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Resisted Side Stepping: The Effect of Posture on Hip Abductor Muscle Activation

Weakness of the hip abductors is present in individuals with a range of musculoskeletal conditions, including femoroacetabular impingement,[8] iliotibial band syndrome,[17,20] patellofemoral pain,[9,33,40,43] and chronic ankle sprains.[22] While the majority of studies measure overall hip abductor strength, reduced strength is typically interpreted as gluteus medius weakness.[20,21,44] This interpretation is scientifically supported in that the gluteus medius has the largest volume and physiological cross-sectional area of the hip abductors.[18,19] Furthermore, the nonoptimal lower extremity kinematics associated with hip abductor weakness, excessive hip adduction and internal rotation and knee abduction during the weight-acceptance portion of the stance phase,[10,28] is consistent with a reduced activation of the posterior portion of the gluteus medius.[20,21,34]

STUDY DESIGN: Controlled laboratory study, repeated-measures design.

OBJECTIVES: To compare hip abductor muscle activity and hip and knee joint kinematics in the moving limb to the stance limb during resisted side stepping, and to determine whether muscle activity was affected by the posture (upright standing versus squat) used to perform the exercise.

BACKGROUND: Hip abductor weakness has been associated with a variety of lower extremity injuries. Resisted side stepping is often used as an exercise to increase strength and endurance of the hip abductors. Exercise prescription would benefit from knowing the relative muscle activity level generated in each limb and for different postures during the side-stepping exercise.

METHODS: Twenty-four healthy adults participated in this study. Kinematics and surface electromyographic data from the gluteus maximus, gluteus medius, and tensor fascia lata were collected as participants performed side stepping with a resistive band around the ankle, while maintaining each of 2 postures: (1) upright standing and (2) squat.

RESULTS: Mean normalized electromyographic signal amplitude of the gluteus maximus, gluteus medius, and tensor fascia lata was higher in the stance limb than in the moving limb ($P \leq .001$). Gluteal muscle activity was higher, whereas tensor fascia lata muscle activity was lower, in the squat posture compared to the upright standing posture ($P < .001$). Hip abduction excursion was greater in the stance limb than in the moving limb ($P < .001$).

CONCLUSION: The 3 hip abductor muscles respond differently to the posture variations of the side-stepping exercise in healthy individuals. When prescribing resisted side-stepping exercises, therapists should consider the differences in hip abductor activation across limbs and variations in trunk posture. *J Orthop Sports Phys Ther 2015;45(9):675-682. Epub 10 Jul 2015. doi:10.2519/jospt.2015.5888*

KEY WORDS: *electromyography, gluteus maximus, gluteus medius, strengthening, tensor fascia lata*

Gluteus medius weakness is hypothesized to result in compensatory excessive use of the tensor fascia lata (TFL).[5,41] Increased TFL recruitment may subsequently lead to further gluteus medius atrophy.[20] Because the TFL also internally rotates the hip,[34] it is theorized that excessive TFL activity may further exacerbate the abnormal lower extremity movement patterns related to gluteus medius weakness.[5,41]

Therapeutic exercises are commonly used by clinicians to increase gluteus medius strength and enhance functional muscle recruitment patterns. These exercises often include a variation of resisted hip abduction, which activates all of the hip abductors, including the TFL.[34] For some patient populations, it is important for clinicians to be mindful of excessive use of the TFL during therapeutic exercis-

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es, and to select exercises that preferentially increase gluteus medius activation.

One popular hip abductor–strengthening exercise is side stepping with an elastic resistance band secured around the lower extremities. Several studies have compared hip abductor muscle activity during resisted side stepping to other strengthening exercises. Jacobs et al[27] found no difference in gluteus medius activity between resisted side stepping and sidelying abduction, or between weight-bearing and non–weight-bearing standing hip abduction, in patients following total hip arthroplasty. Similarly, Distefano et al[13] found no significant difference in gluteus medius activity during resisted side stepping (61% maximum voluntary isometric contraction [MVIC]) and sidelying hip abduction (81% MVIC). The authors also found gluteus maximus activity to be lower during resisted side stepping (27% MVIC) than during sidelying hip abduction (39% MVIC) and all of the other exercises studied.

To our knowledge, only 2 previous studies[6,42] have measured both gluteus medius and TFL muscle activation during resisted side stepping. Selkowitz et al,[42] using fine-wire electromyography (EMG), found lower TFL (13.1% MVIC) compared to gluteus medius (32.2% MVIC) activation, whereas Cambridge et al[6] reported TFL activity of approximately 21% MVIC compared to 29% MVIC for the gluteus medius.

One variation of this resisted side-stepping exercise is related to the desired amount of hip and knee flexion.[26] Patients can either maintain an upright standing posture while side stepping or assume a squat posture. Cambridge et al,[6] Selkowitz et al,[42] and Distefano et al[13] used resisted side stepping performed in a squat posture, whereas Jacobs et al[27] had participants maintain an upright posture. Because no studies have tested both postures, it is not possible to compare results across studies. Determining changes in muscle activation of the hip abductors based on posture variations is potentially useful to optimize exercise prescription and strengthening programs.

Additionally, it may be clinically important to know the relative muscle activation level of the stance versus the moving limb during resisted side stepping. Youdas et al,[47] using resisted side stepping in a squat posture, found higher levels of muscle activation for the gluteus medius (49.9% MVIC) and gluteus maximus (18.1% MVIC) in the stance limb compared to the moving limb (32.8% MVIC and 12.1% MVIC, respectively). Because 40% MVIC is assumed to be the minimum activation level necessary during an exercise to produce strengthening in untrained individuals,[1] adequate strength stimulus would only occur in the gluteus medius of the stance limb.

As exemplified by individuals with femoroacetabular impingement, who often have a combination of limited hip abduction range of motion[29,31,38] and decreased hip abduction strength,[8] there are potential benefits gained from a better understanding of the hip and knee joint motion that takes place during side stepping. To our knowledge, the kinematics of the hip and knee joint during the side-stepping exercise has not yet been well investigated.

The purpose of this study was to analyze hip abductor (gluteus maximus, gluteus medius, and TFL) muscle activity and selected hip and knee joint kinematics during resisted side stepping to determine the relative level of activation between the stance and moving limbs and the effect of posture (upright standing versus squat). We hypothesized that for all muscles, activation would be greater in the stance versus the moving limb. We also hypothesized that for the gluteal muscles, activation would be greater in the squat posture than in the upright standing posture, and conversely for the TFL.

METHODS

Participants

A convenience sample of 24 healthy college-aged adults (12 male, 12 female; mean ± SD age, 22.9 ± 2.9 years; height, 171.1 ± 10.5 cm; mass, 68.6 ± 12.9 kg) participated in this study. The study protocol was approved by the Boston University Institutional Review Board and written informed consent was obtained from each participant prior to testing. To be included in the study, participants had to be between 18 and 50 years of age and report being healthy. Exclusion criteria included back, hip, knee, or ankle pain of greater than 2 weeks in duration within the previous year.

Instrumentation

A surface EMG system (Bagnoli; Delsys Inc, Natick, MA), with a response frequency of 20-450 Hz, a common-mode rejection ratio of greater than 100 dB, and an input impedance of greater than 10^{15} Ω // 0.2 pF, was used to collect data at a sampling rate of 1000 Hz. A transmitter belt unit was worn by participants during data collection and transmitted the EMG signal to the receiver unit via a shielded cable. Electromyographic data were collected using single differential surface EMG sensors (DE-2.1; Delsys Inc). These sensors have 2 parallel bars that are 1 cm long and 1 mm wide, with a distance of 1 cm between them. The skin was prepared by scrubbing the area with a cotton ball soaked with rubbing alcohol. Electrodes were placed over the muscle bellies of the gluteus maximus, posterior portion of the gluteus medius, and TFL bilaterally, according to manufacturer guidelines for surface electrode placements.[30] A disposable ground electrode was placed on the posterior elbow. Electromyographic signal amplitude for each muscle was visually inspected to ensure proper electrode placement.

Three-dimensional trunk and lower extremity kinematic data were collected using a 10-camera motion-capture system (Vicon; OMG plc, Oxford, UK) at a sampling rate of 100 Hz, and synchronized with the EMG data in Vicon Nexus Version 1.8.5 (OMG plc). Retroreflective markers were placed bilaterally on the participant's trunk, pelvis, and lower extremities, and secured with tape. Specifically, markers were placed over the first and fifth metatarsal heads, the calcanei, the medial and lateral malleoli, the medial and lateral femoral epicondyles, the greater trochanters, the anterior superior iliac spines, the sacrum between the posterior superior iliac spines, the iliac crests, the spinous process of the seventh cervical vertebra, the xiphoid process, and the acromion processes. Plastic shells with 4 noncollinear markers were each placed laterally over the shanks and thighs.[7]

Procedures

After securing the surface EMG electrodes over their desired locations, we collected EMG data during MVIC trials. For the MVICs, manual resistance was applied to each muscle group using standard manual-muscle-testing techniques.[23] Following instruction and a practice trial, participants performed a single repetition and held the contraction for at least 3 seconds, while receiving verbal encouragement.

After reflective markers were properly attached to the participant, we collected a static standing trial with the participant in a neutral posture. This trial was used to create a model that included joint centers for the hips and knees. The medial knee and ankle markers were removed after the static trial so that they did not impede movement.

The participant then stood with each foot aligned with the sides of a 12-inch (approximately 30-cm) square floor tile. A resistive elastic band (TheraBand; The Hygenic Corporation, Akron, OH) was wrapped around the participant's ankles, just proximal to the malleoli, and tied so that it was gently stretched (approximately 110% of full unstretched length). The majority of participants used a red (medium) band, and 2 of the stronger participants used a blue (heavy) band. The resistive band position and tension were not altered between trials, so that the resistance level would likely be the same for each trial. The participant was then instructed to side step a distance of 1 floor tile (12 inches [30 cm]), resulting in the feet being approximately 60 cm apart. The participant then moved the other foot so that the feet were once again approximately 30 cm apart and aligned with the edges of the floor tile. The participant repeated this sequence of movement until reaching the other side of the laboratory, approximately 8 side steps. The participant, facing in the same direction, then side stepped in the opposite direction to return to the starting location. The stepping distance of 1 tile for all participants, instead of a height-adjusted distance, was selected for ease of clinical application and was deemed acceptable given the single-group, repeated-measures design of the study.

Postures

Participants performed resisted side stepping while maintaining each of the 2 postures, (1) upright standing and (2) squat (**FIGURE**). For upright standing, the participant was instructed to stand up straight and maintain that posture while side stepping. For the squat posture, the participant was instructed to squat and to maintain the squat while side stepping. The participant was allowed to "self-select" the squat posture. That is, the participant was not given instructions/feedback with regard to depth of the squat or trunk position during the squat. The order of testing of the postures was randomized.

Data Processing

Raw EMG signals were band-pass filtered between 20 and 390 Hz using a fourth-order Butterworth filter with zero phase lag.[32] Filtered EMG signals were processed using root-mean-square smoothing, with a moving window of 100 milliseconds. Root-mean-square data were normalized to peak mean amplitude calculated over a 10-millisecond period that was measured during MVIC testing.

Marker trajectories were low-pass filtered at 6 Hz using a fourth-order Butterworth filter. Commercially available software (Visual3D; C-Motion, Inc, Germantown, MD) was used to calculate joint kinematics based on the marker data. Knee and hip joint angles were defined as the angle between the distal segment and the proximal segment. Joint angles were determined using a Visual3D 8-segment hybrid model with a Cardan x-y-z (mediolateral, anteroposterior, vertical) rotation sequence.[12] The pelvis was defined using the CODA pelvis model.[2] Trunk segment angles were determined with respect to the global coordinate system.

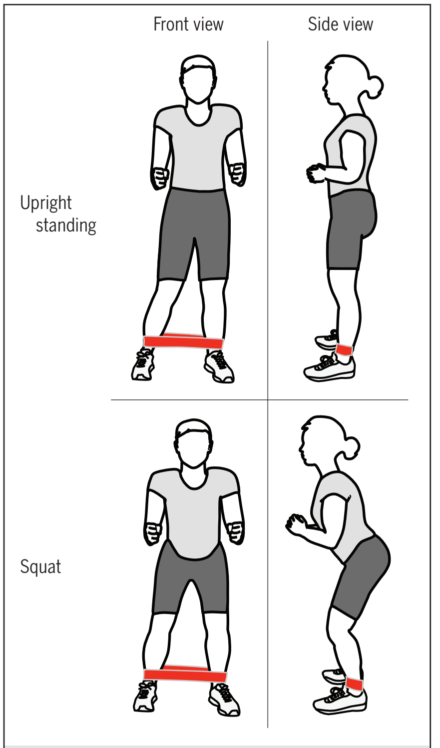

FIGURE. Participant side stepping to the right in the upright standing posture and the squat posture.

Data Analysis

Muscle Activity We calculated the average of the smoothed normalized EMG of each muscle for both the stance and the moving limbs from when the moving foot left the ground (foot-off) until the same foot contacted the ground again (foot-on). Foot-off and foot-on were determined from the lateral velocity of the calcaneal marker of the moving limb, and were verified visually within Visual3D. The stance limb and moving limb were determined by the direction of side stepping, with the stance limb being opposite the direction of stepping. For example, when stepping to the left, data for both the left and right muscles were calculated from left foot-off to left foot-on, with the left limb being the moving limb. Approximately 8 steps were used to calculate the average muscle activity.

Kinematics We were interested in the knee, hip, and trunk positions maintained, as well as the amount of hip abduction occurring at each hip during the side-stepping exercise. Therefore, we calculated the average knee, hip, and trunk flexion angles throughout the side-stepping cycle, as defined by foot-off to subsequent ipsilateral foot-off. Cycle was defined for both the leading limb (in the direction of side stepping) and trailing limb (opposite the direction of side stepping). We also calculated the hip abduction excursion (maximum abduction angle minus minimum abduction angle) of each limb for each step in each posture.

TABLE 1 MUSCLE ACTIVITY LEVEL FOR EACH LIMB IN EACH POSTURE

	Gluteus Maximus	Gluteus Medius	Tensor Fascia Lata
Upright standing posture*			
Moving limb	8.9 ± 4.3	18.7 ± 8.0	45.2 ± 20.3
Stance limb	12.6 ± 6.7	22.9 ± 9.5	56.2 ± 24.5
Squat posture*			
Moving limb	12.1 ± 7.3	23.3 ± 11.2	33.7 ± 16.5
Stance limb	24.6 ± 12.8	35.7 ± 13.8	38.6 ± 25.0
Statistical analysis†			
Limb	<.001	<.001	<.001
Posture	<.001	<.001	<.001
Side	.756	.610	1.000
Limb by posture	<.001	<.001	.066

*Values are mean ± SD percent maximum voluntary isometric contraction.
†Values are P values. Statistical analysis included linear regression with generalized estimating equation correction.*

TABLE 2 PAIRWISE COMPARISONS FOR THE GLUTEAL MUSCLES FOR EACH LIMB IN EACH POSTURE*

Condition	Gluteus Maximus	Gluteus Medius
Upright standing		
Moving versus upright standing, stance	–3.7 (–5.3, –2.0)†	–4.2 (–5.8, –2.6)†
Moving versus squat, moving	-3.2 (–4.8, –1.5)†	–4.6 (–7.1, –2.1)†
Moving versus squat, stance	–15.7 (–20.1, –11.2)†	–17.1 (–21.0, –13.1)†
Stance versus squat, moving	0.5 (–1.5, 2.5)	–0.4 (–3.1, 2.2)
Stance versus squat, stance	–12.0 (–15.4, –8.6)†	–12.9 (–15.9, –9.8)†
Squat		
Moving versus squat, stance	–12.5 (–16.4, –8.6)†	–12.5 (–15.4, –9.5)†

*Values are mean difference between conditions (95% Wald confidence interval) in percent maximum voluntary isometric contraction.
†Significant differences between conditions (P<.001).*

Statistical Analysis

Muscle Activity To determine differences in muscle activity, we ran 3 linear regressions, 1 for each muscle, with 3 within-subject factors: posture (upright standing versus squat), analyzed limb (stance versus moving), and side (left versus right side of the body). As there were repeated measures within each subject, a generalized estimating equation (GEE) correction was applied to the model. Separate models were run for each muscle.

Kinematics We ran 3 linear regressions with GEE correction to compare the average knee, hip, and trunk flexion angles between the 2 postures. The 3 within-subject factors were posture (upright standing versus squat), analyzed limb (leading versus trailing), and side (left versus right side of the body). We also used linear regression with GEE correction to compare the hip abduction excursion of the leading limb to that of the trailing limb throughout the cycle in each posture and for each side.

All analyses were conducted in IBM SPSS Statistics Version 20 (IBM Corporation, Armonk, NY), with an alpha level of .05. The Holm sequentially rejective test was used to adjust reported *P* values for the linear regressions to reduce type I error.[25] The Holm sequential procedure is less conservative than the standard Bonferroni correction,[14] which can significantly increase type II error.[37] All levels of the GEE that were significant were followed up with pairwise comparisons.

The effect size (ES) for paired comparisons was computed using Cohen *d* and the pooled variance across conditions for each muscle. The ES can be interpreted as small, medium, or large, based on values of 0.2, 0.5, and 0.8, respectively.[11] The mean difference between conditions and 95% Wald confidence interval (CI) for the difference were also calculated.

RESULTS

Muscle Activity

FOR THE GLUTEUS MAXIMUS, GLUTEUS medius, and TFL, the individual GEE models revealed main effects of posture (*P*<.001) and of ana-

TABLE 3 Average Knee, Hip, and Trunk Flexion Angles and Hip Abduction Excursion of the Leading Limb and Trailing Limb

	Average Knee Flexion	Average Hip Flexion	Average Trunk Flexion	Hip Abduction Excursion
Upright standing posture*				
Leading limb	7.1 ± 6.8	13.7 ± 7.6	9.7 ± 5.5	11.0 ± 2.1
Trailing limb	10.4 ± 6.5	15.2 ± 7.4	9.7 ± 5.6	16.5 ± 2.5
Squat posture*				
Leading limb	41.1 ± 9.2	43.4 ± 13.3	25.0 ± 8.5	9.9 ± 2.2
Trailing limb	42.7 ± 8.6	44.4 ± 13.2	25.0 ± 8.5	15.2 ± 2.8
Statistical analysis†				
Limb	<.001	<.001	.595	<.001
Posture	<.001	<.001	<.001	<.001
Side	1.000	1.000	1.000	.696
Limb by posture	<.001	.016	.701	.719

*Values are mean ± SD deg.
†Values are P value. Statistical analysis included linear regression with generalized estimating equation correction.

lyzed limb (P<.001) (**TABLE 1**). There was also an interaction effect between limb and posture (P<.001) for the gluteal muscles. There were no effects of side (P≥.610).

For the gluteus maximus and gluteus medius, average root-mean-square EMG signal amplitudes were greater in the squat posture compared to the upright standing posture. Analysis of the interaction using pairwise comparisons revealed that average muscle activation of the gluteus maximus and gluteus medius was greater in the stance limb than in the moving limb for both the upright standing posture (P≤.001; ES, 0.44 and 0.39, respectively) and the squat posture (P≤.001; ES, 1.49 and 1.15, respectively), with the difference between limbs, as reflected by the larger ES values, being greater for the squat posture (**TABLE 2**). The average EMG signal amplitudes in the stance limb were largely greater in the squat posture than in the upright standing posture (P≤.001; ES, 1.43 for the gluteus maximus and 1.19 for the gluteus medius). There was, however, no difference between the moving limb in the squat position and the stance limb in the upright position (P≥.633).

For the TFL, evaluation of main effects revealed that the average root-mean-square EMG signal amplitudes were smaller in the squat posture than in the upright standing posture (P<.001; ES, 0.70) (**TABLE 2**). The activity in the stance limb was higher than in the moving limb (P = .001; ES, 0.40).

Kinematics

The GEE revealed an effect of posture on average knee, hip, and trunk flexion angle (P<.001) (**TABLE 3**). For the knee and hip, there was also an effect of limb (P<.001) and an interaction between limb and posture (P≤.016). There was no effect of limb or interaction between limb and posture for trunk flexion (P≥.595). The average trunk flexion angle was largely greater in the squat posture than in the upright standing posture (P<.001; ES, 2.14; mean difference, 15.3°; 95% CI: 13.2°, 17.5°). The average knee and hip flexion angles were also largely greater in the squat posture than in the upright standing posture in both the leading limb (P<.001; ES, 4.22 for the knee and 2.75 for the hip) and trailing limb (P<.001; ES, 4.23 for the knee and 2.72 for the hip) (**TABLE 4**). The knee and hip of the leading limb were in slightly less flexion than those of the trailing limb in both the squat posture (P<.001; ES, 0.19 for the knee and 0.07 for the hip) and the upright standing posture (P<.001; ES, 0.49 for the knee and 0.20 for the hip).

For hip abduction excursion, the GEE revealed a main effect of posture (P<.001) and of limb (P<.001) (**TABLE 3**). Hip abduction excursion was approximately 1° more in the upright standing posture than in the squat posture (P<.001; ES, 0.71; mean difference, 1.2°; 95% CI: 0.8°, 1.6°) and approximately 5° more in the trailing hip than in the leading hip (P<.001; ES, 2.42; mean difference, 5.4°; 95% CI: 4.2°, 6.7°). There was no effect of side (P≥.696) for any of the kinematic variables.

DISCUSSION

The primary findings of this study were that during resisted side stepping, (1) muscle activity was greater in the stance limb than in the moving limb, (2) muscle activity in the TFL was less, whereas activity in the gluteal muscles was more, in the squat posture than in the upright posture, and (3) hip abduction excursion was greater in the stance hip than in the moving hip.

Understanding the muscular requirements of both the stance and moving limbs is important when treating patients with hip abductor weakness. Our results in healthy individuals indicate that resisted side stepping required higher activation of the hip abductors of the trailing stance limb than that of the leading limb. Greater hip abductor muscle activity in the stance limb can be explained biomechanically. During resisted side stepping, the hip abductors of the stance limb have to produce sufficient torque to stabilize the pelvis and superimposed segments against gravity,[3,34-36] and also to translate the pelvis in the direction of side stepping. Additionally, the hip abductors of the stance limb stabilize the pelvis to provide a stable fixation for the contralateral hip abductors to move the hip into abduction. By contrast, the hip abductors of the moving limb only have to produce torque to move the limb against gravity and to overcome the torque created by the elastic band. Our findings are in agreement with those of Youdas et al,[47] who reported greater activation of the gluteus maximus and gluteus medius in the stance limb (18.1% and 49.9% MVIC, respectively) than in the moving limb (12.1% and 32.8%, respectively) during resisted side stepping in a squat posture. The current study expands on their findings and shows similar results for both the upright standing posture and the squat posture, as well as for the TFL.

Bolgla and Uhl[3] have also previously investigated the magnitude of activation of the hip abductors during various exercises. In their study, they determined that abduction of the left hip while standing on the right limb, without external resistance, required 42% MVIC of the right gluteus medius. In comparison, abduction of the right hip when standing on the left limb only required 33% MVIC of the right gluteus medius. Our study extends their finding to the gluteus maximus and TFL and tests a slightly more flexed hip and knee position as well as a more dynamic movement against external resistance.

The muscle activity of the TFL was less in the squat posture than in upright standing. Biomechanically, the TFL, while a hip abductor, is also a hip flexor.[34] In upright standing, the TFL is active to both abduct the hip and to balance the pelvis on top of the stance limb. In upright standing, activation of the gluteals would extend the hip (or posteriorly rotate the pelvis) if not for the counterbalancing hip flexion moment of the TFL. In a squat position, however, the center of mass of the trunk is anterior to the hip, creating a hip flexion moment due to gravity, and thus reducing the need for the hip flexion moment from the TFL. Therefore, increased activity from the TFL would be counterproductive. This biomechanical explanation for the decreased TFL activity in the squat posture is further supported by the findings of Willcox and Burden,[45] who investigated the effect of pelvis position and hip angle on hip abductor muscle activity during a sidelying clam exercise. They found that activation of the TFL was not affected by pelvis position or hip angle in the non–weight-bearing sidelying position. This indicates that our finding likely is due to biomechanical influences in weight bearing and not simply the position of the hip and pelvis.

TABLE 4 PAIRWISE COMPARISONS FOR AVERAGE HIP AND KNEE FLEXION ANGLES FOR EACH LIMB AND EACH POSTURE*

Condition	Knee Flexion	Hip Flexion
Upright standing		
Leading versus upright standing, trailing	3.3 (2.4, 4.1)†	–1.5 (–2.1, –0.9)†
Leading versus squat, leading	33.9 (30.4, 37.5)†	–29.8 (–33.1, –26.4)†
Leading versus squat, trailing	35.6 (32.2, 39.0)†	–30.7 (–34.2, –27.2)†
Trailing versus squat, leading	30.7 (26.9, 34.4)†	–28.2 (–31.6, –24.9)†
Trailing versus squat, trailing	32.3 (28.8, 35.9)†	–29.2 (–32.6, –25.8)†
Squat		
Leading versus squat, trailing	1.7 (1.0, 2.3)†	–1.0 (–1.5, –0.5)†

**Values are mean difference between conditions (95% Wald confidence interval) in degrees.*
†Significant differences between conditions ($P<.001$).

Because it is hypothesized that the TFL can be a primary hip abductor if there is gluteus medius weakness, which may lead to further underuse of the gluteal muscles,[5,41] it is important to understand how alterations in exercise posture could help preferentially activate the gluteal muscles while reducing activation of the TFL. In this study, when compared to the upright posture, side stepping in a squat posture led to reduced activation of the TFL, while concurrently increasing gluteus medius and gluteus maximus muscle activity. This variation of the side-stepping exercise may be clinically advantageous if targeting activation of the gluteal muscles is desired. But it must be noted that the relative level of activation of the TFL based on normalized EMG signal amplitude was, on average, higher than that of the gluteal muscles for both postures.

While EMG normalization presents numerous challenges that preclude the strict interpretation of muscle activation on a scale of 0% to 100%,[4,46] the normalized EMG data in our study could be interpreted using the classification system proposed by Escamilla et al[16] and Reiman et al,[39] in which 0% to 20% MVIC indicates low muscle activity, 21% to 40% MVIC indicates moderate muscle activity, and 41% to 60% MVIC indicates high muscle activity. Using this classification, gluteus maximus activity was low, except for the stance limb in the squat posture, where it was moderate. Activation of the gluteus medius was moderate in both limbs in the squat posture, but only for the stance limb in the upright standing posture. Tensor fascia lata activity level, however, was moderate bilaterally in the squat posture and high bilaterally in the upright standing posture. It has been suggested that moderate activity may be necessary for improvement in strength,[1] whereas lower activity levels may result in improved muscle endurance[16] or neuromuscular re-education.[15] Therefore, the levels of muscle activity measured in this study suggest that resisted side stepping addresses gluteal endurance or neuromuscular control more than it addresses strength. However, the level of band resistance used in this study was purposefully kept low (a medium-resistance band was used with the majority of participants) to minimize the effects of fatigue while testing multiple conditions. It is assumed that the use of greater elastic resistance would increase the level of muscle activation if strengthening were desired.

While clinicians typically focus on muscle activity levels during these exercises, it is also important to consider joint movement. As expected, knee, hip, and trunk flexion were greater in the squat posture than in the upright standing posture. Our mean hip and trunk flexion angles were substantially higher than those previously reported by Cambridge et al.[6] This difference could be due to differences in task performance; however, based on their figures, our participants were in a similar amount of hip and trunk flexion. The difference could also be due to differences in the models used for angle calculations.

During resisted side stepping, the trailing (stance) limb had greater hip abduction excursion than the leading (moving) limb. The greater hip abduction on the stance limb seems to occur as weight is shifted over to the leading limb after it contacts the ground. This knowledge is particularly important when treating patients, such as those with femoroacetabular impingement, who have concurrent decreased hip abduction range of motion[29,31,38] and decreased hip abduction strength.[8]

There are limitations due to the design of this study. We selected only healthy asymptomatic individuals to participate in this study to allow us to investigate muscle activity without pain affecting the results.[24] Furthermore, we did not measure the level of resistance provided by the band. However, the band was not adjusted between stepping direction or posture, and the same step distance was used, making it likely that the resistance level was the same between testing conditions for a given individual. We also purposefully kept the level of resistance low. As we were testing multiple conditions, the low level of resistance helped to lessen the potential effect of muscle fatigue during testing. Overall, caution should be used in interpreting the MVIC values. Muscle activity was only analyzed during the concentric phase and only measured from a single location on each muscle. Only a single position was used to elicit the MVIC, which contributed to the high variability of normalized EMG. Additionally, given the complex architecture of the gluteal muscles, the normalized EMG may not accurately reflect level of muscle activation. Last, we did not provide cues to the participants during side stepping regarding trunk position or cadence of movement. The goal was to capture typical performance with minimal instruction.

CONCLUSION

The findings of this study indicate that during resisted side stepping, the hip abductors on the stance limb are more active than the hip abductors on the moving limb. In the squat posture, the activity of the gluteal muscles is increased, whereas the activity of the TFL is reduced, compared to the upright standing posture. Overall, the highest gluteal muscle activation is obtained in the squat position while side stepping away from the target hip. The hip abduction excursion of the stance hip is greater than the moving hip. These findings can help guide exercise prescription. ◉

KEY POINTS

FINDINGS: During resisted side stepping, the muscle activity in the hip abductors is greater in the stance limb than in the moving limb. The activity of the gluteal muscles is increased, whereas that of the TFL is reduced, in the squat posture compared to the upright standing posture. The stance hip has greater hip abduction excursion than the moving hip.

IMPLICATIONS: This information can guide the clinician when selecting the direction and posture to be used during resisted side stepping for a patient with hip abductor weakness.

CAUTION: This study was conducted in healthy asymptomatic participants without known hip abductor weakness and without any potential muscle activation or joint motion impairments related to disability or injury.

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