

Muscle activation and fatigue patterns of the gluteus medius and tensor fasciae latae during unilateral hip abduction and lunge exercises

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Published online: March 31, 2026

Accepted for publication: March 15, 2026

DOI:10.7752/jpes.2026.03061

Abstract

Problem Statement: This study aimed to evaluate the myoelectric activation of the gluteus medius (Gmed) and tensor fasciae latae (TFL), and to investigate the occurrence of cross-fatigue during lunge and standing hip abduction (ABD) exercises performed with cable resistance using a crossover machine. **Materials and Methods:** Ten physically active young men participated in three experimental sessions, each separated by 48 h. The first session involved anthropometric assessment and familiarization with the exercise protocols. During the second session, 10-repetition maximum (10RM) tests were performed for both exercises. In the third session, electromyographic (EMG) recordings of the Gmed and TFL were obtained bilaterally during maximum voluntary isometric contraction (MVIC) tests and during the performance of both exercises at 80% of the 10RM. Data normality was assessed using the Shapiro–Wilk test, and non-parametric comparisons were performed using the Friedman test. Post-hoc analyses for statistically significant differences ($p < 0.05$) were performed using Dunn's test for multiple comparisons. Effect sizes (Cohen's d) with 95% confidence intervals (95% CI) were calculated using the Estimation Stats platform. All statistical analyses were performed with GraphPad Prism software (version 8.4.3). **Results:** The findings showed no evidence of cross-fatigue in either the Gmed or TFL following both exercises. Bilateral Gmed activation during the ABD exercise was statistically similar and comparable to the dominant (DOM) limb during the lunge; however, both were significantly greater than the non-DOM (N-DOM) limb activation during the lunge. The TFL exhibited significantly higher activation during ABD compared with the lunge, although no interlimb differences were observed in either exercise. Additionally, the lunge elicited a significantly higher Gmed:TFL activation ratio than the ABD exercise. These results may guide exercise selection in training and rehabilitation programs aiming to preferentially recruit the Gmed during unilateral lower-limb exercises.

Keywords: lunge; hip abduction; gluteus medius; tensor fasciae latae; cross-fatigue

Introduction

In the hip, the gluteus medius (Gmed) and tensor fascia latae (TFL) are key contributors to hip abduction (ABD) in the frontal plane. According to Gottschalk, Kourosh, and Leveau (1989) and Robertson et al. (2008), the Gmed is a large muscle originating near the anterior superior iliac spine and extending along the iliac crest, with its distal insertion on the lateral and superoposterior surfaces of the greater trochanter of the femur. This anatomical arrangement allows the Gmed to function as a primary stabilizer of the pelvis during unipodal tasks (Buckthorpe et al., 2019) and establishes it as the main hip abductor in the frontal plane (Neumann, 2010). Additionally, the Gmed contributes to lateral rotation of the femur when the hip is extended and assists in hip flexion via its anterior fibers, while the posterior fibers are active during hip extension.

The TFL is another key muscle in lower-limb kinematics, contributing not only to hip ABD but also to hip flexion and internal rotation of the femur (Neumann, 2010). Recent studies have emphasized that the coordination between superficial and deep hip muscles is critical for neuromuscular control and joint stability, particularly during functional and resistance-based exercises (Kim et al., 2025; Perraton et al., 2022). Moreover, variations in exercise type, load, and stability demands can substantially influence activation patterns of both the Gmed and TFL, underscoring the importance of exercise selection in both clinical and performance contexts (Goller et al., 2024).

The predominance of the TFL in generating hip ABD relative to the Gmed can result in excessive femoral internal rotation, promoting abnormal forces in the lower limbs during single-leg tasks. This imbalance may contribute to degenerative changes in cartilage and surrounding tissues, as well as impair gait function (Merican et al., 2009; Neumann, 2010; Besomi et al., 2020). Evidence also suggests that strength imbalances between the Gmed and TFL are implicated in patellofemoral disorders (Strauss et al., 2010; Nakagawa et al., 2012), knee osteoarthritis (Hinman et al., 2010), and iliotibial band syndrome (Fredericson et al., 2000; Lee et

al., 2012). More recent studies indicate that altered recruitment patterns of these muscles are associated with hip-related pathologies and functional limitations, further highlighting their importance in rehabilitation strategies (Duke et al., 2025; Posturzyńska et al., 2025).

Given the importance of maintaining balance between these muscles, the Gmed:TFL activation ratio has been widely used as a parameter to guide exercise prescription, particularly for identifying exercises that preferentially recruit the Gmed while minimizing compensatory TFL activation (Selkowitz et al., 2013; Sidorkewicz et al., 2014). In recent years, electromyographic (EMG) studies have aimed to determine which exercises optimize this ratio, showing that different mechanical and neuromuscular demands can substantially influence muscle recruitment patterns (Frigotto et al., 2019; Jardim et al., 2023). Additionally, training under unstable conditions or with external perturbations appears to change activation strategies, potentially enhancing neuromuscular efficiency and motor control (Bao et al., 2025). Interventions such as hip joint manipulation have been shown to increase EMG amplitude and improve hip performance, suggesting that neuromuscular responses can be modulated through both exercise and manual therapy approaches (Studnicki et al., 2024).

Another important consideration when prescribing unilateral lower-limb exercises is the fatigue generated in the limb that is at rest or supporting body weight. Zijdwind and Kernell (2001) observed a small but noticeable contraction of the homologous finger of the resting hand during maximal voluntary contraction (MVC) of the opposite hand. This involuntary activation of the contralateral homologous muscle at rest appears to induce fatigue, referred to as cross-fatigue. Current studies suggest that this phenomenon is mediated by central neural mechanisms involving corticospinal pathways and interhemispheric communication, which may influence motor performance in the contralateral limb (Halperin et al., 2014; Aboodarda et al., 2019).

Despite the growing body of literature on cross-fatigue, most studies have focused on isometric contractions or isolated muscle groups, with limited applicability to dynamic, multi-joint resistance exercises commonly used in practice. Recent investigations have highlighted that exercise modality, intensity, and duration may influence the magnitude of cross-fatigue and cross-fatigue effects, but the evidence remains inconsistent (Prieske et al., 2017; Bao et al., 2025). Therefore, understanding how these mechanisms operate in functional exercises such as lunges remains an important area of investigation.

In addition to neuromuscular factors, the mechanical characteristics of unilateral exercises may impose distinct stability and coordination demands on the supporting limb, thereby influencing bilateral muscle activation patterns (Perraton et al., 2022; Goller et al., 2024). Exercises such as the lunge require dynamic control of the centre of mass and greater involvement of stabilising muscles to maintain postural alignment, whereas isolated movements such as hip ABD may place greater emphasis on local muscle recruitment (Goller et al., 2024; Kim et al., 2025).

Furthermore, from a practical perspective, selecting exercises that optimize muscle activation patterns while minimizing compensatory strategies is essential for both injury prevention and rehabilitation (Duke et al., 2025; Posturzyńska et al., 2025). Although several studies have examined muscle activation under isolated conditions, evidence remains limited regarding how unilateral dynamic exercises influence both limbs simultaneously (Perraton et al., 2022; Bao et al., 2025).

To date, few studies have used traditional dynamic strength training exercises to assess contralateral cross-fatigue (Andrews et al., 2016; Prieske et al., 2017) or the Gmed/TFL activation ratio during single-leg hip ABD or lunge exercises. Additionally, there is a lack of research evaluating bilateral muscle activation simultaneously during these exercises, limiting the understanding of the neuromuscular demands placed on both limbs (Perraton et al., 2022; Goller et al., 2024). This gap in the literature is particularly relevant for exercise prescription in rehabilitation and strength training contexts, where unilateral exercises are commonly used.

Therefore, the objective of this study was threefold: (A) to investigate the muscle activation of the Gmed and TFL bilaterally during a unilateral hip ABD exercise and a lunge exercise; (B) to examine the occurrence of cross-fatigue in the homologous muscles of the contralateral [non-dominant (N-DOM)] limb following a fatiguing dynamic protocol of one set of 10 repetitions at 80% of the 10RM; and (C) to compare the Gmed:TFL activation ratio between the two exercises.

It was hypothesized that lunge and standing hip ABD exercises performed with cables would elicit distinct levels of myoelectric activation in the Gmed and TFL. Specifically, the lunge exercise was expected to produce a more favorable Gmed:TFL activation ratio. Furthermore, it was hypothesized that prior execution of either exercise would induce cross-fatigue, leading to significant changes in the subsequent myoelectric activation of the Gmed and TFL in the N-DOM limb.

Materials and Methods

Ethical Considerations

This study was approved by the CESEM Ethics Committee of the State University of Pará and conducted in accordance with the Declaration of Helsinki. All procedures complied with Brazilian ethical regulations (Resolutions No. 466/2012 and No. 510/2016, and Circular Letter No. 061/2012/CONEP/CNS/GB/MS). Written informed consent was obtained from all participants prior to their inclusion in the study (CAAE: 86747325.6.0000.8767).

Participants

Ten physically active men (mean age: 25.3 years; mean body mass: 75.6 kg; mean height: 172.5 cm) participated in the study. Participants were instructed to avoid energy drinks on the test day and to refrain from physical exercise for 24 h prior to EMG assessments.

Table 1: Mean, standard deviation, and item-total correlation for participants' height, weight, and age

	Mean	Standard deviation	Item-total correlation
Height	172.5	± 7.28	0.757
Weight	75.58	± 12.97	0.729
Age	25.3	± 5.09	0.323

Procedures

All procedures were performed after 3 p.m. at the same location. During the initial meeting, participants' weight, height, and age were recorded. They were then familiarized with the exercise protocol by performing two sets of ten repetitions of the lunge exercise using only body weight, as well as the hip ABD exercise on a low pulley machine with self-selected loads. The exercise pace during familiarization was standardized at 1 s for the eccentric phase and 1 s for the concentric phase, guided by auditory cues from a metronome (Beats Metronome App), with a three-minute rest interval between exercises.

After 48 h, participants completed a 10-repetition maximum (10RM) test for both exercises, performed in random order, with a 5-min rest between exercises, over a total of five attempts. Another 48 h later, the third session took place, during which experimental tests for EMG recording were performed. First, maximum voluntary isometric contraction (MVIC) tests were performed to determine the maximal activity of the Gmed and TFL for data normalization. This was followed by three minutes of the lunge and hip ABD exercises in random order. The hip ABD exercise was performed with the dominant (DOM) limb, while in the lunge exercise, the DOM limb was positioned anteriorly.

We used unilateral hip ABD exercises using cable resistance on a cross-over machine and the squat exercise in the anteroposterior stance of the lower limbs, commonly known as lunges. In the lunge exercise, the DOM limb was positioned anteriorly, and the load was held contralaterally, with the participant holding the dumbbell in the hand opposite the front leg. Knee flexion during the exercise reached approximately 90°. Participants were instructed to maintain an upright torso, preserving the spine's natural curves, so that at the end of the concentric phase, the anterior thigh was parallel to the ground.

In the thigh ABD exercise, the DOM limb performed the movement, and participants were instructed to execute it in a single-leg stance with the pelvis stabilized in the frontal plane, preventing the contralateral pelvis from tilting laterally, anteriorly, or posteriorly, while keeping the spine stabilized and the DOM knee extended.



Figure 1: Images of the contralateral lunge (A and B) and hip ABD using the low pulley on the crossover machine (C and D) exercises

Maximal Voluntary Isometric Contractions (MVIC) Tests

MVIC tests were performed with participants in the lateral decubitus position, pelvis in a neutral alignment, and the DOM limb abducted to 10°, measured using a fleximeter (Sanny Fleximeter – FL6010) (Frigotto et al., 2019). Following a warm-up of two sets of fifteen body-weight squats, participants exerted maximal force for 5 s, with verbal encouragement, while Gmed and TFL activity was recorded. MVIC tests were repeated immediately after each exercise to evaluate cross-fatigue.

Electromyography

EMG recordings were obtained using the New Miotool system (Miotec Equipamentos Biomédicos Ltda, Porto Alegre, Brazil), with digital channel ports connected to recording electrodes (TSD150B, Biopac Systems Inc., CA) and a ground reference electrode (Kendall 100 Series Foam Electrodes, Medtronic, MN). Electrodes

were positioned on both the DOM and N-DOM sides according to the European recommendations for Surface Electromyography for Noninvasive Assessment of Muscles (SENIAM)

The EMG signals were recorded on a microcomputer using Miograph data acquisition software (Miotec) and subsequently processed and exported for analysis in GraphPad Prism 8.4.3. Signals were filtered with a 5th-order Butterworth digital filter, using cutoff frequencies of 20–500 Hz. Two electrodes, each with a 15 mm radius (Kendall Mini Medi-Trace 100 – Tyco Healthcare, São Paulo, SP, Brazil) and spaced 20 mm apart at their centers, were placed on the muscle belly.

Prior to placement, hair was removed, and the skin was cleaned with an abrasive cleanser and alcohol swabs to reduce impedance. Electrodes were aligned according to the orientation of each muscle's fibers, following the guidelines of Leis and Trapani (2013).

The myoelectric activity of the Gmed and TFL muscles on both the DOM and N-DOM hips was assessed following SENIAM recommendations [10] (Figure 1). The mean square EMG signals were recorded throughout each exercise, and these values were then normalized to the corresponding MVIC and expressed as %MVIC.

For each muscle, the complete EMG signal obtained during MVIC was used to calculate the root mean square (RMS) value, and the highest RMS value from the MVIC was used to normalize the signals recorded during the exercises.

The movement rhythm during the exercises was paced using a metronome (Korg Ma-2 Blbk Compact Digital Metronome) set at 60 BPM. To clarify the timing of each phase, an evaluator verbally cued participants in synchrony with the metronome signals. Each participant performed three repetitions of each exercise at 80% of their 10RM, with 1 s for the concentric phase and 1 s for the eccentric phase, facilitating maintenance of consistent cadence. Both exercises followed a 1-0-1-0 tempo (1 s eccentric, 1 s concentric), with a 5-min rest interval between exercises. EMG recordings from the three repetitions were processed to obtain peak and RMS averages, which were subsequently normalized to %MVIC.

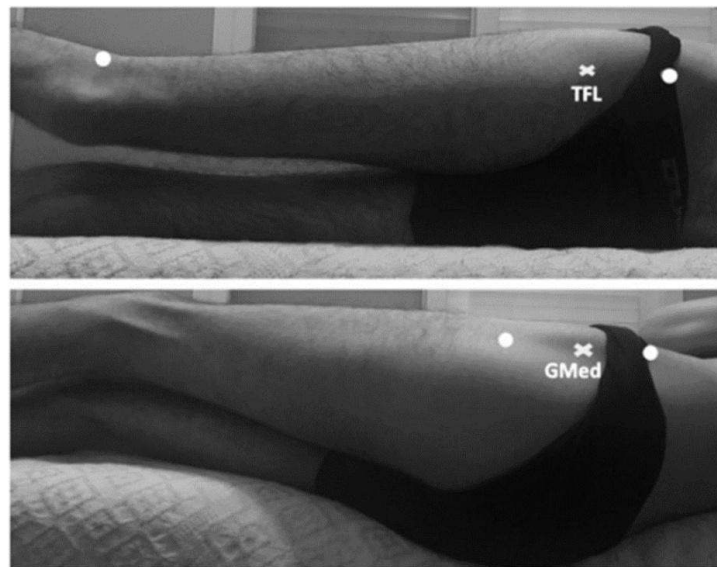


Figure II: Electrode placement. The circular dots indicate the anatomical points recommended by the SENIAM guidelines for proper electrode positioning on X.

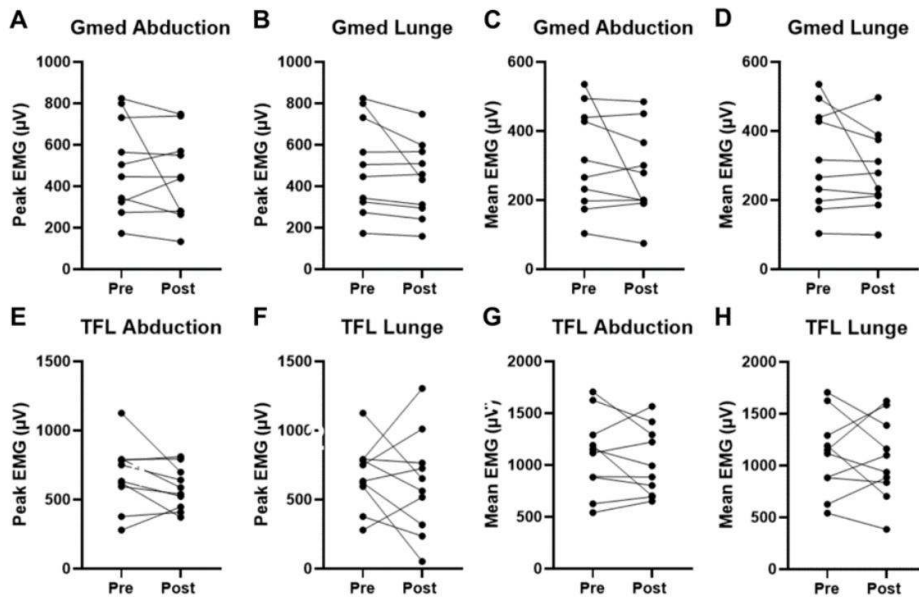
Statistical Analysis

EMG data, expressed as mean $\pm$ standard deviation, were assessed for normality using the Shapiro–Wilk test. Because the data were not normally distributed, the Friedman test was applied. Statistically significant differences ($p < 0.05$) were further examined using Dunn's test for multiple comparisons.

To quantify the magnitude of differences between groups, effect sizes (Cohen's d) with 95% confidence intervals (95% CI) were calculated using the Estimation Stats platform (<https://www.estimationstats.com>) (Ho et al., 2019). Effect sizes were interpreted according to conventional thresholds: trivial (< 0.2), small ($0.2–0.5$), moderate ($0.5–0.8$), and large (≥ 0.8). All analyses were performed using GraphPad Prism software (version 8.4.3).

Results

Regarding cross-fatigue in both the Gmed and TFL, no significant differences were observed in peak or mean activation for either exercise (Graph 1).



Graph I: Graphs showing the evaluation of cross-fatigue in thigh ABD and lunge exercises. A: Peak activation of the Gmed during the MVIC test before and after the hip ABD exercise. B: Peak activation of the Gmed during the pre- and post-exercise MVIC test for lunges. C: Mean activation of the Gmed during the pre- and post-exercise MVIC test for hip ABD. D: Mean activation of the Gmed during the pre- and post-exercise MVIC test for lunges. E: Peak activation of the TFL during the pre- and post-exercise MVIC test for hip ABD. F: Peak activation of the TFL during the pre- and post-exercise MVIC test for lunges. G: Mean activation of the TFL during the pre- and post-exercise MVIC test for hip ABD. H: Mean activation of the TFL during the pre- and post-exercise MVIC test for lunges

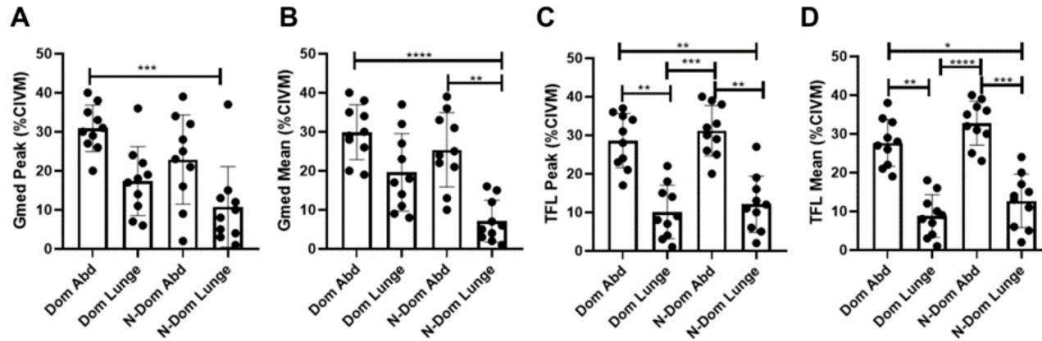
Table II: Mean difference, 95% confidence interval (CI) of the difference, adjusted p-value, and effect size for peak and mean %MVIC of the Gmed and TFL in hip ABD and lunge exercises

Comparison CIVM Pre vs Post exercise				
	Mean Diff	95.00% CI of diff	Adjusted P Value	Effect size Eta squared (η^2)
Gmed Abduction - Comparisons Peak EMG RMS (μV)				
Pre vs Post	-53.93 $\pm$ 97.65	-259.1 to 151.2	0.5875	0
Gmed Abduction - Comparisons Mean EMG RMS (μV)				
Pre vs. Post	-44.84 $\pm$ 61.99	-175.1 to 85.41	0.4788	0
Gmed Lunge - Comparisons Peak EMG RMS (μV)				
Pre vs. Post	-66.55 $\pm$ 92.15	-260.2 to 127.1	0.4794	0
Gmed Lunge - Comparisons Mean EMG RMS (μV)				
Pre vs. Post	-38.74 $\pm$ 59.44	-163.6 to 86.13	0.5228	0
TFL Abduction - Comparisons Peak EMG RMS (μV)				
Pre vs. Post	-92.50 $\pm$ 89.24	-280.0 to 94.99	0.3137	0
TFL Abduction - Comparisons Mean EMG RMS (μV)				
Pre vs. Post	-78.77 $\pm$ 159.9	-414.7 to 257.1	0.6282	0
TFL Lunge - Comparisons Peak EMG RMS (μV)				
Pre vs. Post	-60.61 $\pm$ 138.8	-352.2 to 231.0	0.6675	0
TFL Lunge - Comparisons Mean EMG RMS (μV)				
Pre vs. Post	-41.65 $\pm$ 173.5	-406.2 to 322.9	0.9400	0.003

The comparison of Gmed activation during the exercises showed that for peak activation, the DOM side during hip ABD (Dom Abd) exhibited greater activity than the N-DOM side during the lunge (N-Dom Lunge). No significant differences were found between Dom Abd and the N-DOM side during hip ABD (N-Dom Abd), between Dom Abd and the DOM side during the lunge (Dom Lunge), or between Dom Lunge and N-Dom Lunge (Graph 2A). Analysis of mean Gmed activation indicated that both Dom Abd and N-Dom Abd produced higher activation compared to N-Dom Lunge, while no differences were observed between Dom Abd and N-Dom Abd or between Dom Lunge and N-Dom Lunge (Graph 2B).

Regarding peak myoelectric activity of the TFL, the data showed that both Dom Abd and N-Dom Abd exhibited higher activation levels compared to Dom Lunge and N-Dom Lunge, with no significant differences between Dom Abd and N-Dom Abd or between Dom Lunge and N-Dom Lunge (Graph 2C). For the mean

myoelectric activity of the TFL, results similarly indicated that both Dom Abd and N-Dom Abd had higher activation levels than Dom Lunge and N-Dom Lunge, again with no differences between Dom Abd and N-Dom Abd or between Dom Lunge and N-Dom Lunge (Graph 2D).

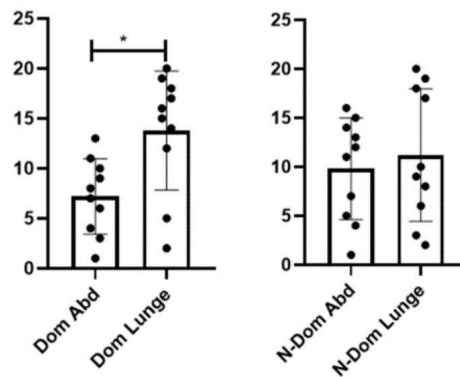


Graph II: A: Peak normalized activation (%MVIC) of Gmed in hip ABD and lunge exercises. B: Mean normalized activation of Gmed in hip ABD and lunge exercises. C: Peak normalized activation of TFL in hip ABD and lunge exercises. D: Mean normalized activation of TFL in hip ABD and lunge exercises. %MVIC: percentage of MVIC; Dom Abd: DOM side in hip ABD; N-Dom Abd: N-DOM side in hip ABD; Dom Lunge: DOM side in lunge; N-Dom Lunge: N-DOM side in lunge; Gmed: gluteus medius; TFL: tensor fascia latae. (.) $p \leq 0.05$; (.) $p \leq 0.01$; (.) $p \leq 0.001$; (****) $p \leq 0.0001$

Table III: Mean difference, adjusted p-value, and effect size for peak and mean %MVIC of the Gmed and TFL in hip ABD and lunge exercises

Comparison Peak Gmed (%CIVM)	Mean Diff	Adjusted P Value	Effect size Cohen's d
Dom ABD vs. Dom Lunge	13.5	0.0589	0.32
Sun ABD vs. N-Sun ABD	8.00	0.7558	0.177
Sun ABD vs. N-Sun Lunge	20.1	0.0007	0.42
Sun Lunge vs. N-Sun ABD	-5.50	>0.9999	0.17
Dom Lunge vs. N-Dom Lunge	6.600	>0.9999	0.13
N-Sun ABD vs. N-Sun Lunge	12.10	0.1239	0.25
Comparison Mean Gmed (%CIVM)	Mean Diff	Adjusted P Value	Effect size Cohen's d
Dom ABD vs. Dom Lunge	10.3	0.2930	0.29
Dom ABD vs. N-Dom ABD	4.50	>0.9999	0.13
Dom ABD vs. N-Dom Lunge	22.80	<0.0001	0.88
Sun Lunge vs. N-Sun ABD	-5.80	>0.9999	0.15
Dom Lunge vs. N-Dom Lunge	12.5	0.1008	0.42
N-Sun ABD vs. N-Sun Lunge	18.30	0.0028	0.63
Comparison Peak TFL (%CIVM)	Mean Diff	Adjusted P Value	Effect size Cohen's d
Dom ABD vs. Dom Lunge	18.50	0.0024	0.67
Dom ABD vs. N-Dom ABD	-2.600	>0.9999	0.19
Dom ABD vs. N-Dom Lunge	16.50	0.0096	0.58
Sun Lunge vs. N-Sun ABD	-21.10	0.0003	0.64
Dom Lunge vs. N-Dom Lunge	-2.00	>0.9999	0.07
N-Sun ABD vs. N-Sun Lunge	19.10	0.0016	0.58
Comparison Mean TFL (%CIVM)	Mean Diff	Adjusted P Value	Effect size Cohen's d
Dom ABD vs. Dom Lunge	18.90	0.0018	0.67
Dom ABD vs. N-Dom ABD	-5.10	>0.9999	0.20
Dom ABD vs. N-Dom Lunge	15	0.0247	0.52
Sun Lunge vs. N-Sun ABD	-24	<0.0001	0.74
Sun Lunge vs. Sun-Sun Lunge	-3.900	>0.9999	0.16
N-Sun ABD vs. N-Sun Lunge	20.1	0.0007	0.4

The results for the Gmed:TFL ratio showed that Dom Lunge exhibited higher values compared to Dom Abd, whereas no significant difference was observed on the N-Dom side (Graph 3, Table 4).



Graph III: Gmed:TFL ratio. A: Comparison of the Gmed:TFL ratio between Dom Abd and Dom Lunge. B: Comparison of the Gmed:TFL ratio between N-Dom Abd and N-Dom Lunge

Table IV: Comparison of the Gmed:TFL ratio

Comparison Mean Ratio Gmed:TFL	95.67% CI of difference	Adjusted P Value	Effect size Cohen's d
Dom ABD vs. Dom Lunge	0.9902 to 14.82	0.0115	0.11
N-Dom ABD vs. N-Dom Lunge	-0.3642 to 1.449	0.6305	0.16

Discussion

Evaluation of mean Gmed activation showed that both the DOM and N-DOM sides during hip ABD (Dom Abd and N-Dom Abd) exhibited higher activation compared to the N-DOM side during the lunge (N-Dom Lunge). Overall, the results showed no evidence of cross-fatigue for either the Gmed or TFL following the exercises. For both peak and mean activation, the Gmed demonstrated similar activity levels on both sides during hip ABD and in the Dom Lunge, although Dom Abd and N-Dom Abd produced higher average activation than N-Dom Lunge. In contrast, TFL peak and mean activation were significantly higher during hip ABD compared to the lunge, but these differences did not result in any significant variation in TFL activity between the anterior and posterior limbs.

It appears that performing a single set of 10 repetitions at 80% of 10RM does not provide a sufficient stimulus to induce a decrease in maximal isometric strength on the contralateral side of the exercised limb, although the results showed that the N-DOM side exhibited similar activation levels to the DOM side for both Gmed and TFL. In contrast, the scientific literature has frequently reported cross-fatigue, or pre-induced fatigue, following protocols involving fatiguing isometric tasks (Halperin et al., 2014; Doix et al., 2013, 2018; Rattey et al., 2006; Martin and Rattey, 2007; Todd et al., 2003; Aboodarda et al., 2019), whereas our protocol used dynamic resistance exercises.

In addition, we used a 5-s MVIC before and after the fatiguing exercise. However, some evidence suggests that such brief post-fatigue MVC protocols may be insufficient to generate enough fatigue to reduce MVC force production in the tested muscles (Halperin et al., 2014b; Prieske et al., 2017). Other studies have used sustained or intermittent long-duration post-exercise MVC protocols to induce fatigue (Amann et al., 2013; Johnson et al., 2014; Halperin et al., 2014b). The studies by Halperin et al. (2014a, 2014b) support this notion, showing that EMG and peripheral nerve activity in the vastus lateralis were impaired after performing a protocol of 12 MVICs of 5 s each, compared to a single MVIC, following fatigue of the contralateral limb. Additionally, Doix et al. (2013) applied a fatiguing protocol of 100 s of MVIC, which only caused a strength reduction in the contralateral limb after the second set, suggesting that more than one set is required for cross-limb fatigue to occur.

Based on this evidence, the absence of cross-fatigue effects in our study may be attributed to the brief 5-s MVIC protocol used after the fatiguing exercise, the performance of only a single set for each exercise, and the use of submaximal loads. Future studies should investigate whether longer MVIC durations, increased numbers of sets, or heavier loads are necessary to induce cross-fatigue in contralateral homologous muscles following unilateral resistance exercises or exercises with anteroposterior positioning.

Our results also indicated that the Gmed and TFL exhibited similar levels of myoelectric activity in both the DOM limb performing the hip ABD exercise and the N-DOM limb supporting single-leg stance. A likely explanation for the lack of significant differences between limbs is the nature of the exercise, which requires high levels of pelvic stability in the frontal plane while the contralateral limb is abducted. To our knowledge, no previous study has assessed Gmed and TFL activity on both sides of the body simultaneously; our study is the first to do so during this type of exercise. Most previous studies have assessed hip abductor muscle activity

during hip ABD exercises performed on the ground in a lateral decubitus position, with the hip maintained in either a neutral or flexed position (McBeth et al., 2012; Selkowitz et al., 2013; Willcox and Burden, 2013; Sidorkewicz et al., 2014). One of the few exceptions, the study by Brandt et al. (2013), evaluated Gmed activity during hip ABD in a single-leg stance using external elastic resistance with the hip in a neutral position. However, their analysis was limited to the exercising limb only, without assessing the contralateral side.

In our study, we used a variation of the lunge in which the external load was held with the upper limb opposite the anteriorly positioned thigh (contralateral lunge). Stastny et al. (2015) reported higher ipsilateral Gmed activation during the contralateral lunge compared to a lunge with the load on the ipsilateral side. In contrast, our findings showed no difference in Gmed or TFL activation between the DOM and N-DOM sides during the contralateral lunge, suggesting that this loading strategy produced a similar contractile demand on both limbs.

When comparing exercises, no significant differences were observed between the DOM and N-DOM sides during hip ABD (Dom Abd and N-Dom Abd) and the DOM side during the lunge (Dom Lunge). However, regarding mean activation, both Dom Abd and N-Dom Abd elicited higher Gmed activation than the N-DOM side during the lunge (N-Dom Lunge). These findings suggest that the N-DOM limb in the posterior position does not generate sufficient motor demand for pelvic stability to substantially activate the Gmed, whereas the Dom Lunge appears to impose greater demand, although no significant difference was detected between Dom Lunge and N-Dom Lunge for Gmed activation.

In contrast, the TFL exhibited higher activation during hip ABD exercises. For both peak and mean activation, TFL activity was greater on both the DOM and N-DOM sides during hip ABD (Dom Abd and N-Dom Abd) compared to the DOM and N-DOM sides during the lunge (Dom Lunge and N-Dom Lunge). This finding is consistent with expectations because hip flexion during the Dom Lunge reduces TFL length and force-generating capacity. A new observation from our results is that even with the hip extended in the N-Dom Lunge, TFL activation remained low, suggesting that in this movement, the TFL is not required to contribute significantly to hip stabilization. In both clinical and non-clinical contexts, the Gmed to TFL (Gmed:TFL) ratio (Lee et al., 2013; Selkowitz et al., 2013; Sidorkewicz et al., 2014) is frequently used to prescribe exercises aimed at enhancing Gmed activity relative to TFL activity. This is particularly important in orthopaedic conditions characterized by Gmed strength deficits and resulting imbalances between these hip abductor muscles (Merican et al., 2009; Neumann, 2010; Besomi et al., 2020; Strauss et al., 2010; Nakagawa et al., 2012; Hinman et al., 2010; Fredericson et al., 2000; Lee et al., 2012).

Our results indicated that the Gmed:TFL ratio was higher on the DOM side during lunge exercises, while no significant differences were observed on the N-DOM side. Although our results demonstrated higher levels of Gmed activation during hip ABD exercises, when the goal is to emphasize a higher Gmed:TFL ratio, the findings of this study indicate that lunge exercises may be a better option compared to hip ABD.

Limitations

Although our study produced relevant findings that contribute to the scientific literature, we acknowledge certain methodological limitations that should be addressed to improve reproducibility in future research. In this study, we applied a load corresponding to 80% of 10RM because participants experienced difficulty maintaining proper mechanics and exercise rhythm during the 10RM test, prompting the use of a lower load. Future investigations should consider implementing higher loads in unilateral exercises or in anteroposterior lower-limb positions to better evaluate pre-induced fatigue in the contralateral limb. An important limitation of this study was the small sample size, which may have influenced the results. Additionally, the only participants were physically active males without consistent resistance training experience, limiting the generalizability of the findings. Populations with higher training levels may exhibit different physiological adaptations and performance patterns. Therefore, future research should apply the same protocols in trained individuals and/or female participants to evaluate the validity of these findings in contexts with greater sport specificity.

Conclusion

This study provides important and novel insights into the neuromuscular behavior of the Gmed and TFL during unilateral resistance exercises, improving our understanding of exercise selection for both performance and rehabilitation. A key finding is that, although hip ABD exercises are commonly prescribed to target the Gmed, they also elicit significantly greater TFL activation. Such co-activation may be undesirable when the goal is to preferentially strengthen the Gmed while minimizing compensatory strategies associated with excessive TFL recruitment.

In contrast, the lunge exercise—particularly when performed with contralateral loading—demonstrated a more favorable Gmed:TFL activation ratio, even without significantly higher absolute Gmed activation. This finding has important implications for clinical and applied settings, suggesting that exercise selection should not be based only on peak or mean activation of a target muscle, but also on the relative contribution of synergistic muscles. Therefore, prescribing exercises according to muscle activation ratios is a more accurate and

functionally meaningful approach, especially for individuals with hip abductor imbalances, pelvic instability, or conditions such as patellofemoral pain syndrome.

Another key contribution of this study is the finding that both DOM and N-DOM limbs exhibit similar activation levels during unilateral hip ABD exercises performed in single-leg support. This underscores that such exercises require substantial bilateral stabilization, particularly in the frontal plane, and highlights the importance of considering both limbs in training and rehabilitation programs. Furthermore, the absence of cross-fatigue effects suggests that the protocol used—consisting of a single set at 80% of 10RM combined with a brief MVIC—does not provide sufficient stimulus to induce contralateral neuromuscular impairment.

From a practical perspective, the findings of this study support a more strategic and evidence-based approach to exercise prescription. When the primary goal is to enhance Gmed function while limiting TFL dominance, lunge-based exercises may be more effective than isolated hip ABD movements. Moreover, the results encourage practitioners to move beyond simplistic interpretations of muscle activation and adopt a more integrative approach that considers intermuscular coordination and functional demands. Collectively, these findings advance knowledge in strength training and rehabilitation by providing practical, scientifically based guidance for optimizing exercise efficiency and clinical outcomes, while also highlighting the need for further research into cross-fatigue mechanisms under dynamic conditions and their implications for training design.

Use of Generative AI statement: During the preparation of this work, the authors did not use any generative artificial intelligence tools.

Funding details: This work received no funding.

Declaration of conflicts of interest: The authors declare no competing interests.

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