

ELECTROMYOGRAPHIC ANALYSIS OF GLUTEUS MAXIMUS, GLUTEUS MEDIUS, AND TENSOR FASCIA LATAE DURING THERAPEUTIC EXERCISES WITH AND WITHOUT ELASTIC RESISTANCE

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ABSTRACT

Background: Strengthening and activation of the gluteus maximus and gluteus medius while minimizing the contribution of the tensor fascia latae are important components in the treatment of many lower limb injuries. Previous researchers have evaluated a myriad of exercises that activate the gluteus maximus (GMax) and gluteus medius (GMed), however, limited research has been performed describing the role of the addition of elastic resistance to commonly used exercises.

Purpose: The primary purpose of this study was to determine the gluteal-to-tensor fascia latae muscle activation (GTA index) and compare electromyographic muscle activation of the GMax, GMed, and TFL while performing 13 commonly prescribed exercises designed to target the GMax and GMed. The secondary purpose of this study was to compare muscle activation of the GMax, GMed, and TFL while performing a subgroup of three matched exercises with and without elastic resistance.

Study Design: Repeated measures cohort study

Methods: A sample of 11 healthy, physically active male and females, free of low back pain and lower extremity injuries, were recruited for the study. Surface electromyography was used to quantify the normalized EMG activation of the gluteus maximus, gluteus medius, and tensor fascia latae while performing 13 exercises. Three of these exercises were performed with and without elastic resistance. The maximal voluntary isometric contraction was established for each muscle and order in which the exercises were performed was randomized to minimize the effect of fatigue.

Results: The relative activation of the gluteal muscles were compared to the tensor fascia latae and expressed as the GTA index. Clams with and without resistance, running man gluteus maximus exercise on the stability trainer, and bridge with resistance, generated the highest GTA index respectively. Significant differences in activation of the TFL occurred between clams with and without resistance.

Conclusions: The findings are consistent with those of previous investigators who reported that the clam exercise optimally activated the gluteal muscles while minimizing tensor fascia latae activation.

Levels of Evidence: Level 2b

Key Words: Elastic resistance, electromyography, gluteus maximus, gluteus medius

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INTRODUCTION

A number of investigators have recently reported an association between abnormal hip mechanics and altered hip muscle performance and a variety of lower extremity and lower back conditions.¹⁻⁹ The gluteus medius (GMed) is the major abductor of the hip and along with the gluteus maximus (GMax) performs most of the external rotation of the hip.¹⁰ The GMax is the major extensor of the hip and is also involved in hip abduction.^{10,11} The GMax inserts on the iliotibial tract, which is commonly referred to as the iliotibial band (ITB). Another muscle that inserts on the ITB is the tensor fascia latae (TFL). This muscle assists the GMed during hip abduction and is assists in internal hip rotation. It is theorized that as a primary muscle responsible for a specific joint movement weakens, the synergistic muscle becomes the new primary muscle responsible for the movement.¹²⁻¹⁴ This theory has been supported by a number of studies reporting individuals with weak GMed and GMax muscles who exhibit signs of increased TFL activation and shortening.¹⁵ This increased TFL activation relative to GMed and GMax activation results in relative internal rotation of the hip and valgus positioning of the knee.^{1,13,15}

The result of this change in mechanics can lead to numerous musculoskeletal problems including a variety of painful conditions of the lower back, hip, and knee. For instance, a weak GMax and GMed, have long been recognized to be associated with chronic lower back pain.¹⁶⁻¹⁸ Weak hip muscles and excessive internal rotation of the hip have also been strongly associated with patellofemoral pain syndrome (PFPS).¹⁻³ Similarly, iliotibial band syndrome (ITBS) is a painful debilitating condition characterized by excessive internal hip rotation, gluteal weakness, and reduced extensibility of the ITB.⁴⁻⁶ Furthermore, atrophy of the GMax and the GMed relative to the TFL has been observed to accompany hip osteoarthritis.^{3,7,8} Finally, weakness of the hip abductors and external rotators resulting in valgus positioning of the knee has been associated with knee osteoarthritis.^{9,19}

Extrapolating on these theorized and observed relationships between weak GMax, weak GMed, and compensatory activity of the TFL that accompany these conditions, clinicians have sought exercises

that activate the GMax and GMed while limiting the recruitment of the TFL. Previous authors have studied the effects of exercises that activate the GMax and GMed.^{15,20-25} Bolgla et al.²² reported that weight bearing hip abduction exercises demonstrated greater activation of the GMed of the weight bearing leg compared with non-weight bearing leg. A recent review of commonly prescribed exercises to strengthen the GMax, and GMed based on electromyography (EMG) activation, described the degree to which each exercise activated the gluteal muscles. This article, however, failed to evaluate the activation of the TFL during these exercises.²³ Other authors have reported increased activation of the gluteal muscles with the addition of elastic resistance, but again did not report TFL activation under these conditions.²⁴ Finally, Cambridge et al.²⁵ reported that placement of the elastic resistance on the knee versus the ankle and foot demonstrated lower activation of the GMax, GMed, and TFL during upright, semi-squat postures during side-stepping gait also called “sumo walks” and “monster walks.”

In one of the few studies that compared GMax, GMed, and TFL activation during various exercises, Selkowitz et al.,¹⁵ reported gluteal muscle activity based on fine wire EMG. They found that GMax and GMed activity was significantly greater than the TFL activity during unilateral and bilateral bridging, quadruped hip extension (knee flexed and hip moving into extension), the clam, sidestepping, and squatting. These authors also developed a gluteal-to-TFL muscle activation (GTA) index that combines the activation of the GMax and GMed muscles compared to the TFL for each of 11 exercises. Higher GTA index values indicate greater activation of the GMax and GMed relative to the TFL. The GTA index was highest for the clams, followed by the side-step, and unilateral bridge exercises. However, despite these results, the authors did not compare exercises with and without elastic resistance, a common modification used during treatment of patients to increase activation of the targeted muscles.

It is important to determine if the addition of elastic resistance to common hip exercises results in similar patterns of muscle activation among the GMax, GMed, and TFL. The primary purpose of this study was to determine the GTA index and compare muscle

activation of the GMax, GMed, and TFL while performing 13 commonly prescribed exercises designed to target the GMax and GMed. The secondary purpose of this study was to compare muscle activation of the GMax, GMed, and TFL while performing a subgroup of three matched exercises with and without elastic resistance.

METHODS

A convenience sample of 11 healthy, physically active males and females, free of low back pain and lower extremity injuries, were recruited for the study. Exclusionary criteria included no hip, back or lower extremity injuries or surgery within the past year. All data collection was performed in an outpatient physical therapy and chiropractic clinic in a repeated measures cohort study. Prior to participation in the study, all subjects were given an explanation of the study and provided written informed consent. This study was approved by an Institutional Review Board for trial in human subjects. Surface EMG was performed using a Noraxon Myosystem 1400A (Noraxon USA, Inc, Scottsdale, AZ) in order to quantify the activation of the GMax, GMed, and TFL. This was performed on the dominant leg while performing five repetitions of 13 exercises, three of which were also performed with elastic resistance (TheraBand®, Performance Health, Akron, OH). Participants wore comfortable, exercise clothing and all exercises were performed without shoes to prevent the influence of footwear differences.

The participants' dominant leg was determined by asking with which leg they would use to kick a soccer ball. The skin was prepped using an alcohol pad and surface electrodes (BIOPAC Systems, Inc. Camino Goleta, CA.) were placed on the GMax, GMed, and TFL muscles of the dominant side, based on the recommendations of Rainoldi et al.²⁶ The GMax electrode was applied half the distance between the greater trochanter and the mid sacral vertebra (S3), at the level of the trochanter, on an oblique angle parallel to the muscle fiber direction. The GMed electrode was placed anterior to the GMax over the proximal 1/3 of the distance between the iliac crest and the greater trochanter, parallel to muscle fiber direction. Finally, the TFL electrode was applied approximately 2 cm below the anterior superior

iliac spine, while the leg was extended, parallel to the muscle fiber direction. The reference electrode was placed over the right acromioclavicular joint.

Participants rode a stationary bike for five minutes with no resistance to warm-up prior to beginning testing. Following the warm-up, maximal voluntary isometric contraction (MVIC) was established for each muscle group. This was completed by using the manual muscle test position for the GMax, GMed, and TFL as described by Selkowitz, et al.¹⁵ For each muscle group, three repetitions, held for five seconds, were performed. The highest average peak value of the three repetitions, from the corresponding manual muscle test, was recorded as the MVIC of each muscle.

The sequence of exercises was randomized in order for each participant to minimize the influence of fatigue. The exercises selected are commonly prescribed for treating painful conditions of the back, hip and knee, and are consistent with the exercises studied by previous researchers.^{15,27} For the exercises that involved elastic resistance, the level of resistance was standardized so that the green colored TheraBand® Resistance Bands were used with the males and red colored bands were used with the females. The length of the resistance bands was determined when the subject had no slack or tension at the starting position of the exercise. The examined exercises included the following 13 exercises, with five repetitions of each exercise: [1] clams without resistance, [2] clams with resistance, [3] side-lying hip abduction without resistance, [4] prone hip extension without resistance, [5] quadruped hip extension without resistance, [6] quadruped hip extension with resistance, [7] bridge without resistance, [8] bridge with resistance, [9] standing hip abduction with resistance on the stance leg, [10] standing hip abduction with resistance on movement leg, [11] standing hip extension with resistance on the stance leg, [12] standing hip extension with resistance on the movement leg, and [13] running man gluteus maximus exercise on the stability trainer.

Visual onset and offset of the EMG signal amplitude was used to select the middle three of five repetitions of each of the 13 trials. The sampling frequency was 1000 Hz and the EMG signals were smoothed,

rectified, and analyzed using a root-mean-square algorithm of 100 ms to determine the peak activation for the GMax, GMed, and TFL. The average of the three repetitions was used for statistical analysis. The peak activation for each muscle was divided by the corresponding MVIC and expressed as a percent MVIC. This resulted in a percent activation for the GMax, GMed, and TFL during each of the exercises. The gluteal-to-TFL muscle activation (GTA) index was calculated as described by Selkowitz et. al.¹⁵ The GTA index employed the mean normalized EMG values to create relative activation ratios of both the GMax and GMed compared to the TFL. The relative activation ratio for each gluteal muscle was multiplied by that muscle's mean normalized EMG value, summed, and then divided by two to provide the GTA index: $\{[(GMed/TFL) \times GMed] + [(GMax/TFL) \times GMax]\} / 2$.¹⁵

The GTA index value for each exercise was rank ordered from greatest (GMax and GMed activation relative to TFL activation) to smallest. These rankings are ordinal level and do not represent equal intervals in the GTA index scores relative to the exercises. A high score on the GTA index indicates there was a high normalized EMG amplitude for both of the gluteal muscles and they were both higher compared to the TFL.¹⁵

A series of repeated measure of variance statistics (R-ANOVA) were calculated to determine if there were differences in the muscle activation of the GMax, GMed, and TFL while performing each of the 13 exercises. A significant ($p < .05$) main effect of muscle detected by the R-ANOVA, indicated post hoc comparisons using Tukey's least significant differences to determine the specific differences between the means. Finally, comparisons were made between the activation of each muscle group with and without resistance during the three matched exercises using paired t-tests.

RESULTS

Five males and six females participated (mean age 27.18 ± 7.33 years and mean BMI 22.92 ± 4.12). Table 1 displays the GTA index and the relative rank of this index during the 13 exercises studied. The clams with resistance, clams without resistance, running man gluteus maximus exercise on the stability

Table 1. Table 1: Ordering of Exercises by Gluteal-to-tensor Fascia Latae Muscle Activation (GTA)** Index.

	GTA Index**	Rank
Clams with resistance	99.54	1
Clams without resistance	87.89	2
Quadruped Hip Extension without resistance	28.29	11
Quadruped Hip Extension with resistance	36.11	8
Bridge with resistance	48.86	4
Bridge without resistance	41.59	7
Standing Hip Abduction with resistance on movement leg	29.59	9
Standing Hip Abduction with resistance on the stance leg	29.34	10
Standing Hip Extension with resistance on the stance leg	23.94	12
Standing Hip Extension with resistance on the movement leg	19.6	13
Prone Hip Extension without resistance	48.57	5
Side-lying Hip Abduction without resistance	44.75	6
Running Man on the Stability Trainer without resistance	70.55	3
**GTA Index = $\{[(GMed/TFL) \times GMed] + [(GMax/TFL) \times GMax]\} / 2$ (Selkowitz, et., al., 2013)		

trainer without resistance, and bridge with resistance generated the highest GTA index respectively. The exercises that ranked lowest on the GTA index included quadruped hip extension without resistance and standing hip extension with resistance on the stance and movement leg.

Table 2 indicates that clams with ($F_{1,10} = 30.77$, $p = 0.00$) and without ($F_{1,10} = 35.07$, $p = 0.00$) resistance produced significantly higher activation of the GMax compared to GMed and TFL and higher activation of the GMed than TFL. Performing prone hip extension without resistance resulted in higher ($F_{1,10} = 10.30$, $p = 0.00$) GMax and GMed compared to TFL. GMed activation while side side-lying hip abduction without resistance was higher ($F_{1,10} = 8.60$, $p = 0.02$) than either GMax or TFL activation. Similarly, activation of the GMed was greater ($F_{1,10} = 5.70$, $p = .004$) than the GMax during standing hip extension with resistance on the stance leg but similar to the activation of the TFL. The only other exercise that elicited differences in activation of the muscle groups was standing hip abduction with resistance on the stance

Table 2. Comparison of Mean Percent Activation While Engaging in Various Exercises With and Without Resistance.

Exercise	Mean % Activation		
	Gluteus Maximus	Gluteus Medius	Tensor Fascia Latae
Clams with resistance †‡£	42.03±19.31	30.48±16.66	13.54±6.32*
Clams without resistance †‡£	36.32±14.62	25.35±10.39	11.16±5.34*
Quadruped Hip Extension without resistance	21.01±11.81	24.15±11.63	18.11±8.02
Quadruped Hip Extension with resistance	26.60±18.83	24.68±13.76	18.23±9.99
Bridge with resistance	38.34±31.43	20.99±9.21	19.16±12.79
Bridge without resistance	31.89±21.36	18.43±8.01	16.31±8.48
Standing Hip Abduction with resistance on movement leg	28.77±12.06	37.68±8.30	37.98±20.04
Standing Hip Abduction with resistance on the stance leg†£	20.29±10.98	45.06±9.84	41.62±13.97
Standing Hip Extension with resistance on the stance leg†£	16.42±8.71	26.86±13.25	20.70±7.70
Standing Hip Extension with resistance on the movement leg	18.73±8.31	21.16±7.88	20.37±11.52
Prone Hip Extension without resistance ‡£	30.98±11.50	23.47±11.62	15.55±9.89
Side-lying Hip Abduction without resistance†‡	34.44±14.37	42.23±18.08	33.18±14.77
Running Man on the Stability Trainer without resistance	50.94±21.38	55.36±22.19	40.11±22.87
† Indicates a significant difference (p<.05) between Gluteus Maximus and Gluteus Medius for a specific exercise ‡ Indicates a significant difference (p<.05) between Gluteus Maximus and Tensor Fascia Latae for a specific exercise £ Indicates a significant difference (p<.05) between Gluteus Medius and Tensor Fascia Latae for a specific exercise *Indicates significant difference (p<.05) in specific muscle activation between exercises with and without resistance			

leg with the activation of the GMax being lower than the GMed and the TFL ($F_{1,10} = 45.28, p = 0.00$). None of the remaining six exercises demonstrated significant differences in activating the GMax, GMed or TFL.

Comparisons in muscle activation of the GMax, GMed, and TFL while performing a subgroup of three matched exercises with and without elastic resistance indicated that the addition of resistance resulted in higher activation of only the TFL during the clams exercise ($T_{df=10} = 2.65, p = 0.02$). Activation of the GMax and GMed were unaffected by the addition of resistance during the clam exercise. The addition of elastic resistance did not affect muscle activation during the quadruple hip extension or bridge

DISCUSSION

Muscle weakness or imbalance of hip abductors and rotators, specifically the GMax, and GMed

resulting in faulty lower extremity kinematics has been observed in a number of debilitating and painful conditions of the back, hip, and knee.¹⁻⁹ There are several possible reasons for this including the inability to control the level of the pelvis and poor control of dynamic valgus at the knee. The results of the current study determined which exercises maximize the activation of the GMed and GMax while minimizing the activation of the TFL. During clams with and without resistance the activation of the GMax was highest followed by activation of the GMed and then the TFL. This difference in activation between the three muscles being studied was not exhibited during any of the other exercises studied. These findings are consistent with previous authors who reported that clam exercises activated the GMax and GMed^{20,23} while minimizing the activation of the TFL.^{15,25}

The ranking of the GTA index in Table 1 was similar to that of Selkowitz et al.¹⁵ Both studies ranked

the three common exercises using the GTA Index in the same order: the clams yielding the highest GTA index rank, followed by bridge, and then quadruped hip extension. In fact, both studies indicated that the GTA index, defined as relative activation of the GMax and GMed compared to the TFL, when performing clams, was approximately twice that of the GTA index when performing either the bridge or the quadruped hip extension. Only clams, bridge, and quadruped hip extension were exercises common to both the study conducted by Selowitz et al.¹⁵ and the current study. Both studies findings indicate that GMax and GMed activation were greater than TFL activation during the clam exercise. While only Selkowitz et al.¹⁵ reported significantly greater activation of the gluteal muscles over the TFL when performing the bridge and quadruped hip extension, the current study observed a similar, although not statistically significant pattern during the same exercises. This indicates a consistent higher activation of the GMax and GMed compared to the TFL during clams only. The lack of a significant difference between activation of the muscles during the bridge and quadruped hip extension compared to Selkowitz et al.¹⁵ may be attributable to the smaller sample size and a high degree of variability of the measures within the current investigation. These consistent findings in activation patterns during these exercises provides evidence to the practitioner that the clams exercise may provide maximum activation of the gluteal muscles while minimizing activation of the TFL. Since this pattern of muscle activation is believed to be optimal for conditions related to hip muscle weakness, these findings in muscle activation patterns and ranking of the GTA index may warrant use of the clams exercise in patients with conditions involving poor hip biomechanics or hip muscle performance.

The results addressing the primary purpose of the study may be associated with a variety of factors. First, this study was conducted among healthy young adults without back or hip problems. It is possible that due to this, six of the thirteen exercises examined had similar activation of the GMax, GMed, and TFL. In addition, previous studies of individuals with back or hip problems indicated differences in the activation patterns of these muscles.^{3,4,18} This

observation supports the theoretical relationships that as one muscle weakens, the synergistic muscle contributes as the new primary muscle.¹²⁻¹⁴ Finally, the results are consistent with the work of previous investigators^{15,20-25} who reported that the clams exercise may be a preferred exercise to activate the gluteal muscles while minimizing the relative activation of the TFL.

The results of the current study indicate that activation of the GMax, GMed, and TFL were predominately not changed as a result of adding resistance to the three exercises studied (clams, bridge, and quadruped hip extension). One possible explanation for this finding is that the level of resistance did not provide a sufficient stimulus to change the percentage activation of the muscles being studied in the young healthy population being studied. Assuming that the exercises elongated the TheraBand® Resistance Bands to twice their resting length (100 percent), the maximum amount of torque generated during the exercise would be 3.7 lbs and 4.6 lbs of force for the red band and green band respectively.²⁸ It is possible that a heavier resistance would have generated a greater activation of these muscles compared to the activation observed when performing the exercises without resistance. Future studies may wish to examine activation patterns of the GMax, GMed, and the TFL with higher levels of resistance applied during the exercises.

Although enlightening, the results of this study need to be interpreted cautiously due to a number of limitations that future investigators may wish to address. First, the sample consisted of a small healthy group with a high degree of variability in the outcome measures. Future studies may wish to examine a larger more homogenous sample of individuals with a similar degree of chronic back pain. Second, muscle activation was based upon surface EMG technology that may have been affected by muscle activity beyond the targeted muscles being studied, e.g. "cross talk," which is an inherent limitation of all surface EMG studies. Future studies replicating this design may wish to employ fine wire technology when measuring muscle EMG activity. Finally, the addition of elastic resistance in this study did not consistently result in a greater degree of muscle activation. This unexpected finding may be addressed by future

researchers applying a greater degree of elastic resistance during the exercises being examined.

CONCLUSIONS

The results of the current study indicate that certain exercises that target the gluteal muscles elicit a higher GTA index than others. The results of the current study provide support for certain exercises that target the GMed and GMax while minimizing the activation of the TFL. Specifically, the clams with and without elastic resistance as well as the running man gluteus maximus exercise on the stability trainer without resistance and the bridge with resistance yielded the highest GTA values. The use of elastic resistance during the clams increased the activation of the GMax and GMed to a greater degree than the increase in the TFL resulting in a higher GTA index and thus supports the use of resistance during this exercise as a way of minimizing TFL relative to Gmax/Gmed activation. These findings can direct clinicians when prescribing exercises to maximize activation of the gluteal muscles while limiting the tensor fascia latae involvement.

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