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Ultrasonography of Gluteal and Fibularis Muscles During Exercises in Individuals With a History of Lateral Ankle Sprain

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Context: Individuals with a history of lateral ankle sprains (LASs) have ankle and hip neuromuscular changes compared with those who do not have a history of LAS.

Objective: To compare gluteus maximus (GMax), gluteus medius (GMed), and fibularis longus and brevis muscle activation using ultrasound imaging during tabletop exercises and lateral resistance-band walking in individuals with or without a history of LAS or chronic ankle instability (CAI).

Design: Cross-sectional study.

Patients or Other Participants: Sixty-seven young adults (27 males, 40 females). Groups were healthy = 16, coper = 17, LAS = 15, CAI = 19. The number of previous sprains was 0 ± 0 in the healthy group, 1.1 ± 0.3 in the coper group, 2.9 ± 2.4 in the LAS group, and 5.3 ± 5.9 in the CAI group.

Main Outcome Measure(s): Ultrasound imaging measures of fibularis cross-sectional area (CSA) were collected during nonresisted and resisted ankle eversion. Gluteal muscle thicknesses were imaged during nonresisted and resisted side-lying abduction and during lateral resistance-band walking exercises (lower leg and forefoot band placement). Separate 4 × 2 repeated-measures analyses of variance and post hoc Fisher least significant difference tests were used to assess activation across groups and resistance conditions.

Results: All groups demonstrated 3.2% to 4.1% increased fibularis CSA during resisted eversion compared with nonresisted. During side-lying abduction, the LAS and CAI groups displayed increased GMax thickness (6.4% and 7.2%, respectively), and all but the CAI group (–0.4%) increased GMed thickness (5.3%–11.8%) with added resistance in hip abduction. During band walking, the healthy and LAS groups showed increased GMax thickness (4.8% and 8.1%, respectively), and all groups had increased GMed thickness (3.0%–5.8%) in forefoot position compared with the lower leg position. Although the values were not different, copers exhibited the greatest amount of GMed thickness during band-walking activities (copers = 23%–26%, healthy = 17%–23%, LAS = 11%–15%, CAI = 15%–19%).

Conclusions: All groups had increased fibularis CSA with resisted eversion. In side-lying hip abduction, individuals with CAI had greater GMax thickness than GMed thickness. Ultrasound imaging of fibularis CSA and gluteal muscle thickness may be clinically useful in assessing and treating patients with LAS or CAI.

Key Words: imaging, hip muscles, lower extremity

Key Points

- Thickness of the gluteal muscles and cross-sectional area of the fibularus muscles increased when resistance was added to exercises.
- During side-lying abduction, individuals with chronic ankle instability may rely on gluteus maximus activity, whereas other groups displayed greater gluteus medius muscle thickness.
- Copers exhibited greater gluteal muscle activation during resisted band-walking tasks.
- Clinicians could use this information to target hip-muscle activity during rehabilitation in patients with a history of an ankle sprain.

Lateral ankle sprains (LASs) are common musculoskeletal injuries among the general population.[1] Many individuals who incur an acute LAS do not perceive their injury as being substantial[2] and do not seek formal medical care.[3] This is concerning as up to 73% of individuals report reinjury,[2] with a history of LAS being the most frequent risk factor for sustaining a subsequent sprain.[3] *Copers* constitute a subset of individuals who sustain an isolated LAS and return to moderate activity without residual symptoms or episodes of instability.[4] Although many individuals can be classified as copers and do not have persistent ankle impairment or activity limitations after the initial injury, up to 40% will develop chronic ankle instability (CAI).[5] Individuals with CAI describe feelings of instability or episodic "giving way" and physical or subjective dysfunction lasting more than 1 year after the initial LAS.[6] The goal of an early treatment program is to minimize long-term health problems, such as CAI.

Sensorimotor impairment is common after LAS. Strength differences in fibularis muscle function have been reported in those with a history of LAS.[7–9] Individuals with CAI have demonstrated decreased eversion strength in neutral (mean difference = 0.46 N·m/kg) and plantar-flexed (mean difference = 0.33 N·m/kg) ankle positions compared with healthy controls.[9] Interestingly, no differences in surface electromyography (EMG) amplitudes were identified between the groups during active eversion for the fibularis longus or brevis muscles.[9] Strengthening exercises have been recommended for targeting eversion weakness in individuals with a history of LAS.[8,9] Various exercises to strengthen these muscles in both open and closed chain positions have been suggested for patient populations. However, few researchers have examined muscle function during therapeutic exercises or evaluated the effects of modifying exercises on function in the presence of an impairment. Studying this type of activity is important because it more closely resembles the activities performed after an LAS.

In addition to changes at the ankle joint, individuals with CAI have shown alterations at more proximal joints during various functional tasks compared with healthy controls.[10,11] The gluteal muscles play an important role in global movement of the hip as well as pelvic stabilization during closed chain exercises.[12] Decreased hip-abduction strength has been identified[13] as an intrinsic risk factor for sustaining an ankle sprain in youth soccer athletes. Furthermore, people with a history of unilateral ankle sprains have displayed diminished ipsilateral hip-abductor and ankle plantar-flexor strength in the affected limb compared with the unaffected limb.[14] Thus, it seems reasonable to assess and target the gluteal muscles during rehabilitation.

Ultrasound imaging (USI) is a noninvasive technique used to visualize anatomic structures and is becoming more commonly used in clinical practice. Cross-sectional area (CSA) and muscle thickness can be measured using USI.[15,16] An activation ratio (AR) can be calculated by normalizing either the CSA or muscle thickness to its resting size to indicate activation above a resting or quiet state.[17] This technique could be thought of as more of a mechanical approach to measuring muscle activity, whereas EMG is more of an electrical approach. Ultrasound imaging has not been extensively used to study muscle activity in individuals with a history of LAS. To our knowledge, the authors of only 1 published study[18] used USI to measure differences in the fibularis longus and brevis muscles between individuals with or without a history of LAS. In the LAS group, the rested CSA of the fibularis longus muscle was smaller than that of the healthy control group.[18]

Surface EMG is a widely accepted and commonly used electrophysiological modality in research[19] that measures neuromuscular electrical activity deep to the electrode.[20] However, this modality has several limitations, including cross-talk from surrounding muscles, electromechanical delay, and irritation or discomfort (fine-wire EMG).[19] Electromyography is frequently used in the research setting, but few practicing clinicians have access to or the training to employ this modality in clinical practice.

To better comprehend any muscular involvement related to the development of CAI, it is necessary to understand muscle function in copers and individuals with a recent LAS. Identifying changes early in the LAS group and later in the CAI group compared with copers may help us to better understand which muscles should be targeted during rehabilitation exercises to have the largest effects. Thus, the purpose of our study was to use USI to measure fibularis and gluteal muscle activity during side-lying and lateral band-walking activities among healthy individuals, copers, and those with LAS or CAI. To our knowledge, no investigators have used USI to describe the gluteal muscles and only 1 group[18] compared the fibularis muscles in individuals with or without a history of ankle sprain.

METHODS

Design

We conducted a descriptive laboratory study using a cross-sectional design. Our independent variable was group (healthy, coper, LAS, and CAI), and our dependent variables were ARs for each muscle (gluteus maximus [GMax], gluteus medius [GMed], and fibularis muscle group) and resistance condition for tabletop exercises (nonresisted and resisted) and during lateral band walking (lower leg and forefoot band placement).

Participants

A convenience sample of 67 individuals (27 males, 40 females; healthy = 16, coper = 17, LAS = 15, CAI = 19) with or without a history of an LAS volunteered to participate in this study (Table 1). This study was part of a larger investigation of foot impairments and functional limitations after LAS and CAI.[21] All participants completed the Godin Leisure Time Questionnaire and reported being physically active 3 times per week for at least 20 minutes. Volunteers were excluded if they had a self-reported history of fracture or surgery to the leg or foot, had any neurologic disorder that might affect balance (eg, diabetes mellitus, lumbosacral radiculopathy), had any soft tissue disorder (eg, Marfan syndrome, Ehlers-Danlos syndrome), were pregnant, or had any contraindication to manual therapy. Healthy individuals were excluded if they had any history of ankle or foot sprain or pain. All participants provided informed consent, and this study was approved by the Institutional Review Board for Health Sciences Research at the University of Virginia in compliance with all applicable federal regulations governing the protection of human participants (#18550).

Copers were defined as having experienced 1 significant LAS at least 12 months before study participation and no episodes of giving way or perceived instability (Identification of Functional Ankle Instability [IdFAI] score ≤10, Foot and Ankle Ability Measure [FAAM]–Activities of Daily Living [ADL] score ≥99%, and FAAM–Sport score ≥97%).[4] The *LAS* group was defined as having sustained a significant LAS that affected function between 2 and 8 weeks before the study. Individuals in the LAS group could have a history of more than 1 ankle sprain and were not included based on FAAM–ADL, FAAM–Sport, or IdFAI score; however, they completed the questionnaires for demographic purposes. Chronic ankle instability participants were classified according to the International Ankle Consortium guidelines.[6] Individuals with *CAI* had to have incurred at least 1 significant LAS at least 12 months before

Table 1. Participants' Demographic Information

Characteristic	Group, Mean ± SD			
	Healthy	Coper	Lateral Ankle Sprain	Chronic Ankle Instability
Sex (males : females), No.	8 : 8	6 : 11	8 : 7	5 : 14
Age, y	19.8 ± 0.8	20.4 ± 2.1	22.0 ± 4.3	20.9 ± 4.8
Height, cm	172.9 ± 10.9	170.9 ± 9.0	174.2 ± 7.7	168.0 ± 9.1
Mass, kg	69.6 ± 15.2	68.9 ± 9.6	72.6 ± 13.0	70.8 ± 14.6
Ankle sprains, No.[a]	0 ± 0	1.1 ± 0.3	2.9 ± 2.4	5.3 ± 5.9
Time since last sprain, mo[a]	0 ± 0	59.3 ± 39.4	0.9 ± 0.6	19.6 ± 13.9
Foot and Ankle Ability Measure score[a]	99.9 ± 0.25	99.4 ± 1.7	76.6 ± 15.3	88.8 ± 6.9
Foot and Ankle Ability Measure–Sport score[a]	100 ± 0	99.3 ± 2.0	46.7 ± 26.9	69.4 ± 16.0
Identification of Functional Ankle Instability score[a]	0.6 ± 1.0	6.9 ± 2.4	23.9 ± 5.3	23.7 ± 3.6
Godin Leisure Time Questionnaire score	81.2 ± 28.2	82.1 ± 72.0	43.3 ± 26.4	71.6 ± 45.4

[a] Difference between groups.

participation, had not sprained their ankle within 8 weeks of participation, experienced sensations of giving way or residual perceived instability, and scored >10 on the IdFAI, <90% on the FAAM–ADL, and <85% on the FAAM–Sport. Participants' demographic information is detailed in Table 1.

Instrumentation

Ultrasound. An ultrasound unit (model Acuson Freestyle; Siemens, Mountain View, CA) with an 8-MHz wireless linear transducer was used to visualize and obtain images of the GMax, GMed, and fibularis muscles. Images were obtained with participants in side-lying position for the tabletop scans and while standing for the lateral band-walking exercises (Figure 1). For the standing and band-walking images of the gluteal muscles, the ultrasound transducer was secured in a foam block and placed on the participant's hip using an elastic band (Figure 1).[22] The transducer was postioned so that both gluteal muscles were visualized in the same image and both fibularis muscles were visualized in the same display (Figure 2).

Resistance Band. Heavy resistance was provided for band-walking exercises using green exercise tubing (Thera-Band, Akron, OH).

Procedures

For each exercise, only the affected limb was assessed. In participants with bilateral CAI, the self-perceived worse ankle was tested. The healthy group's limbs were assessed in random order using a Latin square.

Tabletop Exercises. Participants performed tabletop exercises while in side-lying position. The CSA images for the fibularis muscles were taken at 50% of the distance between the fibular head and lateral malleolus (Figure 1).[18] The test limb was placed on a support block, and the contralateral limb was bent under the participant. For the resting images, the participant was instructed to relax fully. Nonresistance fibularis images were taken when the individual maximally everted the foot. Resistance images were taken in the same position with manual resistance applied by a researcher.

For the GMax and GMed thickness images, the ultrasound probe was placed midway between the iliac crest and greater trochanter where both muscles could be visualized using a technique similar to one previously described (Figure 1).[22,23] Resting measures were taken with the participant side lying and the legs fully relaxed. Nonresistance hip-abduction images were taken when the participant abducted the hip so that the foot was 25.4 cm above the tabletop. Resistance images were taken in the same position as the nonresistance images; however, manual resistance was provided by a researcher and was not standardized. Participants were asked to provide maximal force against resistance and not let the researcher "break" their position. Contractions for all side-lying tabletop measures were isometric. Three images of each condition (rested, nonresistance, resistance) were obtained for the gluteal and fibularis muscles. All images were

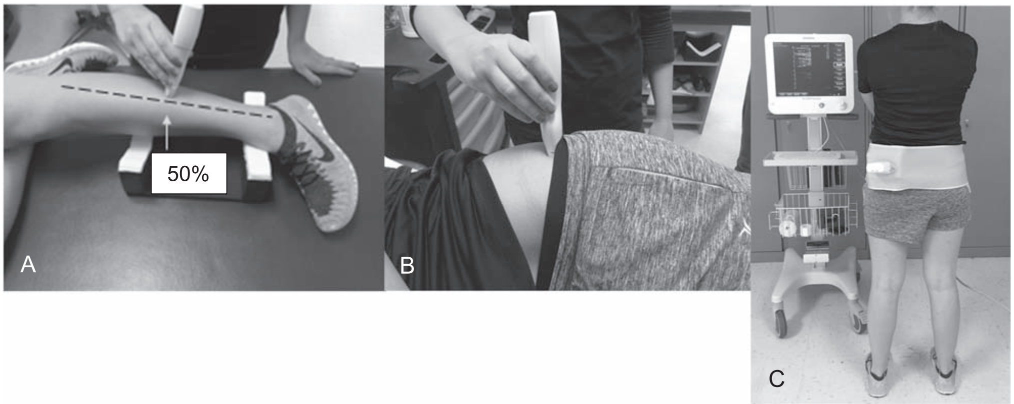

Figure 1. Transducer placement for fibularis and gluteal muscles. A, Fibularis muscle transducer placement. B, Tabletop gluteal muscle transducer placement. C, Quiet standing gluteal transducer placement.

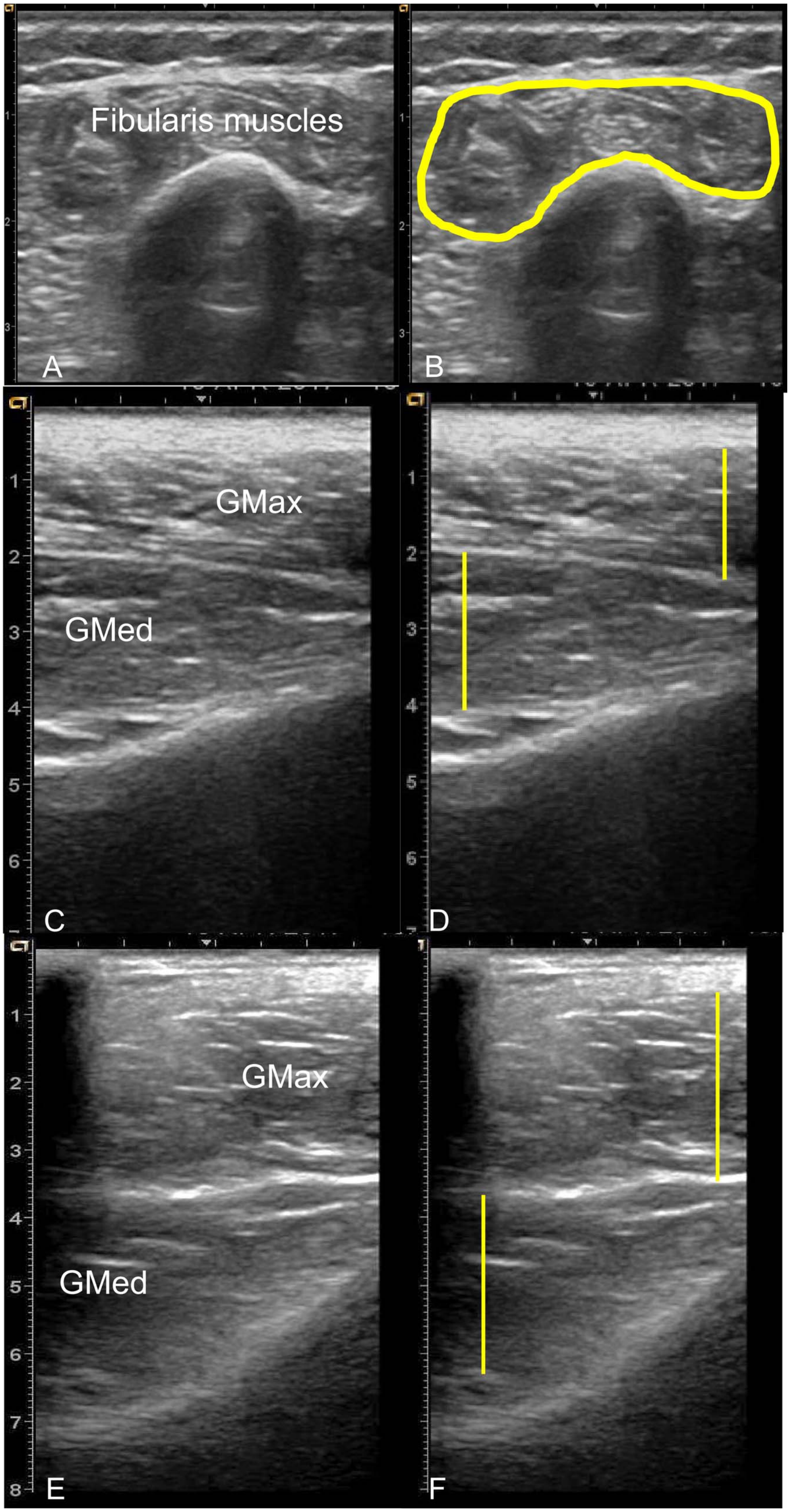

Figure 2. Ultrasound images for the fibularis and gluteal muscles and the corresponding measurement technique. A, Reference image. B, Cross-sectional area measurement. C, Tabletop reference image. D, Thickness measurement. E, Standing reference image. F, Thickness measurement. Abbreviations: GMax, gluteus maximus; GMed, gluteus medius.

captured by a single researcher (J.J.F.) and measured by another researcher (R.M.K.).

Band-Walking Exercises. The ultrasound transducer was placed in a foam block and secured to the hip of the affected limb using an elastic band in the standing position to visualize the GMax and GMed using a technique similar to that used previously (Figure 1).[22] Participants performed 3 sets of 5 lateral band walks while wearing a heavy resistance–level band (placed in each location: lower leg, forefoot) in the direction of the affected side. The tension on the band was not standardized; however, participants were asked to step as widely as possible against the resistance band. One image for each set of lateral band walks was obtained, for a total of 3 images. The band was placed over the lateral malleolus for the lower leg site and over the metatarsals for the forefoot site. The test limbs of healthy participants were randomly assigned and, therefore, the direction in which to perform the task was assigned based on which limb was included in the analysis. Participants were instructed to maintain a partial-squat position and to take 5 lateral steps as widely as they could in the direction of the test limb. Images were taken when the foot contacted the ground at the maximal width of the step. Our method of band walking was intended to simulate exercises used in clinical rehabilitation.

All ultrasound images were taken by a board-certified orthopaedic physical therapist with 15 years of clinical experience and 2 years of USI experience. The images were measured by an athletic trainer with 3 years of clinical experience and 1 year of USI experience who was blinded to group assignments.

Data Processing

Images were measured using ImageJ (version 1.50i; National Institutes of Health, Bethesda, MD). In each condition, 3 images were obtained. The average of the 3 measurements was used in the calculations for ARs in each position. Muscle-thickness measures (cm) were obtained by measuring from the inferior aspect of the superior border of the muscle to the superior aspect of the inferior border of the muscle at the widest portion (Figure 2).[22] Cross-sectional area was determined by tracing the interior aspect of the muscle border to calculate the area (cm^2).[18] Activation ratios for muscle thickness, CSA, and functional ARs were calculated using the following formulas:

$$\text{Thickness AR} = \frac{\text{Muscle Thickness During Abduction}}{\text{Muscle Thickness During Rest}}$$

$$\text{CSA AR} = \frac{\text{Muscle CSA During Eversion}}{\text{Muscle CSA During Rest}}$$

$$\text{Functional AR} = \frac{\text{Muscle Thickness During Band Walking}}{\text{Muscle Thickness During Quiet Standing}}$$

Statistical Analysis

We performed separate 4 × 2 repeated-measures analyses of variance for each dependent variable. The between-subjects factor was group (healthy, coper, LAS, CAI) and the within-subject factor was resistance condition (tabletop: nonresistance or resistance; band walk: lowerleg or forefoot resistance). The post hoc Fisher least significant difference test was conducted when a significant main effect or interaction was identified. The a priori level of significance was set at $P \leq .05$ for all analyses. All data were analyzed using SPSS (version 24.0; IBM Corp, Armonk, NY).

Table 2. Resting Values for Muscle Cross-Sectional Area (CSA) for the Fibularis Muscles and Thickness for the Gluteus Medius (GMed) and Gluteus Maximus (GMax) Muscles[a]

	Group, Mean ± SD			
Variable	Healthy	Coper	Lateral Ankle Sprain	Chronic Ankle Instability
Fibularis CSA, cm^2	3.7 ± 0.8	3.7 ± 0.8	3.7 ± 0.9	3.3 ± 0.7
Thickness, cm				
Tabletop GMed	2.2 ± 0.5	2.0 ± 0.4	2.3 ± 0.4	2.4 ± 0.3
Tabletop GMax	2.4 ± 0.5	2.4 ± 0.5	2.5 ± 0.7	2.5 ± 0.4
Standing GMed	2.2 ± 0.5	2.0 ± 0.4	2.3 ± 0.4	2.4 ± 0.3
Standing GMax	2.4 ± 0.6	2.4 ± 0.5	2.5 ± 0.6	2.4 ± 0.5

[a] No differences among groups.

Intraclass correlation coefficient (ICC [3,1]) values were calculated to determine the intratester reliability of USI measures. Excellent intraclass correlation values were found for the 3 images in the fibularis group (>0.99 for rest, nonresisted, resisted), the GMax (tabletop: >0.99 for rest, nonresisted, resisted; band walking: 0.98 for ankle and forefoot sites), and the GMed (tabletop: >0.99 for rest, nonresisted, resisted; band walking: 0.98 for the ankle, 0.97 for the forefoot).

RESULTS

Demographics

The groups were not different in age, height, or mass. Differences were present in the number of ankle sprains, months since the last ankle sprain, and IdFAI, FAAM–ADL, and FAAM–Sport scores ($P < .001$ for all), as expected based on the inclusion and exclusion criteria. Resting measures of thickness and CSA were not different among groups (Table 2).

Tabletop Measures

Significant main effects for resistance condition were observed in the fibularis muscles ($P < .001$) and the GMax ($P = .029$) for the tabletop exercises. All groups demonstrated increases in AR for the fibularis muscles with resisted compared with nonresisted eversion (% increase: healthy = 3.7%, coper = 3.9%, LAS = 3.2%, CAI = 4.1%). Both the LAS (6.4%) and CAI (7.2%) groups demonstrated increased ARs in the GMax during hip abduction with resistance versus no resistance. A significant resistance-by-group interaction ($P = .007$) was identified for the GMed (Table 3). Post hoc results for the significant resistance main effects and resistance-by-group interactions are detailed in Figure 3. No other significant group main effects or interactions for any muscle were observed.

Table 3. Post Hoc Least Significant Difference Analysis of the Significant Position-by-Group Interactions for Gluteus Medius Activation

	Condition, Mean (95% Confidence Interval)		
Group	Nonresisted	Resisted	Difference
Gluteus medius tabletop (least significant difference = 0.025)			
Healthy	1.11 (1.04, 1.18)	1.17 (1.10, 1.22)	0.06[a]
Coper	1.07 (0.97, 1.15)	1.18 (1.13, 1.23)	0.11[a]
LAS	1.10 (1.03, 1.18)	1.19 (1.11, 1.26)	0.08[a]
CAI	1.11 (1.06, 1.15)	1.10 (1.04, 1.16)	−0.01
Comparison	1	2	Difference (1–2)
Gluteus medius tabletop nonresisted group comparisons			
Healthy versus coper	1.11 (1.04, 1.18)	1.07 (0.97, 1.15)	0.04[a]
Healthy versus LAS	1.11 (1.04, 1.18)	1.10 (1.03, 1.18)	0.01
Healthy versus CAI	1.11 (1.04, 1.18)	1.11 (1.06, 1.15)	0.00
Coper versus LAS	1.07 (0.97, 1.15)	1.10 (1.03, 1.18)	−0.04[a]
Coper versus CAI	1.07 (0.97, 1.15)	1.11 (1.06, 1.15)	−0.04[a]
LAS versus CAI	1.10 (1.03, 1.18)	1.11 (1.06, 1.15)	0.00
Comparison	1	2	Difference (1–2)
Gluteus medius tabletop resisted group comparisons			
Healthy versus coper	1.17 (1.10, 1.22)	1.18 (1.13, 1.23)	−0.01
Healthy versus LAS	1.17 (1.10, 1.22)	1.19 (1.11, 1.26)	−0.01
Healthy versus CAI	1.17 (1.10, 1.22)	1.10 (1.06, 1.15)	0.08[a]
Coper versus LAS	1.18 (1.13, 1.23)	1.19 (1.11, 1.26)	−0.01
Coper versus CAI	1.18 (1.13, 1.23)	1.10 (1.06, 1.15)	0.07[a]
LAS versus CAI	1.19 (1.11, 1.26)	1.10 (1.06, 1.15)	0.09[a]

Abbreviations: CAI, chronic ankle instability; LAS, lateral ankle sprain.

[a] Statistically significant difference ($P \leq .05$).

Band-Walking Measures

Significant main effects for band position were noted for the GMax ($P < .001$) and GMed ($P < .001$) muscles during lateral band walking, and ARs increased when the band was moved from the lower leg to the forefoot. Both the healthy and LAS groups displayed an increased GMax AR in the forefoot band position (4.8% and 8.1% increases, respectively). All groups demonstrated an increased GMed AR with the band in the forefoot position (% increase: healthy = 5.8%, coper = 3.0%, LAS = 4.0%, CAI = 4.3%). Post hoc results for the significant band position main effects are shown in Figure 3. No significant group main effects or interactions for either muscle were present. Activation of the gluteal muscles in the tabletop and band-walking conditions is illustrated in Figure 4.

DISCUSSION

This study was the first to measure the motor activation of the gluteal and fibularis muscles using USI during functional activities among individuals with or without a history of LAS. Our key findings were the increased

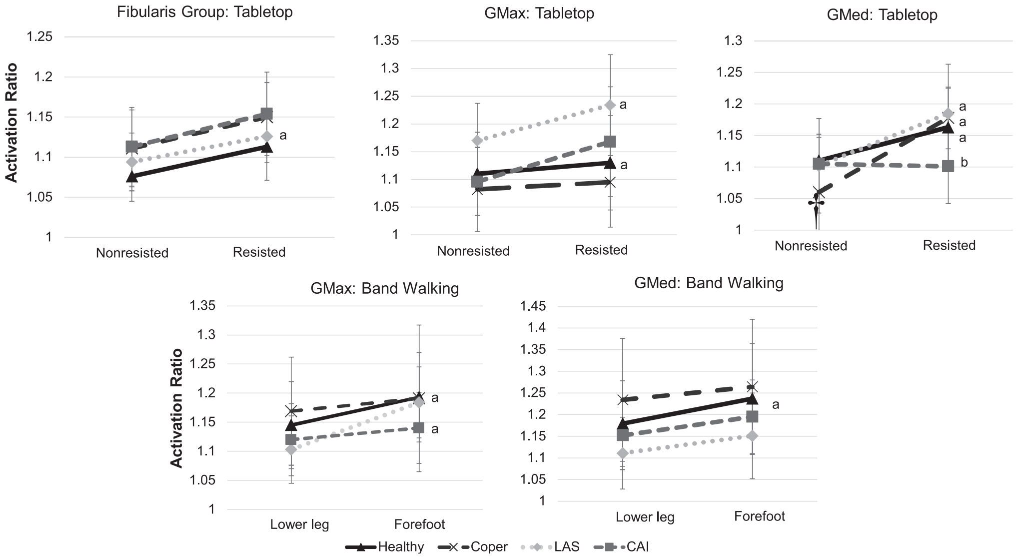

Figure 3. Activation ratios for the fibularis and gluteal muscles during side-lying tabletop exercises and the gluteal muscles during band-walking exercises. [a] Indicates a change in activation ratio between positions. [b] Indicates a difference between groups when an interaction was present. Abbreviations: CAI, chronic ankle instability; GMax, gluteus maximus; GMed, gluteus medius; LAS, lateral ankle sprain.

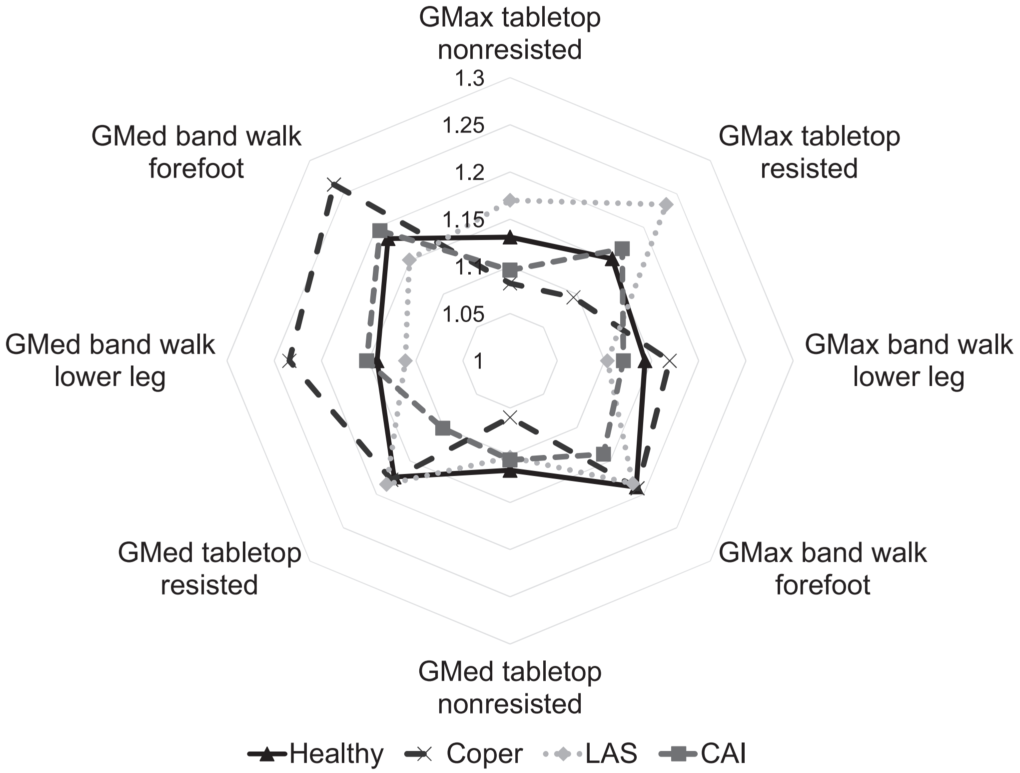

Figure 4. Radar graph of gluteus maximus (GMax) and gluteus medius (GMed) muscle activation during tabletop and band-walking exercises. Abbreviations: CAI, chronic ankle instability; LAS, lateral ankle sprain.

activity of the GMax and fibularis muscles during tabletop exercises and both gluteal muscles during band-walking exercises when the tasks increased in difficulty. We saw an increase in AR during resisted motion compared with nonresisted motion in both the GMax and fibularis across groups. During nonresisted and resisted tabletop hip-abduction exercises, the coper group had a lower level of GMed motor activation compared with the healthy, LAS, and CAI groups.

Tabletop Exercises

No group differences were demonstrated for fibularis muscle activation, which was somewhat surprising. All groups displayed increased fibularis CSA and AR with resisted versus nonresisted eversion. Our results contradict those of a similar USI study conducted by Lobo et al,[18] who found less resting fibularis longus CSA in individuals with a history of LAS compared with a healthy control group. We were not able to clearly differentiate between the fibularis longus and brevis muscles, so we could not replicate the measurement techniques of Lobo et al.[18] Methodologic differences in how the fibularis muscles were measured during our exercise condition may explain the disparate results between studies. Lobo et al[18] assessed the fibularis longus and brevis as discrete muscles, whereas we measured the 2 muscles as a single functional group.

Our findings were consistent with another study[7] that involved using magnetic resonance imaging to measure lower extremity muscle volumes and strength in individuals with or without CAI. Although the CAI group presented with decreased eversion strength compared with healthy participants, fibularis longus muscle volume did not differ. The researchers attributed their results to altered neuromuscular function as opposed to the size of the muscle,[7] which may explain why we observed no differences between groups for the fibularis AR.

Side-lying hip abduction exercises are commonly used in rehabilitation to target gluteal muscle activation.[24] Moderate to high GMed EMG muscle activity is needed to carry out this exercise, as demonstrated by prior investigators.[24] In our study, participants performed a side-lying hip-abduction exercise. Both LAS and CAI groups showed increased GMax muscle activation with manual resistance, but the coper and healthy groups did not. The central motor alteration that occurs after LAS[25] and CAI[26,27] may affect motor recruitment at the hip and explain our results in the tabletop exercises. The possibility of altered hip recruitment is further supported by the earlier findings from our laboratory[10] in which alteration of the GMed during the preswing phase of gait was observed in participants with CAI.

The GMed activation increased from the nonresisted to the resisted condition in the healthy, coper, and LAS groups; however, activation in the CAI group did not change between conditions. In addition, the CAI group had a lower GMed muscle AR with resistance compared with all other groups. Yet when we looked at the gluteal muscle group as a whole, the resisted condition provoked an increase in muscle activation in all groups for at least 1 gluteal muscle. Clearly, the GMed in individuals with CAI functioned differently than in the other groups during side-lying abduction exercises. Individuals with CAI may compensate by using more GMax activation to accomplish the task.

Band Walking

Band-walking exercises have been used to target gluteal muscle activation.[24] When we placed bands around the forefoot, the activity for both gluteal muscles increased compared with the lower leg band placement. Thus, extending the length of the lever arm and introducing an externally applied medial-rotation moment by moving the band placement distally increased the difficulty of the task. The GMed activity increased in all groups when the band was placed around the forefoot compared with the lower leg. For the GMax, muscle activity increased from the lower leg to the forefoot band position in the healthy and LAS groups but not in the coper or CAI groups. This may suggest that individuals who were copers or had CAI relied on the GMed more than the GMax to accomplish the band-walking task. Adjusting the position of the band may be beneficial when the goal of rehabilitation is to increase gluteal muscle activity. Increasing the difficulty of the exercise requires more activation from the gluteal muscle groups as a whole, whether the exercise occurs in an unloaded or loaded joint position. Ultrasound imaging could be used to provide visual biofeedback when the rehabilitation goal is to increase the activation of a specific muscle.

No differences in gluteal muscle activation were identified between groups for the band-walking exercises in either band position. This was somewhat surprising as individuals with a history of LAS have demonstrated differences in hip-muscle function during various tasks when compared with healthy control participants.[10,14,28,29] Although the difference was not significant, the coper group used 7% to 12% more GMed muscle activity than all other groups during the band-walking tasks. Increasing GMed activation may be a strategy that copers use to reduce the risk of subsequent LAS. Targeting increased GMed muscle activity in those with CAI and those who have recently experienced an LAS appears to be an appropriate rehabilitation strategy.

Clinical Implications

Gluteal muscle activation increased similarly during the tabletop and band-walking exercises. Using USI as a platform for visual biofeedback has potential in several areas, including helping patients target activation of specific muscles during rehabilitation. For example, our participants with CAI did not increase GMed activation and relied more on GMax activation during resisted side-lying hip abduction. The USI could allow a patient to visualize the muscle and alter movement according to the goal set by the clinician. Additionally, this tool could be used throughout a rehabilitation program to track muscle activation and hypertrophic changes over time.

LIMITATIONS

Patient positioning was slightly different in our study than in previous research[18,30] to ensure that we could image the fibularis muscles in nonresisted and resisted conditions. Participants performed only uniplanar tasks and, therefore, this information can be applied only to exercises performed in the frontal plane. Lastly, we studied a convenience sample of participants as part of a larger investigation.

CONCLUSIONS

As task difficulty increased with added resistance, regardless of the type of exercise, gluteal and fibularis muscle activity also increased. In the side-lying position, individuals with CAI demonstrated no change in GMed activity between resistance conditions and may rely more on GMax activity. During band walking, activity of the gluteal muscles increased when the bands were placed in a more distal position. Furthermore, copers used 7% to 12% more gluteal activation during resisted band-walking tasks, which may suggest an altered hip strategy among individuals with a history of a single LAS. Clinicians may use this information to target hip-muscle activity for patients during rehabilitation. In individuals with a history of LAS, ultrasound imaging could supply visual biofeedback to target more specific muscle activations while performing the prescribed exercises.

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DISCLOSURE

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