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Comparison Between Single and Combined Clinical Postural Stability Tests in Individuals With and Without Chronic Ankle Instability

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1 **Comparison between single and combined clinical postural stability tests and self-reported**
2 **ankle instability in individuals with and without chronic ankle instability**

3
4 **ABSTRACT**

5 **Objective:** To determine if a single or/and combined clinical tests match group membership
6 based on self-reported ankle function. **Design:** Cross-sectional. **Setting:** Biomechanics
7 Laboratory. **Participants:** From participants, 58 meeting inclusion/exclusion criteria were
8 divided into a **Chronic Ankle Instability (CAI) group (n=25) who reported ≤ 25** on the
9 Cumberland Ankle Instability Tool (CAIT) and a history of moderate-severe ankle sprain(s) and
10 a control group (n=33) who reported ≥ 29 on the CAIT and no history of ankle sprain(s).
11 **Interventions:** Participants completed the following clinical tests: Foot Lift Test (FLT), the Star
12 Excursion Balance Test (SEBT), the Single Leg Hop Test (SLHT), and the Time in Balance Test
13 (TIB) in a randomized order. A linear regression model was applied to determine measures that
14 matched ankle group membership. **Main Outcome Measures:** **The mean of SEBT** reach
15 distance was normalized to % leg length. The mean of number of errors in the FLT was
16 recorded. The SLHT and TIB were reported as time in seconds, and the means were calculated.
17 **Results:** **The most parsimonious combination of tests** (SLHT and SEBT) resulted in correctly
18 matching 70.69% (41/58) of participants into groups, which was significantly better than chance.
19 The multiple correlation coefficients (R value) for combining the SLHT and SEBT was 0.39.
20 **Conclusions:** Using SLHT and SEBT resulted in improved recognition of participants
21 designated into the CAI or control groups. **Self-report perception of ankle function provides**
22 **limited information for clinicians and researchers. Using multiple clinical function tests may be**
23 **more helpful in determining deficits and intervention effectiveness.** **Word Count:** 250

24 **Key Words:** ankle sprain; clinical tests, star excursion balance test, single leg hop test

25 INTRODUCTION

26 Lateral ankle sprains are among the most common injuries incurred during sports
27 participation.^{1,2} An initial ankle sprain often result in repetitive ankle sprains,³ with
28 approximately 80% of individuals experiencing re-spraining of the ankle after their first ankle
29 sprain.¹ Repetitive ankle sprains may have serious long-term consequences, including Chronic
30 Ankle Instability (CAI)³ and Osteoarthritis. CAI can be defined as the sensation of “giving way”
31 at the ankle and as “repetitive lateral ankle instability resulting in several ankle sprains”.^{3,4}

32 The primary ligamentous cause of osteoarthritis (OA) at the ankle joint is repeated ankle
33 sprains.⁵ Preventing repeated ankle sprains, and CAI, may be an important step for decreasing
34 risk of OA at the ankle joint.⁶

35 Currently CAI is identified primarily through self-report questionnaires regarding
36 perception of function and clinical history.⁷ The CAIT showed excellent test-retest reliability
37 (ICC_{2,1}=0.96)⁸ and is recommended to help identify individuals with CAI by the International
38 Ankle Consortium and National Athletic Trainers’ Association (NATA) position statements.^{7,9}
39 However, CAI has also been linked to deficits in postural control and physical function in
40 hopping and changing directions during sports activity.^{10,11} Relying solely on subjective self-
41 report measures to assess a clinical condition is not recommended, and the NATA advocates
42 applying functional tests to assess patients.⁹ The International Ankle Consortium also states that
43 as a multi-factorial problem, multiple types of assessments are necessary in research and clinical
44 practice.⁷ Finding clinical tools that are effective in identifying the presence of CAI in addition to
45 self-report questionnaires may be useful to clinicians and researchers.^{4,11}

46 Non-instrumented clinical postural stability tests may be one option and have shown
47 some utility in assessing CAI.¹¹ Clinical tests have the advantages of being inexpensive, quick to
48 administer, and are feasible in clinical and field settings.¹² However, non-instrumented clinical
49 postural stability tests including up-down hop, single hop, triple-crossover hop for distance,
50 shuttle run, and figure-8 hop have demonstrated mixed results in identifying performance
51 differences among those with our without CAI.^{13,14} Currently, there is no consensus whether a
52 single or combination of clinical tests can accurately and objectively identify those with CAI.

53 Clinicians should be able to appropriately identify objective tests which may be effective
54 at assessing initial deficits in performance and effectiveness of rehabilitation interventions, in
55 cooperation with self-report function questionnaires. Therefore, the purpose of our study was to
56 compare clinical postural stability tests independently and/or in combination with self-reported
57 ankle instability scores among individuals with and without CAI to determine which tests could
58 best match self-report perception of function. Our hypothesis was that single and combined
59 clinical postural stability tests would effectively match with individuals' perceptive ankle
60 condition either CAI or non-CAI based on the CAIT self-reported ankle instability questionnaire.

61 **METHODS**

62 **Participants**

63 An *a priori* sample size estimation was performed (G*Power, Version 3.1.5, Kiel,
64 Germany) with statistical power = 0.80, $P \leq 0.05$ for an independent samples design. Nine
65 participants were calculated to be needed in the CAI and control groups with effect size 1.41
66 using the mean and standard deviation data presented in a similar study using a single leg hop
67 test with 9 participants.¹⁵ Based on table data from a second, similar study using a multiple-hop
68 test, sample size was 10 in each group with effect size 1.36.¹⁶

69 A total of 65 participants between 18 and 25 years of age and participated in physical
70 activity, such as running, walking, lifting weights, or playing sports, for at least 90 min per week
71 were recruited from physical activity classes and club sport teams at a large university. The
72 researcher provided an orientation to participants regarding the test procedures, and participants
73 provided informed consent.

74 Participants were classified into two groups. The CAI group included the following:
75 reported ≤ 25 on the CAIT questionnaire, a history of moderate-severe ankle sprain(s) that
76 required at least 3 days of partial or non-weight bearing, and/or a history of “giving way” with
77 activity.^{17,18} Participants who reported ≥ 29 on the CAIT questionnaire and no history of ankle
78 sprain(s) and “giving way” were placed into the Control group.¹⁹ Participants who had a history
79 of fracture and/or surgery in their lower extremity and suffered any type of other lower extremity
80 injury in the last 3 months were excluded from the study prior to data collection.⁷ Data from 58
81 participants were included for analysis based on inclusion and exclusion criteria (Figure 1) which
82 include the critical information and a comprehensive description for the research participants
83 recommended by the International Ankle Consortium⁷. Our sample size is well within the
84 established limits for meaningful outcomes comparisons of interest. Demographics are reported
85 in Table 1.

86 **Data collection procedures**

87 Following informed consent, participants who met the inclusion completed the
88 Cumberland Ankle Instability Tool (CAIT).⁸ The participants’ age, gender, and leg lengths were
89 measured.

90 Participants completed clinical tests, including the Time in Balance Test²⁰ (TIB), Foot
91 Lift Test²¹ (FLT), Star Excursion Balance Test²² (SEBT) and Single-Leg Hop Test^{23,24} (SLHT),

92 in a randomized order. These tests were selected based on previous research that demonstrated
93 deficits in performance in CAI groups because they would be easy to perform in clinical settings.
94 ^{20-22,24} Also, these clinical tests can be classified into different subsets including static, semi-
95 dynamic, and dynamic tasks. Performance of the TIB, FLT, and SLHT were videotaped with
96 consumer DCR-TRV280 Digital Video Camera Recorder (290K Pixels; Sony®, San Diego,
97 CA).

98 **Non-Instrumented Postural Stability Clinical Tests (Clinical Tests)**

99 *Time in Balance Test*

100 Participants performed the TIB on a stable surface in a single-leg stance according to
101 published directions.²⁰ Participants were instructed to keep their eyes closed and their hands on
102 their hips (at the iliac crests), and remain motionless for as long as possible up to 1 minute. A
103 single rater blinded to injury history and group membership viewed the video at a later date and
104 used a stopwatch to time how long a participant was able to remain in the testing position. The
105 rater stopped timing when the participant lost balance or made an error such as moving the
106 testing foot or touching the floor with the un-tested foot. Three trials were collected on each foot.
107 The maximum length of the test was one minute in each trial. The mean of three trials was used
108 as the TIB score.²⁰

109 *Foot Lift Test*

110 For the FLT, participants stood in a single-leg stance on a stable surface same as the TIB.
111 Participants maintained their balance without opening their eyes and using their other extremities
112 for 30 seconds. Entire testing performance were videotaped. After testing, the single rater
113 watched the video and scored the number of foot lifts, or part of foot lifts.²¹ A “part of foot lift”

114 can be described as lifting any part of the foot such as toes or heel, from the surface.²¹ Also, if
115 the un-tested foot touched the floor, this was considered an error.

116 *Star Excursion Balance Test*

117 Prior to performing the SEBT, leg length was assessed in a supine position from the
118 medial malleolus to the anterior superior iliac spine of each limb to normalize maximum reach
119 distance to limb length.²⁵ Only the posteromedial (PM) (Figure 2) component of the SEBT was
120 performed in a single-leg stance because PM component reach distance was the most highly
121 representative of all 8 components of SEBT in individuals with and without CAI.²² In order to
122 save time in the larger study and avoid fatigue, only this direction was selected for testing.
123 Participants stood barefoot at the center of a grid where two lines were extended at 45° angle
124 from the center to PM direction and marked by athletic tape. Participants were instructed to reach
125 with one foot in the PM direction, while maintaining a single-leg stance with the testing leg.²²
126 Participants had 3 practice trials before test trials. For data collection, participants performed 3
127 trials on each foot in a randomized order. The mean distance from the 3 trials was used as the
128 score of a participant.

129 *Single Leg Hop Test*

130 The participants also performed the SLHT. Participants were instructed to complete a
131 task of lateral hopping (30 cm distance between start point and end point) and then come back to
132 the point where they started for 10 repetitions as fast as they could while meeting the required
133 distance.²⁴ After testing, a single rater watched the video and recorded the finish time to the
134 nearest 0.01 second. Participants completed 2 trials without a practice trial. A 1-minute rest
135 break between tests was provided to avoid fatigue.^{20,21,24}

136 Rater reliability for the single rater scoring the SLHT, FLT, TIB, and SEBT was
137 established prior to data reduction to ensure consistent scoring across participants. The rater
138 developed a set of criteria for each test, determined by published instructions. A single rater,
139 blinded to injury history and group membership scored all the tests. The rater viewed 20
140 preliminary participants' videos, scored them, and then viewed the video again 1 week later. The
141 rater scored the video again, blinded to the initial score. Intra-class correlation coefficients
142 ($ICC_{2,1}$) for tester reliability and standard error of measurement (SEM) were calculated for TIB,
143 FLT, SLHT, and SEBT in Table 2.²⁶ The value of $ICC_{2,1}$ with a consistency of 1.0 is in perfect
144 agreement.²⁷ All videos were played through Windows Live Movie Maker® (Version 12,
145 Microsoft, Redmond, WA).

146 **Data Reduction and Analysis**

147 Means and standard deviations were calculated for participants' demographics and
148 performance on each clinical test. An alpha level of $p \leq 0.05$ was set a priori to indicate statistical
149 significance. Effect sizes (Cohen's d) and Power ($1-\beta$) were also calculated. **Pearson product-**
150 **moment correlation coefficients (Pearson's r values) were calculated to demonstrate the**
151 **relationship between clinical postural stability measures.**

152 **Logistic regression analysis and linear discriminant analysis are equivalent when only**
153 **two groups are used (CAI and Control group).²⁸ Linear discriminant analysis was selected**
154 **because it is appropriate for normally distributed explanatory variables, as these data were.**
155 **Linear discriminant analysis** was used to determine which of the clinical tests best matched
156 group membership (CAI or Control group).²⁹ R (multiple correlation coefficients) values
157 indicated the strength of the association between the dependent (ankle condition) variable. The
158 group membership coded score was 0 = CAI and 1 = Control. Matched scores were rounded to 0

159 when the matched values was less than .5 while a matched score of .5 or higher was rounded to
160 1. Number and percentage of correctly matched group memberships were calculated, and a Z
161 score was calculated to determine if the identification was better than chance. Chance was
162 defined as 50%. The statistical hypothesis was that percent of correct identification of
163 membership was 50% and the alternated hypothesis was “better than chance,” or greater than
164 50%. An alpha level of $p \leq 0.05$ was set *a priori* to indicate statistical significance. The
165 Statistical Package for the Social Sciences™ 20.0 (SPSS, Inc., Chicago, IL) was used to perform
166 all statistical analyses.

167 **Ethical Considerations**

168 This research project was approved by the University of Georgia Institutional Review
169 Board (Study ID#2010103164).

170 **RESULTS**

171 There were no significant differences in means and standard deviations for the
172 demographic characteristics (Table 1). The ICCs for rater reliability in the TIB, FLT, and SLHT
173 and scores in the SEBT are reported in Table 2. Pearson’s *r* values (Table 3) indicated that
174 clinical postural stability tests were not correlated except for the relationship between the SLHT
175 and SEBT ($P < 0.05$)

176 Clinical tests associated with the self-reported ankle condition that were statistically
177 better than chance included a combination of 4 clinical tests (TIB, FLT, SLHT, and SEBT), 3
178 clinical tests (TIB, SLHT, and SEBT), or 2 clinical tests (SLHT and SEBT), indicated by a
179 significant value of the Z-test on a proportion ($Z \geq 1.65$). Approximately 70.69% (41/58) of
180 participants in the CAI and control group based on the self-reported ankle score were correctly
181 assigned to groups by combinations of 4, 3, 2 clinical tests, while chance assignment would be

182 50%. The most parsimonious model would then be 2 clinical tests (SLHT and SEBT). The
183 multiple correlation coefficients (R value) for the regression equation, and number and
184 percentage of correctly matched group memberships are reported in Table 4.

185 **DISCUSSION**

186 Our most important finding was that combining scores on 4 clinical tests (TIB, FLT,
187 SLHT, and SEBT), 3 clinical tests (TIB, SLHT, and SEBT), and 2 clinical tests (SLHT and
188 SEBT) revealed the same and the highest percentage of correct matched value for CAI versus
189 control group membership. It appears a test item cluster of 2 to 4 clinical tests best captures
190 functional performance as it relates to CAI self-report. The SEBT showed the highest matched
191 value as a single clinical test. The percentages of correct match were significantly better than
192 chance (Table 4). Therefore, using two clinical tests (SLHT and SEBT) for assessing CAI may be
193 considered the most clinically efficient while maintaining a relatively high level of accuracy.
194 While the results are lower than a preferred clinical accuracy of at least 80%, they are on par
195 with the clinical utility of other functional tests in this population (65 %).^{11,30,31} Currently, no
196 gold standard clinical test or tests can be recommended for identifying group membership in
197 those with and without CAI, and a combination of tests may be most appropriate as an objective
198 measurement.

199 To our knowledge, no previous studies have utilized a single clinical test and/or
200 combined clinical tests to match with group membership based on a self-report questionnaire.
201 Researchers^{11,24} have suggested future studies should determine whether clinical tests may be
202 useful to identify group membership, and to determine the best combination of clinical tests
203 (postural-stability tests) to identify group membership and establish a guide for CAI, which we
204 have undertaken. Previous studies^{12,24} have only conducted correlations between self-report

205 questionnaire scores and clinical tests and/or to identify postural stability deficits using clinical
206 tests.¹¹ While correlational relationships are relevant, and important step is determining clinical
207 utility of specific tools in order to make recommendations to clinicians. Our findings are a first
208 step in this process, demonstrating that 2 clinical tests have moderate usefulness in matching to
209 accepted group criteria.

210 Clinicians need to use objective measures which demand actual performance ability from
211 athletes throughout rehabilitation protocols to determine progress.^{REF14} Although clinical tests
212 are recommended for use in making decisions for return-to-play (RTP), the clinical tests should
213 not be applied as sole, independent measures. Each clinical test may provide alternate
214 information and combining tests shows a higher percentage of correct group membership
215 identification than any single test. Our findings support test item clustering and offer evidence
216 that clinical tests may be used to offer information about presence of CAI and possibly
217 responsiveness to intervention.

218 Based on the results, we recommend clinicians use multiple clinical test to identify CAI
219 group membership. Applying combined clinical tests may provide more accurate and objective
220 information for identifying group membership into CAI versus control groups based on the self-
221 report questionnaire. Specifically, our findings suggest that clinicians may use the SLHT and
222 SEBT together, which was the most parsimonious model from our study, as screening tools to
223 match up with group membership based on the self-report questionnaire.

224 Limitations

225 Limitations include the use of self-report injury history for the ankle and the low power
226 and moderate effect size on some tests. The correct identification percentage was below 80% and
227 the multiple correlation coefficient values were classified as “weak associations”. This may be

228 due to the nature and different demands of each clinical test, including rotary or multiplanar
229 demands.³² The narrow age range utilized also limits generalizability to other populations.
230 Therefore, the application of these tests to match up with individuals with CAI based on the self-
231 report questionnaire should be done with caution.

232 CONCLUSION

233 We suggest clinicians seeking to determine if a patient has functional deficits secondary
234 to CAI apply combined clinical tests (SLHT and SEBT) as their first step of evaluation and
235 assessment. The clinical tests can be used to quickly and objectively evaluate a patient and
236 appear to have some clinical usefulness. Clinicians may use the combination of clinical tests to
237 quantify functional deficit more objectively than relying solely on self-report measures. While
238 self-report is valuable, information regarding objective function provide a more complete picture
239 for clinicians.

240 Future prospective and treatment efficacy studies could use test item clusters to help
241 determine clinical course after injury and comparative effectiveness of treatment. Developing
242 cutoff score for single and combined clinical tests may help to use specific cutoff score to
243 identify individuals with CAI for clinicians.

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