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Are there Differences in the Muscles Activation during Exercise for Patellofemoral Pain Patients? A Cross-Sectional Study

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SUMMARY

Objective. To compare the activation of the gluteus medius (GM) and tensor fasciae latae (TFL) muscles, during eleven exercises to strengthen the lateral hip region in volunteers with and without pattelofemoral pain.
Methods. Twenty-four females participated in this study, the evaluation was performed through the electromyography analysis of the GM and TFL muscles during exercise, and strength was evaluated through of the contraction isometric volunteers' maximum to the normalization of data of the electromyography.
Results. The exercises: Clam, squatting, single-limb squat, single-limb deadlift, the lateral plank, the hip abduction in orthostatims, sinking exercise, trunk lateral rotation, unilateral bridge, double-leg-kick and lateral elevation. These exercises were used as task to all volunteers. Demonstrated that most asymptomatic patients had greater activation in the GM, while the symptomatic group obtained greater activation values in TFL. In most exercises, the activation of the GM was earlier ($p < 0.05$).
Conclusions. The symptomatic group showed greater activation in the TFL. While the asymptomatic group presented greater activation in the GM in most exercises.

KEY WORDS
Muscle; exercise; electromyography; patellofemoral pain; low limb.

INTRODUCTION

Patellofemoral pain is related to a multifactorial etiology, but it can also be started after an episode of trauma, for example: patellar dislocation (1). Irrespective of the factor that led the patient to complain about the patellofemoral joint, physical exercises are the most recommended for the treatment of patellofemoral pain. It is known that the hip muscles have a great function in the stabilization of this joint, therefore its functions are related to proximal and distal insertion (1). The Patellofemoral Pain (PFP) can lead to impairment of the function of the lower limbs, when the required joint muscle of the hip is ineffective (2-4). In this mode, the muscle's gluteus medius and tensor fascia latae, act toward hip stabilization (4, 5).

The gluteus medius (GM) proximal insertion on iliac crest and the distal insertion in the greater trochanter of the femur (6), act as an abductor and medial rotator of the hip (4).

The other muscle is tensor fascia latae the proximal insertion of its fibers is 1/3 anterior to the outer lib of the iliac crest superior-anterior and deep under the surface to its distal insertion in the iliotibial band (7). This is responsible for the movement of abduction, internal rotation, helping in flexion and extension movements and to act as a lateral strength around the patella, causing lateral glide (2-4). According to Merican and Amis (8), the iliotibial band tension can affect patellofemoral kinematics and may cause misalignment and greater patellar stress in the lateral femoral condyle.

The muscle weakness, according to Maia *et al.* (9), can lead to destabilization of the hip joint that can lead to kinematic change in the knee and other adjacent joints. Therefore, the strength of the muscles can prevent the muscle dysfunction and prevent patellofemoral syndrome (10). In the guideline described by Willy *et al.* (11), about PFP rehabilitation of the lateral region hip muscle strengthening it is considered a recommendation type "A" and level "1" in the evidence.

The electromyography (EMG) evaluation can be used for observation of the activation of the hip muscles, according to De Sá *et al.* (12), this evaluation is a non-invasive method, that studies a pattern of recruitment motor unit and muscular fatigue. This justified this study with the objective of analyzing the exercises that provide better activation of the gluteus medius and tensor fasciae latae muscles, in the muscular strength of the lateral hip region, in volunteers with and without pain in the patellofemoral joint. The objective is to compare the activity of the gluteus medius and tensor fascia latae muscles, during eleven exercises to strengthen the lateral hip region in volunteers with and without pain in the patellofemoral joint.

MATERIALS AND METHODS

This study is characterized by a convenience sample in a cross-sectional clinical measurement study. Thus, the participants were evaluated based on electromyographic analysis in the execution of the exercises performed and lower limb strength test using the load cell. This study was approved by the Ethics Committee under the opinion 2,308,498 (Date of approval: August 30, 2017) and was performed by the Brazilian registry of clinical studies (REBEC) under the code RBR-4fyhhy. It was designed taking into consideration and following the recommendations of the STROBE checklist.

The procedures were performed at the Locomotive Apparatus Evaluation and Rehabilitation Laboratory (LARAL), located in the Federal University of Santa Catarina. The participants of this research are healthy women, aged between 18 and 30 years old, with complaints of patellofemoral joint pain. The sample consisted of 24 participants, divided into two groups, twelve participants for group control (asymptomatic) and twelve participants in the group patellofemoral pain (symptomatic), and both performed the same exercises. The volunteers who agreed to participate in this research received an informed consent form containing the risks and benefits of the exercise. Therefore, the inclusion criteria for sampling are: being within the age range between 18 and 30 years; women; with and without complaint of patellofemoral joint pain. Exclusion criteria for the study are: people who present fractures in the last 6 months; muscle injuries or some diagnosed rheumatologic pathology.

Data collection was performed by a trained evaluator prepared for the application of the tests and to describe the results. The electromyographic analysis of the gluteus medius and tensor fascia latae muscles during the exercises was evaluated using the electromyograph Miotec® (Miotool 400, Software Miograph®) which has an analog-to-digital (A/D) converter of 14 bits of resolution, a data acquisition board of 2,000 Hz and a common-mode rejection of 100 dB, with 20-500 Hz bandpass filter. The electrodes are of the Double model disposable type, maintaining a distance of 20 mm between the poles. The SENIAM (surface electromyography for non-invasive assessment of muscle) recommendations were followed for skin preparation and electrode placement for subsequent EMG signal capture, with variables such as peak of activation. The acquisition of electromyographic signals were analyzed by the contraction performed by each muscle during the exercises, evaluating the activation (Root Mean Square - RMS) (13, 14), and the onset was evaluated in all exercises of the right side and just squat, squat with elastic band and double leg kick (DLK) exercises were evaluated bilaterally. The data of onset was performed by difference between the gluteus medius for tensor fasciae latae, in negative data the GM was the first to activate and in the positive data the TFL activated first.

All exercises started with a verbal command of the evaluator and were performed first without an elastic band and maintained for 6 seconds. The EMG analysis of the gluteus medius and the tensor

Figure 1. Demonstration of the hip lateral muscles strengthening exercises.

(A) Clam exercise with elastic band; **(B)** Clam exercise; **(C)** Swiss Ball Squats with elastic band; **(D)** Swiss Ball Squats; **(E)** Single-limb squat exercise; **(F)** Single-limb deadlift exercise; **(G)** Lateral plank; **(H)** Hip abduction exercise with 90º of hip and knee; **(I)** Hip abduction exercise in standing position; **(J)** Sinking exercise with elastic band; **(K)** Sinking exercise (deadlift); **(L)** Hip lateral rotation in closed kinetic chain; **(M)** Unilateral Bridge Exercise; **(N)** Double leg kick exercise; **(O)** Lateral Lifting Exercise. The arrows show the elastic band.

fasciae latae muscles were analyzed bilaterally during the exercises shown in **figure 1**.

The exercises shown in **figure 1** are described below:

A and B – Clam exercise with and without elastic band: the patient, in lateral decubitus, on a stretcher, with the limbs flexed at 45° of the hip and 90° of the knee, limb tested to the upper side, being performed with both sides. With the heels together, the volunteer performs a hip abduction and returns to the initial position (4).

C and D – Swiss Ball Squats with and without elastic band: with the Swiss ball against the wall, the volunteer supports the lower back in the ball, the lower limbs extended with hip-width opening, feet aligned and hand on the hip, so the volunteer squats up to 90° on the knee and returns the initial position, with variation, using the elastic band around the knee, performing the same movement (15).

E – Single-limb squat exercise: the volunteer balances on one of the lower limbs with a knee and hip flexion of 30°, the hand on the side of the limb to be assessed is positioned on the hip, and thus the individual will be instructed to perform a single leg squat. In which the fingers of the contralateral hand should go towards the outside of the supporting foot until the fingers can touch the floor, and return to the initial position, being performed with both limbs (16).

F – Single-limb deadlift exercise: with single-limb support, the volunteer flexes his knees and hip by approximately 30° and one hand raises his hip. With a hip and trunk flexion, the volunteer should touch, with the middle finger of the other hand, the supported foot, returning to the initial position (16).

G – Lateral plank: the volunteer positioned in lateral decubitus, shoulder at 90° and elbow at 90°, lower limbs aligned, feet together, contralateral upper limb close to the body and head alignment. The volunteer is instructed to raise the hip keeping the spine alignment, being performed on both sides (15).

H and I – Hip abduction exercise with 90° of hip and knee, hand on the contralateral side of the hip. Hip abduction movement will be performed, pushing the wall, maintaining the position, being performed on both sides. Hip abduction exercise in standing position: composed of two variations, where in the first the volunteer is standing with the side of the body leaning against the wall, with hip extension and 90° of knee, hand on the contralateral side of the hip. Performing a force with the hip abduction movement, pushing the wall, running on both sides (15).

J and K – Sinking exercise: initial standing position with knees and hips at 0°, stepping forward with one of the limbs to position it at 90° of knee and hip flexion and contralateral limb with 90° of knee flexion and 0° hip, returning to the beginning (14), which is performed on both sides with variation of the use of the elastic band around the knee of the lower limb that is in front; contralateral rotation of the trunk: in the standing position, with unipodal support of the lower limb and contralateral limb with knee flexion. With the elastic band in the hand, on the contralateral side of the lower limb in support, the movement performed is the rotation of the trunk towards its direction (15).

L – Hip lateral rotation in closed kinetic chain: in the standing position, with unipodal support of the lower limb and contralateral limb with knee flexion. With the elastic band in hand, on the contralateral side of the lower limb in support, the trunk rotation movement will be performed in the contralateral direction of the lower limb in support (15).

M – Unilateral Bridge Exercise: in the supine position, the volunteer with knee flexion at 90° performs hip extension by removing the spine from the ground, removing one of the legs from the floor, aligning with the contralateral and repeating the same movement with both sides (4).

N – Double leg kick exercise: in prone position, hands clasped behind the head, knees in 90° flexion and proprioceptive disc between the malleoli performing a pressure on the disc.

O – Lateral Lifting Exercise: on four supports, performs hip abduction with knees flexed at 90°, which is performed on both sides.

The EMG data processing, the collected signals were processed through algorithms developed in MatLab® software observing the following order of analyses, band-pass digital filter with cut-off frequency of 20 to 500 Hz using a 4th order Butterworth filter. The normalization of the EMG signal was performed by maximum voluntary isometric contraction (MVIC) during the hip abduction exercise and was determined to be the peak of activation of the gluteus medius and the fascia lata tensor muscles during the accomplishment of the MVIC. The gluteus medius and the fascia lata tensor muscles were evaluated during all exercises, through the analysis of the RMS collected during the 6-second isometry in each exercise. In addition to the analysis of muscle activation (RMS), a comparison of the start of activation of the two muscles was performed during all exercises, only squat exercises, squats with the elastic band and DLK were analysed bilaterally, in the other exercises only the right side were evaluated.

The descriptive statistics were the method by which data force hip and knee were verified. Shapiro-Wilk methods were also used for evaluation of normality of the muscle activation data and t-student test for paired samples, by evaluating the muscles from the comparative data analysis RMS. The statistical analysis of data was performed through the GraphPad Prisma® software, version 8.0 (GraphPad Software, La Jolla, California USA).

RESULTS

In the present study, 24 female individuals were evaluated and divided into two groups (**figure 2**). Twelve volunteers in the asymptomatic group had a mean age of 25.75 years, with 75% of them having normal BMI. The symptomatic group, with an average age of 21.4 years, where 58.33% had a high BMI

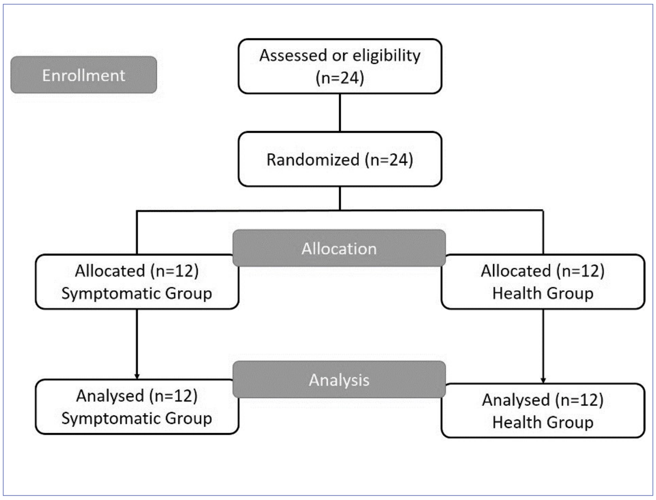

Figure 2. Flowchart of the division of the volunteers.

(overweight), all right-handed and all complained of right knee pain.

The description of the data obtained if the muscle strength of the symptomatic and assymptomatic volunteers was evaluated with a strain gage during hip movements (abduction, adduction, internal rotation and external rotation in **figure 3A**) and knee movements (flexion and extension in **figure 3B**).

All data of the muscle activation (RMS) of the 24 volunteers were evaluated for t-test with significance of $p < 0.05$ exercise were shown in the **table I**, in most exercises there was no statistical difference, just in the hip abduction exercise with hip and knee in 90° of the flexion, with $p < 0.04$, comparing GM and TFL of the left side in both groups, single-limb deadlift ($p < 0.05$) the difference was only in the control group in the two sides evaluated and in lateral lifting exercise the difference was in the GM and TFL of the right side ($p < 0.04$). Most exercises demonstrate that the GM has an early activation when compared to the TFL, the data in **figures 4** and **5** showed there was no difference when comparing the groups.

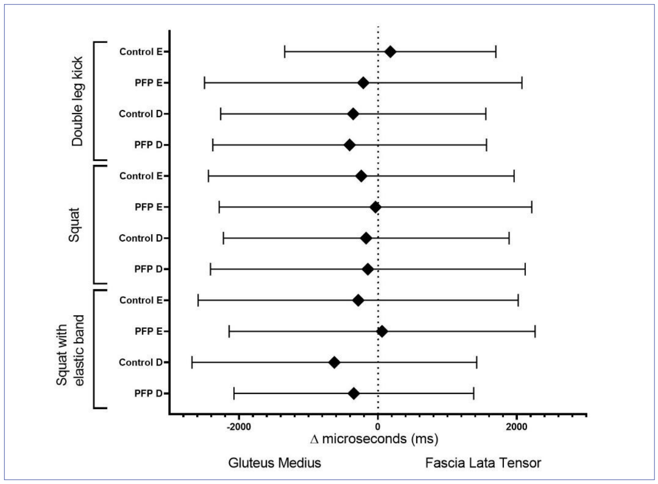

Figure 4. Demonstration of the exercises that the GM has an early activation when compared to the TFL, exercises bilaterally analyzed.

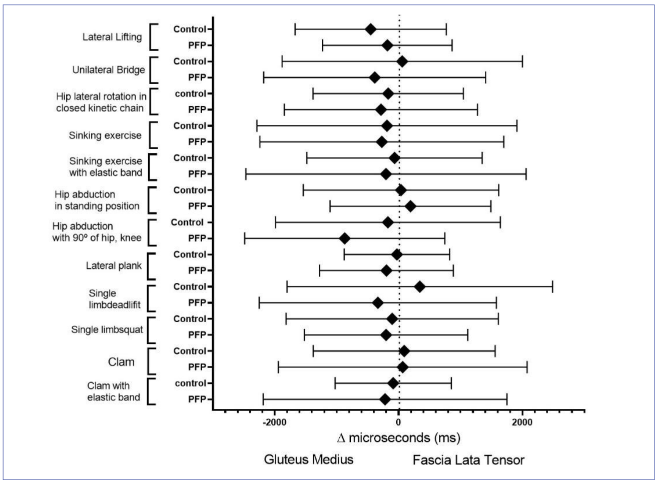

Figure 5. Demonstration of the exercises that the GM has an early activation when compared to the TFL, exercises unilaterally analyzed.

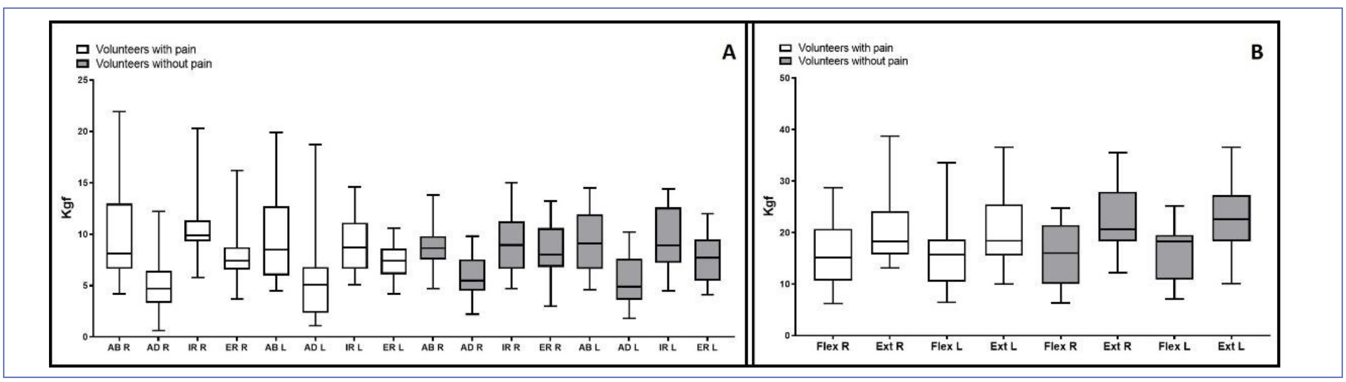

Figure 3. Muscle strength during the hip and knee movements of the 24 volunteers.
(A) Hip; **(B)** Knee.

Table I. Mean (standard deviation) and (minimum and maximum values) of the Root Mean Square by normalized unit of the GMed and TFL muscles among the groups.

	Patellofemoral syndrome group	Control group
	Clam exercise with elastic band	
GM-R	0.196 ± 0.03 (0.2696-0.1362)	0.202 ± 0.04 (0.2957- 0.1121)
TFL-R	0.196 ± 0.04 (0.2762-0.1211)	0.190 ± 0.03 (0.2987- 0.1125)
GM-L	0.193 ± 0.04 (0.2824- 0.0959)	0.216 ± 0.04 (0.3029-0.0925)
TFL-L	0.192 ± 0.04 (0.2552-0.1213)	0.205 ± 0.03 (0.3108-0.1398)
	Clam exercise	
GM-R	0.191 ± 0.04 (0.3199-0.1314)	0.183 ± 0.05 (0.3149-0.0812)
TFL-R	0.202 ± 0.04 (0.2993-0.0938)	0.192 ± 0.04 (0.2877-0.0893)
GM-L	0.208 ± 0.04 (0.2824-0.0903)	0.208 ± 0.04 (0.3054-0.1107)
TFL-L	0.188 ± 0.04 (0.2641-0.1002)	0.209 ± 0.04 (0.3167-0.1332)
	Swiss Ball Squats with elastic band	
GM-R	0.161 ± 0.04 (0.2342-0.0895)	0.194 ± 0.04 (0.2854-0.1047)
TFL-R	0.199 ± 0.03 (0.2523-0.0938)	0.184 ± 0.04 (0.2487-0.0789)
GM-L	0.188 ± 0.02 (0.2388-0.1304)	0.182 ± 0.04 (0.2922-0.1053)
TFL-L	0.216 ± 0.02 (0.2574-0.1171)	0.184 ± 0.04 (0.2526-0.0824)
	Swiss Ball Squats	
GM-R	0.164 ± 0.05 (0.2536-0.0737)	0.200 ± 0.03 (0.2568-0.1117)
TFL-R	0.196 ± 0.04 (0.2473-0.0663)	0.203 ± 0.03 (0.2684-0.1126)
GM-L	0.188 ± 0.05 (0.2782-0.0546)	0.178 ± 0.04 (0.2688-0.0834)
TFL-L	0.197 ± 0.03 (0.2487-0.0917)	0.194 ± 0.03 (0.2348-0.0891)
	Single-Limbsquat exercise	
GM-R	0.162 ± 0.04 (0.2175-0.061)	0.180 ± 0.03 (0.2429-0.1121)
TFL-R	0.190 ± 0.04 (0.2501-0.0634)	0.167 ± 0.04 (0.02583-0.0736)
GM-L	0.180 ± 0.04 (0.2865-0.111)	0.181 ± 0.03 (0.2341-0.1082)
TFL-L	0.202 ± 0.04 (0.2888-0.0833)	0.180 ± 0.04 (0.2541-0.0621)
	Single-Limbdeadlifit exercise	
GM-R	0.157 ± 0.04 (0.2713-0.0648)	0.209 ± 0.04 (0.2989-0.1313)
TFL-R	0.174 ± 0.03 (0.2437-0.1067)	0.144 ± 0.04 (0.2411-0.0684)
GM-L	0.170 ± 0.03 (0.2354-0.1125)	0.192 ± 0.04 (0.2848-0.1181)
TFL-L	0.182 ± 0.03 (0.2375-0.0963)	0.156 ± 0.04 (0.2509-0.0598)
	Lateral Plank	
GM-R	0.142 ± 0.02 (0.2269-0.0979)	0.161 ± 0.04 (0.2309-0.0686)
TFL-R	0.145 ± 0.03 (0.1909-0.0859)	0.165 ± 0.03 (0.2466-0.0914)
GM-L	0.159 ± 0.04 (0.2824-0.0609)	0.153 ± 0.04 (0.1674-0.092)
TFL-L	0.170 ± 0.04 (0.2528-0.0915)	0.165 ± 0.03 (0.2737-0.0989)
	Hip abduction exercise with 90° of hip and knee of the flexion	
GM-R	0.199 ± 0.06 (0.3671-0.1087)	0.195 ± 0.04 (0.2825-0.0948)
TFL-R	0.186 ± 0.03 (0.2589-0.1218)	0.185 ± 0.03 (0.2427-0.1125)
GM-L	0.183 ± 0.04 (0.2824-0.1019)	0.191 ± 0.05 (0.3605-0.1253)
TFL-L	0.213 ± 0.04 (0.2922-0.1281)	0.191 ± 0.04 (0.2745-0.0987)

	Patellofemoral Syndrome Group	Control Group
Hip abduction exercise in standing position with 90º knee of the flexion		
GM-R	0.154 ± 0.03 (0.2457-0.0758)	0.178 ± 0.04 (0.3034-0.082)
TFL-R	0.164 ± 0.03 (0.2442-0.0567)	0.165 ± 0.03 (0.2292-0.0808)
GM-L	0.191 ± 0.04 (0.2824-0.0953)	0.165 ± 0.04 (0.2777-0.0929)
TFL-L	0.084 ± 0.03 (0.2084-0.0355)	0.087 ± 0.02 (0.1327-0.05)
Sinking exercise		
GM-R	0.208 ± 0.03 (0.2892-0.1294)	0.172 ± 0.04 (0.2405-0.098)
TFL-R	0.191 ± 0.03 (0.2665-0.1061)	0.190 ± 0.04 (0.2816-0.1055)
GM-L	0.169 ± 0.04 (0.2824-0.0886)	0.187 ± 0.04 (0.3474-0.1186)
TFL-L	0.165 ± 0.05 (0.2999-0.0821)	0.187 ± 0.05 (0.2865-0.0761)
Sinking exercise with elastic band		
GM-R	0.210 ± 0.03 (0.2877-0.145)	0.179 ± 0.04 (0.2512-0.0846)
TFL-R	0.206 ± 0.03 (0.2681-0.1073)	0.196 ± 0.03 (0.2967-0.102)
GM-L	0.172 ± 0.04 (0.2648-0.094)	0.185 ± 0.04 (0.2846-0.0956)
TFL-L	0.160 ± 0.05 (0.2711-0.072)	0.188 ± 0.03 (0.2665-0.1121)
Hip lateral rotation in closed kinetic chain		
GM-R	0.178 ± 0.04 (0.2671-0.1063)	0.185 ± 0.04 (0.2929-0.0972)
TFL-R	0.161 ± 0.04 (0.2626-0.0845)	0.180 ± 0.03 (0.2463-0.0979)
GM-L	0.169 ± 0.04 (0.2509-0.0691)	0.197 ± 0.04 (0.2845-0.0929)
TFL-L	0.195 ± 0.04 (0.2602-0.071)	0.184 ± 0.03 (0.2318-0.0928)
Unilateral Bridge exercise		
GM-R	0.144 ± 0.02 (0.2065-0.0659)	0.163 ± 0.04 (0.2488-0.0642)
TFL-R	0.150 ± 0.02 (0.2188-0.0923)	0.161 ± 0.03 (0.2525-0.0973)
GM-L	0.166 ± 0.03 (0.2824-0.0635)	0.173 ± 0.04 (0.2766-0.0428)
TFL-L	0.162 ± 0.03 (0.2202-0.0999)	0.172 ± 0.03 (0.2786-0.0391)
Double Leg Kick exercise		
GM-R	0.197 ± 0.04 (0.2582-0.1117)	0.205 ± 0.04 (0.2959-0.0953)
TFL-R	0.198 ± 0.04 (0.2603-0.0943)	0.195 ± 0.05 (0.2672-0.0745)
GM-L	0.180 ± 0.03 (0.2444-0.0953)	0.188 ± 0.03 (0.2593-0.0858)
TFL-L	0.198 ± 0.03 (0.2592-0.0902)	0.195 ± 0.05 (0.2906-0.0674)
Lateral Lifting exercise		
GM-R	0.200 ± 0.06 (0.3325-0.1235)	0.213 ± 0.06 (0.3387-0.1262)
TFL-R	0.168 ± 0.05 (0.2701-0.634)	0.152 ± 0.04 (0.2506-0.0638)
GM-L	0.185 ± 0.03 (0.2542-0.0741)	0.201 ± 0.05 (0.3562-0.1429)
TFL-L	0.175 ± 0.04 (0.2676-0.1092)	0.178 ± 0.04 (0.2871-0.1043)

GM-R: Gluteus medius right; TFL-R: Fascia lata tensor right; GM-L: Gluteus medius left; TFL-L: Fascia lata tensor left.

DISCUSSION

Physical exercises are recommended as one of the main interventions in injuries of the patellofemoral joint. According to Vetrano *et al.*, (17) therapeutic exercises can be performed as the first intervention for this patient profile. Therefore, the present study evaluated the exercises that provide greater activation of the gluteus medius and tensor fasciae latae muscles. It is seen that being overweight may be an auxiliary factor of knee pain, producing an overload on the joints (18), and onset during all exercises.

The clam exercise verified that muscle activation in asymptomatic volunteers is higher in the left medius gluteus

(GML) and lower in the right tensor fasciae latae (TFLR) and in symptomatic volunteers the values of right GM and right TFL activation appear almost equal, and the lowest value is concentrated in the left TFL which presented in exercises with elastic band. In the exercise without the elastic band, the values had larger oscillations, which can be related to the resistance that the elastic band provides during the exercise. Thus, the symptomatic patients presented higher activation values in the left GM and lower values in the left TFL, while the asymptomatic group presented almost equal values between the left GM and left TFL, where the right GM presented lower muscle activation. It is noted that the gluteus medius in the graphs presents high values of muscle activation in exercises with and without elastic band, and the tensor fasciae latae despite presenting significant activations, has lower values. Considering that the hip has important functions in our body, there is a significant number of injuries that affect not only the hip, but also the knee joint, and these exercises contributes during physical therapy in the rehabilitation process of these injuries (19, 20).

In the squatting exercise with a Swiss ball, it was found that the symptomatic group had higher activation value in the left TFL and lower in the right GM. The asymptomatic group had greater muscle activation in the right GM. It is noteworthy that the results presented, comparing the groups, are inversely proportional. That being said, it is seen that this exercise has been used in the rehabilitation of the lower limbs, since it is a movement that involves several body regions. During this movement, besides the contraction of several muscles, the activation of the lumbopelvic stabilization muscles is also performed. Therefore, patellofemoral dysfunctions in this exercise are associated with the weakness of hip stabilizers, so squats activate these stabilizers avoiding dysfunctions (21).

In the single-limb squat exercise graph, asymptomatic patients presented higher activation in left and right GM, while in symptomatic patients values were higher in left TFL and lower in right GM. This exercise can analyze the mid-lateral movement of the knee. Consequently, by assessing the neuromuscular activation of some muscles, it can avoid dysfunctions. Therefore, GM dysfunction causes a strength deficit and misalignment in the knee region, causing the so-called “knee valgus” (16).

The single-limb deadlift exercise demonstrated that asymptomatic volunteers had relatively high activation in GM and lower activation in right TFL. In symptomatic volunteers, the highest activation values were in left TFL and lowest in right GM. Thus, the inverse form of the values presented between asymptomatic and symptomatic volunteers is noted. It can be considered that the position of these exercises may influence the need for activation of the gluteus medius to stabilize the pelvis and execute the movement. Also, this exercise presents a pelvic need, mainly involving hip extension and flexion, involving gluteus maximus functions (15, 16). Thus, it was evaluated that in asymptomatic volunteers the GM was highly activated, having significant values also in the symptomatic ones, however, they presented higher values in the TFL.

The lateral plank exercise in the asymptomatic volunteers showed higher activation value in right and left TFL. The symptomatic volunteers had a higher result in left TFL and a lower result in right GM. The lateral plank exercise evaluates and tests the muscles of the anterolateral trunk and the lumbar square; however, it can cause pain during the prolonged position. In spite of that, it can be used to evaluate the usefulness of gluteus medius resistance in a rehabilitation context (22).

The hip abduction exercise in orthostatism with variations of the exercise demonstrated that in the first variation, the asymptomatic volunteers presented higher right GM activation and lower left TFL activation. Regarding the symptomatic group, the highest activation was in left GM and the lowest in left TFL. In the second variation of the exercise, the asymptomatic volunteers had higher activation in right GM and lower activation in right TFL. The symptomatic volunteers had higher activation results in left TLF and lower values in left GM. In the graph of the first position, there were larger oscillations in relation to that of the second position. This is an exercise that works different muscles of the body, which are the TFL, gluteus maximus, medium and minimum. During movement, the gluteus muscles are optimized when the spine moves into flexion (15).

The results of the sinking exercise demonstrated that in the exercise performed with elastic band, the asymptomatic volunteers had higher activation in the right TFL and lower in the left GM. The symptomatic volunteers had a higher value in right GM and a lower value in left TFL. When performing the exercise without using the elastic band, the asymptomatic volunteers had higher activation value in right TFL and lower in right GM. In the symptomatic group, the activation was higher in right GM and lower in left TFL. The oscillations between the graphs when performing the exercise with and without the elastic band were not large, considering the balance of movement in the exercise provided by the elastic band. Also, the bottom provides a different positioning compared to the standard squat, due to that fact there is a more considerable number of muscles involved in the movement. Thus, the knee muscles are recruited during exercise, although they have a significantly good number in the activation of the TFL as well as the GM in symptomatic volunteers (4, 16).

In the trunk lateral rotation exercise, asymptomatic volunteers had higher activation value in left GM and lower in right TFL. The symptomatic group had higher value in left tensor fascia latae and lower value in right tensor fascia latae, this can be related to the tension increase of the serratus anterior and trapezius muscles in the contralateral trunk position.
In the unilateral bridge exercise, asymptomatic volunteers had higher activation value in left GM and lower in right TFL. The symptomatic group had higher activation value in left GM and lower in right GM. Unilateral bridging motion, analyzed from knee extension, aims to assess muscle endurance. Thus, trunk and pelvis stability are measured, identifying imbalances generated by the lack of maintenance of trunk, pelvis and lower limb alignment. Thus, contributing to the understanding of injuries that may occur (3, 22, 23).
Based on this study, it was possible to verify which exercises provided greater activation of the gluteal middle muscles and tensor fasciae latae. In this way, some exercises activate one muscle more than another does, however, it can be affirmed that the great majority of asymptomatic patients had greater activation in the gluteus medius, while the symptomatic group had greater activation in the tensor fasciae latae muscle.
Among the limitations of this study, we can mention the sample being composed of only females, and the results may not be translated to a sample composed of a homogeneous sample of men and women. In addition, for future studies, one can consider checking the muscle activation of other lower limb muscles.

CONCLUSIONS

In conclusion, the present study evaluated the exercises that provide greater activation of the gluteus medius and tensor fasciae latae muscles, to analyze muscle strengthening related to pathologies caused by muscle weakness. However, some exercises activate one muscle more than another, considering that the vast majority of asymptomatic patients had greater activation in the gluteus medius, whereas the symptomatic group had greater activation in the tensor fasciae latae. Still, one can observe the difficulties that the symptomatic group presented to performing the movements. Therefore, these exercises are a way to improve the efficiency of rehabilitation and gain muscle strength needed to reduce injuries caused by muscle weakness.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

DLD: participants analysis, data collection, writing – original draft. JM: participants analysis, data collection. JD, RIB, HUK: writing – original draft. LMSN, MCRF: data evaluation, statistical analysis. AMM: supervision.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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