain less active in order to optimally strengthen the target muscle (GM) and balance the system. When the exercise objective is to strengthen the GM while simultaneously reducing TFL activity, the HAF should be utilized. This exercise may also be more appropriate for the deconditioned individual or those with lower quarter muscle imbalances.

CONCLUSION

This study examined the relative differences in hip abduction EMG activity during 2 commonly used non-weight bearing rehabilitation exercises in healthy, active, pain-free individuals. The muscles under consideration were the gluteus medius and the tensor fascia latae. The sidelying hip abduction exercise demonstrated the highest levels of activity for both of the muscles under consideration. This pattern of gluteus medius activity during SHA is consistent with the results from prior research (Bolgla & Uhl, 2005; Distefano et al., 2009). Few studies have examined tensor fascia latae activity levels, during these exercises, and the ratio of activity levels between this muscle and the GM. Results from this study demonstrated that the hip abduction with knee flexion exercise was more effective in activating the GM while simultaneously reducing the TFL activity. As these muscles work agonistically to produce hip abduction, selecting an exercise that would more effectively target the GM may be an important consideration in treating individuals with lower quarter injuries or muscle imbalances. We believe that clinicians may use this information when developing and progressing therapeutic exercise programs.

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