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Chronic Ankle Instability and Hip Muscle Function: a systematic review

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Abstract

Purpose/background

The connection between hip strength and knee function is widely accepted in rehabilitation[1-6]. The beginnings of evidence supporting a connection between the hip and ankle in people with chronic ankle instability (CAI) causes clinicians to question how the hip and the ankle may interact in this population. The purpose of this review is to provide a cohesive summary of the current available evidence examining hip muscle function in people with chronic ankle instability so that clinicians are better able to treat these patients.

Methods

An electronic search of PubMed was performed to locate studies published in peer-reviewed journals that directly examined hip muscle function in people with chronic ankle instability. Studies published between January 1, 2010 and September 1, 2017 were identified using varying combinations of the keywords “ankle”, “hip”, chronic ankle instability”, and “muscle activity”.

Results

Nine of 9 included articles suggested that clinicians manage the entire kinetic chain, rather than just the local ankle deficits, in people with chronic ankle instability. Seven of 9 articles directly demonstrated the presence of proximal neuromuscular changes in people with CAI and 6 of 9 articles found differences in hip muscle performance in people with CAI versus healthy controls. Varying study techniques, subject classification styles and outcome measures limit generalizability of results but most studies reported findings consistent with neuromuscular changes effecting both distal and proximal musculature in people with CAI

Conclusions

Clinicians should include assessment and intervention for proximal muscle function changes when treating patients with chronic ankle instability, as there is evidence that proximal neuromuscular changes effect movement patterns in this population. More research is needed to further elucidate the neuromuscular changes that are found in this population and to determine how clinicians can best manage these deficits to improve function in people with CAI.

Introduction

Lateral ankle sprains are the most common injury among athletes[7] and effect between 2 and 7 people per 1000 in the general population[8]. Up to 60% of these individuals develop chronic ankle instability[8] but the etiology and best practices for management of chronic ankle instability remain unclear[8]. Current conservative treatment for chronic ankle instability includes ankle eversion strengthening, bracing/strapping, lateral wedging, functional training and proprioceptive training[7]. With the exception of functional training, most of the interventions supported in the literature focus on local ankle treatment and do not look proximally at the remainder of the kinetic chain[9].

There is strong evidence supporting the use of hip strengthening for people with knee pain[1-5] and decreased hip abductor and external rotator strength has been identified as a predictor of non-contact anterior cruciate ligament tears in athletes[6]. This connection between the hip and knee is widely accepted in rehabilitation and emerging evidence has shown a connection between muscle function of the hip in people with chronic ankle instability (CAI).[10-12] [9,13,14] Studies on this topic are highly variable in methods, measures and results, making it difficult for clinicians to apply the available evidence to patient care. The purpose of this review is to provide a cohesive summary of the current available evidence relating hip muscle performance and activity in people with CAI so that clinicians are better able to treat patients with chronic ankle instability.

Methods

An electronic search was performed on the PubMed database using the keywords “hip muscle performance” OR “hip muscle strength” OR “hip muscle endurance” OR “hip muscle activity” OR “gluteus medius” OR “gluteus maximus” OR “hip abductor” OR “hip adductor” OR “hip internal rotator” OR “hip external rotator” AND “chronic ankle instability” OR “ankle instability” OR “recurrent ankle sprain” with exclusion keywords pertaining to cadaveric studies, age-extreme studies and surgical interventions.

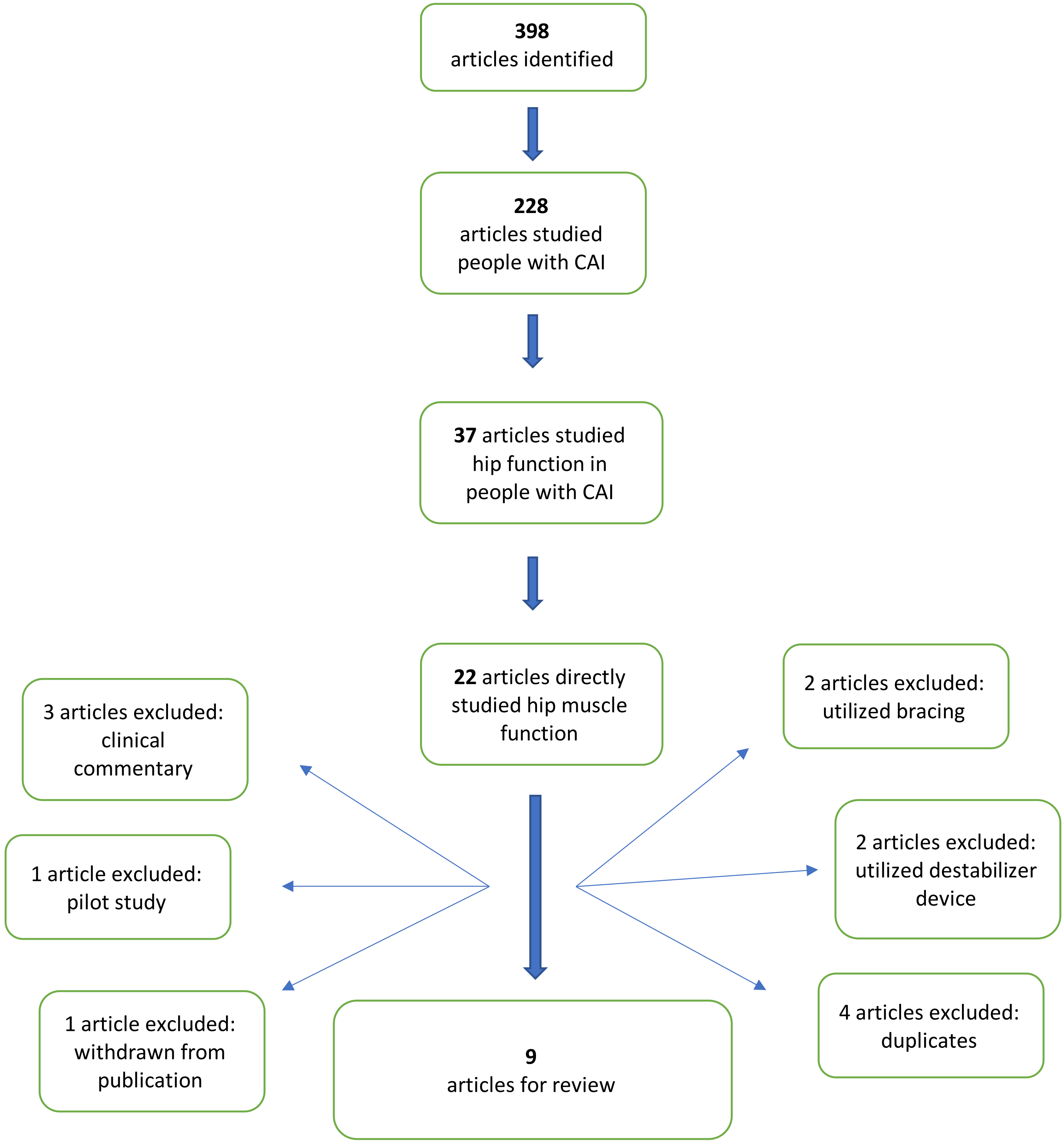
Inclusion criteria

Study selection criteria included: (1) articles published in peer-reviewed journals between January 1, 2010 and September 1, 2017, (2) articles written in English, and (3) studies examining people with chronic ankle instability and directly reporting on hip muscle function.

Study selection

The initial search returned 398 studies which were narrowed to 9 articles utilized for this review based on the inclusion criteria (see Figure 1). Studies were excluded if they utilized external bracing, destabilizer devices, were pilot studies or were clinical commentary rather than original research or literature reviews.

Figure 1.
Results of electronic search of PubMed for hip muscle activity in people with CAI



Results

The search returned 9 articles studying hip muscle function in people with chronic ankle instability during varying tasks including treadmill walking, jumping, single-limb eyes-closed balance, star excursion balance testing, forward and rotational lunging, lateral hopping (with and without fatigue), ball kicking, side-cutting, walking while turning, and single-leg rotational squatting. All studies utilized surface electromyography (EMG) to gather data regarding amount and/or timing of muscle activity. Table 1 summarizes clinically-relevant findings of these studies.

In 2014, Feger et al.[9] gathered surface EMG data of 15 participants with CAI and 15 healthy individuals during single-limb eyes-closed balance, forward lunging, lateral hopping and the star excursion balance test (SEBT) in the anterior, posteromedial and posterolateral directions. EMG amplitude was recorded in two different regions of the lower extremity: distal (tibialis anterior, peroneus longus, lateral gastrocnemius) and proximal (rectus femoris, biceps femoris and gluteus medius) and muscle activity in each region and total muscle activity was analyzed. The CAI group demonstrated statistically significant decreases in muscle activity during all four tasks. Moderate-to-large differences in proximal muscle activity were found at pre-initial contact during forward lunging and there was a significant decrease in rectus femoris activity during single-limb eyes-closed testing in the CAI group. Subjects with CAI also showed decreases in total muscle activity (with statistically significant decreases in distal muscle activity) at pre-initial contact during lateral hopping and at post-initial contact during forward lunging. There was a significant decrease in total lower extremity muscle activation during single-limb eyes-closed balance testing for the CAI group. There were no significant proximal or total lower extremity muscle activation changes during the SEBT task. The authors suggest that their findings of decreased muscle activity in the CAI group demonstrate the presence of a change in neuromuscular control that is likely task-specific. Management of centrally-mediated changes in both proximal and distal muscle activation in people with CAI is encouraged in light of these findings.

In 2015, Feger et al.[13] published a second study with the same cohort from their 2014 study[9] where they utilized surface EMG signals of anterior tibialis, peroneus longus, lateral gastrocnemius, rectus femoris, biceps femoris and gluteus medius to study muscle activity during treadmill walking. Findings included earlier activation of all muscles tested in the CAI group, though statistical significance was only found for earlier activation time of peroneus longus ($p < 0.001$) and rectus femoris ($p = 0.03$). There was no difference in amount of muscle activity between groups, as measured by EMG amplitude, in any of the tested muscles. The authors suggest that the earlier activation of all tested muscles in the CAI group is a compensatory, feed-forward neuromuscular pattern developed by people with CAI in order to "brace" the entire lower extremity for ground contact during normal walking. They suggest that, although this pattern may be a sufficient compensation for normal walking, it is insufficient to stabilize during more challenging tasks.

Rios et al.[14] recorded EMG activity of people with CAI and of healthy controls during a ball-kicking task performed on rigid and foam surfaces. EMG activity was recorded on the stance leg (involved side for the CAI group) using surface electrodes placed over soleus, medial and lateral heads of the gastrocnemius, tibialis anterior, peroneus longus, biceps femoris, rectus femoris, gluteus medius, erector spinae and rectus abdominis. The CAI group showed decreased activity of muscles surrounding the ankle and increased activity of the muscles surrounding the hip during kicking. These findings, combined with their concurrent analysis of postural sway, lead authors to conclude that people with CAI compensate for decreased stability about the ankle by increasing hip/trunk stability and decreasing postural sway during functional tasks. Although they did not investigate timing of muscle activity in this study, they suggest that future studies should investigate timing of muscle activation, as their results indicate that there may be a feed-forward neuromuscular change present in this population.

In 2013 Webster et al.[11] utilized surface EMG to study the activity of gluteus maximus and gluteus medius during a rotational lunge and single-leg rotational squat in individuals with and without CAI. The CAI group demonstrated significantly decreased gluteus maximus activation during the unilateral rotational squat when compared to the control group. The authors state that continued decreased function of gluteus maximus in this population may contribute to poor control of the entire lower extremity during closed kinetic chain activity and may contribute to instability. Although they did not study timing of muscle activity, the authors report that these findings support previous studies that attribute changes in proximal muscle activity to neuromuscular changes occurring with the development of CAI.

In 2016, Webster et al.[12] studied muscle activation during a lateral hopping task after fatigue in 16 people with CAI and in 16 healthy, matched controls. Key findings include higher EMG amplitude of gluteus medius activation in the CAI group just before landing the lateral hop. The study also found a moderate to strong effect size of higher, although not statistically significant, activation of gluteus maximus pre-landing, post-fatigue. The CAI group showed a statistically significant increase in activation of gluteus maximus in the pre-landing phase when compared to the control group. Based on the changes in muscle activation pre-landing in the CAI group, the researchers concluded that a central, feed-forward, protective neuromuscular response is responsible for the proximal muscle changes seen in people with CAI.

Koldenhoven et al.[10] studied EMG activity of gluteus medius of 17 people with CAI and 17 healthy controls during treadmill walking. Results revealed statistically significant increases in gluteus medius activity during the final 50% of stance and the first 25% of swing phase of gait. Authors suggest that this may be a neuromuscular technique used by people with CAI to increase stability during ambulation by increasing base of support or to stabilize while ambulating with a supinated foot.

Terada et al.[15] utilized a group of 19 individuals with CAI and 19 healthy, matched controls to examine differences in neuromuscular control at the knee during a stop-jump task. Although this study focused on control of the knee in people with CAI, this article was included in this review because researchers recorded EMG activity of the medial and lateral hamstrings, which function to extend the hip. Authors found no significant differences in hamstring activation in the CAI group but did find significant increases in activation of the vastus medialis oblique, which they attributed to a central, feed-forward neuromuscular mechanism. Hip flexors, abductors, adductors, rotators and gluteal muscles were not assessed in this study. Despite unremarkable findings in the hamstrings, the authors' conclusion that changes found at the knee may be due to a feed-forward neuromuscular mechanism are notable within the context of this review, which has shown several instances of neuromuscular changes proximal to the ankle in people with CAI.

Son et al.[16] compared movement strategies of individuals with CAI, lateral ankle sprain copers and controls during a jump landing/cutting task. EMG activity was recorded in the tibialis anterior, peroneus longus, medial gastrocnemius, vastus lateralis, medial hamstrings, gluteus maximus, and gluteus medius. The CAI group showed decreased activation proximally at gluteus medius and gluteus maximus but statistical significance was not reached. Kinematic data gathered during this study revealed that the CAI group demonstrated movement patterns that decreased activation requirements of the hip abductors, which may explain these findings. Although the landing strategy employed by the CAI group should have increased demand on gluteus maximus, EMG activity showed decreased gluteus maximus activity. The authors attributed this finding to the presence of a previously-studied feed-forward neuromuscular control pattern in the CAI group. Despite statistically-insignificant findings regarding hip muscle activity in this study, the authors suggest that an altered neuromuscular pattern is present in people with CAI, which remains consistent with previous findings of studies included in this review.

Koshino et al.[17] studied EMG activity of 10 athletes with CAI and 10 healthy control athletes during walking, walking with side-turning, and side-cutting. There were no significant differences in muscle activation of any of the proximal muscles that were studied (gluteus medius, gluteus maximus, rectus femoris, semitendinosis) during any of these tasks but there were differences in kinematics at the ankle and the hip during the more-demanding side-cutting task in the CAI group. The authors did not study muscle activation timing in this study and suggest that further study include a temporal component so as to reveal a possible neuromuscular change occurring in people with CAI.

Table 1.

Authors and Year	**Findings**	**Clinical relevance**	**Limitations**
Feger et al. [9], 2014	There are centrally-mediated, task-specific decreases in proximal and distal muscle activity in people with CAI.	Clinicians should address proximal and distal changes in muscle activation in people with CAI. Rehabilitative efforts should utilize safe but objective goals so that patients do not unconsciously select to perform tasks at a lower intensity due to fear of instability.	Kinematic and kinetic data was not collected so quality of movement cannot be measured. Risk of type II error is increased: the study utilized a relatively small sample size (30 subjects) and techniques (sEMG) that resulted in large standard deviations.

Feger et al.[13], 2015	People with CAI activate lower extremity muscles earlier and for longer duration than controls during treadmill walking.	People with CAI may develop compensatory neuromuscular patterns that are adequate for routine tasks but are not effective at decreasing future injury risk.	Utilized independent t-tests, increasing type I error rate. Statistical significance for activation time was only found for peroneus longus and rectus femoris.
Rios et al.[14], 2015	People with CAI increase proximal muscle activation to improve postural stability. This may be a compensation for decreased distal neuromuscular function.	Balance re-training during rehabilitation efforts may actually be targeting proximal musculature in people with CAI.	It is unclear how the changes in balance strategy in people with CAI impact function. Timing of muscle activity and kinematic analyses were not carried out so anticipatory/reactionary adjustments are unclear.
Webster et al.[11], 2013	There are differences in activity of the posterolateral hip musculature during functional exercises in people with CAI. These differences may result in decreased control of the involved lower extremity during closed kinetic chain activity.	Clinicians should implement exercises targeting the gluteus medius and maximus for people with CAI. The rotational squat shows higher gluteus maximus activation and may be especially beneficial for this population.	This study utilized a low sample size (9 individuals in each group) and had low statistical power but still observed a moderate to large effect size for the decreased activation of gluteus maximus during the rotational squat. It is unclear whether the proximal changes were present prior to injury or if they occurred following development of CAI.
Webster et al.[12], 2016	Neuromuscular changes that exist in people with CAI occur both distally and proximally and these changes have larger effect sizes post-fatigue. There is likely a	When treating patients with CAI, clinicians should consider the entire lower extremity kinetic chain with special focus on the gluteal muscles. Functional fatigue	Type II error is possible due to small sample size. This controlled laboratory study cannot accurately simulate real-life function.

	central, feed-forward neuromuscular response present.	may need to be incorporated into the rehabilitative protocol.	
Koldenhoven et al.[10], 2016	People with CAI demonstrated increased activation of gluteus medius during late stance phase and early swing phase during treadmill walking.	Clinicians should evaluate patients with CAI for altered motor control throughout the gait cycle.	Small sample size: 17 subjects in each group. EMG data for the uninvolved limb was not gathered so comparisons can only be made between the involved limb in people with CAI and that of healthy controls.
Terada et al.[15], 2014	A central, feed-forward mechanism may be present in people with CAI, resulting in changes in vastus medialis oblique activation during a stop-jump task. There are no significant changes in hamstring activity.	Clinicians should treat CAI as a global, rather than local, injury.	Hip flexors, abductors, adductors, rotators and gluteal muscles were not assessed in this study.
Son et al.[16], 2017	People with CAI demonstrate altered movement patterns during functional tasks but do not demonstrate significantly different muscle activity during these tasks when compared to copers and controls.	Clinicians should consider a multi-joint rehabilitation effort that emphasizes movement quality when treating people with CAI because abnormalities at the ankle joint will impact biomechanical control of the entire kinetic chain.	Pre-landing data was not analyzed so the presence/absence of a feed-forward neuromuscular strategy is unclear based on the results of this study. EMG normalization process may have created error in measuring muscle activity.

Koshino et al.[17], 2016	There were no differences in proximal muscle activity during an athletic maneuver in people with CAI but people with CAI demonstrate differences in kinematics at the hip during the same maneuver.	Clinicians should take motion at the hip joint into account when treating athletes with CAI. Differences in kinematics may be task-specific.	Timing of muscle activation was not studied but further research into timing of muscle activity may explain kinematic differences seen during demanding tasks in people with CAI. Very small sample size: only 9 participants in each group.

Discussion

Despite disparate study techniques among the articles that were included in this review, there is a common theme of the existence of a proximal neuromuscular change in people with CAI discussed in all of the studies in this review. Seven[9-15] of 9 studies directly demonstrated changes in proximal neuromuscular control and the remaining two articles[16,17] discussed the importance of further investigation into timing of muscle activation and kinematic profiles during functional tasks to further elucidate possible neuromuscular changes present in this population. These findings lead each author to suggest that clinicians manage patients with CAI by assessing and addressing both proximal and distal deficits and include neuromuscular training that targets the entire kinetic chain. One author also makes specific suggestions regarding the management of gluteus maximus and medius in this population and suggests using the unilateral rotational squat to target these muscles.[11]

There are limitations to this review that deserve consideration when interpreting the results. First, there is not a standard definition of chronic ankle instability that has been used to classify patients. The authors of the studies that were reviewed utilized varying definitions to classify their subjects. Classification of subjects into the CAI groups utilized varying outcome measures including the Foot and Ankle Ability Measure (FAAM-ADL, FAAM-sports), the Foot and Ankle Disability Index (FADI, FADI-sports), the Cumberland Ankle Instability Tool (CAIT), the Ankle Instability Instrument (AII) and a range of initial injury statuses. This resulted in a wide range of clinical presentations grouped together in the "chronic ankle instability" groups across studies, which may explain the varied and sometime contradictory outcomes of when assimilating conclusions from the studies.

Another limitation of this review is the focus on muscle function. The range of results of increased and decreased muscle activity and changes in timing of muscle activation seen in studies included in this review may be further explained with kinematic profiling. Son et al[16] found that there were differences in landing strategy in the CAI group that resulted in decreased demand being placed on some posterolateral hip musculature, which may explain the presence of task-specific changes in muscle activity demonstrated by the studies included in this review. Additionally, kinematic profiling may allow further insight into task performance between groups: as Feger[9] suggested, if permitted, people with CAI may self-select to perform a task at a lower level of intensity than their uninjured counterparts. Additional study should examine hip kinematics in people with chronic ankle instability to further examine the available evidence on this topic.

The cumulative evidence from this study suggests that practitioners should address the entire kinetic chain in the evaluation and treatment of patients with CAI. Further study is needed to determine whether normalizing hip muscle activity can improve function in this population or if addressing these changes following a lateral ankle sprain can prevent the development of chronic ankle instability.

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