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Original Article (short paper)

Gluteus Medius and Tensor Fascia Latae muscle activation levels during multi-joint strengthening exercises

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Abstract — **Aim:** To compare the activation of GMed and TFL in four multi-joint exercises in strength training protocols and to verify if the level of muscle activation is indicated for strength gains in resistance training protocols. **Methods:** Eleven recreational lifters had normalized muscle activation of GMed and TFL assessed during ten maximal repetitions of four multi-joint exercises: (1) bilateral supine bridge (BiBRG); (2) bilateral supine bridge with hip abducted (BiBRG-AB); (3) unilateral supine bridge (UniBRG) and (4) single-leg squat (SLS). **Results:** A load of exercises was significantly greater for the BiBRG and BiBRG-AB compared to the UniBRG and SLS ($p<0.001$). We observed that GMed activation was significant greater compared to TFL among the four exercises ($p=0.004$) [BiBRG: Δ=26.2%; BiBRG-AB: Δ=27.3%; UniBRG: Δ=24.5% and SLS: Δ=18.8%]. Additionally, GMed activation was classified as moderate (<40%iMVC) and TFL activation was classified as low (<20%iMVC) in all exercises. **Conclusion:** Our results demonstrated that GMed is more active than TFL in all analyzed exercises. However, the level of activation observed for GMed was below that recommended to strength gain in resistance training programs.

Keywords: hip abductor, gluteus medius, EMG, resistance training, exercises

Introduction

Gluteal muscles present great importance for the stability and movement of the lower limb in space. For that, the gluteus medius (GMed) has been highlighted due to its role of stabilizing the hip, specifically the femoral head in the acetabular fossa[1] and the pelvis during gait, as well as to eccentrically control the action of the hip and therefore, helping to avoid excessive knee valgus during weight-bearing activities[2]. Additionally, GMed also helps to perform hip abduction[3]. However, a previous study pointed the tensor fascia latae (TFL) as the main muscle of hip abduction[1]. The conditions in which this behavior was evidenced was when the load increased during hip abduction, forcing the GMed increases its role of stabilizer while the TFL increases its role as the primary hip abductor[4].

Gluteus medius weakness is present in some musculoskeletal disorders, such as patellofemoral pain syndrome[2,5]. These patients commonly present an increase in hip adduction and internal rotation during single-leg tasks, such the squat[2]. In these case, how the GMed presents hip abductor and external rotator functions, could act to avoid the poor alignment[3]. Additional to the changes in hip kinematics, an increase in lateral displacement of patella also is observed [6], contributing to patellofemoral joint stress and pain[7]. One possible explanation for the increased lateral displacement of the patella may be due to a high tension applied into iliotibial tract[8], once the superficial and intermediate layers of the iliotibial tract serve as the tendon for the TFL[9]. Therefore, given that GMed weakness is related to changes in hip kinematics and high tension in iliotibial tract increasing the lateral displacement of the patella, the training programs that aimed at strengthening hip abductors have been seeking to strengthen primarily GMed rather than TFL[10-12].

The choice of exercises in training programs can be made based on the number of joints involved in the movements. A recent systematic review demonstrated that people performing resistance training may not need to include single-joint exercises in their program to obtain equivalent results in terms of muscle activation and long-term adaptations such as hypertrophy and strength[13], demonstrating that only multi-joint exercises are sufficient. However, when multi-joint exercises that focus on GMed were analyzed, great variability of activation was observed for the same exercise. In this perspective, previous studies used a classification according to the percentage of isometric maximum voluntary contraction (iMVC), being low (< 20% iMVC), moderate (20-40% iMVC), high (40-60% iMVC) and very high (>60% iMVC)[14,15]. Thus, low to moderate values were found for bilateral supine bridge[16], moderate to high for unilateral supine bridge[16] and low to very high for single-leg squat[16]. This variability makes it difficult to choose the exercise in rehabilitation or resistance training programs, since muscle activation above 40% of isometric maximum voluntary contraction (iMVC) are indicated for strength gains[17,18]. A possible reason for this great variability may be the type of load applied in different studies, ranging from body mass[11] to elastic resistance[19] since the intensity of exercise changes the pattern of muscle activation[20]. Although the use of maximal repetitions is the most common method for determining intensity in resistance training and broadly used in previous studies to determine muscular activation[20,21], the literature lacks studies regarding the muscle activation that involves maximal repetitions in the most common multi-joint exercises focusing strengthening of GMed[16].

Even though it is necessary to strengthen GMed to play its role as a stabilizer, it's possible that healthy strength-trained individuals may present some degree of GMed weakness, as demonstrated in football players[22]. A previous study observed that strength-trained participants presented lumbar extensor disuse atrophy, even with several free-weight exercises providing stimulus to lumbar extensor muscles[23]. Therefore, there is a need to verify if multi-joint exercises used in resistance training programs are cable of strengthening GMed. Due to the lack of evidence regarding the importance of strengthening GMed over TFL in training protocols, and considering the role played by TFL in anterior knee pain, together with the evidences that multi-joint exercises are enough to promote neuromuscular improvement, this study aimed a) to compare the activation of GMed and TFL in four multi-joint common exercises in resistance training protocols in recreational lifters; b) to classify the types of the exercises according to the level of activation, observing whether the level of activation reaches the recommended to promote strength gains in resistance training protocols.

Methods

Participants

The recruitment was conducted through disclosure in social media and at the surrounding area of the university campus. Eleven males, without history of lower limb injury and at least 3 months experience in strength training volunteered to participate in the study (age: 29.18 ± 4.51 years; body mass: 84.01 ± 14.48 kg; height: 1.74 ± 0.07 m; body fat: 16.34 ± 3.33%; strength training experience: 6.61 ± 4.91 years). The study was approved by the Ethics Committee in Human Research from the university (76759817.7.0000.5668) and all participants signed an informed consent form before taking part in the study.

Procedures

Data were collected in two sessions separated by a minimum of seven and a maximum of 10 days. During the first session, participants were familiarized with the methods and procedures of the study. Then, the ten-repetition maximum test (10RM) was performed to estimate the load for each exercise (bilateral supine bridge (BiBRG) – Figure 1A; bilateral supine bridge with hip abducted (BiBRG-AB) – Figure 1B; unilateral supine bridge (UniBRG) – Figure 1C and single-leg squat (SLS) – Figure 1D). Testing order was randomly defined and there was a five minutes rest between trials. In the second session, muscle activation during three isometric maximum voluntary contractions (iMVCs), separated by five minutes of rest, was collected using surface electromyography. Participants performed the four exercises (10RM load), while simultaneously recording GMed and TFL muscle activation. All EMG evaluations were performed in the preferred limb.

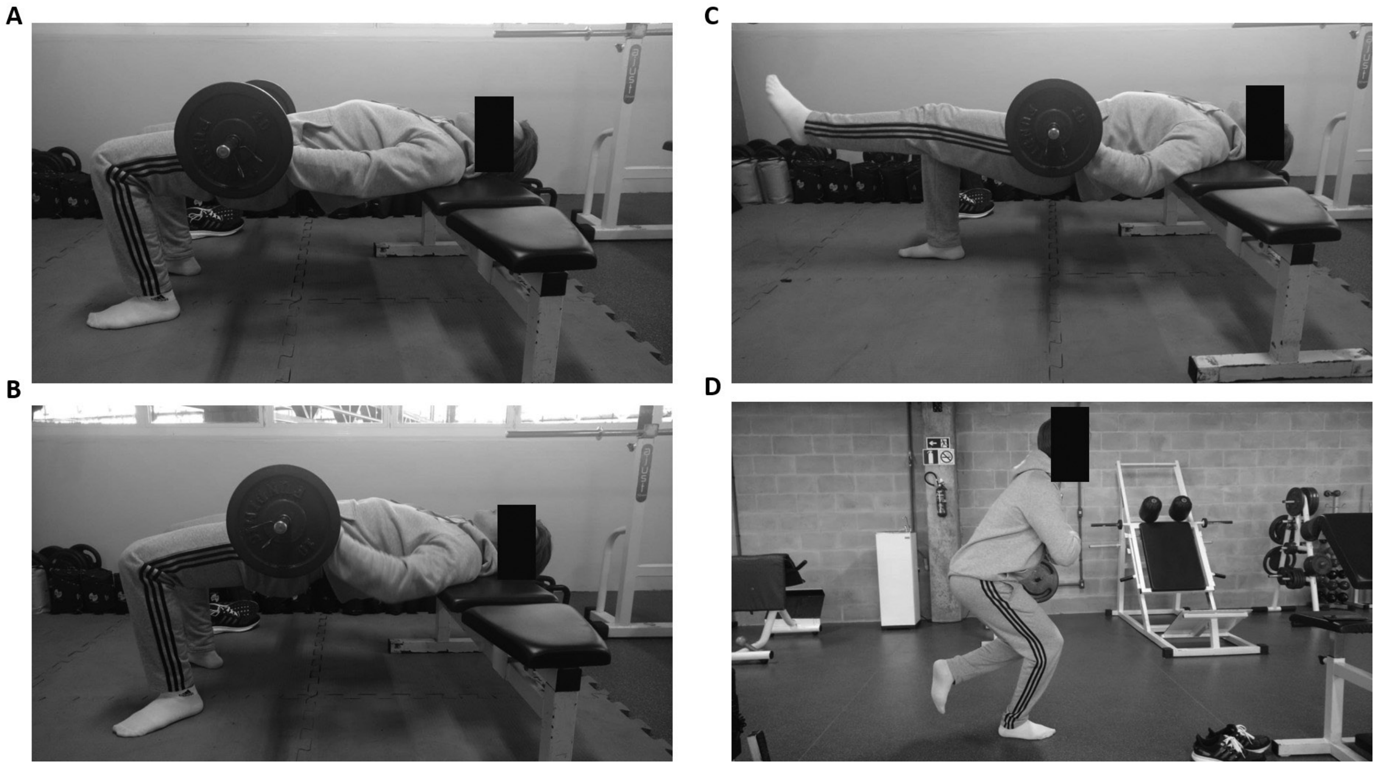

Figure 1. Multi-joint exercises analyzed. Bilateral supine bridge (BiBRG) (A), Bilateral supine bridge with hip abducted (BiBRG-AB) (B), Unilateral supine bridge (UniBRG) (C) and Single-leg Squat (SLS) (D)

Isometric maximum voluntary contraction (iMVC)

The iMVC was performed with the subject in a side-lying position and the hip of the preferred leg positioned at a 10º abduction angle[24] (Figure 3) applying maximum force against a rigid structure, while pelvis was kept in a neutral position. GMed and TFL activation signal were monitored during iMVC (Miotec – Biomedical Equipments, Porto Alegre, RS, Brazil). Subjects were verbally motivated during the three trials of iMVC and there was a five minutes rest to postpone fatigue effects[20].

Figure 2. Isometric maximal voluntary contraction (iMVC) for hip abductors. Maximal test was performed with hip at 10º of abduction.

10RM tests

Participants performed a 10RM test to determine the load to be used in each exercise. All subjects warmed up with a low self-selected load. The load for the 10RM test was changed until subjects achieved task failure in the tenth repetition, and it was defined using a maximum of three trials and always using bars and free-weights. If a fourth trial was required, a new session was scheduled in order to avoid fatigue effects in load definition. A metronome was set at 60 beats/min to pace the execution of the exercises, being 2 beats for eccentric phase and 2 beats for concentric phase. During all exercises, the participants were oriented to perform eccentric and concentric phases at the maximum of the range of motion. A five-minute rest was enforced between each ten-repetition trial. The final loads obtained through the 10RM tests were used during exercise execution, with the same characteristics previously described, while muscle activations were recorded. The exercises order for performing the 10RM tests and to record muscle activation during exercises was randomized[20].

Muscle activation acquisition and signal processing

Surface electromyography was used to measure the activation of GMed and TFL during iMVCs and four multi-joint exercises. A four-channel electromyography system (Miotool 400, Miotec – Equipamentos Biomédicos, Porto Alegre, RS, Brazil) was employed using a bipolar configuration, with sampling signals at 2KHz and 14 bits of resolution. Two electrodes with 15mm radius (Kendall Mini Medi-Trace 100 – Tyco Healthcare, São Paulo, SP, Brazil) and 20 mm of the distance between centers were attached to the skin on the muscle belly after careful shaving and cleaning of the area, with an abrasive cleaner and alcohol swabs, to reduce the skin impedance. Positioning for electrodes placement followed the recommendation from SENIAM. A reference electrode was placed over the skin of the tibia as a neutral site for the EMG signals.

EMG signals were analyzed in the data acquisition software (Miograph – Equipamentos Biomédicos, Porto Alegre, RS, Brazil). A band-pass digital filter (5th order Butterworth with cut-off frequencies of 20-500Hz) was applied to the signals. Whole EMG signal during iMVC from each muscle was selected to compute the root mean square value (RMS). iMVCs that showed higher RMS of each muscle were used for normalization of the signals from the ten repetitions of each exercise.

The RMS of each muscle during the four exercises were computed for the second, fourth, sixth and eighth trials during the concentric and eccentric phases of motion[20]. All exercises were recorded by a webcam connected to a computer during exercises, which was employed to define the start and the ending of each repetition and the concentric and eccentric phases of the exercise. Thus, RMS value obtained during the entire trial (which had 2 beats per phase, totaling[2] seconds per phase) was used to analysis. The average of the four RMS values (second, fourth, sixth and eighth trials) were computed for each muscle during each exercise and converted to percentages of the iMVC[20].

Statistical Analysis

The sample size was determined a priori using the data obtained of similar previous studies for the GMed and TFL muscle activation[11,25]. Based on the mean and standard deviation of SLS[25], BiBRG[11], and UniBRG[11], we calculate the effect size (Cohen's *d*). Assuming the effect size obtained in each outcome (0.03, 0.37 and 0.37, respectively), $\alpha = 0.05$ and $\beta = 0.80$ in a factorial ANOVA, a minimum of 10 participants were needed to observe significant differences between exercises. Sample size calculation was performed using the software G*Power 3.0.10.

Data normality was tested through the Shapiro-Wilk test. Data sphericity was tested by the Mauchly test and the Greenhouse-Geisser correction factor was used when the sphericity was violated. For the load during the four multi-joint exercises, a repeated-measures one-way ANOVA was performed. For RMS of GMed and TFL during each exercise, a factorial ANOVA (4 exercises vs 2 muscles) was performed. When an interaction between factors was found, a Bonferroni post-hoc analysis was performed. The effect size was calculated for each ANOVA (η^2) and paired comparison [GMed vs TFL during each exercise] (*d*). Cohen's *d* were interpreted based on the following classification (<0.2: trivial; >0.2: small; >0.50: moderate; >0.80: large)[26].

Also, GMed and TFL muscle activation among exercises were classified as low (< 20%iMVC), moderate (20-40%iMVC), high (40-60% iMVC) and very high (>60%iMVC)[14,15]. Results are presented in the text and figures as mean ± standard deviation. All statistical analysis was performed with a statistical package

(SPSS 20.0 for Windows, SPSS Inc., Chicago, IL. USA) and significance was defined as $p<0.05$.

Results

There were significant differences in the load for the 10RM tests among the four exercises ($F_{3,30}=81.57$; $p<0.001$). The load was significantly greater for the BiBRG and BiBRG-AB compared to the UniBRG and SLS ($p<0.001$). No differences were observed between BiBRG and BiBRG-AB ($p=0.998$) and between UniBRG and SLS ($p=0.196$) (Figure 3).

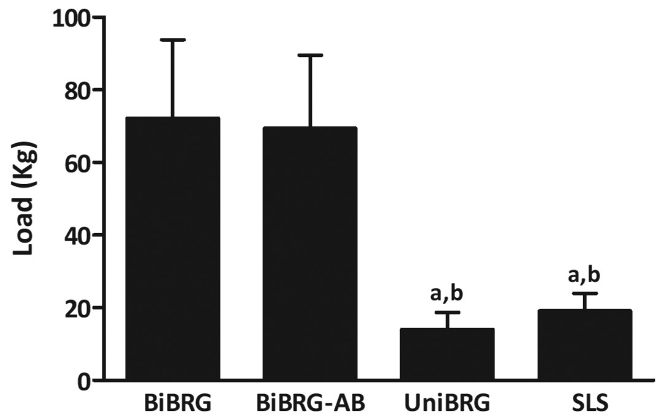

Figure 3. Load (Kg) during 10RM (mean±SD) of bilateral supine bridge (BiBRG), bilateral supine bridge with hip abducted (BiBRG-AB), unilateral supine bridge (UniBRG) and single-leg squat (SLS). a – different of BiBRG; b – different of BiBRG-AB

No exercises ($F_{3,30}=1.09$; $p=0.365$; $\eta^2=0.09$) and exercise*muscle interaction ($F_{3,30}=1.06$; $p=0.377$; $\eta^2=0.09$) were observed. However, there was a significant difference between muscle activation during exercises ($F_{3,30} = 13.66$; $p=0.004$; $\eta^2=0.57$). We observed that GMed activation was significant greater compared to TFL among the four exercises ($p=0.004$) [BiBRG: $\Delta=26.2\%$; BiBRG-AB: $\Delta=27.3\%$; UniBRG: $\Delta= 24.5\%$ and SLS: $\Delta= 18.8\%$]. Moreover, a large effect size favors GMed was demonstrated for all multi-joint exercises ($d>1.49$). Furthermore, for all exercises, GMed activation was classified as moderate (<40% iMVC) and TFL activation was classified as low (<20% iMVC)[14,15] (Figure 4).

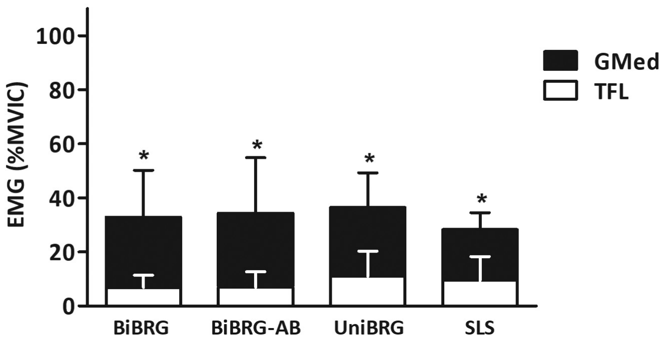

Figure 4. Muscle activation responses (mean±SD) during four multi-joint strengthening exercises. * different between GMed and TFL

Discussion

To our best knowledge, this is the first study to analyze the level of activation of GMed and TFL during multi-joint exercises using ten maximal repetitions, intensity commonly indicated in strength training for hypertrophy[27]. The main results observed indicate that: (i) GMed was more active than TFL in all exercises; (ii) GMed and TFL had moderate and low activation levels, respectively, in all exercises. Thus, the activation values of GMed in the four exercises were below that indicated for strength gain[17,18].

Single-leg squat (SLS) is a widely used exercise for measuring GMed impairment through kinematics[2], so its use in training protocols tends to overload and strengthen GMed due to its pelvic stabilization role. However, the level of activation presents high variability in previous studies (from 17 to 82% of the iMVC[16]). Although the SLS is similar to other squats, a greater stabilization is required to maintain vertical alignment, since the trunk needs more vertical alignment over the stance limb[15]. DiStefano, Blackburn, Marshall, Padua[28] reported greater GMed activity during a full single-leg squat (until the touch of the long finger of one hand on the ground). Thus, this larger excursion from the body' center of mass toward the ground could explain the necessity for higher activity of the GMed to stabilize the pelvis. This requirement for pelvic stability in the frontal plane probably justifies the important contribution of GMed during this exercise[29]. A previous study observed greater GMed activity in anterior knee pain patients during single-leg jump[30], which was explained as an attempt to stabilize the lower limb during dynamic tasks. However, a smaller GMed activation also was observed in anterior knee pain patients combined with higher hip adduction and internal rotation during single-leg squat[2]. Our study did not measure frontal plane kinematics during SLS, which could help to explain our results due to a possible change in muscle activation behavior according to kinematic response. Still, poor lower limb alignment during single-leg-tasks[2,30] was also observed in this musculoskeletal disorder[31]. Additionally, changes in the lower limb alignment helped to explain the greater variability observed in GMed activation during SLS[16].

Our results concerning the activation of GMed during SLS are similar to two previous studies[24,28]. The methods used (hip position for iMVC and cadence of the movement during the squats) were similar to ours, differing only in the presence of external load in our study. On the other hand, both previous studies observed high activation values of GMed (64% iMVC[28] and 82% iMVC[24]). Even the study of Boren, Conrey, Le Coguic, Paprocki, Voight, Robinson[24] is similar to ours in what regards the iMVC position and the cadence during movement, a possible lack of motivation during the iMVC justifies finding the higher value reported by the study. Moreover, the study by DiStefano, Blackburn, Marshall, Padua[28], performed the iMVCs in a more shortened position of the hip abductors (25º of hip abduction), which may have caused a lower maximal activation[32] and, them, the higher activation values during exercise. Additionally, there was no exact control for cadence of movement for the participants to perform squat slowly, which may also justify the different results, since the angular velocity presents a direct impact on the muscle activation level[33].

Regarding the different types of bridge, our study performed the unilateral supine bridge (UniBRG) and bilateral supine bridges (with hip in neutral position (BiBRG) and with hip abducted (BiBRG-AB). The variation of hip abduction was used based on a previous suggestion of coaches. However, we did not observe differences in muscle activation between all bridges variations. Regarding the BiBRG, our results (33%) were similar to those reported by Ekstrom, Donatelli, Carp[34] for the activation of GMed (28%), even if presenting differences in hip position for iMVC and in the cadence for the exercise. However, our values were higher than those found by Selkowitz, Beneck, Powers[11] (15%). One possible hypothesis is related to the load employed in our study, which leads to higher levels of muscle activation[20].

The UniBRG exercise in previous studies demonstrated higher GMed activation values than those reported in our study (35% vs 55%[24] and 47%[34]). Although we did not observe a significant difference between the uni- and bilateral bridges, it is worth mentioning that the absolute load displaced in the BiBRG and BiBRG-AB was significantly higher than the UniBRG. Thus, one justification is the fact that unilateral exercises incorporate a greater need for pelvic stabilization, which increases the participation of GMed[1]. Another aspect regards the knee flexion degree during bridge's exercises. Lehecka et al.[35] observed changes in the pattern of gluteal activation in the unilateral bridge exercise with 135º of knee flexion compared to the same exercise performed at 90º of flexion. The authors explained these results by the lower hamstring activation observed in the position with 135º knee flexion compared to the 90º flexion position (23.49% vs 75.34%, respectively). Thus, this mechanical disadvantage of the hamstrings at 135º of flexion would allow greater activation of the gluteal musculature. Thus, as our study performed the movement at 90º of knee flexion and with maximum load, justifying the moderate activation observed for the GMed.

In all exercises investigated, TFL muscle activation was low in our study. TFL strengthening needed to be minimized[11], mainly in anterior knee pain patients, since TFL tendon composes iliotibial tract[9] and their elevated tension causes a higher lateral displacement of patella[8]. One justification on low TFL activation is regarding the absence of hip flexion, abduction, and internal rotation movements during the four exercises, which are performed by this muscle[36]. Han, Yi, You, Cynn, Lim, Son[25] observed a moderate activation of TFL (~30% iMVC) during SLS, differing from what was observed both in our (9.4%) and in Selkowitz, Beneck, Powers[11] (4.6%) studies. The main reasons for the moderate activation pointed out by the authors is the possible role of TFL in preventing pelvic drop[25], since the participants presented GMed weakness. Thus, TFL acts similar to the GMed function[29]. However, this role of TFL needs to be considered with caution. Han, Yi, You, Cynn, Lim, Son[25] defined the presence of GMed weakness based on a subjective method. Additionally, a recent study demonstrated that patients with GMed atrophy (which is related to its weakness) did not demonstrate differences in TFL muscle structure when compared to healthy subjects[37], which contradicts the possibility of TFL to act similarly to the GMed in preventing a pelvic drop.

The presence of hip rotation seems to be a variable that modifies the pattern of activation of the hip abductors, leading us to keep the hip in a neutral position to the rotation. Lee, Cynn, Choi, Yoon, Jeong[38] observed an increase in GMed activation during side-lying hip abduction associated with internal rotation compared to the neutral position (60% vs 45%). The possible mechanism for these findings pointed out by the authors may be that the hip internally rotated causes an increase in GMed length, which can produce more muscle activity[38]. In addition, when the side-lying hip abduction was performed with external hip rotation, the TFL presented greater activation compared with the neutral position. One reason brought up by the authors was the hip abduction with external rotation, although causing a mechanical disadvantage in the abductor function of TFL, potentiates its function as a hip flexor, increasing its muscle activity.

One of the characteristics of our study was the monitoring of the activation of GMed and TFL during multi-joint exercises using 10 maximal repetitions. Most of the studies investigating the activation of these muscles did not control exercise intensity, which may affect muscle activation. In addition, 10 maximal repetitions are indicated for strength gains in training protocols[27]. Another important aspect is that our participants are trained in resistance training, which did not occur in previous studies[11,24,34]. However, the training level does not appear to be a variable that affects muscle activation in exercises with low[39] and high external load[40]. Therefore, although our results showed higher activation of GMed compared with TFL in all exercises, their levels of activation were moderate (<40% iMVC). Previous studies indicate that for strength gains, muscle activation during exercises should be greater than 40% iMVC[17,18]. Therefore, even that only multi-joint exercises in resistance training programs obtain equivalent results compared to single-joint exercises in long-term adaptations, such as hypertrophy and strength[13], all multi-joint exercises used in our study (and stated in previous studies to strengthen GMed[11,16]) are actually unable to achieve the minimum activation expected to promote strength gains[17,18]. Thus, we believe that the inclusion of single-joints exercises is needed during resistance training programs to promote muscle strength gains in hip abductors, mainly in the GMed.

One important limitation of the present study was that the range of motion was not measured during the performance of each selected exercises, which can directly impact muscle activation[41]. Even so, the researches gave the participants the orientation to perform the eccentric phase at the maximum of the range of motion. Additionally, we used the RMS value during entire repetition (concentric and eccentric phases), similar to previous studies[11,20]. We believe that another method of analysis (such as the use of peak value) during each exercise could change the results. Another limitation concerns the non-monitoring of the gluteus minimus since it is also an important hip abductor[36]. However, based on its origin and insertion, it does not appear that this muscle could present different responses to those observed for GMed. The monitoring of the gluteus maximus, which is a powerful hip extensor and external rotator with its superior fibers having an abductor function[3] and the activation of this muscle, could present differences according to the load and the great needed to pelvic stability in unilateral exercises. Since all of our exercises involved hip extension and knee extension in the closed kinetic chain, beyond the gluteus maximus, the hip adductors and hamstrings also act to hip extension[3], while quadriceps promotes knee extension. Thus, future studies should monitor these muscles once they may be useful to determine their contribution during exercises and modifications regarding the double and single-leg stance.

Finally, although several studies pointed out a minimum of 40% iMVC to strength gains[17,18,42], we failed to observe long-term studies confirming that. The theory behind this affirmation is based on the relationship between loads and muscle activation since loads of 40% of 1RM have been shown to increase strength[43]. Therefore, 40% iMVC may provide sufficient stimulus for strength gains[34]. However, during dynamic contractions, the relationship between load and activation is not linear[44]. moreover, since the joint angle to perform iMVC changes the EMG amplitude (smaller in shortening position compared with more stretching)[32] and is different between studies, a level of activation based on maximum contraction to recommend an exercise for strength gains needs caution. Future studies are necessary to confirm the relationship between the level of activation and strength gains through a long-term study involving resistance training, as well as perform the maximal contraction to normalize activation during exercise in a position that muscle produces a high level of force based on their force-length relationship.

Conclusions

Our results demonstrated that GMed is more active than TFL in all analyzed exercises using maximal repetitions. However, the level of activation observed during exercises used in our study was below the recommendation for strength gains. Thus, we believe that to strengthening GMed, may be necessary to include single-joint exercises in resistance training programs.

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