Clinical Balance Measures in Patients With Chronic Ankle Instability, Copers, and Uninjured Controls

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ABSTRACT

The primary aim of this investigation was to determine if the time-in-balance and/or foot lift test scores differed among uninjured controls, copers, and patients with chronic ankle instability (CAI). The secondary aim was to determine if a relationship exists among the clinical balance measures, self-reported function, and injury characteristics of patients with CAI. A total of 57 participants (19 per group) completed the time-in-balance and foot lift test. No significant differences for time-in-balance ($F_{(2,54)} = 1.186, P = .313$) or number of foot lifts ($F_{(2,54)} = 1.517, P = .229$) scores were identified. A moderate positive correlation ($r = 0.465, P = .045$) was observed between foot lifts and the foot and ankle ability measure. Time in balance had a moderate negative correlation with foot lifts ($r = -0.480, P = .038$). The results suggest that these clinician-oriented postural control outcomes (time-in-balance and foot lifts) cannot discriminate among controls, copers, and CAI and do not correlate with the defining characteristics of CAI. Further research is needed to develop more robust clinician-oriented postural control tests capable of detecting CAI-associated postural control impairments. [Athletic Training and Sports Health Care. 2017;9(1):11-16.]

Following a lateral ankle sprain, 30% to 40% of individuals develop chronic ankle instability (CAI). However, some individuals (copers) who have a history of lateral ankle sprain recover to their pre-injured level of function without residual symptoms or recurrent ankle sprains. Although the exact mechanism of how copers restore normal function remains unknown, understanding the differences among patients with CAI, copers, and controls is important if we are to elucidate factors responsible for the development of CAI and evaluate assessments that may be capable of identifying those individuals who are more likely to develop CAI following an initial lateral ankle sprain. To this end, Doherty et al. recently completed a prospective cohort analysis in an effort to identify predictors of CAI and found that the inability to complete jumping and landing tasks within 2 weeks of the first-time lateral ankle sprain was predictive of CAI development. Successfully identifying those more likely to develop CAI gives clinicians the opportunity to target those at increased risk and hopefully lower the incidence of CAI. A reduced CAI incidence is important because CAI is a leading cause of the compromise of the talar articular surface and post-traumatic osteoarthritis of the ankle.

Postural control outcomes could be particularly useful in a test battery because increased postural instability is a risk factor for recurrent ankle injury. Previously, differences in a variety of postural control outcome measures have been identified between copers and individuals with CAI. For example, Wikstrom et al. identified multiple research-oriented postural control outcomes, using an instrumented force platform, capable of discriminating between established copers and those with CAI. However, the number of clinician-oriented postural control outcomes (ie, postural control assessments that can be captured in any clinical setting with minimal equipment) capable of discriminating between these groups remains limited due to a paucity of research on the topic. To date, Plante and Wikstrom demonstrated that the posteriomedial...
reach of the Star Excursion Balance Test (SEBT) could discriminate between established copers (ie, those who sustained their initial lateral ankle sprain for more than 12 months prior to testing) and patients with CAI.

Despite the paucity of CAI to coper research using clinician-oriented measures of postural control, other clinician-oriented outcomes have identified CAI-associated balance impairments relative to uninjured controls. For example, the number of foot lifts in single-leg stance with eyes closed was significantly fewer in uninjured participants relative to patients with CAI. Similarly, individuals with CAI showed shorter time in single-leg stance relative to participants without CAI. In fact, Arnold et al. recommended that future research establish the clinical validity of these tests due to their large CAI to control effect sizes and simplicity of use. However, the ability of these tests to discriminate between established copers and patients with CAI has yet to be established. Therefore, the primary purpose of this investigation was to determine if the time-in-balance and/or foot lift test scores differed among uninjured controls, copers, and patients with CAI. We hypothesized that patients with CAI would have shorter time-in-balance and more foot lift errors compared to copers and healthy controls. The secondary aim of this study was to determine if a relationship exists among clinical balance measures, self-reported function, and injury characteristics of patients with CAI. We hypothesized that the time-in-balance and foot lift measures would have significant relationships with self-reported function scores, the total number of sprains, and the number of giving-way episodes in patients with CAI.

**METHODS**

**Study Design**

A case-control design was employed for this study. The independent variable was group (CAI, copers, and controls) and the dependent variables were the time in balance (seconds) and the number of foot lifts during single-limb eyes-closed balance. This study was approved by the university’s institutional review board and all participants read and provided written informed consent before data collection.

**Participants**

A total of 57 participants (19 per group) from the university community volunteered to participate in this investigation. All participants were between 18 to 45 years of age and required to be involved in at least 90 minutes of aerobic exercises a week. Inclusion criteria for CAI included a history of at least one ankle sprain and a minimum of two giving-way episodes within the past 12 months. Copers were defined as individuals with a maximum of two previous ankle sprains and no pain, weakness, or instability in the involved ankle. We allowed copers to have had a maximum of one episode of giving way within the past 12 months if they reported no recurrent ankle sprains. Only 2 of 19 copers reported a single giving-way episode. Uninjured healthy controls were included if they had no previous history of ankle sprain or giving-way episodes. Exclusion criteria for all groups included a history of lower extremity surgery, a history of lower extremity fracture, any balance disorders (eg, vertigo), acute lower extremity and head injuries in the past 3 months, or chronic musculoskeletal conditions. Although not used as inclusion criteria, all participants completed the Foot and Ankle Ability Measure (FAAM) Activity of Daily Living (ADL), FAAM-Sport (FAAM-S), and the Ankle Instability Instrument (AII). This investigation was initiated prior to the recommendations made by the International Ankle Consortium and Wikstrom and Brown. If the participant (n = 5) reported bilateral ankle instability, the limb with lower self-reported function was used as the test limb. The test limb for controls was the dominant limb, defined as the limb that the participant would use to kick a soccer ball.

**Procedures**

All participants completed the time-in-balance test and the foot lift test during a single testing session. Both tests were performed barefoot. The time-in-balance test measured the amount of time that the participant could remain motionless in single-limb stance with eyes closed on a firm floor. Participants were instructed to keep their hand on their hips and the non-test limb was slightly flexed at the knee and hip. Time, using a stopwatch, was stopped when any part of the test foot was moved off of the floor (eg, the medial foot was raised due to the participant leaning laterally or the heel shifting laterally due to a partial loss of balance) or the contralateral foot touched the floor. Three trials were performed with the maximum length of each trial set at 60 seconds. A 30-second rest was performed between trials. Less time in balance represented worse
postural control. The foot lift test assessed the number of foot lifts during eyes-closed single-limb stance on a firm surface. Participants stood on the test limb for three 30-second trials in a test position identical to the position used for the time-in-balance test. An error was recorded any time part of the stance foot lost contact with the ground (e.g., the toes were raised, the heel lifted off the ground, or the medial foot lifted due to excessive supination), the contralateral limb touched the ground, and each second that the contralateral foot remained on the floor. A 30-second rest period occurred between trials. Higher numbers of foot lifts represented worse postural control. During this investigation, two investigators (MC and RLB) collected foot lift data. Because multiple team members collected data, foot lifts can occur rapidly, and lifts are often subtle, inter-rater reliability was established prior to data collection. In brief, a series of 17 foot lift tests were videotaped. After an instructional and group review session using four videos, the remaining 13 video clips were independently assessed by three of the authors (MC, RLB, and EAW [experienced rater]). The inter-rater correlation coefficient was found to be 0.914.

### Results

Descriptive demographic data, injury history information, and questionnaire scores can be seen in Table 1. In brief, post-hoc analyses revealed that the CAI group showed significant differences in all injury history information and questionnaire scores compared to copers and control groups. Means, standard deviations, between-group effect sizes, and 95% CIs can be seen.

### Table 1: Participant Demographics, Injury Characteristics, and Questionnaire Scores

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>CAI (N = 19)</th>
<th>COPERS (N = 19)</th>
<th>CONTROLS (N = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>21.37 ± 2.45</td>
<td>21.79 ± 3.66</td>
<td>21.47 ± 2.82</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.91 ± 9.87</td>
<td>173.12 ± 8.44</td>
<td>168.84 ± 11.87</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>83.57 ± 32.97</td>
<td>72.30 ± 13.47</td>
<td>69.46 ± 15.73</td>
</tr>
<tr>
<td>FAAM-ADL (%)</td>
<td>84.59 ± 9.57</td>
<td>99.37 ± 1.70</td>
<td>100 ± 0</td>
</tr>
<tr>
<td>FAAM-S (%)</td>
<td>70.70 ± 1281</td>
<td>97.70 ± 3.58</td>
<td>100 ± 0</td>
</tr>
<tr>
<td>All (no. of yes responses)</td>
<td>6.11 ± 2.13</td>
<td>2.37 ± 1.86</td>
<td>0</td>
</tr>
<tr>
<td>Total no. of sprains</td>
<td>4.37 ± 3.13</td>
<td>1.32 ± 0.48</td>
<td>0</td>
</tr>
<tr>
<td>Giving way episodes in past 12 months</td>
<td>5.11 ± 3.03</td>
<td>0.11 ± 0.32</td>
<td>0</td>
</tr>
<tr>
<td>Tested limbs</td>
<td>Right: 11, Left: 8</td>
<td>Right: 13, Left: 6</td>
<td>Right: 13, Left: 6</td>
</tr>
</tbody>
</table>

CAI = chronic ankle instability; FAAM = the Foot and Ankle Ability Measure; ADL = Activity of Daily Living; FAAM-S = FAAM-Sport; AII = Ankle Instability Instrument

a Indicates significant differences compared to control group (P < .001).
b Indicates significant differences compared to copers (P < .001).

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### Statistical Analysis

Separate one-way analyses of variance (ANOVA) were used to analyze participant demographics (age, weight, and height). Injury characteristics (the number of sprains and the number of giving-way episodes), and questionnaire scores (FAAM-ADL, FAAM-S, and AII “yes” responses) were analyzed using independent sample Kruskal–Wallis non-parametric tests because Kolmogorov–Smirnov normality tests demonstrated statistical significance (P < .001). Separate Mann–Whitney post hoc tests were conducted to identify significant differences among the groups for these outcomes. For the time-in-balance and foot lift tests, separate one-way ANOVAs were conducted to determine if significant differences existed among the groups. The longest time-in-balance trial and the average of the three foot lift trials were used for analysis, as previously established. Between-group effect sizes and 95% confidence intervals (CIs) were also calculated to provide clinical meaningfulness to the data. Tukey’s post hoc tests, when appropriate, were conducted to assess the location of group differences. The Pearson correlation coefficient test was used to measure the relationship between the balance measures (time in balance and foot lifts), self-reported function scores (FAAM-ADL, FAAM-S, and AII), and injury characteristics (the total number of sprains and the number of giving-way episodes) of the CAI group. A priori alpha level was set at 0.05 for all statistical analyses.
TABLE 2
Mean, SD, Between-Group Effect Size, and 95% CIs for Time-in-Balance and Foot Lift Tests

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>CAI (N = 19)</th>
<th>COPERS (N = 19)</th>
<th>CONTROLS (N = 19)</th>
<th>CAI TO CONTROL EFFECT SIZE</th>
<th>CAI TO COPER EFFECT SIZE</th>
<th>COPER TO CONTROL EFFECT SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in balance (s)</td>
<td>9.83 ± 7.02</td>
<td>16.02 ± 16.93</td>
<td>14.55 ± 12.94</td>
<td>0.32 (-0.035 to 0.93)</td>
<td>0.34 (-0.33 to 0.94)</td>
<td>0.07 (-0.70 to 0.57)</td>
</tr>
<tr>
<td>No. of foot lifts (errors)</td>
<td>12.30 ± 6.08</td>
<td>11.63 ± 6.28</td>
<td>9.30 ± 4.09</td>
<td>-0.41 (-1.01 to 0.33)</td>
<td>-0.08 (-0.71 to 0.57)</td>
<td>0.26 (-0.40 to 0.87)</td>
</tr>
</tbody>
</table>

SD = standard deviation; CI = confidence interval; CAI = chronic ankle instability

TABLE 3
Correlation Among Clinical Balance Measures, Self-Reported Function, and Injury Characteristics in CAI Group (n = 19)

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>TIME-IN-BALANCE</th>
<th>FOOT LIFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-in-balance</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Foot lift</td>
<td>-0.480</td>
<td>0.038</td>
</tr>
<tr>
<td>FAAM-ADL</td>
<td>-0.288</td>
<td>0.232</td>
</tr>
<tr>
<td>FAAM-S</td>
<td>-0.381</td>
<td>0.107</td>
</tr>
<tr>
<td>All</td>
<td>0.381</td>
<td>0.107</td>
</tr>
<tr>
<td>Total no. of sprains</td>
<td>0.442</td>
<td>0.058</td>
</tr>
<tr>
<td>No. of giving ways</td>
<td>0.175</td>
<td>0.473</td>
</tr>
</tbody>
</table>

FAAM = the Foot and Ankle Ability Measure; ADL = Activity of Daily Living; FAAM-S = FAAM-Sport; All = Ankle Instability Instrument

DISCUSSION

There is limited research on the ability of clinician-oriented postural control outcomes to discriminate among patients with CAI, copers, and uninjured healthy controls.8-15 Therefore, the primary purpose of this study was to determine if the time-in-balance or foot lift test scores differed among these groups as a first step toward determining if these tests might be part of a robust assessment battery capable of identifying those at an increased risk of developing CAI following an acute lateral ankle sprain. However, the results did not support our a priori hypothesis because no group differences were identified.

Previous researchers found that instrumented postural control outcomes can discriminate among controls, copers, and patients with CAI during both static7,16 and dynamic postural control assessments.17,18 However, not all investigations identified group differences between patients with CAI and copers,19 and some illustrated that certain but not all outcomes differed between these groups.17 Clinician-oriented postural control data between copers and patients with CAI are limited, with only a single study quantifying dynamic postural control between the groups. Specifically, patients with CAI displayed shorter posteromedial reach distances during the SEBT relative to copers and controls.8 Although other non-postural control clinician-oriented outcomes have been studied,8,15 including several functional hop tests, most have failed to reveal group differences. These results suggest that current clinician-oriented assessments are not sensitive enough to capture CAI-associated postural control impairments relative to established copers despite the fact that clinician-oriented movement assessments20,21 and postural control assessments8-10 have detected impairments in patients with CAI compared to uninjured controls.

For example, previous studies15,14 found that uninjured controls showed longer time in balance during single-leg stance with eyes closed than those with ankle instability. Although Chrintz et al.14 demonstrated that the time-in-balance test correlated well with functional ankle instability, individuals with isolated anteri-
or talofibular ligament damage did not have single-leg stance impairments. However, those with an isolated calcaneofibular ligament injury and both anterior talofibular ligament and calcaneofibular ligament damage had balance impairments. In the current investigation, we did not quantify the status of the individual lateral ligaments, but similarly found no differences between uninjured controls and those with CAI. Additionally, our time-in-balance results in all groups were shorter than times previously reported by Linens et al.\textsuperscript{10} Indeed, Linens et al.\textsuperscript{15} reported a time-in-balance score of 28.99 ± 17.30 (mean ± standard deviations) seconds in the CAI group compared to the current mean of 9.83 ± 7.02 seconds in those with CAI. Differences in the inclusion criteria may explain the results. Whereas the Cumberland Ankle Instability Tool was used for inclusion criteria previously, no diagnostic questionnaire was used as inclusion criteria in this study. Another possible explanation is that the operational definition of foot movement could have been different between the research groups, but this is speculative because the exact definition was not previously provided. Despite these potential methodological explanations, we are confident in our CAI data based on the number of CAI studies that use 10-second balance trials and the difficulty associated with longer trials (ie, an increasing number of failed trials) with this population.

Similar to time-in-balance results, the number of foot lifts was not able to detect postural control impairments in those with CAI relative to copers and uninjured healthy controls. However, previous studies demonstrated that participants with a history of an ankle sprain had more foot lifts compared to uninjured controls.\textsuperscript{9,22} More specifically, Hiller et al.\textsuperscript{9} found that those with unilateral ankle instability (n = 19) made 25.10 ± 2.30 errors, whereas an external control group (n = 20) made 12.7 ± 1.80 errors. On the contrary, Linens et al.\textsuperscript{15} found that those with chronic ankle instability (n = 17) made 5.57 ± 2.38 errors, whereas a healthy control group (n = 17) made 3.20 ± 2.68 errors. Interestingly, the current values fall between those previously reported. The variability among the studies may also be due to differences in the study samples. Although both investigators recruited participants with self-reported ankle instability, different CAI severity scales (ie, Cumberland Ankle Instability Tool vs AII) and injury characteristics were reported, making direct comparisons of the samples difficult.

Although group differences were not observed, the existence of significant correlations could suggest that an individualistic response exists within the CAI population. The number of foot lift tests was correlated with a marker of CAI. However, a moderate positive correlation was observed, which suggests that as the number of foot lifts increased, so did self-reported function. This result is difficult to explain, but may represent a postural control strategy that allows patients with CAI to have higher levels of self-reported function. The foot lift test was also not predictive of recurrent ankle sprains in a recent prospective study,\textsuperscript{23} suggesting that even if the foot lift test was able to discriminate between established copers and patients with CAI, early performance on this test may not be predictive of CAI development.

The current investigation was not without limitations. First, we did not use any validated instruments to categorize participants. However, average scores on self-reported function questionnaires (FAAM-ADL, FAAM-S, and AII) were consistent with inclusion criteria requirements used in previous studies.\textsuperscript{4,13} Second, we had a relatively small sample size, but the size was consistent with previous studies\textsuperscript{9,15} that have looked at the discriminatory ability of these clinician-oriented tests.

**IMPLICATIONS FOR CLINICAL PRACTICE**

The lack of significant differences among CAI, coper, and control groups suggests that these clinician-oriented assessments may not be sensitive enough to discriminate static postural control impairments among the groups. The lack of differences between the CAI and control groups also contradicts previous findings and counters the recommendation made by Arnold et al.\textsuperscript{11} The lack of meaningful correlations among these postural control tests and markers of CAI also suggests that there may be limited use for these assessments. Those with CAI have been shown to use more of a hip strategy than an ankle strategy to reposition the center of gravity within the base of support during static postural control.\textsuperscript{24,25} Therefore, clinician-oriented tests that capture whole body control may be the most appropriate to investigate. The SEBT may be such an example. The SEBT discriminates between patients with CAI and uninjured controls and between patients with CAI and established copers. Furthermore, select SEBT outcomes are indicative of lower extremity injury risk.\textsuperscript{26,27}
and poor performance in the posterolateral direction of the SEBT 6 months after a lateral ankle sprain is predictive of CAI development.3

Similarly, other whole body movement assessments have been able to detect functional limitations in patients with CAI compared to uninjured controls.20,21 However, further research is needed to determine the ability of these whole body movement assessments to discriminate between patients with CAI and established copers.

The results suggest that these clinician-oriented postural control outcomes (time in balance and foot lifts) cannot discriminate among controls, copers, and patients with CAI. Further research is needed to develop more sensitive and robust clinician-oriented postural control tests capable of detecting CAI-associated postural control impairments and hopefully predicting CAI development.

REFERENCES


