Altered Ankle Kinematics and Shank-Rear-Foot Coupling in Those With Chronic Ankle Instability

Lindsay K. Drewes, Patrick O. McKeon, Gabriele Paolini, Patrick Riley, D. Casey Kerrigan, Christopher D. Ingersoll, and Jay Hertel

Context: Kinematic patterns during gait have not been extensively studied in relation to chronic ankle instability (CAI). Objective: To determine whether individuals with CAI demonstrate altered ankle kinematics and shank-rear-foot coupling compared with controls during walking and jogging. Design: Case control. Setting: Motion-analysis laboratory. Participants: 7 participants (3 men, 4 women) suffering from CAI (age 24.6 ± 4.2 y, height 172.6 ± 9.4 cm, mass 70.9 ± 8.1 kg) and 7 (3 men, 4 women) healthy, matched controls (age 24.7 ± 4.5 y, height 168.2 ± 5.9 cm, mass 66.5 ± 9.8 kg). Interventions: Subjects walked and jogged on a treadmill while 3-dimensional kinematics of the lower extremities were captured. Main Outcome Measures: The positions of rear-foot inversion–eversion and shank rotation were calculated throughout the gait cycle. Continuous relative-phase angles between these segments were calculated to assess coupling. Results: The CAI group demonstrated more rear-foot inversion and shank external rotation during walking and jogging. There were differences between groups in shank-rear-foot coupling during terminal swing at both speeds. Conclusions: Altered ankle kinematics and joint coupling during the terminal-swing phase of gait may predispose a population with CAI to ankle-inversion injuries. Less coordinated movement during gait may be an indication of altered neuromuscular recruitment of the musculature surrounding the ankle as the foot is being positioned for initial contact.

Keywords: ankle sprain, gait, continuous relative phase

One of the most common athletic injuries is the lateral ankle sprain.\textsuperscript{1–5} Frequently caused by landing on an irregular surface, hypersupination of the ankle joint often leads to mechanical and sensorimotor deficits.\textsuperscript{1,2,4,6–8} Because, in part, of these harmful effects, subjects with a history of lateral ankle sprains may be...
more likely to suffer recurrent ankle sprains.\textsuperscript{4,6–9} The occurrence of repetitive bouts of lateral instability resulting in numerous ankle sprains has been defined as chronic ankle instability (CAI).\textsuperscript{10} In addition, one potential cause of CAI is functional instability determined by subjective complaints of the ankle joint repeatedly “giving way.”\textsuperscript{7,9,10}

It has been suggested that biomechanical abnormalities in gait, relating to an inverted foot position at initial contact, may predispose a subject to ankle sprain.\textsuperscript{5,11} Those with CAI have been shown to spend more time on the lateral aspect of the foot during the stance phase than healthy controls.\textsuperscript{2,4} Subjects with self-reported CAI have also demonstrated a more inverted foot position at heel strike.\textsuperscript{8,11} Researchers have focused on gait mechanics in the last 10\% of swing and the first 10\% of stance, defining this window as a critical period when most ankle sprains occur.\textsuperscript{6} There is evidence to suggest there is a highly coupled relationship between shank rotation and rear-foot eversion and inversion within this time frame in a healthy population.\textsuperscript{12} Peak rear-foot eversion and peak shank internal rotation were shown to occur close together in the stance phase. During running, the coupling between the rear foot and shank was more coordinated, suggesting that coupling was caused by external loads applied during stance as a function of the anatomy.\textsuperscript{12} To date, no one has examined this coupling relationship in a population with CAI.

Previously, a relationship between knee pathologies and the joint-coupling relationship between tibial internal rotation and pronation of the foot has been suggested.\textsuperscript{13} A novel method of analyzing this relationship is the use of the continuous relative phase (CRP). CRP compresses 4 variables (angular displacement and velocity of the proximal and distal segments) into 1 measure. To calculate CRP, the phase angle of the proximal segment is subtracted from the phase angle of the distal segment for each data point in the gait cycle. The phase angle quantifies the behavior of the segment, taking angular displacement and angular velocity into account.\textsuperscript{14,15}

There may be an altered coupling relationship of CRP measures for the shank and rear-foot segments in those with CAI compared with healthy controls, suggesting a more variable (ie, less stable) interaction between these segments. Although much of the previous literature discusses joint coupling in the stance phase, we believe that the shank and rear-foot segments are coupled, moving in relationship to one another, during the swing phase because of neuromuscular activity and the nature of the joint surfaces as the foot is being positioned for the next heel strike. A less stable or less coordinated coupling relationship may be deleterious to foot positioning during the terminal-swing phase in individuals with CAI. Synchrony in the rear-foot-shank coupling may be essential to avoid a lateral ankle sprain. Our purpose was to determine whether individuals with CAI demonstrated altered ankle kinematics and joint-coupling relationships compared with healthy controls during walking and jogging.
Methods

In this case-control study, we compared the degrees of motion for rear-foot inversion–eversion and shank rotation and the corresponding phase angles between these segments in subjects with and without CAI throughout the gait cycle during walking and jogging.

Subjects

Fourteen subjects volunteered for the study. Seven (3 men, 4 women) were healthy (age 24.7 ± 4.5 years, height 168.2 ± 5.9 cm, mass 66.5 ± 9.8 kg) and 7 (3 males, 4 females) had CAI (age 24.6 ± 4.2 years, height 172.6 ± 9.4 cm, mass 70.9 ± 8.1 kg). Control subjects were gender and age matched to CAI subjects. An independent-sample t test did not reveal a statistically significant difference in age, height, or mass between groups, \( P > .05 \). All subjects were recruited as a convenience sample from a university campus. Healthy subjects had never sustained an ankle sprain and did not have a history of lower extremity injury in the last 12 months or previous lower extremity surgery. CAI subjects had a history of more than 1 ankle sprain on the same ankle, their ankle-sprain history could be unilateral or bilateral, and they had not suffered an ankle sprain in the last 2 months. CAI subjects were included based on their scores on a modified Ankle Instability Instrument (AII),\(^{16}\) the Foot and Ankle Disability Index (FADI), and the Foot and Ankle Disability Index-Sport (FADI-S).\(^{17}\) The modified AII is used to classify the degree and severity of ankle instability. The FADI was used to determine self-reported ankle dysfunction during activities of daily living. The FADI-S asked functional, sport-specific questions related to activities. CAI subjects had to score below a 90% on the FADI and FADI-S. The CAI group had an average of 15 ± 9.4 self-reported previous ankle sprains and an average of 6 ± 4.2 months since their most recent ankle sprain. They reported an average score of 81.7% ± 8.3% on the FADI and of 67.6% ± 13.7% on the FADI-S. The CAI subjects had an average of 7.1 ± 1.8 “yes” responses on the AII. For subjects with self-reported bilateral CAI (n = 3), the ankle they reported as being subjectively more symptomatic was used for analysis. Healthy, matched controls scored an average of 0.14 on the AII and 100% ± 0.0% on both the FADI and FADI-S.

Subjects in both groups did not suffer from peripheral neuropathies or have any illnesses or injuries known to affect gait, other than CAI in the pathological group only. Subjects were not blinded to our investigation regarding our purpose of identifying differences in gait between the 2 groups, but they were not given information about the body segments in which we hypothesized we would observe differences. Before participation, subjects provided informed consent. The study was approved by the University of Virginia’s institutional review board.
Instruments

Gait analysis was performed in a university motion-analysis laboratory with a 10-camera motion-analysis system (model 624, VICON Motion Systems, Inc, Lake Forest, CA) in addition to a multiaxis strain-gauge force plate imbedded under a custom-built treadmill (AMTI, Watertown, MA). Force and video were sampled at 120 Hz. Dynamic trial data were filtered using a Woltring filter.18,19

Testing Procedures

Anthropometric measurements were taken during setup for the VICON data processing. A modified marker set was designed according to Pohl et al,12 including a combination of markers from the VICON plug-in gait model and additional shank and foot markers to allow for a more specific measurement of shank rotation and rear-foot motion. A total of 24 markers, 12 for each extremity, were placed on the following landmarks: the posterior superior iliac spine, anterior superior iliac spine, midlateral thigh, lateral tibiofemoral joint line, lateral mid-shank (plus 3 additional markers to form an array on the shank), lateral calcaneus, calcaneal tuberosity, sustentaculum tali, and second metatarsal head. The custom marker set allowed for more specific measure of shank rotation in the transverse plane and subtalar motion in the frontal plane.

For dynamic trials, the experimenter set the pace at 4.83 km/h for walking and 9.66 km/h for jogging. Subjects were given time to adjust to the pace of the treadmill before data collection. Gait analysis for all subjects was performed by the same investigator. Walking always preceded jogging, and subjects were given the option of a rest before jogging. Data were collected continuously at each pace until there were three 15-second trials with sufficient data to process at each pace. In no case were more than 5 trials required to obtain adequate data. The investigator was not blinded to group assignment; however, procedures were identical for both groups.

Data Reduction

For both walking and jogging, each trial consisted of 15 seconds of gait cycles. The stride cycles for each limb were resampled to 100 frames through a custom program in MatLab 7.04 (Mathworks Inc, Natick, MA) in which data were organized to 100 frames for each percent of the gait cycle. This was done individually for each subject based on the average stride-cycle time for the involved limb. An average of 14 stride cycles was analyzed for walking and 21 stride cycles for jogging in each trial. Kinematic data from each trial were reduced to 100 frames representing heel strike to the following heel strike for each limb. Relative-phase calculations comparing subtalar motion with shank rotation were performed in a custom program through MatLab. CRP measures provided a method of quantifying the coordination between 2 segments throughout the gait cycle by combining spatial and temporal components of movement for 2 segments into 1 variable20–23:

\[ \phi_{\text{relative phase}} = \Phi_{\text{distal segment}} - \Phi_{\text{proximal segment}} \]
To calculate CRP for shank rotation and rear-foot inversion–eversion, phase plots were generated for each. A phase plot consisting of a 4-quadrant polar-coordinate plot in which the angular velocity (\(\omega\)) of the segment was plotted over its angular position (\(\theta\)) for each of the 100 data points in the normalized gait cycle was generated. To calculate phase angles, phase-plot data were normalized to range from 1 to –1 on the vertical and horizontal axes.\(^{14}\) Phase angles were then generated based on the velocity and position of each data point in accordance with methods established by Hamill et al.\(^{14}\) A phase angle was calculated in reference to the polar position for each data point along the phase plot and converted from radians to degrees.\(^{14}\) Normalized phase angles ranged from 180° to –180° based on their location on the phase plot.

A CRP value of 0° indicates an in-phase relationship between the 2 segments. A value of 180° indicates an out-of-phase relationship between the 2 segments. A positive phase angle indicated that the distal-segment phase angle was greater than that of the proximal segment, whereas a negative phase angle indicated that the proximal phase angle was greater than that of the distal.\(^{22–24}\) In this case, an in-phase relationship meant that the phase angles of the 2 segments were equal. This would indicate that the segments were highly coupled, moving in a coordinated and predictable pattern resulting in a very stable relationship. An out-of-phase relationship (closer to 180° or –180°) would indicate that the 2 segments were uncoupled, moving in an uncoordinated and unpredictable pattern, and thus there is an unstable relationship between the adjacent segments.\(^{22–24}\) Positive CRP values indicated that the distal segment was ahead of the proximal segment in phase space, and vice versa for a negative CRP value.\(^{24}\) The slope of the relative-phase angle indicated which segment was moving faster in phase space; a positive slope indicated a faster-moving distal segment, and a negative slope indicated a faster-moving proximal segment.\(^{15,24–26}\)

Mean absolute relative phase (MARP) is a method of characterizing relative-phase curves from the entire gait cycle into a single measure. The MARP can be used to quantify the nature of the coordination pattern by determining whether interacting segments generally demonstrate a more in-phase or out-of-phase relationship during the gait cycle.\(^{15,26}\) A low MARP indicates that the oscillating segments have a more in-phase relationship; a high value indicates that they have a more out-of-phase relationship.\(^{25}\) MARP is calculated by averaging the absolute values of the ensemble CRP curve points:

\[
\text{MARP} = \frac{1}{N} \sum_{i=1}^{N} |\phi_{\text{relative phase}}|\]

where the variable \(N\) is the number of points in the relative-phase mean ensemble and \(\phi_{\text{relative phase}}\) is the relative-phasing relationship between 2 segments.

Deviation phase (DP) of the CRP is used to estimate the variation in the CRP relationship, or coordination, between 2 segments through a movement pattern. The DP provides information about the stability of the neuromuscular system during a dynamic task such as walking or jogging.\(^{14,15,26}\) A small DP value indicates a more stable (less variability) organization of the neuromuscular system to complete a task; a large DP value indicates less stability (more variability) in the organization of the system to complete a task.\(^{25}\) The DP was calculated by averaging the standard deviations of CRP values across trials.
\[ DP = \sum_{i=1}^{N} |SD_i| / N \]

where \( N \) is the number of points in the relative-phase mean ensemble and \( SD_i \) is the standard deviation of the mean ensemble at the \( i \)th point.

**Statistical Analysis**

The independent variable was group (control, CAI) for all analyses. Three of the dependent variables were compared across the entire gait cycle in walking and jogging: degrees of rear-foot inversion–eversion and shank rotation and the CRP angle. For these measures, group means and associated 95% confidence intervals (CI) were calculated across all 100 points of the gait cycle. A curve analysis using an alpha level of \( P < .05 \) was performed across the entire gait cycle to identify increments in which the CI bands for the 2 groups did not cross each other (ie, there were statistically significant differences at the .05 level). Mean differences between groups were calculated at the intervals identified as being significantly different. Microsoft Excel 2002 (Microsoft Corp, Redmond, WA) was used to graph all means and CIs. MARP, DP, and static rear-foot angles were compared for both walking and jogging using independent \( t \) tests with the alpha level set at \( P < .05 \). SPSS version 14.0 was used for statistical analysis (SPSS, Inc, Chicago, IL).

**Results**

**Kinematics**

**Walking.** For the inversion–eversion kinematics we found a significant difference between groups throughout the entire gait cycle, wherein 1% of the gait cycle defines initial contact and 100% defines terminal swing (Figure 1). The CAI mean difference was \( 2.07^\circ \pm 0.29^\circ \) more inverted through the gait cycle than the healthy population.

For shank rotation we found differences of \( 7.00^\circ \pm 0.90^\circ \) in the first 2%, \( 8.22^\circ \pm 1.10^\circ \) from 7% to 62%, \( 6.07^\circ \pm 0.49^\circ \) from 65% to 76%, and \( 6.86^\circ \pm 1.40^\circ \) from 80% to 100% of the gait cycle (Figure 2). In all cases, the CAI subjects were more externally rotated than controls.

**Jogging.** For the inversion–eversion kinematics we found significant differences of \( 1.35^\circ \pm 0.35^\circ \) between groups during the first 2%, \( 1.78^\circ \pm 0.23^\circ \) from 23% to 33%, \( 1.57^\circ \pm 0.34^\circ \) from 42% to 58%, and \( 1.90^\circ \pm 0.30^\circ \) from 78% to 100% of the gait cycle (Figure 3). For all significant differences, the CAI subjects demonstrated more inversion than controls.

For shank rotation during jogging we found significant differences of \( 6.20^\circ \pm 0.99^\circ \) from 48% to 55% and \( 7.26^\circ \pm 0.97^\circ \) from 81% to 96% of the gait cycle. The CAI subjects demonstrated more shank external rotation than controls (Figure 4).

Given the kinematic differences during walking and jogging, we wanted to determine whether static rear-foot alignment differed between groups. The CAI group demonstrated \( 5.3^\circ \pm 2.5^\circ \) of rear-foot inversion, and the control group demonstrated \( 5.8^\circ \pm 1.4^\circ \) of rear-foot inversion during standing. There was no statistical significance between these means (\( P = .70 \)).
For the walking CRP data we identified a significant difference from 94% to 97% of the gait cycle. The average difference in this time frame was a phase angle of 42.99° ± 8.68°. The CAI group was more out of phase than the healthy controls, and the positive difference indicates that the rear foot was moving ahead of shank rotation in phase space (Figure 5).

For the jogging CRP data, we identified a significant difference of 47.00° ± 4.15° from 47% to 53% and a significant difference of 48.30° ± 6.03° from 84% to 93%. Similar to the walking results, the CAI group was more out of phase than the healthy controls, and the positive mean difference indicates that the rear foot was moving ahead of shank rotation in phase space (Figure 6).

There were no significant differences between groups for the MARP and DP measures during walking or jogging (P > .05). The MARP during walking for the CAI group was 11.10° ± 11.24° and was 11.92° ± 10.00° for the controls. The mean DP for the CAI group during walking was 18.15° ± 6.67° and was 16.28° ± 5.23° for the control group. During jogging, the CAI group had a mean MARP of 11.39° ± 7.64° and the control group had 13.57° ± 10.12°. The mean DP during jogging was 17.21° ± 8.24° for the CAI group and 22.85° ± 19.08° for the control group.

**Figure 1** — Rear-foot inversion–eversion during walking. Throughout the entire gait cycle, there was a significant mean difference of 2.07° ± 0.29° between chronic-ankle-instability (CAI) and control subjects. CAI subjects demonstrated more inversion than controls.

**Coupling Relationships**

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The CAI group had more rear-foot inversion and shank external rotation than healthy controls during both walking and jogging throughout the gait cycle. Altered segmental kinematics, especially during foot positioning within terminal swing and initial contact, are important to note because this time frame falls within the critical period as described by Monaghan et al. They reported a significant difference of $6^\circ$ to $7^\circ$ more inversion in those with ankle instability during this period. Similarly, Delahunt et al reported a more inverted foot position before, at the instant of, and immediately after heel strike in subjects with functional instability of the ankle joint than in a control group. Proper positioning of the foot during this time frame is critical to avoiding a lateral ankle sprain and has been demonstrated via cadaver and computer modeling. Konradsen and Magnusson evaluated the ability of subjects with functional instability to replicate an ankle-inversion joint angle in a non-weight-bearing position and found a significant difference in the angles of unstable ankles compared with stable ankles in controls, with an average absolute error of $2.5^\circ \pm 0.4^\circ$.

**Figure 2** — Shank rotation during walking. Within the first 2% of the gait cycle, there was a significant mean difference of $7.00^\circ \pm 0.90^\circ$; from 7% to 62%, a significant mean difference of $8.22^\circ \pm 1.10^\circ$; from 65% to 72%, a significant mean difference of $6.07^\circ \pm 0.49^\circ$; and from 80% to 100%, a significant mean difference of $6.86^\circ \pm 1.40^\circ$, between chronic-ankle-instability (CAI) and control subjects. CAI subjects demonstrated more shank external rotation whenever there were significant differences.

**Discussion**

**Kinematics**

The CAI group had more rear-foot inversion and shank external rotation than healthy controls during both walking and jogging throughout the gait cycle. Altered segmental kinematics, especially during foot positioning within terminal swing and initial contact, are important to note because this time frame falls within the critical period as described by Monaghan et al. They reported a significant difference of $6^\circ$ to $7^\circ$ more inversion in those with ankle instability during this period. Similarly, Delahunt et al reported a more inverted foot position before, at the instant of, and immediately after heel strike in subjects with functional instability of the ankle joint than in a control group. Proper positioning of the foot during this time frame is critical to avoiding a lateral ankle sprain and has been demonstrated via cadaver and computer modeling.

Konradsen and Magnusson evaluated the ability of subjects with functional instability to replicate an ankle-inversion joint angle in a non-weight-bearing position and found a significant difference in the angles of unstable ankles compared with stable ankles in controls, with an average absolute error of $2.5^\circ \pm 0.4^\circ$.
Ankle Kinematics With Chronic Ankle Instability

and 1.7° ± 0.2°, respectively. Although this difference is small, it may be of clinical significance because an increase in inversion decreases the distance between the lateral border of the foot and the ground. It is important to use caution when generalizing these results to a dynamic gait pattern that includes both stance and swing phases.

Docherty and Arnold28 have additionally discussed an altered force sense in subjects with functionally unstable ankles. Their subjects demonstrated deficits in force-sense reproduction. In this case, force-sense reproduction is the ability to detect muscle tension and force around the ankle joint. Muscle tension levels must be adequate to support the ankle. Damage from repeated ankle sprains to the neuromuscular structures surrounding the ankle affects the ability of those with functionally unstable ankles to detect forces around the ankle and avoid injury.28 It is also possible that subjects in our study suffered from force-sense deficits that affected shank and rear-foot position throughout the gait cycle.

The increased error in the inversion-angle positioning associated with CAI identified in previous research,6 combined with our finding of increased inversion during the late swing phase, may lead to individuals with CAI suffering more episodes in which the inverted positioning of the foot at initial contact forces the ankle into hyperinversion. Computer modeling has shown that increased inversion angle at initial contact increases the probability of a hyperinversion episode.1,27

Figure 3 — Rear-foot inversion–eversion during jogging. Within the first 2% of the gait cycle, there was a significant mean difference of 1.35° ± 0.35°; from 23% to 33%, a significant mean difference of 1.78° ± 0.23°; from 42% to 58%, a significant mean difference of 1.57° ± 0.34°; and from 78% to 100%, a significant mean difference of 1.90° ± 0.30°, between chronic-ankle-instability (CAI) and control subjects. CAI subjects demonstrated more rear-foot inversion whenever there were significant differences.
Results of our study and previous studies report significant differences between groups with a small difference between means, leading to the discussion of clinical significance and meaningfulness of the results despite statistically significant results. Although this difference may not incur a sprain in a controlled environment such as running on a flat surface or treadmill, it may be more influential on an uneven surface or with quick changes in direction. We acknowledge that there are limitations to the interpretation of clinical meaningfulness in our results, which showed small mean differences in rear-foot motion.

**Coupling Relationships**

To our knowledge, our results are the first identification of rear-foot-shank-coupling differences associated with CAI. When examining CRP data, we identified a more out-of-phase relationship in the CAI subjects in both walking and jogging. During walking, the CAI subjects were significantly more out of phase than the healthy controls during the terminal swing phase. In jogging, we identified a more out-of-phase relationship in the CAI subjects during initial swing and terminal swing. This out-of-phase relationship indicates an altered joint-coupling relationship between the shank and the rear foot. These segments are less coordinated as the foot is being positioned before initial contact. A synchronous relationship during this period may be critical to avoiding a lateral sprain.
ankle sprain. This altered coupling relationship in subjects with CAI may be a predisposing factor to their self-reported pathology because the positioning of the foot leading up to heel strike is greatly influenced by the degrees of tibial rotation and rear-foot inversion. The larger magnitude of rear-foot motion in the terminal swing phase was characteristic in our healthy population, but it is worth noting that in the CAI subjects, the rear-foot motion was occurring at a much greater rate than tibial rotation in phase space. This combined with the more loosely coupled relationship may predispose the population to frequent episodes of the ankle “giving way.” An unstable, or less coordinated, movement pattern between these 2 segments would negatively influence foot positioning in preparation for the next heel strike. The lack of coordination might be caused by a problem with the motor-control pattern brought about by altered neuromuscular recruitment in the lower extremity during walking and jogging in those with CAI.

We also see a greater extent of asynchrony for the CAI subjects in the jogging trials than in the walking trials. It is possible that as the locomotion task increased in velocity, the constraints imposed on an individual became greater. As a subject increases the pace of gait, the task becomes more complex and it may become more difficult to maintain the same level of synchrony demonstrated during the less demanding task of walking.
Limitations and Future Directions

There were a few limitations to our study. All subjects performed the dynamic trials barefoot. This was necessary because we could not have detected subtalar foot motion as accurately while they wore athletic shoes. It has been previously reported that there was not a difference in kinematic collection of rear-foot motion in the frontal plane and shank rotation during the stance phase in subjects wearing sandals.\textsuperscript{29} This is another direction for future research to consider to obtain results more generalizable to athletic shod conditions. A second limitation was that uniform speeds of 4.83 km/h and 9.66 km/h were used for all subjects regardless of body type, height, and leg length. This may not have been a preferred walking or jogging pace for every individual, so we may not have captured data at each subject’s preferred walking and jogging gait speeds. Previous research has reported an effect of walking speed on muscle function and gait kinematics.\textsuperscript{30,31} Another limitation of the study was combining the analysis for subjects with bilateral and unilateral CAI. Future studies should compare gait kinematics of those with bilateral and unilateral ankle instability, as well as include side-to-side comparisons in both healthy and unilateral CAI populations.

Figure 6 — Continuous relative-phase measures during jogging. From 47\% to 53\% there was a significant difference of 47.00° ± 4.15°, and from 84\% to 93\%, a significant difference of 48.30° ± 6.03°, in phase space. Chronic-ankle-instability (CAI) subjects were more out of phase than control subjects during initial swing and terminal swing. The positive value indicates that the rear foot was moving ahead in phase space compared with the shank rotation or shank rotation was lagging in comparison with rear-foot motion in phase space.
Another point of discussion is that the number of previous ankle sprains reported in our subject population is larger than in previous investigations. The large average number of previous sprains combined with average scores on the FADI and FADI-S gave us confidence that it was an impaired group we were observing for this comparison with a control group. It is important to note that all trials in this study were completed successfully, without incidence of ankle sprain. In future studies we need to determine whether the altered ankle kinematics and coupling predispose CAI subjects to more ankle sprains. We must also determine the effectiveness of clinical interventions such as taping, bracing, orthotics, and rehabilitation exercises on the restoration of normal kinematics and shank-rear-foot coupling.

In conclusion, significant differences in the kinematics of rear-foot inversion and shank rotation and the coupling parameters between these motions were found between subjects with and without CAI before heel strike during both walking and jogging. This may indicate the influence of foot positioning during swing phase on the risk of sustaining recurrent ankle sprains.

References