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# Lower Limb Joint Kinetics During a Side-Cutting Task in Participants With or Without Chronic Ankle Instability

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***Context:*** Individuals with chronic ankle instability (CAI) demonstrate altered lower limb movement dynamics during jump landings, which can contribute to recurrent injury. However, the literature examining lower limb movement dynamics during a side-cutting task in individuals with CAI is limited.

***Objective:*** To assess lower limb joint kinetics and sagittal-plane joint stiffness during the stance phase of a side-cutting task in individuals with or without CAI.

***Design:*** Cohort study.

***Setting:*** Motion-capture laboratory.

***Patients or Other Participants:*** Fifteen physically active, young adults with CAI (7 men, 8 women; age = 21.3 ± 1.6 years, height = 171.0 ± 11.2 cm, mass = 73.4 ± 15.2 kg) and 15 healthy matched controls (7 men, 8 women; age = 21.5 ± 1.5 years, height = 169.9 ± 10.6 cm, mass = 75.5 ± 13.0 kg).

***Intervention(s):*** Lower limb 3-dimensional kinematic and ground reaction force data were recorded while participants completed 3 successful trials of a side-cutting task. Net internal joint moments, in addition to sagittal-plane ankle-, knee-, and hip-joint stiffness, were computed from 3-dimensional kinematic and ground reaction force data during the stance phase of the side-cutting task and analyzed.

***Main Outcome Measure(s):*** Data from each participant's stance phase were normalized to 100% from initial foot contact (0%) to toe-off (100%) to compute means, standard deviations, and Cohen d effect sizes for all dependent variables.

***Results:*** The CAI group exhibited a reduced ankle-eversion moment (39%–81% of stance phase) and knee-abduction moment (52%–75% of stance phase) and a greater ankle plantar-flexion moment (3%–16% of stance phase) than the control group ($P$ range = .009–.049). Sagittal-plane hip-joint stiffness was greater in the CAI than in the control group ($t_{28} = 1.978$, $P = .03$).

***Conclusions:*** Our findings suggest that altered ankle-joint kinetics and increased hip-joint stiffness were associated when individuals with CAI performed a side-cutting task. These lower limb kinetic changes may contribute to an increased risk of recurrent lateral ankle sprains in people with CAI. Clinicians and practitioners can use these findings to develop rehabilitation programs for improving maladaptive movement mechanics in individuals with CAI.

***Key Words:*** lateral ankle sprain, change of direction, motor-control strategy

**Key Points**

- Individuals with chronic ankle instability (CAI) displayed altered ankle-joint kinetics and greater proximal-joint stiffness than healthy control participants during the stance phase of a side-cutting task.
- The differences in ankle-joint kinetics and hip-joint stiffness provide insight into potential movement adaptations that occur during a side-cutting task due to the sensorimotor and mechanical constraints of CAI.
- The altered movement patterns likely contribute to the recurrent lateral ankle-sprain paradigm in individuals with CAI.
- Researchers and clinicians can use these findings to develop effective rehabilitation and training programs for improving lower limb movement patterns and to mitigate the risk of recurrent injury in individuals with CAI.

Lateral ankle sprain (LAS) is among the most commonly reported lower extremity injuries due to athletic participation.[1] This injury accounts for 7.3% of all reported injuries sustained in National Collegiate Athletic Association athletics, with the highest incidence rates reported in basketball (10.8 per 10 000 athlete-exposures), soccer (7.9 per 10 000 athlete-exposures), and volleyball (6.9 per 10 000 athlete-exposures).[2] Whereas many athletes decline proper medical treatment after lateral ankle-ligament trauma to reduce time missed from participation due to injury, approximately one-third of individuals will develop chronic ankle instability (CAI) after an LAS.[3] This condition is characterized by a wide spectrum of long-term sensorimotor and mechanical deficits that cause the ankle joint to "give way" or subjective feelings of ankle-joint instability during functional or dynamic movements, leading to recurrent damage to the lateral ankle-ligament complex.[4]

Lateral ankle sprain occurs due to excessive subtalar inversion, internal rotation, and talocrural plantar flexion of the ankle complex.[5,6] Dynamic movements, such as jump landings or rapid changes of direction, require preparatory plantar flexion and inversion of the ankle complex to attenuate impulse loads during ground contact.[7,8] This increases the propensity for an LAS because the foot's center of pressure could continue to deviate laterally during ground contact, increasing the moment arm of the subtalar joint.[5] Therefore, inversion and internal-rotation moments generated from the ground reaction force can augment the strain on the anterior talofibular and calcaneofibular ligaments and, consequently, increase the risk of the lateral ankle ligaments reaching or exceeding maximum load to failure, causing an LAS.[6,9]

Investigators have demonstrated altered lower limb movement dynamics during jump landings at 2 weeks[10,11] and 6 months after a first-time, acute LAS[12] and in individuals who developed CAI.[13–15] More specifically, proximal-segment alterations and reduced ankle neuromuscular control were observed when individuals who developed CAI performed dynamic movements, such as jump landings and side-cutting tasks.[15–18] This indicates that the chronically unstable ankle is unable to effectively attenuate impulse loads imposed on the ankle complex and results in an intralimb redistribution of impact-force attenuation in which greater reliance is placed on the proximal joints to protect the injured ankle during dynamic movements.[16,18] Researchers[13,15,19] have suggested that longitudinal alterations to spinal- and supraspinal-level motor-control strategies, which arise from the sensorimotor constraints of CAI, are likely an underlying mechanism in developing CAI and recurrent lateral ankle sprains. Therefore, an assessment of lower limb movement dynamics during sport-specific tasks that pose substantial risks for LAS in individuals with CAI is warranted.

Much of the literature has been focused on the lower extremity kinematic and neuromuscular alterations associated with CAI during jump landings.[20] Whereas individuals with CAI have demonstrated altered lower limb kinematics and neuromuscular control during a side-cutting task,[17,21] we are unaware of any investigations of lower limb joint kinetics and stiffness during a side-cutting task in cohorts with CAI. Identifying lower limb joint kinetic and energetic alterations during sport-specific tasks that isolate loading on the lateral ankle structures, such as side cutting, would further elucidate movement dynamics that are associated with recurrent LASs in individuals with CAI. Therefore, the purpose of our study was to assess lower limb joint kinetics and sagittal-plane joint stiffness during the stance phase of a side-cutting task in individuals with or without CAI. We hypothesized that individuals with CAI would display altered lower limb joint kinetic patterns and more proximal joint stiffness than healthy individuals serving as controls.

## METHODS

### Participants

Estimating sample size using G*Power software (University of Düsseldorf, Düsseldorf, Germany), we determined that 13 participants in each group would be needed to achieve a desired power of 0.80 with a moderate effect size and the $\alpha$ level set at .05.[22] Fifteen participants with self-reported CAI (7 men, 8 women; age = 21.3 ± 1.6 years, height = 171.0 ± 11.2 cm, mass = 73.4 ± 15.2 kg) and 15 healthy matched controls (7 men, 8 women; age = 21.5 ± 1.5 years, height = 169.9 ± 10.6 cm, mass = 75.5 ± 13.0 kg) who were involved in competitive or recreational sports at the time of the study completed the study procedures. The selection criteria for participants with CAI were based on the recommendations from the International Ankle Consortium: (1) self-reported history of 2 or more LASs, with 1 of those LASs occurring within the 12 months before the study; (2) history of an LAS that required non–weight-bearing activity or immobilization for more than 24 hours; (3) self-reported history of the affected ankle giving way; or (4) a Cumberland Ankle Instability Tool (CAIT) score of $\leq$24.[23] Exclusion criteria for both groups were (1) a history of surgery or fracture to either lower extremity, (2) any musculoskeletal injury to the lower extremity in the 3 months before the study, or (3) diagnosis of any musculoskeletal or neurologic disorder. All participants provided written informed consent, and the study was approved by the Institutional Review Board at Mississippi State University.

### Instrumentation

Twelve infrared cameras (model Bonita 10; Vicon, Oxford, United Kingdom) recording at 200 Hz were used to collect 3-dimensional lower limb kinematic data. Retroreflective marker sets (ie, clusters), which were constructed from thermoplastic, were attached to the participants' posterior pelvis and bilaterally on the thighs, shanks, and feet using double-sided tape.[8] Nylon therapeutic wraps were placed around the clusters to further minimize movement artifact of the markers during the side-cutting task. Ground reaction force data were also collected using a portable force platform (model AccuGait; Advanced Mechanical Technology Inc, Watertown, MA) sampling at 1000 Hz during the side-cutting task. The kinematic and ground reaction force data were collected simultaneously and time synchronized using MotionMonitor software (version 9; Innovative Sports Training Inc, Chicago, IL).

### Procedures

Participants attended a single familiarization session. During this session, the CAIT and injury history questionnaires were completed, which allowed each participant to subjectively report the level of ankle instability and the total number of LASs sustained. We also obtained anthropometric data and provided participants with a detailed description of the testing procedures. The primary investigator (J.D.S.) instructed the participants in the side-cutting task. They could practice the side-cutting task as many times as desired during this session to reduce any potential learning effects. After the familiarization session, participants returned to the laboratory within 72 hours to complete their experimental testing session wearing the low-top athletic shoes of their choice.

Upon arrival at the laboratory for the testing session, participants performed a dynamic warm-up protocol that lasted approximately 5 minutes. This warm-up consisted of 2 sets of 10-yd (9-m) skips, high knees, submaximal jogging, exaggerated gait swings, and lunges. Next, they completed the side-cutting task, which was modified from that used in previous investigations[17,21] of cohorts with

CAI. For this task, participants were positioned 70 cm away from the center of the force platform, which was situated so the top of the force platform was level with the ground, and instructed to stand on their nontesting limb with approximately 45° of knee and hip flexion. They received an oral cue to perform an anterior jump and land with their testing limb on the force platform. After contacting the force platform with the testing limb, participants subsequently changed their direction 45° to the contralateral side and ran as quickly as possible for 3 m. The 45° side-cutting angle was marked on the ground to provide a visual representation of the proper cutting angle and the required running distance. Participants completed 5 practice trials on the limb that was tested before any trials were recorded to ensure they were contacting the force platform with their entire foot. Next, a total of 3 successful trials of the side-cutting task were completed and recorded. The *testing limb* in the CAI group was defined as the limb subjectively reported on the CAIT questionnaire as having the affected ankle, whereas the testing limb of the control group was sex matched to a participant in the CAI group with a similar age, height, mass, and limb dominance. The *dominant limb* was determined by asking participants which limb they would use to kick a ball. A trial was repeated if the participant's entire foot did not contact the force platform during the side-cutting task. The cumulative total of the 3 successful trials from each participant was used in the statistical analysis.

## Data Processing

We constructed each participant's lower limbs using the MotionMonitor software to determine the ankle-, knee-, and hip-joint centers. The *joint centers* were defined in the software by placing a retroreflective measurement sensor on prominent anatomic landmarks to estimate the centers of the foot and the ankle, knee, and hip joints. The *ankle-joint center* was defined using the medial and lateral malleoli and the distal second phalanx, whereas the *knee-joint center* was defined using the medial and lateral femoral condyles. The *hip-joint center* was defined using the anterior-superior iliac spine and L5-S1 joint. The proximal segment served as the reference point in the software for creating the foot and the ankle, knee, and hip joints. The ankle- and knee-joint centers were calculated using the centroid method and the hip-joint center was calculated using the method of Davis et al.[24] The primary investigator located the prominent anatomic landmarks for all segment constructions.

Ankle, knee, and hip kinematics were calculated using the angle-orientation method of Grood and Suntay.[25] Time-synchronized lower limb kinematic and ground reaction force data were filtered with a low-pass, third-order Butterworth filter that had a frequency of 15 Hz. Anthropometric data and the time-synchronized kinematic and ground reaction force data were used to compute net internal joint moments of the ankle, knee, and hip using an inverse-dynamics procedure in the MotionMonitor software. Net internal joint moments were computed and analyzed in the sagittal, frontal, and transverse planes during the stance phase of the side-cutting task and normalized to body mass (Nm/kg) for each participant. The *stance phase* was defined as the time interval from when the vertical ground reaction force exceeded 15 N after initial foot contact until the vertical ground reaction force was less than 15 N (ie, toe-off). Each participant's stance phase was normalized to 100% from initial foot contact (0%) to toe-off (100%) for the statistical analysis.[16,18,21] Furthermore, we computed sagittal-plane ankle-, knee-, and hip-joint stiffness as the change in net internal joint moment divided by the angular displacement between initial contact and peak dorsiflexion and knee and hip extension during the stance phase of the side-cutting task.[15,16]

## Statistical Analysis

Descriptive and dependent variables are reported as mean ± standard deviation. Independent-samples *t* tests were used to compare descriptive characteristics and CAIT scores between CAI and control groups. To compare stance-averaged ankle, knee, and hip net internal joint moments during the side-cutting task between the CAI and control groups, 2-tailed independent-samples *t* tests were computed for each discrete time during the stance phase. Cohen d effect-size data were calculated for all dependent variables as the difference in means divided by the pooled SD and were interpreted as *small* (< 0.40), *moderate* (0.40–0.80), or *large* (> 0.80).[22] The $\alpha$ level was set at .05. All statistical analyses were performed using the statistical software package in Excel (version 2016; Microsoft Corp, Redmond, WA).

## RESULTS

The CAI and control groups were similar in age ($t_{28}$ = 0.349, *P* = .73), height ($t_{28}$ = 0.271, *P* = .79), and mass ($t_{28}$ =0.393, *P* = .70). The CAI group (18.8 ± 3.4) had a lower CAIT score than the control group (29.7 ± 0.6; *P* < .001) and reported 6.0 ± 3.2 total LASs.

Sagittal-, frontal-, and transverse-plane stance-averaged net internal joint moments during the side-cutting task are presented in Figures 1 to 3. The CAI group demonstrated greater ankle plantar-flexion moment from 3% to 16% of the stance phase than the control group (mean difference = 0.22 ± 0.08 Nm/kg; *P* range = .01–.049; Cohen d range = 0.62–0.97; Figure 1A). In the frontal plane, the CAI group showed less ankle-eversion moment from 39% to 81% of the stance phase (mean difference = 0.13 ± 0.02 Nm/kg; *P* range = .009–.049; Cohen d range = 0.62–0.92; Figure 2A), which also coincided with less knee-abduction moment from 52% to 75% of the stance phase (mean difference = 0.27 ± 0.03 Nm/kg; *P* range = .27–.049; Cohen d range = 0.63–0.75: Figure 2B) than in the control group. We observed no other differences in sagittal-, frontal-, or transverse-plane net internal joint moments between groups during the side-cutting task.

The Table describes the sagittal-plane ankle-, knee-, and hip-joint stiffness for each group during the task. We noted no differences between groups for sagittal-plane ankle-joint stiffness ($t_{28}$ = 1.330, *P* = .09; Cohen d = 0.50) or knee-joint stiffness ($t_{28}$ = 0.180, *P* = .43; Cohen d = 0.05). Conversely, the CAI group demonstrated greater hip-joint stiffness than the control group (mean difference = 0.12 Nm/kg/°; $t_{28}$ = 1.978; *P* = .03; Cohen d = 1.00).

## DISCUSSION

We conducted this investigation to assess lower limb joint kinetic patterns and sagittal-plane joint stiffness

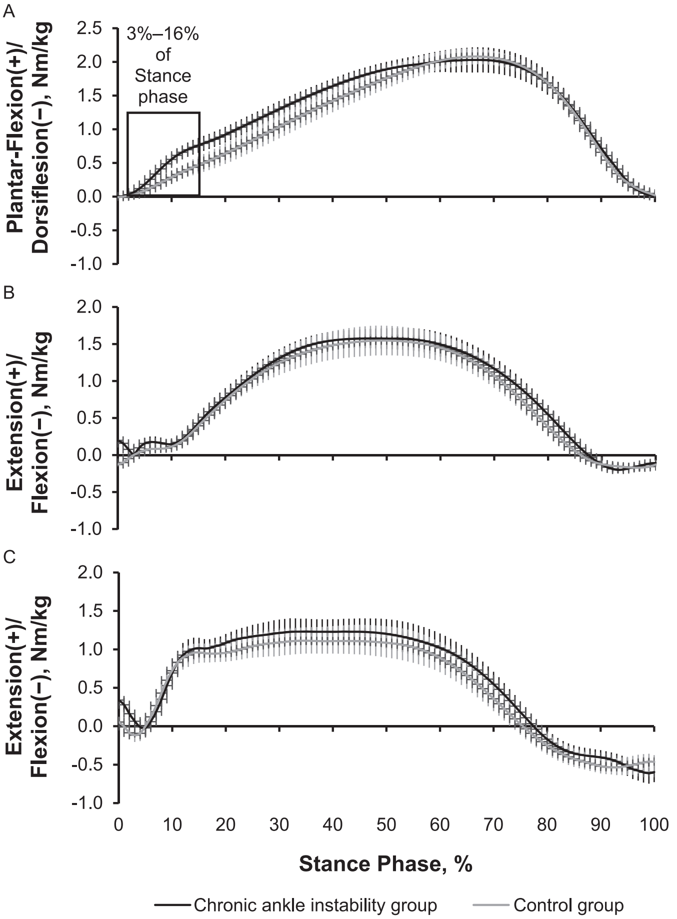

**Figure 1. Sagittal-plane net internal joint moments for the chronic ankle instability and control groups during the stance phase (0% = initial contact, 100% = toe-off) of the side-cutting task (mean ± SD). A, Ankle. The boxed area indicates a difference ($P < .05$). B, Knee. C, Hip.**

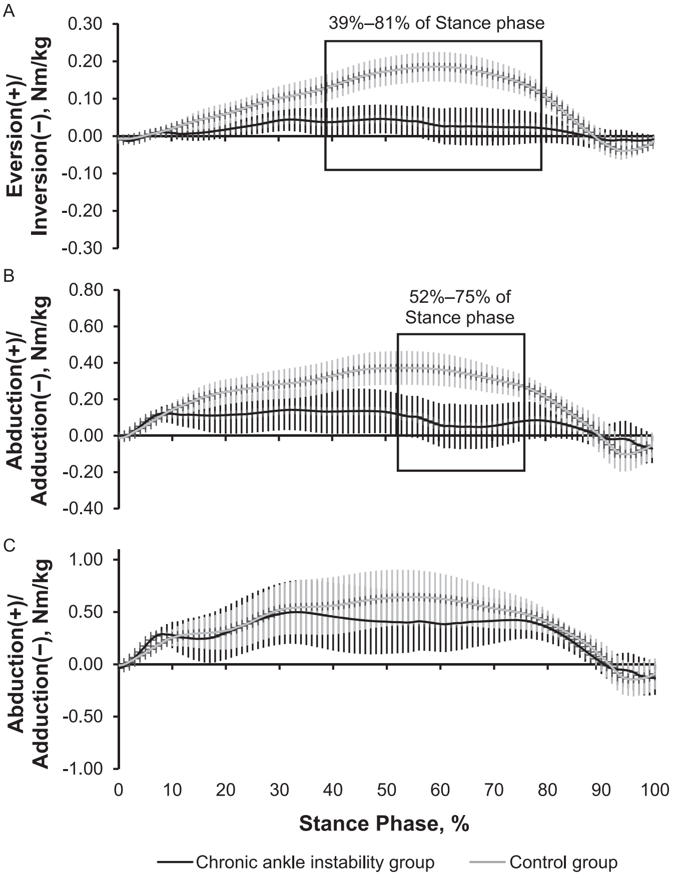

**Figure 2. Frontal-plane net internal joint moments for the chronic ankle instability and control groups during the stance phase (0% = initial contact, 100% = toe-off) of the side-cutting task (mean ± SD). A, Ankle. The boxed area indicates a difference ($P < .05$). B, Knee. The boxed area indicates a difference ($P < .05$). C, Hip.**

during the stance phase of a side-cutting task in individuals with or without CAI. Our main findings were that individuals with CAI displayed an increased plantar-flexion moment during the initial contact phase (3%–16% of the stance phase) and reduced ankle-eversion and knee-abduction moments during the midstance (39%–81% of stance phase) to late-stance phase (52%–75% of stance phase) when performing the task. Whereas we found no between-groups differences for sagittal-plane ankle-joint or knee-joint stiffness, the CAI group demonstrated increased sagittal-plane hip-joint stiffness during the side-cutting task compared with the control group. These results supported our hypothesis that increased proximal-joint stiffness would be observed in the CAI group, but the findings in lower limb joint kinetics only partially confirmed our initial hypothesis.

Increased ankle plantar-flexion moment was present in the CAI group from 3% to 16% of the stance phase during the side-cutting task (Figure 1A). Although we did not examine lower extremity kinematics, we speculate that the greater dorsiflexion angle during the early-stance phase might explain the increased plantar-flexion moment in the CAI group. Individuals with CAI are known to display a greater ankle-dorsiflexion angle and less sagittal-plane motion during jump landings than healthy control participants.[13,18,20,26] This sagittal-plane ankle-joint alteration reflects the mechanical constraints associated with CAI[27] and the fact that greater talocrural dorsiflexion places the joint in a more tightly packed position to protect the chronically unstable ankle when performing dynamic maneuvers. As a result, these changes in sagittal-plane motion reduce sagittal-plane energy absorption at the ankle during initial foot contact and, therefore, likely explain the greater plantar-flexion moment observed in the CAI group. However, these findings do not support previous reports[16,18] of a reduced ankle plantar-flexion moment during the midstance to late-stance phases of a landing and jump of 90° to the contralateral side in the CAI group compared with ankle-sprain copers and control individuals. The discrepant findings regarding ankle plantar-flexion moment may be attributed to differences in the dynamic-movement tasks used. Movements that are multiplanar closely mimic real-time sporting maneuvers and isolate lateral ankle loading, such as the side-cutting task performed in our study, and likely will not elicit the same sagittal-plane ankle-joint kinetic alterations previously demonstrated in cohorts with CAI during single-legged jump landings.[16,18]

In contrast, we observed a reduced ankle-eversion moment from 39% to 81% of stance phase with moderate to large effect sizes in the CAI group (Figure 2A). During a side-cutting task, greater mediolateral ground reaction forces, in addition to increased subtalar-inversion and

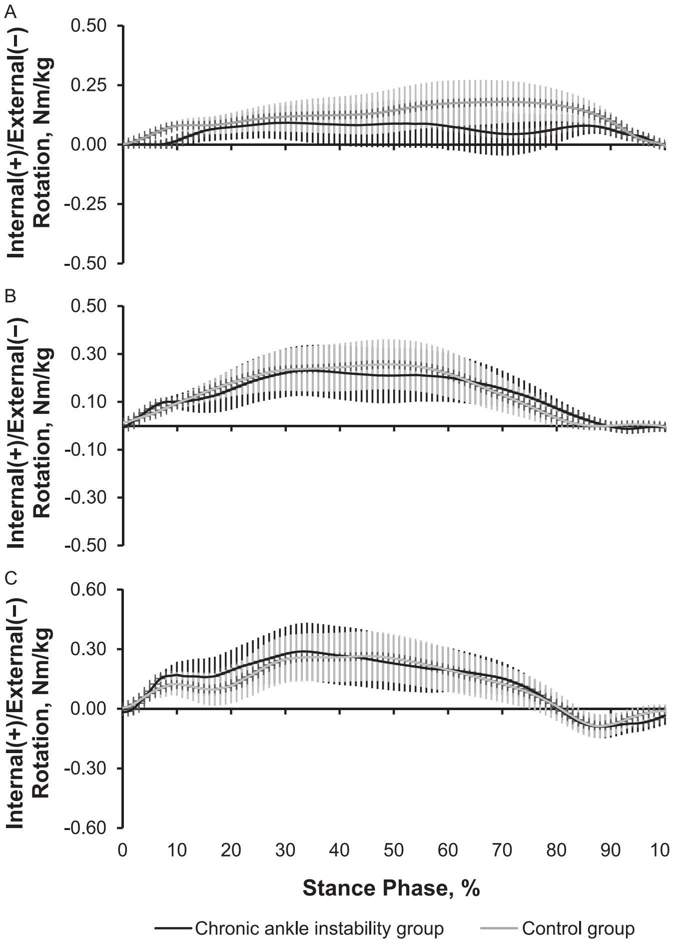

**Figure 3. Transverse-plane net internal joint moments for the chronic ankle instability and control groups during the stance phase (0% = initial contact, 100% = toe-off) of the side-cutting task (mean ± SD). A, Ankle. B, Knee. C, Hip.**

internal-rotation angles in preparation to rapidly change direction, can augment the inversion moment of the ankle complex.[7] Individuals with CAI exhibited reduced neuromuscular control, particularly in the peroneus longus and peroneus brevis, during the prelanding and postlanding phases of jump landings[14,18] and, in more recent investigations, during side-cutting tasks.[19,21] The reduced ankle-eversion moment demonstrated by our CAI group, in combination with previous findings of reduced neuromuscular control,[14,18,19,21] provides evidence of centrally mediated motor-control alterations that reduce dynamic frontal-plane joint stabilization. The impairments in sensorimotor function related to CAI likely contribute to the ankle complex potentially being in a more inverted and internally rotated position in preparation for ground contact and when the lateral ankle is loaded during the ground-contact phase of a side-cutting movement. Whereas the interaction between frontal-plane ankle kinematics and moments during a side-cutting task in participants with CAI is still unclear, it seems reasonable based on recent evidence[16,18] that reduced ankle-eversion moments indicate the lateral ankle musculature is unable to control frontal-plane movement eccentrically when the lateral ankle is loaded during ground contact. This could lead to the ankle complex giving way into excessive inversion and result in a recurrent LAS.

Reductions in ankle-eversion moment also coincided with less knee-abduction moment from 52% to 75% of the stance phase in the CAI group than in the control group (Figure 2B). Given that the ankle and knee joints are linked via the kinetic chain, perceptions of an unstable ankle could result in less deviation of the tibia in the frontal plane to attain stability in the proximal segments and reduce lateral ankle loading in participants with CAI. Examinations of proximal-segment frontal-plane biomechanical measures during dynamic tasks in CAI cohorts are limited, but researchers have reported reduced knee-abduction moments[18] and frontal-plane hip variability[28] in individuals with CAI during single-legged jump landings. In addition, greater hip-abduction angles during the preparatory and early to midstance phases have been found in participants with CAI during a side-cutting movement.[17] Although we did not find differences in frontal- or transverse-plane hip moment between groups, the literature has indicated that proximal-segment movement alterations in individuals with CAI appear to be task dependent.

The knee- and hip-extensor moment patterns previously exhibited during the stance phase of jump-landing in CAI cohorts[15,16,18] were not present in this study. However, the CAI group displayed greater sagittal-plane hip-joint stiffness than the control group, with a large effect size (Table). The joint-stiffness calculation uses joint kinetic and kinematic data to provide an estimate of the applied forces that cause changes in movement patterns at each joint.[15] The increased hip-joint stiffness in the CAI group reflected a hip-dominant movement strategy during the side-cutting task. Researchers have provided evidence that a hip-dominant movement strategy was used by individuals in the acute[10,11,29] and chronic[15–18,21] stages of LASs. Whereas the cause of this longitudinal dynamic-movement adaptation is unknown, the evidence suggested that a hip-dominant movement strategy was used at various stages after an LAS. Thus, the injured ankle joint may be unable to adequately withstand impact and rotational forces during the ground contact phase of a side-cutting task. To protect the unstable ankle from recurrent injury, a compensatory intralimb load redistribution occurs to increase reliance on the proximal joints to attenuate impact forces, maintain overall body equilibrium, and prevent excessive ankle-joint displacement. Dynamic-movement adaptations that transfer

**Table. Sagittal-Plane Joint Stiffness During the Side-Cutting Task**

| Joint | Group, Nm/kg/° (Mean ± SD) | | $t_{28}$ Value | *P* Value | Mean Difference (95% Confidence Interval) | Cohen d Effect Size |
|---|---|---|---|---|---|---|
| | Chronic Ankle Instability | Control | | | | |
| Ankle | −0.06 ± 0.01 | −0.08 ± 0.04 | 1.330 | .09 | 0.02 (−0.01, 0.04) | 0.50 |
| Knee | −0.16 ± 0.16 | −0.17 ± 0.20 | 0.180 | .43 | 0.01 (−0.12, 0.15) | 0.05 |
| Hip | −0.25 ± 0.15 | −0.14 ± 0.09 | 1.978 | .03[a] | 0.12 (−0.24, 0.01) | 1.00 |

[a] Between-groups difference ($P < .05$).

reliance from the distal ankle joint to the proximal joints appear to be used long after a first-time lateral ankle sprain.[10–12,16,18] Consequently, this erroneous movement pattern appears to be an underlying factor contributing to recurrent LASs in individuals with CAI. Therefore, clinicians and practitioners should also examine proximal-segment movement patterns when using dynamic movements to assess the LAS injury risk in individuals with CAI.

The lack of between-groups differences in frontal- and transverse-plane hip moment could possibly be attributed to the noticeably greater standard deviation of the mean in the CAI group (Figures 2C and 3C). Brown et al[28,30] reported increased frontal-plane ankle variability and reduced frontal-plane knee and hip variability during jump-landing tasks in cohorts with CAI. We did not compute a coefficient of variation or statistically analyze kinetic variability during the side-cutting task, but the wide standard deviation of the mean in the frontal- and transverse-plane hip moments in the CAI group could indicate more variable proximal-movement strategies in individuals with CAI. Consequently, greater variability during jump landings has been suggested to increase the risk of the ankle giving way during dynamic movements.[28,30] However, the side-cutting task that we used may cause frontal- and transverse-plane movements that are more variable than previously reported in CAI cohorts during jump landings,[28,30] which warrants further investigation. Examining lower limb variability during change-of-direction tasks would provide clinically relevant information to practitioners and clinicians regarding the possible link between movement variability and recurrent LASs in individuals who develop CAI.

Whereas we observed differences in lower limb joint kinetics and stiffness, some limitations should be considered when interpreting our results. First, we did not report muscle-activity data, which may limit the interpretation of our findings. Examining neuromuscular control during the side-cutting task would further elucidate the differences we observed in joint kinetics and stiffness between the CAI and control groups. Second, we were unable to compute frontal- or transverse-plane joint stiffness because it was difficult to accurately quantify these measures due to the smaller moments and joint displacements of the participants. Future studies of larger CAI cohorts are warranted to adequately determine these measures during sport-specific tasks and enhance the effect of our findings. Third, the side-cutting task that we used was simulated, and participants knew the direction to which they would be changing. Research in which protocols have been implemented to investigate the differences between anticipated and unanticipated change-of-direction tasks in individuals with CAI is limited. These data would further emphasize the clinical implications of our findings and identify movement strategies that contribute to the ankle giving way during dynamic movements typically observed in real-time injury scenarios.

## CONCLUSIONS

Our findings suggested that individuals with CAI displayed altered ankle-joint kinetics and increased proximal-joint stiffness compared with healthy control participants during the stance phase of a side-cutting task. The differences in ankle-joint kinetics and hip-joint stiffness provide insight into potential movement adaptations during a side-cutting task due to the sensorimotor and mechanical constraints of CAI. These altered movement patterns likely contribute to the recurrent LAS paradigm in individuals with CAI. Furthermore, our results may provide useful data to researchers and clinicians for developing effective rehabilitation and training programs to improve lower limb movement patterns and mitigating the risk of recurrent injury in individuals who develop CAI.

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