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The Influence of Varying Hip Angle and Pelvis Position on Muscle Recruitment Patterns of the Hip Abductor Muscles During the Clam Exercise

Clinicians commonly target the hip abductors when treating low back pain[1] and lower extremity injuries such as patellofemoral pain,[6] iliotibial band syndrome,[35] and chronic ankle sprains.[16] Previous investigations have used electromyography (EMG) to determine which rehabilitation exercises facilitate activation of the hip abductors to improve lower extremity and pelvis stability.[4,20] Specifically, studies have addressed how various weight-bearing and non–weight-bearing exercises influence activation of the gluteus medius (GMed)[4,22] and gluteus maximus (GMax).[3,5,13,14] However, there is limited information regarding the influence of various hip abductor exercises on tensor fasciae latae (TFL) activation.

STUDY DESIGN: Within-subject, repeated-measures design.

OBJECTIVES: To determine the influence of pelvis position and hip angle on activation of the hip abductors while performing the clam exercise.

BACKGROUND: Therapeutic exercises are regularly employed to strengthen the hip abductors to improve lower-limb and pelvis stability. While previous studies primarily have compared the activity of hip abductor muscles between various exercises, few studies have examined the influence of varying the techniques of particular exercises on the relative activation of hip abductor muscles. Such information could be used to facilitate appropriate exercise instruction.

METHODS: Muscle activation in 17 healthy, asymptomatic volunteers during 6 variations of the clam exercise was analyzed with surface electromyography. Electromyographic signals were recorded from the gluteus maximus, gluteus medius, and tensor fasciae latae. Normalized data were examined using 2-way, repeated-measures analyses of variance.

RESULTS: The magnitude of gluteus maximus and gluteus medius activation was significantly greater when the pelvis was in neutral rather than reclined. Furthermore, gluteus medius activation was greatest when the hip was flexed to 60°. Activation of the tensor fasciae latae was not influenced by pelvis position or hip angle.

CONCLUSION: A neutral pelvis position is advocated to optimize recruitment of the gluteus maximus and gluteus medius during the clam exercise. Increasing the hip flexion angle increases activation of the gluteus medius. Tensor fasciae latae activity was relatively low and generally unaffected by variations of the clam exercise. *J Orthop Sports Phys Ther 2013;43(5):325-331. Epub 13 March 2013. doi:10.2519/jospt.2013.4004*

KEY WORDS: *clam exercise, EMG, gluteus maximus, gluteus medius, tensor fasciae latae*

The fiber orientation and insertion of the abductor muscles dictate their function. In contrast to the GMed, which is primarily a hip abductor, the GMax also is a hip extensor and external rotator, whereas the TFL is a hip flexor and internal rotator.[8] Consequently, when excessive internal rotation is observed as a component of an individual's gait or movement pattern, it is conceivable that the TFL was recruited as the dominant hip abductor.[31] Preferential recruitment of the TFL has been suggested to result in disuse and atrophy of the GMed, further exacerbating the overactivity of the TFL.[15]

When prescribing exercises to strengthen the hip abductors, the relative activation of all muscles should be considered. Activation of the 3 primary hip abductors has been reported by Selkowitz et al,[32] who evaluated 11 multiplanar exercises, and Sieve,[34] who studied 3 non–weight-bearing exercises. Although both studies concluded that the type of exercise (eg, step-up, squat, sidelying abduction) influences hip abductor activity, neither investigation provided informa-

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tion about how exercise technique (ie, how the body is positioned to perform the type of exercise) may affect hip abductor recruitment.

A common therapeutic exercise used during the early stages of hip abductor strengthening is the "clam" or "clam shell."[23] Of the several studies that have investigated hip abductor recruitment during the performance of this exercise,[13,32,34] only DiStefano et al[13] addressed technique modification by evaluating the influence of hip angle on GMax and GMed activity. The study did not, however, evaluate the TFL. The studies that have evaluated the TFL during the clam exercise[32,34] only evaluated the exercise in 1 position.

The purpose of the current study was to assess the concurrent activity of the GMax, GMed, and TFL during different variations of the clam exercise. Variations in hip angle and pelvis position were evaluated to determine the influence on muscle activity. Such variations were chosen based on previous research[13] and the need to explore the influence of common faults in positioning seen in clinical practice. The findings of this study may provide valuable information on how hip abductor recruitment is affected by positioning during the clam exercise and may be used to facilitate appropriate exercise instruction.

METHODS

Participants

Twenty-seven healthy individuals volunteered to participate in this study, from 17 of which EMG data were acceptable for inclusion in the analysis (**TABLE**). Participants were recruited from Manchester Metropolitan University, Leeds City College, and the City of Salisbury Athletic and Running Club. To be included, participants had to perform moderate-intensity physical activity, such as walking, cycling, or participating in sports,[39] for at least 60 minutes, 3 days per week. Exclusion criteria were low back or lower extremity pain and/or injury at the time of testing. Participants provided informed consent and were advised of the testing procedures, which were approved by the Ethics Committee of the Department of Exercise and Sport Science, Manchester Metropolitan University.

TABLE Demographics of Participants*

Characteristic	Men (n = 10)	Women (n = 7)
Age, y	25 ± 5	23 ± 4
Height, cm	182 ± 8	165 ± 4
Mass, kg	77 ± 13	60 ± 11

Values are mean ± SD.

Procedures

All testing was performed on the dominant limb, defined as the limb used to kick a ball (right dominant, 15; left dominant, 2).[13] EMG signals were recorded using EMGworks acquisition hardware and software (Delsys Inc, Boston, MA) at a sampling frequency of 1080 Hz. Amplifier characteristics included a bandwidth of 20 to 500 Hz, common-mode rejection ratio greater than 80 dB, and input impedance greater than 100 MΩ. Prior to electrode placement, the skin was shaved to reduce impedance and cleaned with isopropyl alcohol. Single-differential surface EMG electrodes were placed over the GMax, GMed, and TFL, and a reference electrode was placed over the center of the patella of the dominant leg. The electrodes were located in accordance with recommended guidelines.[27] For the GMed, the electrode was placed one third of the distance from the greater trochanter and the iliac crest. The GMax electrode was placed one third of the distance from the second sacral vertebra and the greater trochanter. The TFL electrode was located 75 mm from the anterior superior iliac spine, along a line oriented 30° anterior to the line joining the anterior superior iliac spine and the greater trochanter.

Potential cross-talk was evaluated through visual inspection of EMG signals during manual muscle tests that attempted to isolate the target muscles from the adjacent muscles. However, it is recognized that during hip abduction, it is difficult to isolate the EMG signals of specific muscles due to their shared actions. Furthermore, electrode size, shape, location, interelectrode distance, and thickness of subcutaneous tissue can also affect cross-talk.[24] The influence of some of these factors was minimized by using relatively small electrodes (10 × 1 mm) with a small interelectrode distance (1 cm).

Prior to performing the clam exercises, EMG data were collected during maximum voluntary isometric contractions (MVICs) for normalization purposes. The resistance for each MVIC was provided manually and held for 5 seconds. The MVIC positions were based on the recommendations of Kendall et al.[21] After pilot testing, the GMed MVIC position was modified to resist abduction at 90° of knee flexion, as this reduced activity in the TFL while increasing activity in the GMed and GMax. The GMax MVIC was performed with participants in the prone position and the knee flexed to 90°, with resistance applied to the lower part of the posterior thigh during isometric hip extension. The MVIC of the TFL was performed with participants in the supine position, with resistance applied during flexion, abduction, and medial rotation of the hip with the knee extended. Participants received standardized verbal encouragement during MVIC testing.

To monitor knee, hip, and spine motion during testing, 4 monoaxial electrogoniometers (Delsys Inc) were used (**FIGURE 1**). For the knee, the electrogoni-

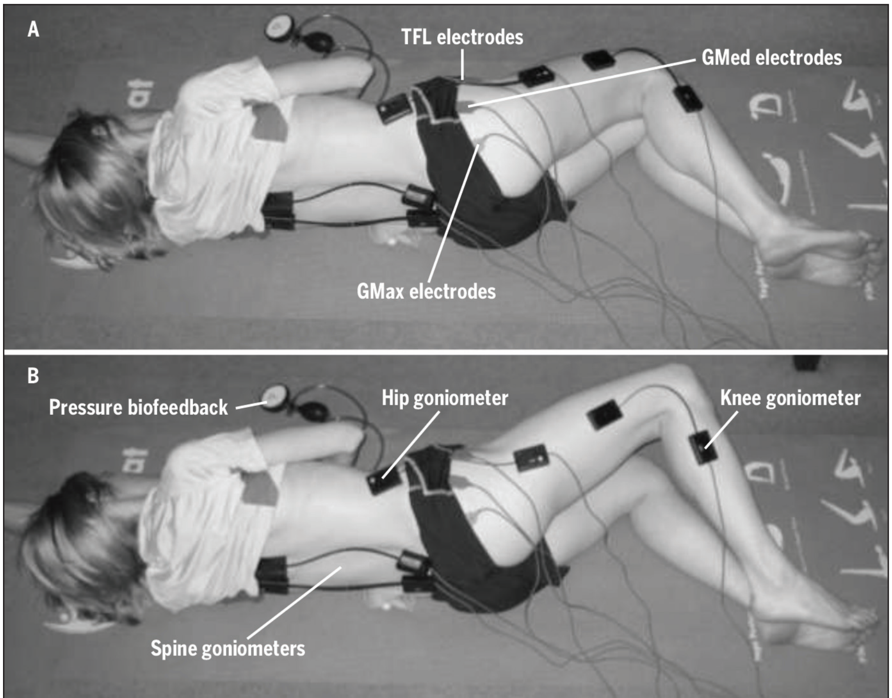

FIGURE 1. The start (A) and end (B) of the range of motion of the clam exercise, with the pelvis in neutral and 30° of hip flexion. Locations of the electromyography electrodes (A) and electrogoniometers and pressure biofeedback device (B) are shown. Abbreviations: GMax, gluteus maximus; GMed, gluteus medius; TFL, tensor fasciae latae.

ometer was positioned so that its central axis was over the lateral tibiofemoral joint line, with one component on the distal lateral thigh and the other on the proximal lateral lower leg. For the hip, the electrogoniometer was positioned with its central axis over the ischial tuberosity, its proximal component on the lateral pelvis, and its distal component on the proximal lateral thigh. For the spine, 2 goniometers, one oriented to assess stability in the sagittal plane and the other in the frontal plane, were placed lateral to the spinous processes, with their proximal component approximately level with the greatest kyphotic curvature of the thoracic spine and their distal component approximately level with L5. Data were sampled at 120 Hz and synchronized with the recording of EMG data.

Stability of the lumbar spine and pelvis also was monitored using a pressure biofeedback unit.[7] This instrument has been used extensively to detect and monitor impairments in lumbopelvic stability.[10,18,25,28-30,36,38] The reliability of pressure biofeedback measurements has been shown to improve when the protocol is standardized.[12] The pressure biofeedback unit consisted of an inflatable cuff connected to a pressure gauge and inflation device. Once the bag was inflated, the lumbar spinous processes were palpated and a rigid ruler was placed along the length of the spine to visually establish that the spine was straight in the coronal plane.[10] With the cuff inflated and positioned under the waist, the participant was required to maintain a constant pressure of 40 mmHg while performing the clam exercise. The gauge provided immediate feedback to help the participant maintain the target pressure. Pressure changes of ±5 mmHg from the target pressure were permitted to accommodate transient changes resulting from breathing.[10] A manual goniometer, which is reliable when used with standardized procedures,[9,17] was used to confirm the starting position of the hip.

Clam exercises were performed with the participant positioned in sidelying on the floor, with the spine in neutral and the knees flexed to 90°. The participant abducted the top (dominant) knee as far as possible, while keeping the heels together and the pelvis and spine neutral, then returned to the starting position (**FIGURE 1**). A bar was positioned at each participant's maximal knee height, which provided feedback to standardize repetitions. Each participant was instructed to breathe normally and to raise and lower the limb over a period of 3 seconds in each direction to the beat of a metronome.

Three hip angle variations (0°, 30°, and 60°) of the clam exercise were performed with the pelvis in neutral. The 3 hip angle variations were repeated with the pelvis reclined to 35°. Pelvis recline was defined as the angle between a line joining the left and right anterior superior iliac spines and the vertical (**FIGURE 2**). To achieve this position, participants were verbally instructed to roll the pelvis backward from neutral to a point at which a 35° angle was reached, as measured with a goniometer. This reclined position typically is considered a faulty technique for the clam exercise. Pilot testing indicated 35° to be an appropriate amount of pelvis recline, representing the greatest degree of compensation that would be observed in clinical practice.

All variations of the clam exercise (6 conditions) were performed on the same occasion (without removal of the electrodes) in a random order. Ten 6-second repetitions of each condition were performed. Participants were provided 3 minutes of rest between each condition.

Data Processing

The hip electrogoniometer data were used to determine the onset of movement for each clam exercise repetition. A single repetition of the clam cycle was defined as the 6-second period following movement onset, as confirmed by the electrogoniometer data. EMGworks software (Delsys Inc) was used to process raw EMG signals from each repetition of each exercise, using a root-mean-square with a 0.15-second window and an overlap

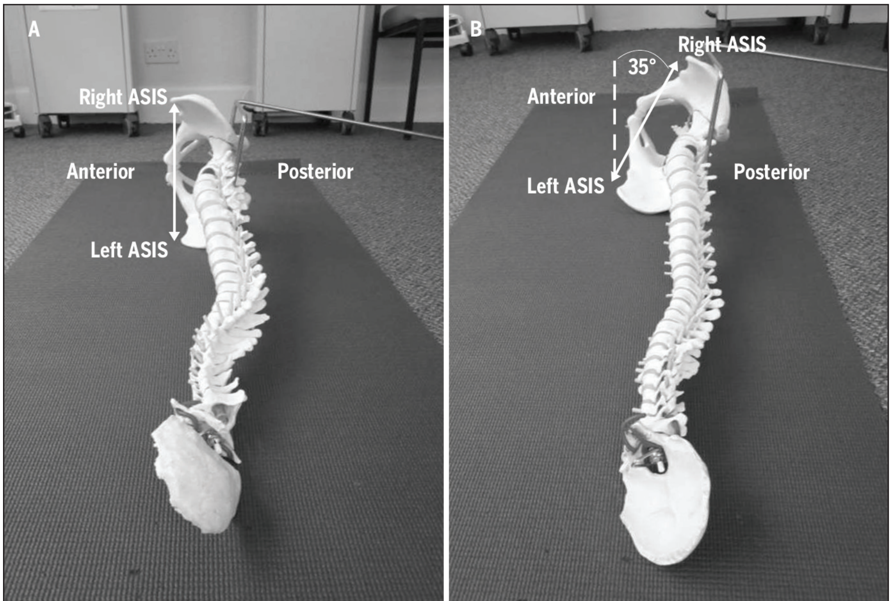

FIGURE 2. The pelvis in neutral (A) and reclined (B) positions. Abbreviation: ASIS, anterior superior iliac spine.

of 0.0625 seconds over the entire time course of the contraction. For each MVIC trial, a 2-second section was selected when the EMG appeared most stable and contained the greatest magnitude. MVIC data were processed using the root-mean-square method (same window length and overlap) described above. Mean root-mean-square values from the exercise conditions were then normalized as a percentage of their respective MVIC value, then averaged across repetitions.

Statistical Analysis

To determine the variability of normalized EMG values within participants, the coefficient of variation was calculated for the 10 repetitions from each condition. The coefficient of variation is an appropriate measure of absolute variability but assumes the presence of heteroscedasticity in the data.[2] Therefore, variability between participants also was analyzed using the intraclass correlation coefficient (ICC) and the standard error of measurement as estimates of precision. A Cronbach alpha, 2-way mixed, absolute-agreement model was selected for the ICCs, which is designed to take into account systematic and random error[37] and is appropriate for the analysis of a particular procedure without generalizing the reliability findings.[40] The ICC (model 3,1) was run for each muscle across the 10 repetitions of each condition.[33] Values less than 0.75 were deemed to be indicative of poor to moderate reliability and those greater than 0.75 indicative of good reliability.[26]

Mean normalized EMG data (averaged over the 10 repetitions) were compared across the 6 clam positions using a 2-by-3 analysis of variance with repeated measures (pelvis position by hip angle). This analysis was repeated for each muscle. For all analyses of variance, data that failed the Mauchly test of sphericity were corrected with the Greenhouse-Geisser method. SPSS software (SPSS Inc, Chicago, IL) was used for all statistical analysis. In the case of a significant main effect for hip angle or a significant hip angle-by-pelvis position interaction, pairwise comparisons using a Bonferroni adjustment were employed.

RESULTS

Muscle Activation

With respect to GMax activation, there was no significant hip angle-by-pelvis position interaction or main effect for hip angle. However, there was a significant main effect for pelvis position ($F_{1,16}$ = 24.1, P<.001). When averaged across all hip angles, performing the clam exercise in the neutral pelvis position resulted in greater GMax activation compared to the reclined position (17.8% versus 10.1% MVIC) (**FIGURE 3**).

With respect to GMed activation, there was no significant hip angle-by-pelvis position interaction. However, main effects for pelvis position ($F_{1,16}$ = 39.8, P<.001) and hip angle ($F_{1.6,26.0}$ = 11.4, P = .001) were significant. When averaged across all hip angles, performing the clam exercise in the neutral pelvis position resulted in greater GMed activation compared to the reclined position (20.2% versus 14.1% MVIC) (**FIGURE 3**). When averaged across pelvis positions, post hoc testing revealed that GMed activity with the hip at 60° of flexion was greater than at 0° of flexion (19.8% versus 14.6% MVIC) (**FIGURE 3**). With respect to TFL activation, there was no significant hip angle-by-pelvis position interaction or main effect for hip angle or pelvis position (**FIGURE 3**).

Reliability of EMG Data

Considering within-participant variability during each condition and for each muscle, the coefficients of variation for individual participants ranged from 4% to 61%. ICC values ranged from 0.78 (TFL) to 0.95 (GMed) across all conditions. Thus, all muscle activation data were considered to be reliable. The standard error of measurement of the EMG data ranged between 1.0% and 4.1% MVIC.

DISCUSSION

The aim of the current study was to evaluate changes in hip abductor activity during variations of the clam exercise. Overall, activation of the GMax and GMed was significantly greater with the pelvis in a neutral position when compared to a reclined angle of 35°, regardless of hip angle. In addition, the GMed was recruited to a greater extent, regardless of pelvis position, when the clam exercise was performed with the hip flexed to 60° compared to 0°. In contrast to the gluteal muscles, TFL activation was unaffected by pelvis position or hip angle.

A previous study[13] that addressed the influence of the degree of hip flexion during the clam exercise used angles of 30° and 60°, whereas the current study also included 0°. Both the DiStefano et al[13] study and our investigation found a nonsignificant increase in GMax activity as the hip angle changed from 30° to 60°. However, unlike the current study, DiStefano et al[13] reported that the magnitude of GMed activation was not affected by hip angle. While it is difficult to explain the varied findings between the 2 studies, it is logical that the activation of both the GMax and GMed would increase with hip flexion, due to changes in the resistance moment arm. As the hip is flexed from 0° to 60° during the clam exercise, the center of mass of the thigh is located more anteriorly in relation to the hip. Thus, the gravitational moment arm of the leg about the hip would be greater during the movement with the hip in a more flexed position. To overcome the greater external torque, the abductors would likely need to generate greater force, which could explain the higher activation levels in the GMed and GMax at greater angles of hip flexion. Furthermore, GMax activation would be expected to increase with hip flexion, owing to changes in the muscle moment arm, which varies with hip position.[19] As the hip is flexed, the moment arm for the GMax decreases in the direction of external rotation.[11] Thus, as the hip becomes more flexed, the mechanical leverage of the GMax for performing external rotation reduces. The clam, being a combination of abduction and external rotation, would, therefore, require greater activation from the GMax to perform this exercise with the hip in a more flexed position.

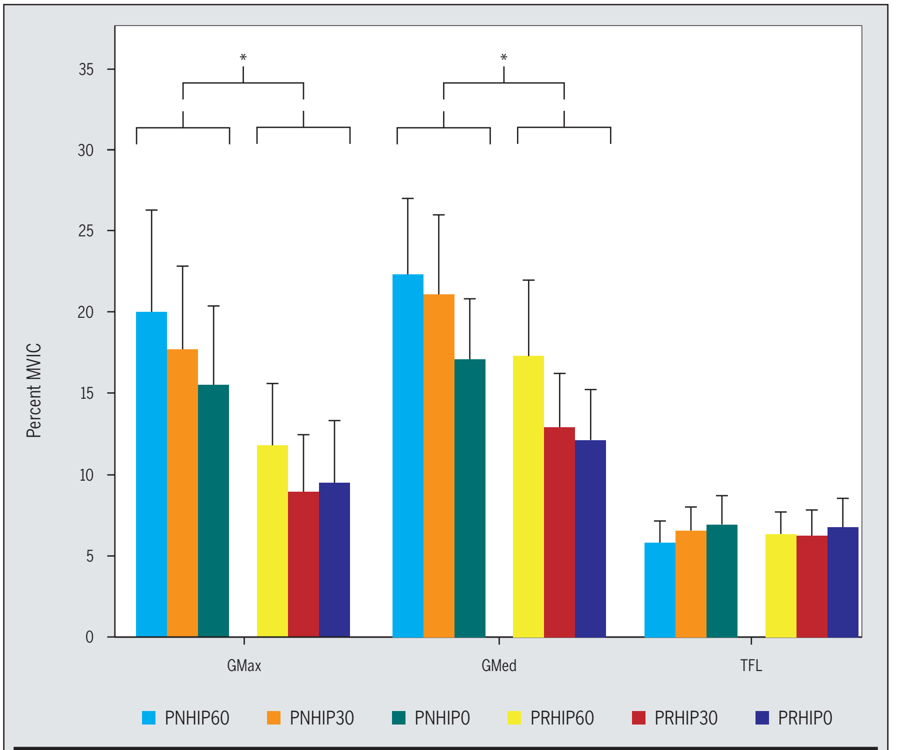

FIGURE 3. Mean (95% confidence interval) normalized EMG (% MVIC) for the 3 muscles across the 6 exercise conditions. *Significant main effect for pelvis position (data collapsed across hip flexion angles). Abbreviations: EMG, electromyography; MVIC, maximum voluntary isometric contraction; PNHIP0, pelvis neutral, hip in 0° of flexion; PNHIP30, pelvis neutral, hip in 30° of flexion; PNHIP60, pelvis neutral, hip in 60° of flexion; PRHIP0, pelvis reclined, hip in 0° of flexion; PRHIP30, pelvis reclined, hip in 30° of flexion; PRHIP60, pelvis reclined, hip in 60° of flexion.

The higher activation of both the GMax and GMed with the pelvis in a neutral position, as opposed to a reclined position, is more difficult to explain. Given that the angle of hip flexion was similar between the 2 conditions (neutral and reclined), it is unlikely that changes in muscle or gravitational moment arms could explain the greater activation seen in the neutral position. Although it is possible that another hip abductor (ie, the gluteus minimus) could have been recruited to assist in the movement with the pelvis in the reclined position, our results demonstrate that it was not the TFL.

Although we did not compare activation levels between muscles, our results clearly show that the TFL was activated to a lesser extent than the GMax or GMed. This finding is consistent with Selkowitz et al,[32] who found that exercises involving hip extension and external rotation optimized gluteal muscle activation while limiting TFL activity. Notably, the resisted clam exercise was shown to produce 50% less TFL activity than the GMax. In contrast, Sieve[34] evaluated the clam exercise under conditions similar to those used in our study (ie, unresisted motion) and reported that TFL activation was higher than that of the GMax. Increased activation of the TFL during the clam exercise reported in Sieve's study[34] might have been the result of insufficient stabilization of the pelvis, resulting in a suboptimal clam exercise being performed.

In the current study, activation levels for the GMax and GMed were relatively low during the clam exercise (10%-20% MVIC). Comparing this to previous studies, Boren et al[5] reported activation values of 47% and 53% MVIC, and DiStefano et al[13] reported values of 38% to 40% and 34% to 39% MVIC for the GMed and GMax, respectively, during the clam exercise. It is difficult to compare activation levels between studies, even when they are normalized to MVIC, owing to numerous factors, including EMG processing methods and positioning of limbs during the MVICs.[5] As such, findings from the current and previous studies cannot be used to predict strengthening effects. Although the observed changes in muscle activation in the current study were statistically significant between positions, it is yet to be established whether these changes are clinically relevant. Regardless of whether the clam exercise provides the necessary training stimulus for strength gains, our findings show that this exercise preferentially activates the gluteal muscles while limiting activation of the TFL.

There are certain limitations of our study that should be acknowledged. Each participant performed the clam exercise by raising the knee to the maximum height, as opposed to a fixed height for all participants. Although this method, as opposed to using a standard height for all participants, might have introduced variation in muscle activation levels between individuals, it was chosen to improve the external validity of the findings. In addition, our study only evaluated healthy participants; therefore, the findings are not generalizable to patient populations.

CONCLUSION

EMG analysis of the GMed, GMax, and TFL during variations of the clam exercise was performed. A neutral pelvis position resulted in greater recruitment of the GMax and GMed when compared to a reclined pelvis position. Increasing the hip flexion angle increased activation of the GMed. TFL activity was relatively low and generally unaffected by variations of the clam exercise. ◉

KEY POINTS

FINDINGS: Performing the clam exercise with the pelvis in a neutral position, as compared to a reclined position, resulted in higher recruitment of the GMax and GMed. Increasing the hip flexion angle significantly increased activation of the GMed. TFL activation was unaffected by variations of the clam exercise.

IMPLICATIONS: The findings of this study provide valuable information on how hip abductor recruitment is affected by clam exercise positioning. Specifically, our results will aid clinicians in prescribing modifications of the clam exercise to optimize gluteal muscle recruitment.

CAUTION: Data were obtained in healthy individuals; therefore, the findings may not be generalizable to patient populations.

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