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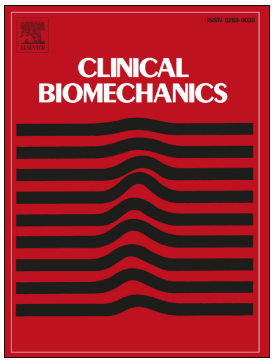

Gluteus medius dysfunction in females with chronic ankle instability is consistent at different walking speeds

Alexandra F. DeJong, Rachel M. Koldenhoven, Joseph M. Hart, Jay Hertel

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Gluteus medius dysfunction in females with chronic ankle instability is consistent at different walking speeds

Authors:
Alexandra F. DeJong MEd, ATC[1]
210 Emmet Street South, Charlottesville, VA, USA 22904-4407

Rachel M. Koldenhoven PhD, ATC[2]
601 University Drive, San Marcos, TX, USA 78666-4616

Joseph M. Hart PhD, ATC[1]
210 Emmet Street South, Charlottesville, VA, USA 22904-4407

Jay Hertel PhD, ATC[1]
210 Emmet Street South, Charlottesville, VA, USA 22904-4407

Affiliation:
[1]University of Virginia Exercise and Sports Injury Lab, 210 Emmet Street South, Charlottesville, VA, USA 22904-4407
[2]Texas State University Biomechanics/Sports Medicine Lab, 601 University Drive, San Marcos, TX, USA 78666-4616

Corresponding Author:
Alexandra F. DeJong
Email: afd4au@virginia.edu

Present/Permanent Address:
PO Box 400407 Memorial Gymnasium, Charlottesville, VA, USA, 22904

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Background: **Patients with** chronic ankle instability often present with altered gait mechanics compared to ankle sprain copers. There is increasing evidence to suggest proximal neuromuscular alterations contribute to the injury etiology, however little is known about how these changes manifest during gait. The purpose of this study was to investigate ipsilateral gluteus maximus and medius functional activity ratios throughout treadmill walking at three speeds (preferred, 120% preferred, and 1.35 meters per second) in chronic ankle instability patients compared to copers.
Methods: 28 females (14 chronic ankle instability, 14 copers) walked at the three gait speeds in randomized order. Ground reaction forces and 10-second gluteal ultrasound clips were simultaneously recorded. Clips were reduced using ground reaction forces to extract 55 measurement frames. Normalized gluteal thickness measures were used to determine functional activity ratios. 2x3 analyses of variance were run to assess group and speed effects on gluteal outcomes throughout walking using statistical parametric mapping. Post-hoc t-tests, mean differences, and Cohen's d effect sizes were assessed for significant findings ($P \leq .05$).
Findings: The chronic ankle instability group had significantly decreased gluteus medius activity throughout the entire gait cycle when compared to the coper group, independent of gait speed ($P < .001$, mean differences: 0.10-0.18; d: 1.00-3.17). There were no significant group or speed main effects, nor an interaction for gluteus maximus activity.
Interpretation: Gluteal dysfunction throughout walking was identified in chronic ankle instability. The coper group remained within healthy reference muscle activity ranges, suggesting that proximal muscle activation alterations are associated chronic ankle impairments.

Keywords: Functional ankle instability, lateral ankle sprain, locomotion, real-time ultrasound imaging

1. Introduction

Lateral ankle sprains continue to be one of the most prevalent lower extremity musculoskeletal injuries, especially among young and active individuals.[1] Although some ankle sprain patients are able to "cope" following initial injury, approximately 40% develop chronic ankle instability (CAI).[2,3] **Patients with** CAI subjectively report dysfunction one year or longer following initial injury, including residual pain and episodes of the ankle "giving way" during functional daily activities including walking.[5–74–6] Conversely, lateral ankle sprain copers are able to return to regular activities of daily living and sporting activities without reporting perceived ankle instability, giving way, or recurrent sprains.[7] As such, gait analyses have been conducted to identify underlying factors that influence disparate ankle sprain patient outcomes.

Previous research has identified local ankle deficits during walking when comparing **patients with** CAI against lateral ankle sprain copers, including increased plantarflexion,[8,9] decreased tibialis anterior activation,[9] and greater frontal plane motion during terminal swing.[10] These findings are key because ankle sprains or "giving way" events occur as the limb transitions from swing to initial foot contact gait phases, and thus altered foot and ankle positioning may increase susceptibility to repeated injury.[3,5,6] However, it is important to consider that **movement control systems throughout the lower extremity may be altered,[11] and as such local ankle deficits** should not be considered in isolation. Proximal stabilizing muscles have therefore been increasingly examined in ankle sprain populations due to their known influence on global functioning and bone and joint alignment throughout the lower extremity.

Gluteal muscle weakness has been found to be a risk factor for sustaining a lateral ankle sprain,[13] and deficits such as decreased strength and altered activation during functional exercises have been shown to uniquely persist with **patients with** CAI.[14–16] These maladaptations have manifested during gait with decreased hip extension during propulsive gait phases.[17] However, to our knowledge there are currently no studies that have examined gluteal muscle activity throughout the entire gait cycle in **patients with** CAI compared to lateral ankle sprain copers. As the gluteal muscles **have a key role in forward propulsion and pelvic stabilization** during gait,[18] it is important to gain further insight **into gluteal muscle adaptations during the locomotion** following ankle injury.

Musculoskeletal ultrasound imaging (USI) has previously been used during walking as a non-invasive means to measure gluteus maximus (GMAX) and medius (GMED) activity, or muscle thickness changes from quiet standing measures, between individuals with CAI and healthy counterparts.[19] **Patients with** CAI were found to have bilaterally decreased gluteus medius (GMED) activity throughout all phases of gait, postulated to influence overall lower extremity dysfunction. However, it remains unknown if GMED adaptations are unique to individuals with CAI, or if any history of ankle sprain influences hip neuromuscular control. Given that gait continues to be a functional activity that is problematic in **patients with** CAI alone, it would be important to understand if there is a proximal influence to this pathology, such as is seen in patients with patellofemoral pain.[20] Further, it would be beneficial to understand if gluteus maximus (GMAX) activity differs between ankle sprain patient groups to contextualize to previous hip extension deficits identified during limb propulsion.[17] Though GMAX differences have not previously been found with CAI when compared

against healthy individuals, it is plausible that GMAX activity may differ in one-time ankle sprain cases as a hypothetical coping mechanism.

The purpose of this study is to compare CAI and coper groups' unilateral GMAX and GMED functional activity using USI throughout treadmill walking at three gait speeds. Three paces were selected to determine if gluteal muscle activity is affected by speed, and to emulate daily walking conditions. Our primary hypothesis was that participants **with CAI** would have decreased GMED activity during the stance phase compared to copers, and similarly that participants **with CAI** would have decreased GMAX activity during terminal stance to early swing phases. We additionally expected that these differences would be influenced by speed, such that increased walking speeds would result in progressively decreased GMAX and GMED activity within the CAI group.

2. Methods

2.1 Participants

Potential participants were recruited from a university setting and screened using a brief Qualtrics survey to ensure that participants fit the respective injury categories. All participants were required to be young adults between 18-30 years of age, and recreationally active for at least 1.5 hours per week. Inclusion and exclusion criteria for potential CAI and coper groups followed the guidelines set forth by the International Ankle Consortium.[3]

Participants with CAI were required to have at least one significant ankle sprain sustained 12 months or more prior to study enrollment with residual disability, classified as ≤90 on the Foot and Ankle Ability Measure (FAAM) Activities of Daily Living (ADL), and ≤85 on the FAAM-Sport subscale. Copers were classified as having one significant

ankle sprain at least 12 months prior to study collection without any residual disability, determined as ≥99 on the FAAM-ADL, and ≥97 on the FAAM-Sport.

Individuals were excluded if they had any lateral ankle sprains within six weeks of collection procedures and/or currently participating in ankle rehabilitation. Additionally, individuals with any history of lower extremity or spinal fractures or surgeries, lower extremity injuries other than ankle sprains, neuropathy, muscular abnormalities, and/or current pregnancy were excluded from participation.

Upon reporting for testing, all participants completed additional patient-reported outcome measures, including the Identification of Functional Ankle Instability (IdFAI), International Physical Activity Questionnaire (IPAQ), Tampa Scale for Kinesiophobia (TSK-17), and the Patient-Specific Functional Scale (PSFS). Participants' demographic information is reported in Table 1. Although several males were screened and fit the criteria for CAI, only females were included in this sample to ensure that CAI and copers were sex-matched.

2.2 Procedures

2.2.1 Instrumentation

A dual-belt treadmill with imbedded force plates (Bertec Corporation, Columbus, OH, USA) sampled at 1000 Hz was used for walking trials and to collect ground reaction forces for initial contact timing. Ground reaction force data was recorded using MotionMonitor^{TM} software (Innovative Sports Training, Chicago, IL, USA) throughout walking collection procedures.

B-mode GMAX and GMED ultrasound images and video clip data were collected using a portable Siemens ACUSON Freestyle Ultrasound System (Siemens Medical

Inc., Mountain View, CA, USA) with an 8 MHz wireless linear transducer. The transducer was secured during collection procedures using a custom Velcro belt with foam block that has been previously described.[19,21,22]

2.2.2 Walking Collection

This evaluation was completed as a part of a larger study.[23] For the purpose of this report, subjects reported to the laboratory for a single collection session. Following MotionMonitor™ and treadmill systems set-up and calibration, the ultrasound transducer was placed unilaterally on the ipsilateral hip of the ankle sprain limb for all participants using previously established methods.[19,21,22] The USI transducer was prepared with aqueous gel and housed in a rectangular foam block. The transducer and block were secured around the waist with the Velcro belt so the transducer head was secured midway between the greater trochanter and the posterior superior iliac spine.[21] The depth of USI penetration was adjusted until the superior and inferior GMAX and GMED fascial borders were clearly in the USI monitor view without exiting the screen during walking. At this point, an investigator with three years of USI experience (AFD) captured and saved three quiet bipedal standing images as a static reference for gluteal muscle thickness.

For walking collection, the treadmill speed was gradually increased until participants indicated a preferred walking pace for a 5-minute warm-up prior to collection. Participants were asked halfway through the warm-up if the speed was still comfortable, and the pace was adjusted as necessary. Following warm-up, preferred, 120% of preferred (fast), and 1.35 meters/second (standard) walking speed trials were performed using a block-randomization scheme (Table 1). MotionMonitor with ground

reaction force data and USI video clips were recorded in tandem through communication between two examiners controlling each of the respective systems for each given walking speed. Each video clip yielded a 10-second trial with approximately nine complete gait cycles and 150 USI frames. Collection procedures for this analysis were then complete.

2.3 Data Processing

QuickTime player software (Version 7.7.9, Apple, Inc., 2016©) was used to play USI video clip files while ground reaction force data was simultaneously referenced on a separate monitor. A change in ground reaction force from zero to 20 Newtons was accompanied by a slight movement in the USI clip frame, thus confirming initial contact timing during each gait cycle to orchestrate USI video synchronization. The first three gait cycles of the USI video files were omitted and the subsequent five full gait cycles were used for analysis to ensure consistently clean data across videos and participants.[24] The USI video and MotionMonitor frames were recorded at the fourth initial contact event as the “start” frame for data reduction. The videos were then played synchronously for five strides until the ground reaction force fell below the 20-Newton threshold, at which point the videos were paused and the frame numbers were recorded as the “stop” frames for reduction.

Each USI video clip was reduced to 11 still image frames (10% interludes from 0-100% of the gait cycle) for each gait cycle, yielding 55 total measurement frames per video clip. The frame numbers were calculated using Equation 1, and captured as still images using the Macintosh screenshot function (macOS High Sierra, Version 10.13.6, Apple Inc.© 2018).

Equation 1: [21] $$\boldsymbol{Frame\ Intervals} = \frac{(End\ Frame - Start\ Frame)+1}{55}$$

USI frame measurements were performed using ImageJ software (ImageJ 1.50i, National Institutes of Health, USA). GMAX and GMED muscle thickness measures were taken from the inferior portion of the superior fascial border to the superior aspect of the inferior fascial border. The averages of the five muscle thickness measures were obtained at each 10% increment for all participants and walking speeds. Muscle thickness during walking was normalized to quiet standing measures to obtain FARs:

Equation 2:[25] $$\boldsymbol{Functional\ Activity\ Ratio} = \frac{muscle\ thickness_{during\ activity}}{muscle\ thickness_{quiet}}$$

2.4 Statistical Analysis

Based on prior findings comparing CAI and healthy cohorts, we expected to observe a minimum thickness difference of 0.17(SD 0.15cm) with a moderate effect size (Cohen's d=0.60).[19] These findings were used to perform *a priori* sample size estimation with alpha set ≤0.05 and 80% power accounting for 15% attrition, and reflected the need for 14 participants in each group.

Participant demographics and patient-reported outcome measures were compared between groups using independent t-tests in SPSS (IBM SPSS Statistics, v25). Statistical parametric mapping (SPM) was used to perform separate 2x3 analyses of variance (ANOVAs) to assess the effect of group (CAI and coper) and speed (preferred, fast, standard) on GMAX and GMED outcomes from 0-100% of the gait cycle in 10% increments. Significant findings were further assessed using post-hoc SPM t-tests. SPM analyses were performed using MATLAB (spm1d v0.4, MathWorks, Inc., USA).[26] Cohen's d effect sizes were to determine the extent of significant differences, with <0.2-0.49 interpreted as a small effect, 0.5-0.79 as moderate, and >0.8 as large.[27] Effect

sizes were assessed using Excel (Microsoft, v16.23, 2019) and Tableau (Tableau Software, Inc., 2019). The significance level was set to *P*=.05 for all analyses.

3. Results

The CAI and coper groups did not significantly differ in age, height, mass, physical activity, or kinesiophobia (Table 1). Per the inclusion criteria, the CAI group had significantly decreased FAAM-ADL and Sport measures, and reported increased IdFAI scores (Table 1). The CAI group had faster preferred gait speeds by 0.15 m/s when compared to the coper group (*P*=.01, Table 1). However, the majority of participants **with CAI** reported some level of difficulty with running (N=11), and some reported difficulty with walking or hiking on the PSFS (N=6, Supplementary Table).

3.1 GMED Outcomes

The coper group presented with significantly increased GMED mean FARs across the entire gait cycle when compared to the CAI outcomes for all walking speeds (*P*<.001, Figure 1a). However, there were no significant differences in GMED FARs across the three walking speeds for either group (Figure 2b). When examining the extent of GMED muscle thickness changes from quiet stance, the CAI group presented with GMED FARs that remained below 1 across the entire gait cycle, indicating that muscle thickness during gait was less than resting thickness measures (Figure 3a). Conversely, the coper group presented with FARs above resting values from 10-80% of the gait cycle, or from early stance to late swing (Figure 3a). The mean differences throughout the gait cycle between groups for GMED FARs ranged from 0.10 to 0.19, accompanied by large effect sizes, from d=1.00 to 3.17 (Figure 4). The largest effects were noted during the stance phases for each walking speed.

3.2 GMAX Outcomes

There were no significant differences for GMAX outcomes when comparing CAI and coper groups (Figure 1b), nor when comparing preferred, fast, or standard walking speeds (Figure 2b). Further, there was not a significant interaction among groups or speeds for GMAX measures. GMAX mean FARs remained above resting thickness (FARs>1.0) from approximately 10-50% of gait, or from early to late stance. However, measures remained below resting thickness during swing phases for both groups (Figure 3b).

4. Discussion

The findings from this study expand upon our previous USI investigation on gluteal muscle changes in **patients with** CAI during bouts of walking.[19] By comparing CAI and coper groups, we have provided insight into gluteal muscle adaptations across different subsets of ankle sprain patients. Our results overwhelmingly support that **patients with** CAI have depressed GMED activity throughout the entire gait cycle when compared against copers, and thus our primary hypothesis was confirmed. However, these differences were consistent regardless of walking speed and not exaggerated with increasing pace as we hypothesized. Additionally, we found no significant differences in GMAX activity among groups or walking speeds. Impaired GMED activity may therefore play a role in the lasting impairments down the kinetic chain during gait that manifest with **patients with** CAI,[5,8,28] especially as these participants reported varying levels of difficulty with walking on patient-reported outcome measures.

4.1 GMED Outcomes

When closely examining the GMED adaptations in the present study in conjunction with the previous USI gait research, it appears that CAI FAR values remained within a similar range of values even across this different cohort of participants (DeJong 2019 – CAI GMED FARs: 0.95-1.02; Current study – CAI GMED FARS: 0.91-0.99). When examining the coper findings with regards to the published GMED FAR data, the copers more closely resembled the healthy participant ranges (DeJong 2019 – healthy GMED FARs: 1.11-1.16; Current study – coper GMED FARs: 1.03-1.12). Increased GMED activity may therefore contribute to improved movement strategies in these one-time ankle sprain patients.

Ankle sprains are known to occur during the transition from terminal swing to initial foot contact,[5] and the GMED mean difference and effect size data suggest that GMED differences were notably highest during stance. Previous ankle sprain gait studies have noted GMED onset latency with increasing ankle laxity,[29] which may help to explain into the larger mean differences further into the stance phase. Although we are unable to determine onset timing from USI data, we are able to determine the extent of muscle activity through our normalized thickness data.[25] The cumulative gluteal muscle gait data suggests that there are neuromuscular maladaptations during movement in **patients with** CAI; however, it would be beneficial in future studies to pair EMG and USI data to provide a global view into these proximal adaptations.

Altered hip muscle activity and lower extremity kinematic malalignment have been noted in chronic lower extremity injuries such as patellofemoral pain,[20] and thus would be important to explore in the context of CAI. The decreased GMED FAR that was noted in the CAI group from initial contact through to midstance may similarly heighten

lower extremity dysfunction if this primary hip stabilizer cannot effectively offer frontal plane stability.[30] As these USI data were collected as a part of a larger study, there is published information on hip frontal plane kinematics throughout the gait cycle in an overlapping cohort.[23] We therefore are able to begin to draw some inferences between GMED activity and hip motion throughout walking. It was determined that the CAI group was more adducted compared to the coper group, particularly in the later part of stance through to early swing.[23] This suggests that there are ramifications on lower extremity biomechanics with the GMED FAR differences; however, it appears that there may be a slight delay between the USI mechanical changes and hip kinematics. Future steps are necessary to draw concrete connection between gluteal muscle USI activity and kinematics during walking.

4.2 GMAX Outcomes

We expected to find CAI and coper group differences for GMAX outcomes as previous gait analyses have reported decreased hip extension kinematics during terminal stance to early swing.[17] We did not identify any significant GMAX FAR differences between groups for any gait speed, which coincided with the reference kinematic data from the larger study with no statistical differences in hip sagittal plane kinematics.[23] Although individuals with CAI present with hip extension strength deficits, there does not appear to be an impact on GMAX activity during gait.[19] Further, there is typically minimal GMAX activity during locomotion compared to other activities requiring more propulsive forces from the hip, such as running, jumping, and squatting.[18,31] As such, there is more information supporting GMAX deficits in individuals with CAI during activities and exercises that require more gluteal muscle contractile force.[32] Conversely,

GMED activity is more important during gait for hip motion control to avoid excessive pelvic drop and rotation.[18,33] **We believe this may be why previous research has solely focused on quantifying GMED activation during gait in patients with CAI**.[28,34]

USI findings from this study and previous work support that GMAX activity is not compromised in CAI populations during walking, nor do copers employ a greater extent of GMAX activity throughout gait.[19] Therefore, GMAX activity may not need to be specifically addressed clinically during gait-training **or neuromuscular education exercises** for **patients with** CAI and there should instead be an increased focus on GMED activity patterns and neuromuscular control.

Albeit not statistically significant, we did note that GMAX activity patterns differed across gait more than previously reported trends in muscle activity; typically the GMAX is more activated during propulsive and swing phases of gait as opposed to during the stance phase.[18] Interestingly, we observed that GMAX activity was highest during stance for both copers and CAI groups, and that FARs fell below 1 during swing phases. Thus, ankle sprain history may be associated with a more synergistic pattern of GMAX and GMED activity instead of the expected agonistic contractions, which may be a compensatory mechanism following initial injury.[35] Given that GMAX and GMED activities were both above resting values during stance for the coper group, the combined actions of the proximal stabilizing musculature may reflect an adaptive movement strategy.[36] Therefore, increasing GMED activity during walking may benefit **patients with** CAI to maximize the synergistic actions of the muscles to appear more

like coper groups. Future research should seek to determine if GMED biofeedback would support this theory.

4.3 Gait Speed

Contrary to our hypotheses, gait speed did not appear to influence the extent of GMAX or GMED muscle activity. We suspect that the findings were consistent across groups because both average walking speeds were within 0.50 m/s of the standardized gait speed. We were surprised to find that preferred gait speed was statistically higher for participants **with CAI** than copers. These differences may be attributed to the fact that all participants were moderately active. **Gait speed changes can present a constraint on patients' motor control systems, however the changes noted in this study may not be practically meaningful** as the group preferred **walking gait** speeds were within 0.15 m/s of one another (Table 1). The fact that gluteal muscle data did not differ significantly across gait speeds is important because this suggests that future gait analyses can be conducted at a single speed without a significant influence on outcome measures. Using a standardized speed may therefore be preferable to maintain consistency across groups and lead to generalizable findings from gait analyses across future studies.

4.4 Implications for Sports Medicine Practice

We propose that these USI data should be considered as a foundation for future clinical gait-training interventions. Our findings support that there is a relationship between proximal neuromuscular control and ankle sprain patient trajectories following initial injury. We found specific gluteal adaptations in the coper group that appear to result in more successful movement strategies as these individuals have been avoid to

future injury and ankle giving way episodes. Therefore, especially in earlier stages of recovery where patients may be experiencing residual pain around the ankle joint, it may be beneficial to target GMED activity to facilitate healthier movement patterns. As USI is a tool for clinicians and patients to visualize dynamic muscle activity in real time, this may be a viable biofeedback option to encourage increased GMED activity during walking.

It is also important to note that there are distal strategies employed by coper patients that may contribute to their gait strategies, such as ankle positioning at initial contact.[8–10] Therefore, we believe that interventions that employ a global approach to gait-training may be most beneficial to **patients with** CAI once they are at a later rehabilitation stage. There have been promising results from gait-training studies that used an elastic band around participants' lower limbs to force patients to encourage a less inverted foot positioning;[37] this approach may also help target the GMED as patients need to work against an internal rotation moment from the force at the shank. Evidence that this approach leads to global successes in CAI patient outcomes,[38] and should be considered clinically for gait-training interventions.

4.5 Limitations and Future Directions

As we did not evaluate gluteal EMG outcomes, we are unable to draw conclusions on the extent of hip muscle activation throughout gait between these patient groups. We instead chose to use USI using reliable placement and measurement techniques to overcome limitations such as muscle crosstalk with surface EMG,[21,22] and through this technique determine gluteal muscle thickness changes during movement. We did not directly analyze kinematics in conjunction with gluteal USI outcomes in our

analyses, and thus future steps are needed to draw firm connections between FARs and hip kinematics. It would be beneficial to elucidate these relationships among measurement techniques for a holistic view of proximal adaptations in this patient population. Although males were screened and considered for participation in this study, only females were included to ensure that **patients with** CAI and copers were sex-matched; we are therefore unable to extrapolate these outcomes to male patients. Finally, we did not measure muscle activity bilaterally and therefore cannot determine if significant differences were present between coper and CAI patient groups as well. However, previous research suggests that CAI adaptations are centrally-mediated and we support that clinical interventions should include both limbs.[35]

5. Conclusions

The CAI group presented with decreased GMED activity throughout the entire gait cycle regardless of walking speed when compared against an ankle sprain coper group, however there were no significant differences in GMAX activity. The GMED discrepancy between groups suggest that ankle sprain copers are able to utilize proximal stabilizers to a greater extent which may contribute to successful longitudinal outcomes following initial injury. Targeting neuromuscular control of the GMED during gait should be considered clinically for more efficacious movement strategies for **patients with** CAI.

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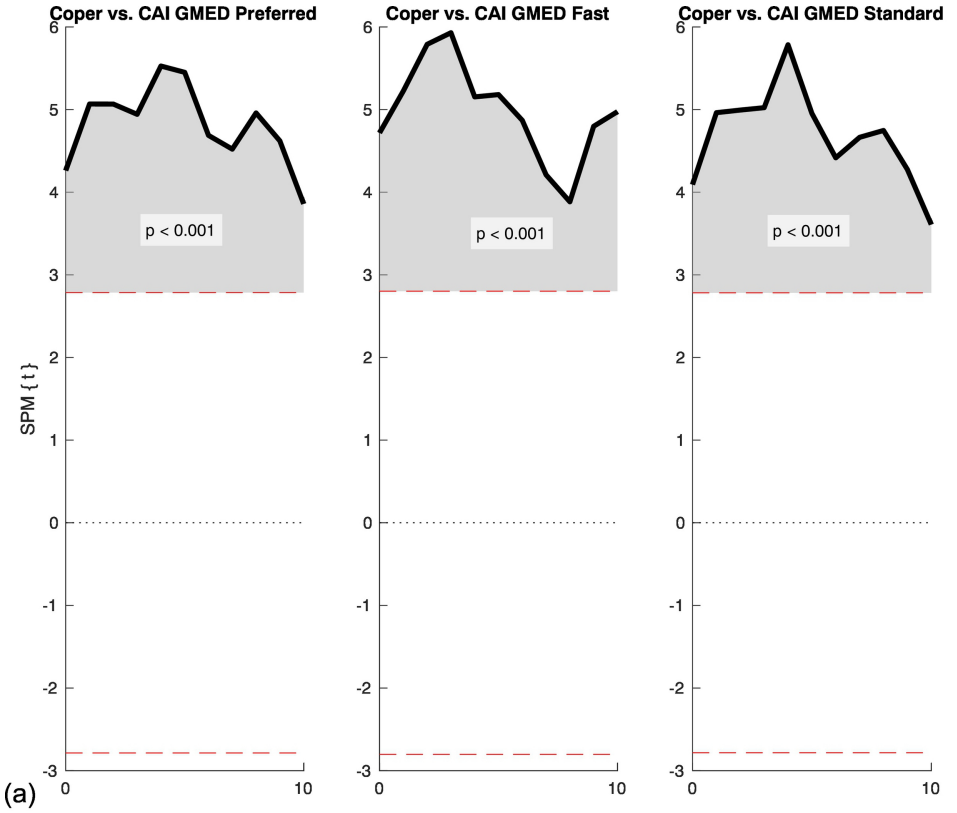
Table 1. Participant Demographics, Patient Reported Outcome Measures, and Walking Speeds

	CAI (N=14)	Copers (N=14)	*P*-value
Age (years)	21(3)	21 (2)	.43
Height (cm)	168.4 (8.4)	166.7 (4.4)	.50
Mass (kg)	68.9 (14.4)	64.3 (7.0)	.29
IPAQ	5123.7 (3283.1)	4872.3 (2395.9)	.82
TSK-17	34.1 (5.6)	30.8 (4.0)	.08
FAAM-ADL (%)	85.9 (10.5)	99.9 (0.3)	<.001*
FAAM-Sport (%)	67.1 (16.7)	98.7 (1.8)	<.001*
IdFAI	21.1 (3.6)	11 (3.3)	<.001*
Preferred Walking Speed (m/s)	1.04 (0.13)	0.89 (0.13)	.01*
120% of Preferred Walking Speed (m/s)	1.24 (0.15)	1.07 (0.15)	.01*

*Abbreviations: CAI, Chronic Ankle Instability; IPAQ, International Physical Activity Questionnaire; TSK-17, Tampa Scale of Kinesiophobia 17-item scale; FAAM-ADL, Foot and Ankle Ability Measure Activities of Daily Living subscale; FAAM-Sport, Foot and Ankle Ability Measure Sport subscale; IdFAI, Identification of Funcational Ankle Instability. * denotes a significant group difference at P≤.05.*

Highlights:

- Gluteus medius activity was significantly lower in chronic ankle instability patients during gait
- Copers presented with gluteal muscle activity within healthy reference muscle ranges
- Gluteus maximus and medius activity was consistent across various walking speeds
- Targeting gluteus medius activity may be considered with chronic ankle instability patients


Coper vs. CAI GMED Preferred
Coper vs. CAI GMED Fast
Coper vs. CAI GMED Standard
p < 0.001
p < 0.001
p < 0.001
SPM {t}
(a)

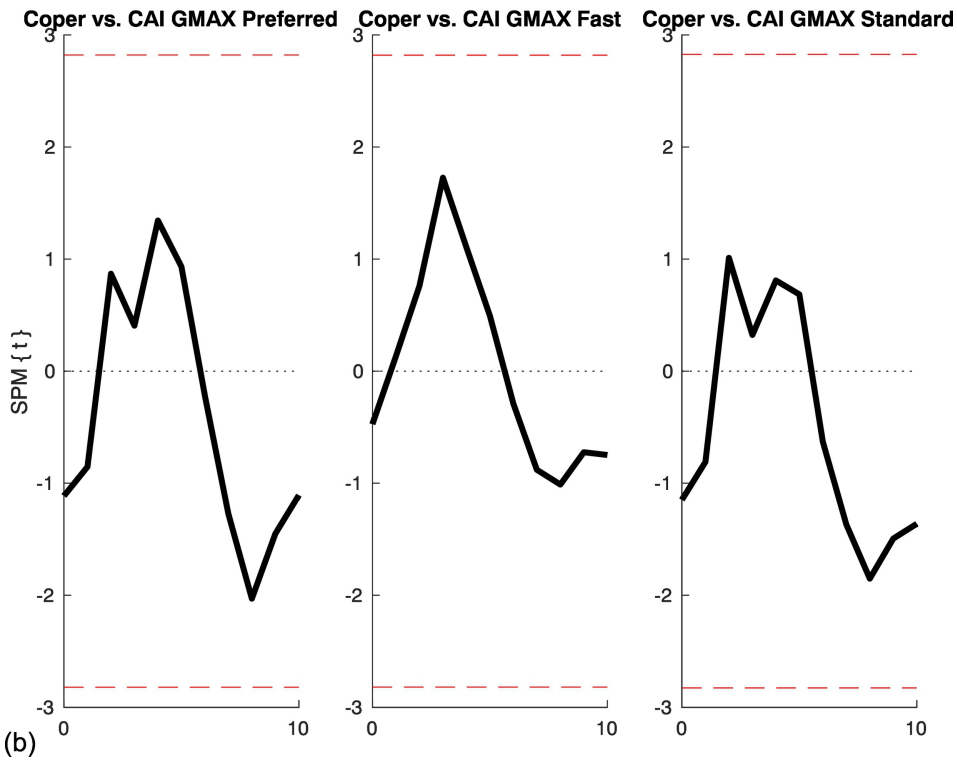
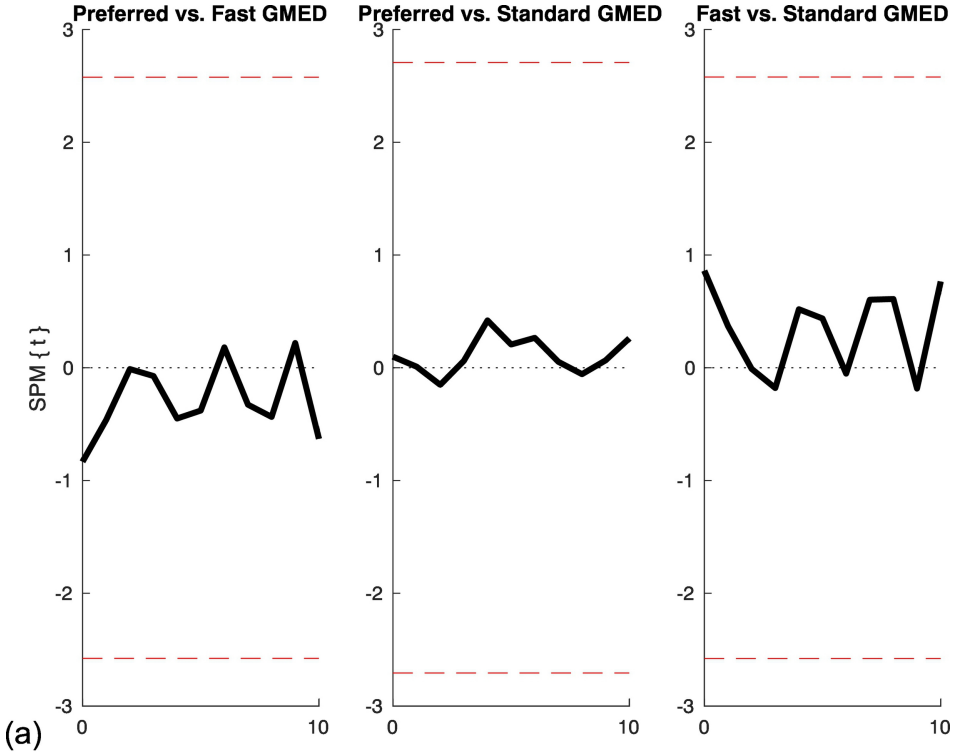
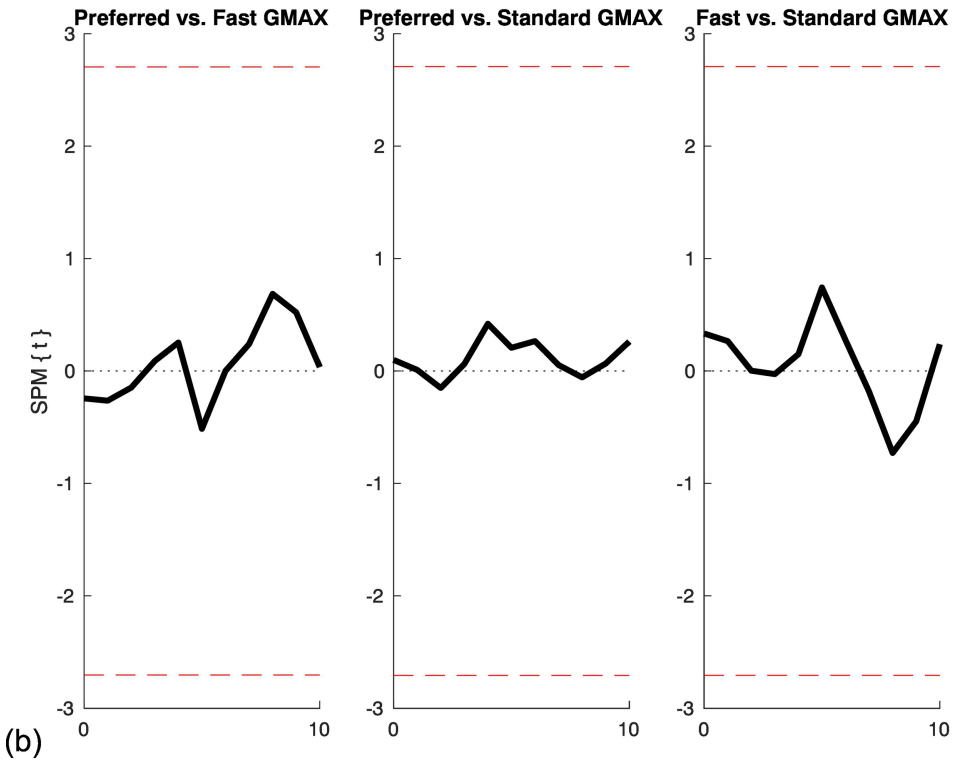

Coper vs. CAI GMAX Preferred
Coper vs. CAI GMAX Fast
Coper vs. CAI GMAX Standard
SPM {t}
(b)

Figure 1

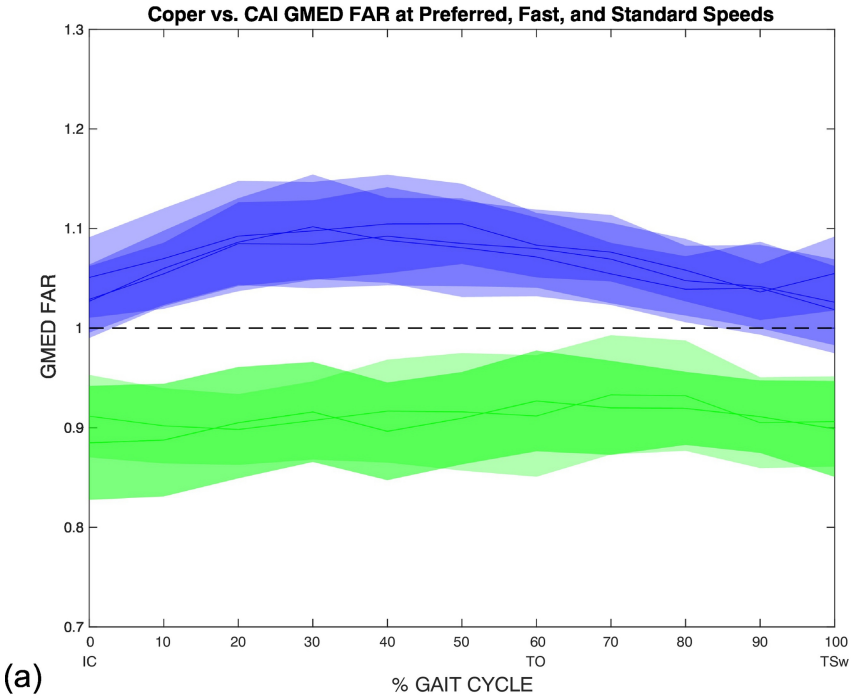

Preferred vs. Fast GMED
Preferred vs. Standard GMED
Fast vs. Standard GMED
SPM {t}
3
2
1
0
-1
-2
-3
0
10

(a)

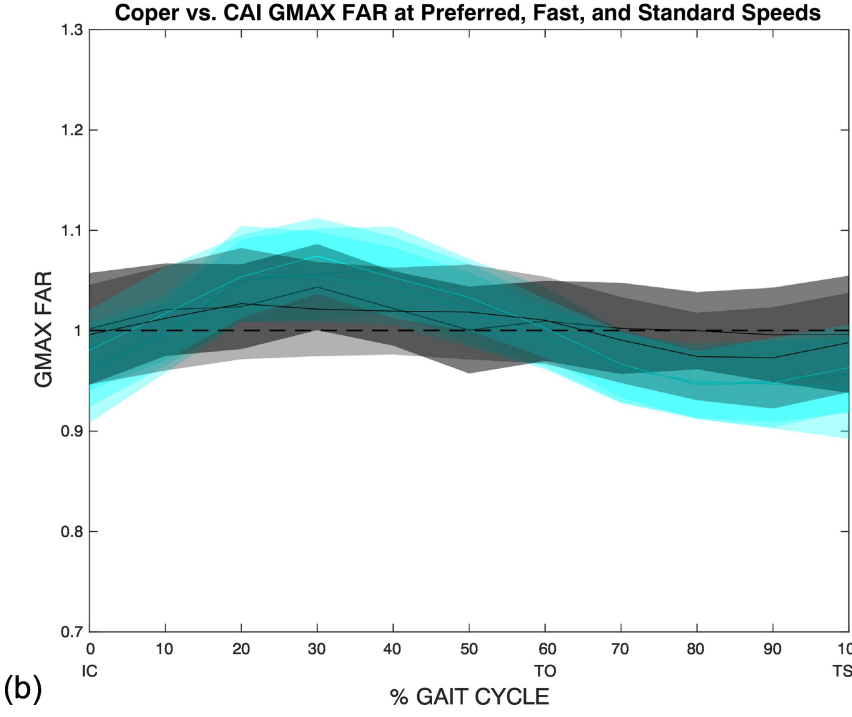

Preferred vs. Fast GMAX
Preferred vs. Standard GMAX
Fast vs. Standard GMAX
SPM {t}
3
2
1
0
-1
-2
-3
0
10

(b)

Figure 2


Coper vs. CAI GMED FAR at Preferred, Fast, and Standard Speeds
COPER SWS
95%CI
CAI SWS
95%CI
COPER FST
95% CI
CAI FST
95%CI
COPER PWS
95%CI
CAI PWS
95%CI
GMED FAR
1.3
1.2
1.1
1
0.9
0.8
0.7
0
10
20
30
40
50
60
70
80
90
100
IC
TO
TSw
% GAIT CYCLE

(a)


Coper vs. CAI GMAX FAR at Preferred, Fast, and Standard Speeds
COPER SWS
95%CI
CAI SWS
95%CI
COPER FST
95% CI
CAI FST
95%CI
COPER PWS
95%CI
CAI PWS
95%CI
GMAX FAR
1.3
1.2
1.1
1
0.9
0.8
0.7
0
10
20
30
40
50
60
70
80
90
100
IC
TO
TSw
% GAIT CYCLE

(b)

Figure 3

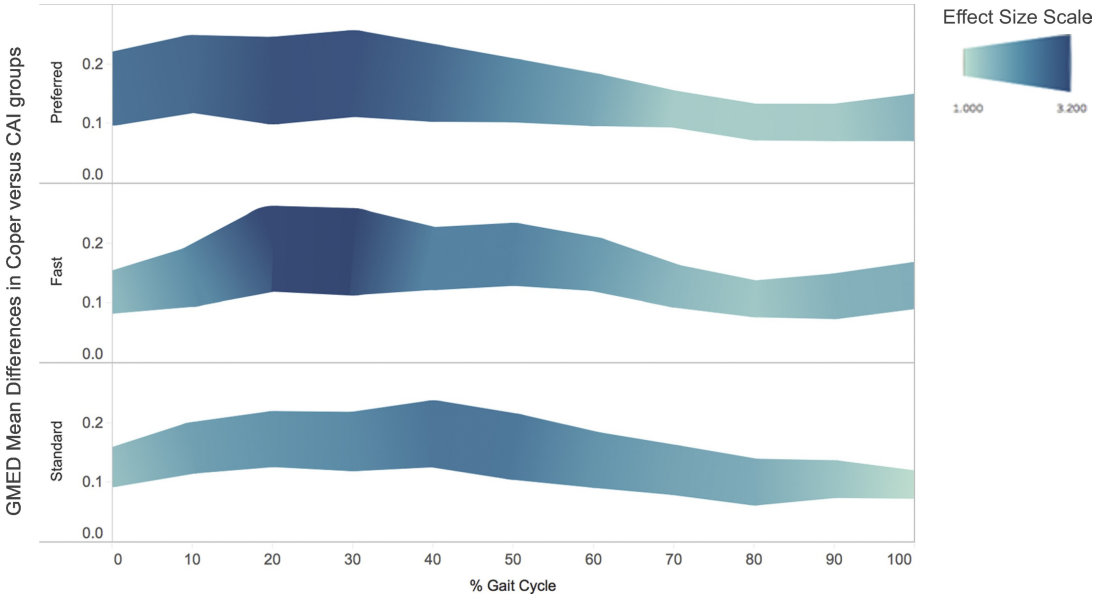

GMED Mean Differences in Coper versus CAI groups
Preferred
Fast
Standard
0.2
0.1
0.0
0
10
20
30
40
50
60
70
80
90
100
% Gait Cycle
Effect Size Scale
1.000
3.200

Figure 4