Introduction: Longitudinal analyses of participants with a history of first-time lateral ankle sprain are lacking. This investigation combined measures of inter-joint coordination and stabilometry to evaluate eyes-open (condition 1) and eyes-closed (condition 2) static unipedal stance performance in a group of participants with chronic ankle instability compared to ankle sprain 'copers', both recruited 12-months after sustaining an acute first-time lateral ankle sprain.

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closed single-limb stance respectively.

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Authors:

Cailbhe Doherty¹

Chris Bleakley³

Jay Hertel⁴

Brian Caulfield¹

John Ryan⁵

Kevin Sweeney⁶

Matthew R Patterson⁶

Eamonn Delahunt¹,²

1. School of Public Health, Physiotherapy and Population Science, University College Dublin, Dublin, Ireland.

2. Institute for Sport and Health, University College Dublin, Dublin, Ireland.

3. Sport and Exercise Sciences Research Institute, Ulster Sports Academy, University of Ulster, Newtownabbey, Co. Antrim, Northern Ireland.

4. Department of Kinesiology, University of Virginia, Charlottesville, VA, United States.

5. St. Vincent’s University Hospital, Dublin, Ireland.

6. Insight Centre for Data Analytics, University College Dublin, Dublin, Ireland.

Address for Correspondence:
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ABSTRACT

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Key words: ankle joint [MeSH]; biomechanical phenomena [MeSH]; kinematics [MeSH]; kinetics [MeSH]; postural balance [MeSH]
INTRODUCTION

Lateral ankle sprain (LAS) injury pervades a variety of activities, with between 0.88 [CI 95%: 0.73 – 1.02] and 7 [CI 95%: 6.82 – 7.18] injury events occurring per 1,000 exposures, depending on the activity type (11). The prevalence of this injury in a wide range of sports and activities is further complicated by its capacity to deteriorate into an array of chronic sequelae and injury recurrence, collectively termed “chronic ankle instability (CAI)”(16-18), which has been linked to limitations in future physical activity participation (1).

Although CAI is considered a multifaceted condition with a range of consequences, persistent deficits in single-limb stance (SLS) postural control strategies are well established in individuals with CAI (19, 25, 36), and may be consequent upon a potential change in neural signalling following the initial ankle joint trauma (14). This theory has since been tested in a number of studies comparing individuals with a history of LAS to uninjured controls (13, 35, 37), with a new hypothesis emerging whereby the long-term outcome following LAS is dependent upon the success or failure of the newly adopted post-LAS postural control strategies (33, 34). This has yet to be confirmed however, as there is currently an absence of longitudinal investigations which prospectively track the restoration or degradation of postural control strategies after an initial LAS.

More recently, ankle sprain ‘copers’, who have a history of LAS and experience a restoration of pre-injury levels of function in the year following initial injury (16, 33), have been compared to individuals with CAI during SLS (36); this is considered to provide a stronger, more relevant comparison in laying the foundation for longitudinal analyses and the development of clinical outcome models for the CAI paradigm (33). Recently published material from our laboratory was developed according to this paradigm: individuals with an
acute, first-time LAS were evaluated in comparison to a non-injured control group during eyes-open and eyes-closed SLS using kinematic and kinetic measures of joint position and platform stabilometry respectively (7). A follow-up analysis of these same individuals 6-months following the initial assessment revealed a hip-dominant postural control strategy prevailing during the prescribed tasks of SLS, again in comparison to non-injured controls (9). In this latter investigation, an adjusted coefficient of multiple determination (ACMD) statistic was utilised to evaluate waveform similarity between lower extremity 3-D joint angular displacements in the determination of inter-joint ‘coupling’ strategies during 20 seconds of eyes-open and eyes closed SLS (9). We believe novel insight was gained by combining these laboratory measures and considered the increase in observed coupling between sagittal plane hip and frontal plane ankle motion in LAS participants to lend to a hypothesis that these individuals adopt a hip-dominant strategy in the maintenance of single-limb postural control, to compensate for a dysfunctional ankle joint (9). This theory is in agreement with the model of human postural control proposed by Nashner and McCollum, in which an ‘ankle strategy’ is appropriated to the fine tuning of static postural control, and a ‘hip strategy’ is employed to tackle more substantial postural control disturbances (28); the LAS group in the aforementioned studies were considered to have reduced capacity to utilise their ankle strategy, thus adopting the more proximal hip strategy in its place (7, 9).

The measure of platform stabilometry employed in the aforementioned investigations from our laboratory was the fractal dimension (FD) of the center of pressure (COP) path. The FD is a unit-less measure that conceptualises the complexity of the COP path using a value between 1 (a straight line or low complexity) and 2 (a convoluted line or high complexity)(23). In addition to a hip-dominant kinematical strategy, LAS participants were also shown to display a bilaterally reduced FD of the COP path during eyes-closed SLS.
within 2 weeks of incurring their initial injury (7), and on their involved limb only 6 months following their initial sprain (9). This was interpreted as a reduced ability to utilise the available base of support on removal of visual afferents (5, 7, 9).

The current study is a continuation of those previously described and forms part of a larger longitudinal analysis of the LAS cohort. Specifically, we sought to evaluate this group 12-months following initial acute first-time LAS injury occurrence, thus allowing for participant segregation as CAI or ankle sprain “coper” status. Kinematic and stabilometric measures were combined to compare stance limb inter-joint coordination and COP path complexity during eyes-open and eyes-closed SLS between CAI and “coper” participants. We hypothesised that individuals with CAI would exhibit the same hip-dominant coupling strategies for completing eyes-open and eyes-closed SLS as their counterparts 6-months following acute LAS occurrence, whereas “coper” participants would not due to a superior capacity to employ an ankle-based balance strategy in isolation. Furthermore, we hypothesised that during eyes-closed SLS CAI participants would be less able to utilise the base of support available to the stance limb, as evidenced by a reduced FD of the COP path.

METHODS

Participants

As part of the larger longitudinal study conducted in our laboratory, eighty-two individuals presenting with a first-time acute LAS were recruited from a University-affiliated hospital emergency department. These individuals were required to attend three test sessions and complete a number of movement tasks within 2-weeks of sustaining their initial injury, with further follow-up at 6 months and 12 months. Testing procedures for these participants in the acute phase of their injury has previously been reported (5, 6, 8, 10). A total of seventy-one
of the original eighty-two participants returned for the third test session (i.e. 12 month follow-up); the current investigation relates to the data collected for these individuals at this time-point. Participant characteristics for the individuals included in the current analysis are presented in Table 1. The following exclusion criteria were utilised for both limbs (where applicable) at the time of recruitment: (1) no previous history of ankle sprain injury (excluding the initial acute episode); (2) no other severe lower extremity injury in the last 6 months; (3) no history of ankle fracture; (4) no previous history of major lower limb surgery; (5) no history of neurological disease, vestibular or visual disturbance or any other pathology that would impair their motor performance. Participants provided written informed consent, and the study was approved by the University Human Research Ethics Committee.

Participants’ designation as CAI or coper status was completed according to recently published guidelines (16). Self-reported ankle instability was confirmed with the Cumberland Ankle Instability Tool (16); individuals with a score of <24 were designated as having CAI while “copers” were designated with a score of ≥24, to avoid the potential for false positives in this group (39). Additionally, to be designated as a coper, participants must have returned to pre-injury levels of activity and function (36). Finally, the activities of daily living and sports subscales of the Foot and Ankle Ability Measure (FAAMadl and FAAMsport) were utilised as a means to evaluate general self-reported foot and ankle function (16). All participants completed the CAIT and subscales of the FAAM on arrival to the testing laboratory.

Based on these criteria, twenty-eight individuals were designated as having CAI, and forty-two as “copers” (Table 1). One ‘coper’ participant was excluded because he did not return to pre-injury levels of activity participation.
Collection methods for this study have been previously documented (9). Briefly, following
the collection of anthropometric measures required for the calculation of internal joint centres
of the lower extremity joints, each participant was instrumented with the Codamotion
bilateral lower limb gait set-up according to the manufacturer guidelines (Charnwood
Dynamics Ltd, Leicestershire, UK). A neutral stance trial was used to align the subject with
the laboratory coordinate system and to function as a reference position for subsequent
kinematic analysis (40). Participants then performed three, 20 second trials of quiet SLS
barefoot on a force plate with their eyes open on both limbs, each separated by a 30 second
rest period. Following another 2 minute rest period, participants then attempted to complete
three 20 second SLS trials with their eyes closed. Participants were required to complete a
minimum of three practice trials on each limb for each condition prior to data acquisition.
Participants who were unable to complete a full trial of unilateral stance after five attempts on
the relevant limb were not included in the analysis for that limb. The test order between legs
was randomized. For both conditions of the SLS task, participants were instructed to stand as
still as possible with their hands resting on their iliac crests while adopting a postural
orientation most natural to them; the position of the non-stance limb was not dictated in the
sagittal plane as part of experimental procedures. Trials were deemed invalid if the subject
lifted their hands off their iliac crests, placed their non-stance limb on the support surface,
moved their non-stance hip into a position > 30 degrees abduction, adducted their non-stance
limb against their stance limb for support or if the foot placement assumed by the participants
relative to the support surface changed in any way over the course of a trial. In addition a trial
was deemed as failed in the eyes closed condition if the subject opened their eyes at any
point.

Kinematic and Kinetic Data Processing
Three Codamotion cx1 units were used to acquire data on 3-D angular displacements at the
hip, knee and ankle joints for both limbs during the SLS tasks. Two AMTI (Watertown, MA)
walkway embedded force plates were used to acquire kinetic data. Kinematic and kinetic data
acquisition was made at 100 Hz. The Codamotion CX1 units were time synchronized with
the force plates. Kinematic and COP data were analysed using the Codamotion software and
then converted to Microsoft Excel file format. Temporal data were set with the number of
output samples per trial at 2000 + 1 in the data-export option of the Codamotion software,
which represented the complete unilateral stance trial as 100%, for averaging and further
analysis.

Pairwise comparison of 3-D temporal angular displacement waveforms for the hip, knee and
ankle joints of the stance limb were made using the ACMD statistic (22) to determine the
similarity of a given pair of waveforms during both conditions of SLS. There were three joint
pairs (hip/knee, hip/ankle, and knee/ankle) in three dimensions, with twenty-seven resultant
ACMD values for each individual SLS trial. The mean ACMD from three trials of unilateral
stance was used as a representative ACMD for each participant for the eyes-open and eyes-
closed conditions separately, with subsequent calculation of group (CAI and coper) means.

ACMD values ranged from 0 (no similarity) to 1 (two identical curves) (22).

In addition, mean values of all joint angular ranges (maximum value−minimum value) during
testing in each task were computed for comparison between CAI and coper participants.

The kinetic data of interest was the COP, the location of the vertical reaction vector on the
surface of a force-plate) path (30). COP data acquired from trials of the unilateral stance were
used to compute FD of the COP path using an algorithm previously published and described
by Prieto et al (30). FD was calculated based on the 20 second interval for each SLS trial,
and averaged across the three trials for each participant on each limb and grouped
accordingly. The COP time series were passed through a fourth-order zero phase Butterworth low-pass digital filter with a 5-Hz cut-off frequency (38).

Data Analysis and Statistics
For both groups, the limb injured at the time of recruitment was labelled as “involved” and the non-injured limb as “uninvolved”. For all outcomes, we calculated mean (SD) scores for the involved and uninvolved limbs of the CAI and coper groups. Participant demographics were compared between the CAI and coper groups using multivariate analysis of variance. The independent variable was group (CAI vs control). The dependent variables were gender, age, body mass and height. The significance level for this analysis was set a priori with a bonferonni adjusted alpha level of p < 0.0013 (0.05/4 dependent variables) (21).

To test our hypothesis that the CAI group would display bilateral changes in inter-joint coordination patterns as determined using the ACMD statistic for pairwise comparison between 3-D joint angular displacement curves, we undertook a series of independent samples t-tests comparing CAI involved limb vs coper involved limb, and CAI uninvolved limb vs coper uninvolved limb for the eyes-open and eyes-closed conditions. The mean joint range of motion in both conditions was also computed for all joints in all planes for comparison groups. The significance level for these analyses were adjusted for multiple tests using the Benjamini-Hochberg method for false discovery rate (<5%) (3) in two groups (ACMD and joint ranges) each with two levels (eyes-open and eyes closed).

In order to test our hypothesis that the CAI group would display altered COP path trajectory FD during the SLS task, an independent samples two-sided t-test was undertaken for each limb in each condition. The significance level for this analysis was set a priori with a Bonferroni adjusted alpha level of 0.0013 [0/05/(2 x limb, 2 x condition)].
All data were analyzed using Predictive Analytics Software (Version 18, SPSS Inc., Chicago, IL, USA).

RESULTS

Regarding participant demographics, there was no statistically significant difference between the CAI and coper groups on the combined dependent variables, $F(4, 62) = 0.69, p = 0.60$; Wilk’s Lambda = 0.96; partial eta squared = 0.04 (Table 1).

All participants completed the eyes-open SLS task on both limbs. Of the twenty-eight CAI participants, ten (36%) completed the SLS task with their eyes closed on both their involved and uninvolved limbs. Of the forty-two coper participants, thirty-three (76%) completed the SLS task with their eyes closed on both their involved and uninvolved limbs.

In an exploratory analysis, the concurrent validity of eyes-closed SLS task completion in determining the extent of disability was established by calculating Pearson correlation coefficients between CAIT scores and eyes-closed SLS task completion (15). The ability of task completion to determine outcome (CAI vs coper) was then tested for sensitivity and specificity.

There was no correlation between CAIT score and eyes-closed SLS task completion ($r = 0.004, n = 70, p = 0.97$). Post-hoc analysis using independent samples t-tests were performed to compare the CAIT scores of the subgroups of CAI and coper participants who succeeded and failed at the eyes-closed SLS task to explain this finding. The p-value for this post-hoc analysis was set a priori with a bonferonni adjustment at $p < 0.025$. This analysis revealed that copers who were able to complete the task actually had significantly greater disability than those who couldn’t, and likewise for the CAI participants. The results of this post-hoc analysis for both sub-groups of CAI and coper participants are presented in Table 2.
The capacity of eyes-closed SLS task completion to predict outcome (CAI vs coper) was statistically significant (p = 0.003), with a C-statistic of 0.71; the resultant prediction equation yielded a sensitivity of 0.64 and a specificity of 0.78, with a positive likelihood ratio of 2.93.

Regarding inter-joint coordination, the CAI group displayed significantly increased similarities in joint angular motions based on ACMD values between sagittal plane hip motion and frontal plane ankle motion on their involved limb compared to coper participants in the eyes open condition only. ACMD values for the eyes open and eyes closed conditions are presented in Tables 3 and 4 respectively. There was no significant difference in ranges for any of the lower extremity joints in any dimension (Table 5).

Regarding the kinetic variables of interest, CAI participants displayed reduced stance limb FD compared to coper participants on their involved limb in the eyes closed condition only (Table 6).

DISCUSSION

The primary finding of this motion analysis investigation was that individuals with CAI exhibit greater coupling of hip and ankle motion during eyes-open SLS compared to ankle sprain “copers”. Specifically, CAI participants in the current study displayed greater sagittal-plane hip to frontal-plane ankle motion, in what may be considered a compensatory strategy to accommodate what is now a chronically unstable ankle, as determined using the CAIT. Furthermore, the CAI group also demonstrated a reduced FD of the COP path on their involved limb compared to “copers” during the eyes-closed condition. In light of previously published material on the group as a whole within two-weeks of their injury (7), and then 6-months following (9), it is apparent that the abatement of the hip-strategy during the eyes-open condition, and the greater FD of the stance limb COP path in the eyes-closed condition,
may independently or in combination be conducive to superior outcome. The design of the
current study however means that this cannot be confirmed.
To our knowledge, this is the first documented evaluation of postural control in a first-time
LAS population exactly 12-months following initial injury using kinematical measures of
inter-joint coordination and platform stabilometry. The advantage of the experimental design
is that all participants were recruited at the time of their first ankle sprain injury, thereby
securing the homogenous subgroups of ankle sprain outcome. As we have alluded to, this
study is part of a longitudinal analysis designed to develop an outcome model for the
predictors of instability following ankle sprain injury.
The use of “copers” provides a superior comparison group to individuals with CAI than non-
injured controls because copers have had the same exposure, but are not characterized by the
same symptom sequelae as those individuals who develop CAI. There are a limited number
of previous analyses which have evaluated SLS postural control using measures of platform
stabilometry in ankle sprain coper participants in comparison to individuals with CAI (31,
36). Wikstrom et al. (36) identified that ankle sprain coper participants’ stance limb COP
paths exhibits a lower velocity in both the antero-posterior and the medio-lateral axes of the
foot than individuals with CAI during a similar task. Shields et al.(31), demonstrated that the
standard deviation of the COP path and it’s range were significantly lower in “copers”
compared to subjects with CAI, a finding the authors interpreted as being demonstrative of
better postural control predictability. The issue regarding the application of these ‘traditional
measures’ of COP excursion which quantify the length, area and velocity of the COP path,
apart from their questionable reliability (12), is that they have previously yielded inconsistent
or even contradictory findings in ankle sprain populations (26). By contrast, the FD measure
utilised in the current analysis is a reliable measure (12) which has previously been successful
in characterising a degeneration in stability of the postural control system in the transition
from eyes-open to eyes-closed stance (4). Furthermore, because we have adopted the FD
calculation in analysing the COP paths of these participants during SLS within 2-weeks (7) of
incurring their initial injury and 6-months later (9), its use enables us to directly compare our
findings across time points relevant to the development of CAI or ankle sprain coper status.
Consistent with the investigations of these participants 2-weeks and 6-months following
injury occurrence comparing them to healthy controls (7, 9), the findings of the current study
revealed that individuals with poorer outcome (<24 on the CAIT in this study, ‘injured’ status
in those previously described), exhibit reduced FD of the COP path in the eyes closed
condition only, with an associated large effect size. This was previously interpreted as a
reduced ability to utilise the available base of support during SLS, isolated to instances where
the task condition dictated the removal of visual afferents (5). However, that only ten (36%)
of the individuals with CAI completed the eyes-closed task raises concerns over the potential
for statistical error of this observation. Post hoc power analyses for the eyes-closed condition
showed that we had strong observed power to detect group differences for this significant
finding (observed power = 0.81). However, the case of a non-significant finding close to
significance for condition 2 (p = 0.012 for the kinematic measures with a false discovery rate
of <5%) was associated with low statistical power (0.22), thus providing a potential
explanation as to why previous research of this group as a whole identified hip-ankle
coupling in the eyes-closed condition (7, 9), and the current research does not. A post hoc
sample size calculation for this specific analysis based on the difference in mean and SD
values between groups was completed. From this calculation, it was determined that a sample
of 24 CAI and 56 ankle sprain coper participants would have been required to complete the
task for strong statistical power to be achieved. It is therefore possible that these relationships
may be strengthened with an expanded sample size.
The observation that a lower proportion of the CAI group were able to complete the balance task prompted an exploratory correlation analysis of CAIT score and task completion. The absence of significance for this analysis can be explained by the fact that subgroups of CAI and ankle sprain coper participants who were unable to complete the task actually had less disability than their counterparts who did complete the task. However, in a 2x2 binary comparison dichotomising the groups as a whole (CAI vs coper; completed vs uncompleted), it was revealed that being able to complete the task had moderate specificity and sensitivity in predicting CAI status.

The apparent difficulty CAI participants had in completing eyes-closed SLS may represent an impaired capacity to compensate and re-weight dependence according to the availability of sensory afferents, or to rely on the remaining somatosensory and vestibular afferents when visual ones have been removed (24). It is generally accepted that there is redundancy of these three afferents in maintaining SLS (29), whereby a selective priority is placed based on the availability of reliable information (27). This allows the fully functioning somatosensory system to maintain postural control and stability in the presence of altered afferent signals (24). However, prescribing an eyes-closed constraint during the SLS task imposes somatosensory demands beyond the capacity of even healthy individuals, impairing their ability to exploit available redundancies in the maintenance of static postural control (7). This impairment is seemingly magnified in individuals with musculoskeletal injury on the basis of the current findings, and in light of the evidence previously outlined of participants with a recent history of ankle sprain (7, 9). Thus, a decay in somatosensory afferents, as may occur with acute LAS injury and which is considered to contribute to instability persistence (14), combined with loss of visual input, challenged the ability of the central nervous system to re-weight available information with an appropriated coordination response (13, 27) in individuals with CAI. This then manifested in a deterioration of eyes-closed unilateral
standing postural control and stability in the CAI group, with less effective utilisation of the supporting base on the involved limb (7). It is also plausible that the somatosensory deterioration associated with CAI development manifested in a compensatory strategy for the successfully completed balance task as evidenced by the significantly greater ankle-hip coupling evident on the involved limb in the eyes open condition for this group. Whereas the ankle strategy of human postural control is more suited to subtle corrections, the hip strategy is considered ideal for substantial disturbances of equilibrium (24). Tropp (32) previously utilised kinematic measures of sway amplitude at the ankle, hip and trunk to confirm the existence of these strategies. He also identified the impaired postural control capacity of individuals with ankle instability in utilising their ankle strategies for SLS, based on an increased number of postural corrections at the trunk required by this group (32). In another kinematic analysis of participants with a history of ankle sprain during an SLS task, Huurnink et al. (20) failed to identify differences in kinematic outcome measures (ankle and hip angular velocities) between participants with and without a history of ankle sprain. We believe the use of the ACMD statistic in the current study to have specifically identified an increased reliance on the more proximal hip strategy in the CAI group, on the basis of the greater waveform similarity between sagittal plane hip motion and frontal plane ankle motion. During normal control of SLS, the foot’s narrow base of support makes it necessary to employ the hip strategy in controlling substantial medio-lateral disturbances of postural stability, while ankle movements may only achieve fine-tuning of medio-lateral sway (2). The basis of CAI may be belied by an impaired capacity to fulfil this medio-lateral fine-tuning, with subsequent transition to the more proximal hip in sagittal plane motion. Herein lies a significant limitation of the current analysis; these and any other hypotheses regarding the neuromechanical predictors of CAI still unclear, although the current study is part of a project designed to tackle this issue.
The clinical implications of this study are two-fold: first, in light of the evidence presented on these individuals during their ‘recovery’, it would seem that the capacity to perform static postural control tasks will challenge the individual to perform subtle corrections with ankle movements. A SLS task and derivations of such may therefore possess value in being part of a rehabilitation programme. Based on previous evidence, we would recommend though that the patient only progresses to such tasks when they are sufficiently able to complete them (5). Second, the use of eyes-closed SLS as a clinical test to quantify disability and functional capacity should be considered. There is further potential for future research to confirm this. In conclusion, the results of the current study suggest that participants with CAI are separated by ankle sprain copers in their exhibition of a hip-dominant balance strategy during a task of eyes-open unilateral stance.

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Conflict of Interest: No conflicts of interest were associated with the authors and the results of this research.

REFERENCES


Table 1. Demographics and self-reported disability/function questionnaire scores for the CAI and coper groups.

<table>
<thead>
<tr>
<th>Demographic:</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Mass (kg)</th>
<th>Height (m)</th>
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<tr>
<td></td>
<td>n</td>
<td>Male</td>
<td>Female</td>
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<tr>
<td>CAI</td>
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<td>17</td>
<td>11</td>
<td>23.21</td>
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<tr>
<td>Coper</td>
<td>42</td>
<td>26</td>
<td>16</td>
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<th>FAAMadl</th>
<th>FAAMsport</th>
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<td>95%CI</td>
<td>Mean</td>
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<tr>
<td>CAI</td>
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<td>20.03 to 23.61</td>
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<tr>
<td>Coper</td>
<td>27.88</td>
<td>27.23 to 28.52</td>
<td>98.01</td>
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Abbreviations: CAI = chronic ankle instability; CAIT = Cumberland Ankle Instability Tool; FAAMadl = activities of daily living subscale of the Foot and Ankle Ability Measure; FAAMsport = sport subscale of the Foot and Ankle Ability Measure; CI = confidence interval.
Table 2. Subgroup analysis of CAI and coper participants’ CAIT scores comparing those who succeeded to those who failed the eyes-closed SLS task (CAI vs CAI; coper vs coper).

*indicates significantly significant difference between CAI or coper subgroups.

Abbreviations: CAI = chronic ankle instability; CAIT = Cumberland Ankle Instability Tool; SLS = single limb stance.

<table>
<thead>
<tr>
<th>Eyes-closed SLS</th>
<th>CAI</th>
<th>Coper</th>
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<tr>
<td>Successful</td>
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<td>n=33</td>
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<td>CAIT (/30)</td>
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<td>27.39</td>
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<td>Failed</td>
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<td>n=42</td>
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Table 3. Mean ACMD values with associated SDs and p-values for both the involved and uninvolved limbs of LAS and control participants in the eyes-open condition.

<table>
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<th>CAI</th>
<th>Coper</th>
<th>CAI</th>
<th>Coper</th>
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Table 3.
*Denotes statistically significant between-groups difference; ‘/’ denotes comparison between two joints/planes of motion. Abbreviations: ACMD = adjusted coefficient of multiple determination; CAI = chronic ankle instability; SD = standard deviation; F = frontal plane of motion; S = sagittal plane of motion; T = transverse plane of motion.
Table 4. Mean ACMD values with associated SDs and p-values for both the involved and uninvolved limbs of CAI and coper participants in the eyes-closed condition.

<table>
<thead>
<tr>
<th>Joint pair</th>
<th>Hip/ankle</th>
<th>Knee/ankle</th>
<th>Hip/knee</th>
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</thead>
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</tr>
<tr>
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</table>
‘/’ denotes comparison between two joints/planes of motion. Abbreviations: ACMD = adjusted coefficient of multiple determination; CAI = chronic ankle instability; SD = standard deviation; F = frontal plane of motion; S = sagittal plane of motion; T = transverse plane of motion.
Table 5. Mean joint angular range values with associated SDs and p-values for both the involved and uninvolved limbs of CAI and coper participants in the eyes-open and eyes-closed conditions. Values are reported in degrees.

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<tr>
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<th>Eyes open</th>
<th>Eyes closed</th>
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</tr>
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<tr>
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*Denotes statistically significant between-groups difference; Abbreviations: CAI = chronic ankle instability; SD = standard deviation; F = frontal plane of motion; S = sagittal plane of motion; T = transverse plane of motion.
Table 6: Statistical output for the comparison of fractal dimension scores for the involved and uninvolved limbs between CAI and coper groups during the eyes-open and eyes-closed single limb stance task. Abbreviation: CAI = chronic ankle instability.

<table>
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