EVALUATION OF THE CUMBERLAND ANKLE INSTABILITY TOOL
AS A PREDICTOR OF ANKLE RE-INJURY
IN COLLEGIATE ATHLETES

by

Emily M. Henderson

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Emily M. Henderson

Approved: 

Thomas W. Kaminski, Ph.D., ATC, FNATA, FACSM
Professor in charge of thesis on behalf of the Advisory Committee

Approved: 

William B. Farquhar, Ph.D.
Chair of the Department of Kinesiology and Applied Physiology

Approved: 

Kathleen S. Matt, Ph.D.
Dean of the College of Health Sciences

Approved: 

James G. Richards, Ph.D.
Vice Provost for Graduate and Professional Education
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ABSTRACT

**Context:** Lateral ankle sprains (LAS) are one of the most commonly occurring injuries amongst the athletic population, with as high as 70% suffering from residual symptoms and going on to develop chronic ankle instability (CAI). The Cumberland Ankle Instability Tool (CAIT) has been proposed to detect the presence and severity of CAI; yet its use as a predictor of future ankle sprains has not been examined. **Objective:** The primary purpose of this study was to evaluate the CAIT as a predictor of ankle re-injury following one or more LAS in a group of collegiate athletes over time. **Design:** Cross-sectional survey design. **Setting:** All participants were asked to complete a follow-up CAIT and Ankle History Questionnaire electronically at their own convenience. **Patients or Other Participants:** A total of 40 male and 26 female student-athletes from an NCAA Division I institution participated in this study. **Main Outcome Measures:** All follow-up CAIT scores were distributed and collected electronically via Qualtrics Survey Software. Self-report injury history was cross-referenced manually with official documentation through the University’s sports medicine department. Sensitivity and specificity were both calculated using an online software program. A Spearman rank correlation was used to assess the relationship between initial and follow-up CAIT scores over time in addition to the relationship between initial CAIT score and the number of subsequent re-injuries that followed. **Results:** Overall, sensitivity was much higher when using a CAIT cut-off score of $\leq 27$, while specificity was much higher with a cut-off score of $\leq 25$. A strong
relationship was seen between initial CAIT and follow-up CAIT scores within groups and across all subjects (r=.492; p<.001). A slightly higher correlation was seen between initial CAIT score and number of subsequent re-injuries when using self-report of injury (r=.267; p=.010) as compared to an official documentation method of reporting (r=.245; p=.018). **Conclusions:** The CAIT was not a good predictor of ankle re-injury in this cohort of collegiate athletes. A positive relationship was seen between self-report and official documentation methods of previous injury history, suggesting an accurate recall of injuries through self-report. Initial and follow-up CAIT scores were found to have a strong relationship, suggesting a potential lasting effect of CAIT scores. These results warrant future research examining the various methods of reporting of injury history, as well as further analysis of internal reliability and consistency of CAIT questions in an effort to better refine the instrument for use as an ankle re-injury predictor.

**Key Words:** Chronic ankle instability, Ankle sprain, Coper and Non-coper, CAIT

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Chapter 1

INTRODUCTION

Lateral ankle sprains (LAS) are one of the most commonly occurring injuries amongst the general population, accounting for upwards of 20% of all joint-related injuries. ¹ More specifically, studies have also shown that 60% of sports injuries fall under the category of sprains, luxations and ligament tears with the ankle being the most affected joint. ² Collegiate athletics, with such an inherently high rate of injury exposures, offers an ideal population to study when the primary outcome of interest is re-injury. In a study conducted by Hootman et al. in 2007 as a summary of 16 years (1988-2004) of NCAA injury surveillance data it was found that more than 50% of injuries were to the lower extremity. ³ Furthermore, ankle ligament sprains were the most common injury of the included 15 sports, accounting for 15% of all reported injuries.³

It has been reported that 32-74% of individuals with a previous history of LAS will suffer from residual or chronic symptoms and go on to develop chronic ankle instability (CAI).¹ Chronic ankle instability has been classified as a condition involving ankle pain and swelling with activity, recurring episodes of “giving-way”, repetitive ankle sprains and restrictions of or a failure to return to levels of previous activity. ⁴ Previous studies have utilized healthy controls as a comparison group to assess the differences between those with and those without CAI. Recently, researchers have begun using “copers” as an alternative comparison group⁵, which may be a more appropriate
model for comparison. Currently, the term coper is used to describe an individual with a history of LAS who is able to return to participation in demanding dynamic activities involving jumping and cutting without recurrent injury, subsequent loss of function, or development of CAI. The most important factor in defining a coper is the absence of subsequent re-injury, essentially highlighting the ability to “cope” from the detrimental effects resulting from initial injury.

To date, most research has been directed towards changes and impairments that occur as a result of CAI rather than potential predictors of the pathology. With ankle re-injury being arguably the most detrimental of the various signs and symptoms involved with CAI, a valuable prediction of re-injury may give clinicians the tool necessary to better treat these injuries, in turn creating more optimal outcomes. Additionally, it would offer a guide for which individuals at a high risk of re-injury could be identified. Current literature in regards to potential predictors of re-injury is limited, with only a history of previous ankle injury proving to be significantly predictive of future re-injury. Other risk factors that have been identified include reduced dorsiflexion range-of-motion and deficits in postural control, proprioception and functional instability.

With CAI offering a primarily “symptom-based” presentation due to its complexity and multi-factorial nature, patient questionnaires or surveys have become a widely used tool in identifying the pathology. One such questionnaire is the Cumberland Ankle Instability Tool (CAIT). First published by Hiller in 2006 the CAIT is a 9-item, 30-point questionnaire that is utilized without comparison to the contralateral ankle. Respondents may score between 0 and 30 with lower scores indicating decreased ankle
stability, and a higher score indicating increased stability. The reliability and validity of this subjective, perception-based clinical tool has been tested in the past, but not in regards to its use as a predictor of potential copers and non-copers and/or subsequent re-injury. A cut-off score of ≤27 on the CAIT identifies the ankle as “unstable”. Since the introduction of the CAIT and its proposed cut-off score of ≤27, some have suggested utilizing the CAIT with a lower cut-off score over concerns that such a high score may be suboptimal for use within the CAI population. In 2014, Wright et al. proposed a recalibration of the CAIT using a cut-off score of at least ≤25 to allow individuals membership in the CAI population. Ultimately, findings in this study supported their proposed hypothesis that a lower cut-off score would enhance the usefulness of the CAIT. This finding also supports the recommendations put out by the International Ankle Consortium.

In 2014, Pourkazemi et al. performed a systematic review investigating predictors of CAI after an initial LAS. This study focused only on three predictors due to the limited literature available: postural control, perceived instability, and severity of the initial sprain. We know that the history of a previous sprain is the most frequently reported risk factor for re-injury, but the underlying reason for this increased risk is unknown. Although a history of previous injury has been proven as a reliable predictor of re-injury, not all individuals with a history of LAS are going to re-sprain their ankle. A reliable guide or classification scheme is needed to create an accurate model for identifying individuals at an increased risk for re-injury.
In the assessment of perceived instability as a predictor of CAI, a study completed by Hiller et al. in 2008 determined that CAIT scores did not predict re-sprain in a population of youth dancers. Their study focused on using the CAIT to predict either ipsilateral or contralateral re-injury in this population. We intend to focus on the predictive value of the CAIT in regards to the ipsilateral ankle only, due to the fact that treatment for a previous injury is often focused only on the injured ankle. Although the theory of a change to central motor processing resulting in a bilateral change following unilateral injury is valid and has been proven and confirmed in the past, isolation just to the injured side will offer insight into the strength of rehabilitation programs being used by clinicians. Additionally, in Hiller’s 2008 study, the predictive accuracy of each of the chosen intrinsic risk factors was determined using a predictive model and backwards stepwise Cox regression. We have chosen to treat the CAIT as a diagnostic tool and will assess its predictive value through measures of sensitivity and specificity.

Our study is the first to examine the CAIT in a collegiate population over three years for a more thorough assessment of the lasting effect of the implications of an individual’s CAIT score. Due to the highly subjective nature of CAI, we have chosen to analyze our data using both self-report and official documentation methods to determine previous history of injury. We contend that many injuries, or innocuous episodes of “giving-way”, that go unreported to healthcare professionals may be reported through a self-report mechanism, yet not be officially documented. Furthermore, no studies have examined the predictive abilities of the CAIT utilizing two different cut-off scores (<25 vs <27).
Of importance to clinicians and researchers alike, is the prevention of re-injury following a history of one or more previous LAS. In order to best prevent these injuries, individuals at an increased risk for re-injury must be accurately identified so that the true effect of preventative rehabilitation programs can be determined. Therefore, the primary goal of this study is to evaluate the effectiveness of the CAIT in predicting ankle re-injury (or potential copers and non-copers) following one or more LAS in a group of collegiate athletes over time.
Chapter 2

MATERIALS AND METHODS

2.1 Design

Cross-sectional survey design.

2.2 Participants

A total of 102 male and female collegiate athletes were asked to participate in this study. These subjects were identified from a larger University-based prospective research database. The identified subjects ranged in age from 19-23 and participated in the following sports: men’s basketball, women’s basketball, men’s soccer, women’s soccer, men’s lacrosse, women’s lacrosse, field hockey, women’s volleyball and football. All subjects gave their informed consent (UD IRB # 131714-7) for participation in the study. Subjects were excluded from the study if they had a history of fracture or surgery to the lower extremity on the involved limb(s) being used for testing. Any subjects indicating no prior history of LAS upon completion of the initial CAIT were also excluded from participation.

2.3 Procedures

Cumberland Ankle Instability Tool:

This tool is a self-assessed and perception based survey of an individual’s ankle instability consisting of 9 questions. Respondents may score between 0 and 30 with lower scores indicating decreased ankle stability, and higher scores indicating increased
stability. For the purpose of this study we will be utilizing cut-off scores of both \( \leq 25 \) and \( \leq 27 \) in distinguishing between stable versus unstable ankles.

**Ankle History Questionnaire:**

This form is a general questionnaire used to gather basic demographic information and ankle injury history including any lower extremity surgery or fracture.

Each participant completed an initial CAIT questionnaire as part of a separate ongoing prospective ankle injury study. For this study, the qualified participants were then asked to complete follow-up CAIT and ankle history questionnaires. These data were then compared to initial CAIT and ankle history questionnaire responses. Self-reported ankle injury history was derived from the ankle history questionnaire. Additionally, each subject’s officially documented injury history was obtained from the University’s sports medicine clinic.

It is important to note that the initial testing timeline varied amongst the 102 identified subjects that were asked to complete a follow-up survey; resulting in three subject groupings (Table 1). Using Qualtrics (Qualtrics, LLC – Salt Lake City, Utah) survey software, both the CAIT and Ankle History Questionnaire were created into a simple online survey format. Subjects received an email containing a link, which directed them to the full survey. Prior to completing both questionnaires, each athlete was given two sets of instructions (Figures 1 and 2). All requests for follow-up questionnaires were distributed and completed at the same time during the Fall 2014 academic semester. Once returned, all survey response data was collected and recorded for statistical analysis.
2.4 Statistical Analysis

A separate analysis was performed for each of the three groups of subjects (1-year, 2-year, and 3-year athletes) and for each of the two CAIT cut-off scores (≤25 and ≤27). Statistical analyses were also completed using the two methods of reporting for injury history (self-report vs official documentation). Subject status of subsequent injury and no injury were used as variables to calculate sensitivity and specificity using Marley Watkins Software (www.edpsychassociates.com) for diagnostic utility. The relationship between initial CAIT scores and number of subsequent ankle re-injuries and between initial and follow-up CAIT scores were calculated using Spearman rank correlations. Correlational analyses were performed using SPSS statistical software (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) and all data were analyzed with an alpha level set *a priori* at P≤0.0.
Chapter 3
RESULTS

A total of 66 athletes (males = 40, females = 26; age = 20.4±1.1 yrs.; height = 179.0±11.9 cm.; mass = 83.0±20.9 kg.) out of the 102 that received a follow-up survey responded (65% response rate). Survey responses on both ankles for each subject were reviewed, but only ankles with a history of injury were included in data analysis. Of the eligible 132 ankles, 6 were excluded due to a history of fracture or surgery, while an additional 33 were excluded due to no history of LAS. Figure 3 provides a flow chart representing the 93 ankles that were included for data analysis.

The average number of previous sprains across all ankles was 1.6±1.2 (Group 1 1.6±1.0; Group 2 1.3±0.5; Group 3 2.0±1.8). Figure 4 provides an overview and breakdown of injury history for all of the 93 included ankles, which was obtained through self-report upon initial testing. On follow-up testing subjects reported an average of 0.6±1.1 re-injuries via self-report (follow-up Ankle History Questionnaire) compared to an average of 0.3±0.6 re-injuries reported with official documentation. Overall, there was a strong relationship between the two reporting methods (Spearman’s rho=.538, p<.001).

Utilizing a Marley Watkins software program for diagnostic utility the CAIT proved to be far more sensitive of a tool in predicting re-injury across all three groups when using a cut-off of ≤27. Conversely, the CAIT proved to be much more specific when a cut-off of ≤25 was used. Sensitivity is the ability of a test (or survey in this case)
to correctly identify a positive result when the condition (ankle re-injury) exists, while \textit{specificity} is the ability of a test to correctly identify a negative result when the condition is not present.

This shift in sensitivity and specificity between the two different cut-off points was seen when using both self-report injury history and official documentation of injury history. In an overall assessment of \textit{all subjects} using the self-report documentation method, a cut-off score of $\leq 25$ had a sensitivity of 47.22\% and specificity of 71.93\% with a positive likelihood ratio of 1.68 and a negative likelihood ratio of 0.73. When assessing the self-report method with a cut-off score of $\leq 27$, the CAIT had a sensitivity of 75\% and a specificity of 42.11\% with a positive likelihood ratio 1.29 and a negative likelihood ratio of 0.594. In an overall assessment of \textit{all subjects} using the official documentation method, a cut-off score of $\leq 25$ had a sensitivity of 48.15\% and a specificity of 69.7\% with a positive likelihood ratio of 1.59 and a negative likelihood ratio of 0.74. When assessing the official documentation method with a cut-off score of $\leq 27$, the CAIT had a sensitivity of 75\% and a specificity of 40\% with a positive likelihood ratio of 1.25 and a negative likelihood ratio of 0.625. Additionally, sensitivity and specificity of the CAIT across all three groups and across time remained consistent at each cut-off score and again with each method of reporting. Tables 2-4 offer a summary of sensitivity and specificity values along with positive and negative likelihood ratios for each of the \textit{three groups}. Figures 5-8 illustrate the consistency of these results over time.

There existed significant relationships between initial CAIT and follow-up CAIT scores for all three groups and overall for all subjects (Table 5).
Lastly, we were interested in the relationship between initial CAIT score and the number of subsequent LAS. Amongst all subjects the mean initial CAIT score was 26.4±3.1. Upon follow-up of subsequent LAS the self-report average across all subjects was 0.6±1.1 LAS versus 0.3±0.6 LAS reported through official documentation. This appears to indicate a slight inflation of self-report of subsequent LAS by student-athletes. When data from all subjects were included in the correlational analysis there was a significant relationship between initial CAIT score and self-report of subsequent LAS (r=-.267; p=.010) as compared to a correlation between initial CAIT and official documentation of subsequent LAS (r=-.245; p=.018). In other words, as initial CAIT score decreased the chances for a greater number of subsequent LAS increased. Interestingly, there was also a significant correlation between the initial CAIT score and self-report of subsequent LAS in Group 1 (r=-.353; p=.024). However, the correlation between initial CAIT and official documentation of subsequent LAS for Group 1 was not significant. Furthermore, within each of the other two groups, no significant correlations were seen, despite the fact that a significant correlation was seen across all subjects.
Chapter 4

DISCUSSION

The CAIT is one of the first tools that have been shown to be a valid and reliable measure for use in classifying those with CAI. In this study, we aimed to use the CAIT not only in regards to the presence of CAI, but also by taking previous research one step further and investigating the interaction between the CAIT and ankle re-injury, which is one of the primary indicators of CAI. Our study was also one of the first to use a re-test format with the CAIT across three time periods of one, two, and three years (Group 1, Group 2, and Group 3). Other studies have only performed 1-2 week follow-ups in the same group of subjects.

In regards to our choice to distribute this survey electronically versus administering the survey on paper, our response rate was quite high. In a 2001 review study investigating response rates of e-mailed surveys, of the 31 studies included in the investigation (1986-2000), an average 36.83% response was found. Despite the fact that more and more Americans are actively utilizing e-mail, the response rate to surveys appears to be decreasing. In 1986, the studies involved in this review exhibited an average 61.5% response rate, which declined fairly rapidly to 24% in 2000. A total of 66 out of the 102 surveyed athletes returned the follow-up CAIT and Ankle History Questionnaire resulting in a fairly high response rate of 65%. Perhaps our higher than
normal response rate is due in part to the three rounds of reminder e-mails that were sent following the initial distribution of the survey and questionnaire.

Out of the 93 ankles (all with a history of LAS) that were included in this study, 38.7% (36/93) suffered from re-injury when using self-report compared to the 30.1% (28/93) that suffered from re-injury according to official sports medicine documentation. Eighty out of the 93 included ankles reported a history of 1 or 2 previous LAS (via self-report on initial testing), with the remaining 13 reporting a history of 3, 4, 5, or 8 previous LAS. These findings are consistent with previous studies, which have reported 28% 17, 29% 18 and 54% 19 of participants reporting at least one subsequent LAS at a 12-month follow-up after receiving usual care. Regardless of which documentation method is used, these numbers are alarmingly high and as clinicians and researchers alike it must be a priority to reduce this risk. These findings are in agreement with a recent position statement put out by the International Ankle Consortium who suggested that as many as 32-74% of individuals with a history of ankle sprain will go on to suffer from repetitive ankle sprains, among other various residual symptoms. 1

Our innovative study design, which utilized two methods of reporting for injury history, suggests a need for a more widely accepted definition of “injury” for future research in the field of CAI. Every individual is going to define and relate to the word “injury” differently when utilizing a self-report method. This might lead one to argue that official documentation is the more accurate approach. Contrary to this thought, we know
from Hertel that as many as 55% of individuals sustaining an ankle sprain will not seek evaluation or treatment from a healthcare provider. Although an official documentation method may seem more accurate, many injuries are likely missed due to such a high rate of underreporting. Additionally, a greater number of ankle injuries may be reported when using self-report. Ultimately, this definition of injury must be based upon exactly what it is that the research is aimed towards. Perhaps self-report may be the method of choice when using a perception-based tool such as the CAIT, so as not to discredit any episodes of “giving-way” as perceived by the individuals completing the survey that may not have been officially reported to healthcare providers. Conversely, official documentation may be the more appropriate method when dealing with concrete laboratory measures such as strength or balance measures. Interestingly enough, our study revealed fairly consistent and reliable agreement between the two methods of reporting. In examining the correlation between each of the two methods of injury documentation, self-report and official sports medicine documentation, it was found that the two had a moderate to strong positive correlation ($r=.538$, $p<.001$). This relationship is also reflected in the fact that there were differences in sensitivity and specificity values between the two cut-off points ($\leq25$ and $\leq27$). Each cut-off point exhibited different sensitivity and specificity values but these values remained fairly consistent within each group when comparing each method of reporting. In other words, in Group 1 sensitivity and specificity values were fairly similar at a cut-off point of $\leq25$ when utilizing both self-report and official documentation of injury history. This was seen with all three groups.
In past research, CAI researchers have utilized some form of reporting to examine previous history of LAS.\textsuperscript{5,8,21-24} Interestingly, the actual form (self-report versus official documentation) is frequently left out of research methodology.\textsuperscript{5,21,22} For example injury history may be reported as part of inclusionary and exclusionary criteria, but with no explanation as to where that information is derived from.\textsuperscript{5} This perhaps suggests a limitation to how results from previous studies have been interpreted, as some researchers have chosen to use a documented injury history and others a self-report history. We suggest that future research should incorporate a self-report of injury history when utilizing a highly perception-based tool such as the CAIT.

Based upon the inconsistent sensitivity and specificity values derived in this study, we argue that the CAIT is not a valid predictor of subsequent LAS in individuals with a history of ankle sprain. This finding was evident when CAIT cut-off scores of both $\leq 25$ and $\leq 27$ were used. Traditionally, when choosing a diagnostic tool or test in clinical practice, it is most beneficial to find the tool/test that is high in both sensitivity and specificity in order to create the most optimal and accurate outcomes in our evaluations. In the prediction of ankle re-injury, what is arguably most important is the ability of a tool to consistently rule in a “positive” result or accurate risk of future re-injury. Our results proved to be more specific at a cut-off of $\leq 25$ versus that of $\leq 27$. This data may suggest that the CAIT has the potential be a useful predictor of re-injury when using a lower cut-off score. Our study did not produce results, which would traditionally support the use of a particular diagnostic test due to a high sensitivity and specificity, although a lower cut-off score did illustrate a greater accuracy to “rule in” and essentially predict
subsequent LAS. From a clinical perspective, we argue that the ability to “rule in” re-injury versus “rule out” is of much greater importance. When utilizing the CAIT as a prediction tool and choosing a cut-off score to implement, researchers must keep in mind exactly what the goal is. Ultimately, clinicians are more concerned with accurately identifying the high-risk population so that this risk may be reduced through the implementation of extended rehabilitation programs. Therefore, a tool that is more specific, even at the cost of being less sensitive, may have the potential to be a clinically useful tool. Additionally, researchers should also keep in mind that a CAIT cut-off score, which is set too low, might result in a higher number of unwanted false negatives (i.e. missed re-injuries). This scenario creates implications for future research with regards to cut-off scores when using the CAIT as a predictive tool.

No other study has assessed the sensitivity and specificity of the CAIT in regards to its use as a predictor of re-injury, although it’s reliability and validity has been investigated in the past. In 2006, Hiller et al. determined that the CAIT had a sensitivity of 82.9% and specificity of 74.7% with an excellent test-retest reliability (ICC=.96) when used to identify the presence and severity of instability. Unfortunately, these values did not hold true when investigating the CAIT as a predictor of re-injury as was the case in our study. 

There existed strong relationships between initial CAIT and follow-up CAIT scores for all three groups and overall for all subjects. These results support our original hypothesis and suggest a potential trend, which may be of great clinical importance. The consistency amongst these scores, despite lengthened follow-up periods (1, 2, and 3 years)
compared to the follow-up periods that have traditionally been used (1-2 weeks)\textsuperscript{7,8} suggests that the implications of an individual's CAIT score based upon their responses can be expected to hold true over time. If an ideal cut-off score can be determined, the CAIT may potentially be a tool of predictive ability with a lasting effect: future research is warranted in this area.

Contrary to our hypothesis we did not find a strong relationship between lower CAIT scores and an increased number of subsequent re-injury within each of the three groups. This finding might suggest that although proven valid and reliable\textsuperscript{7} in detecting both the presence and severity of CAI, the CAIT might actually be more useful in addressing just presence alone as opposed to the severity of the pathology. Although this finding is contrary to our initial hypothesis it is consistent with results of Linde et al. in which the number of re-sprains was found to be independent of the severity of the initial sprain.\textsuperscript{23} Not only is the number of re-sprains independent of initial severity, but also the likelihood of the development of impairment and activity limitation.\textsuperscript{24} A history of previous ankle sprain has been shown to be the most frequently reported risk factor for subsequent LAS.\textsuperscript{10,11} This is illustrated in the high rates of re-injury that were seen in this study with a population reporting a history of one or more LAS (self-report = 34.92%; official documentation = 25.39%). Intuitively it makes sense that a history of previous LAS would translate to a lower CAIT score, yet the lower CAIT score does not necessarily suggest a greater risk for subsequent LAS. Despite the fact that subsequent LAS rates were indeed high, decreasing values in CAIT score were not found to be a valid predictor of these re-injuries.
Although a significant relationship was seen between initial CAIT and subsequent LAS amongst all subjects, this relationship did not present itself within each of the groups. A significant correlation between initial CAIT score and subsequent number of LAS was seen only in Group 1 when utilizing the self-report method, and was not seen with official documentation data. There were however, no significant correlations within any of the other two groups with either of the two methods of documentation. This finding may suggest that perhaps athletes were able to more accurately recall their injury histories after only one year versus the other two groups at two and three years. Additionally, it might also lend itself to the subjective nature of this perception-based tool.

The results of this study make an argument for much needed research in the future. Although the CAIT has been studied extensively and proven to be a reliable tool, questions of internal reliability and consistency have arisen from our study. Based upon initial CAIT scores and subsequent injury, many individuals did not score as expected according to the intended purpose of the CAIT. For example, upon careful scrutiny of each initial CAIT questionnaire, many individuals whom were not included in the actual study due to no history of LAS (75/126 ankles), scored below 30 on their initial CAIT score. With no history of LAS, a higher score is to be expected, although many of these individuals were scoring lower (often times low enough to be categorized as unstable), primarily due to their responses for questions 8 (TYPICALLY, when I start to roll over (or “twist”) on my ankle, I can stop it…) and 9 (After a TYPICAL incident of my ankle rolling over, my ankle returns to “normal”…) of the CAIT. This observation suggests a
need for future research in regards to internal consistency and reliability of each question, in addition to being a potential limitation of the current study. Of further interest is in regard to the design and presentation of the CAIT itself. It may be beneficial to present the survey as two separate sets of questions, set apart from one another, for each ankle. This re-designed presentation may lend itself better to the inherent subjectivity that is often a limitation seen in survey research. With this format, subjects may be more inclined to think about their response for each ankle and answer more truthfully.

Lastly, it is worthwhile to consider the potential limitations associated with incomplete official documentation by clinicians. It was expected that official documentation and self-report histories would reveal many inconsistencies, but the results of this study have shown a strong relationship between the two methods, which we found to be quite interesting. It is possible that there may have been an incomplete reporting and official documentation of injury by clinicians and physicians. Finally, although our 65% response rate was significantly higher than expected, it is possible that our overall results may have been quite different had we received a higher response rate resulting in a larger subject pool.
Based on our results, we do not recommend using the CAIT as a predictive tool in assessing risk for re-injury following one or more initial LAS. Our findings are in agreement with previous research and imply a need for future research in regards to both contralateral and ipsilateral ankle re-injury. A strong relationship between initial and follow-up CAIT scores suggests a lasting implication of ankle stability status according to an initial CAIT score. Although a relationship between lower initial CAIT scores and an increased number of subsequent LAS existed amongst all subjects, the same was not seen amongst each of the individual groups. This finding suggests that severity of instability may be similar to that of the severity of the initial injury. It has been proven that re-injury is independent of severity of the initial sprain; perhaps re-injury is also independent of the severity of instability as well. This observation implies the need for future research and follow-up on the relationship between the severity of instability and number of subsequent re-injuries that follow. Lastly, the surprisingly high correlation between the two methods of reporting offers support for the use of self-report of injury in future survey research, especially when a perception-based survey is being utilized. We argue that a standard definition of “injury” is needed to establish more congruency amongst studies assessing CAI using the CAIT. Overall, these findings suggest a need for
more prospective studies with a primary focus on predictive risk factors for re-injury in an unstable population.

TABLES

Table 1: Testing Timeline

<table>
<thead>
<tr>
<th>GROUP</th>
<th>CAIT 1</th>
<th>CAIT 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-year student athlete</td>
<td>Fall 2011</td>
<td>Fall 2014</td>
</tr>
<tr>
<td>2-year student athlete</td>
<td>Fall 2012</td>
<td>Fall 2014</td>
</tr>
<tr>
<td>1-year student athlete</td>
<td>Fall 2013</td>
<td>Fall 2014</td>
</tr>
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</table>
Table 2: Sensitivity and Specificity of the CAIT Using Cut-off Scores of \( \leq 25 \) and \( \leq 27 \) – Group 1

<table>
<thead>
<tr>
<th></th>
<th>( \leq 25, \text{SR} )</th>
<th>( \leq 27, \text{SR} )</th>
<th>( \leq 25, \text{OD} )</th>
<th>( \leq 27, \text{OD} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.5</td>
<td>0.75</td>
<td>0.556</td>
<td>0.667</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.828</td>
<td>0.448</td>
<td>0.813</td>
<td>0.406</td>
</tr>
<tr>
<td>(+) Likelihood Ratio</td>
<td>2.9</td>
<td>1.359</td>
<td>2.963</td>
<td>1.123</td>
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<tr>
<td>(-) Likelihood Ratio</td>
<td>0.604</td>
<td>0.556</td>
<td>0.547</td>
<td>0.820</td>
</tr>
</tbody>
</table>

SR = self-report method of injury history; OD = official sports medicine documentation method of reporting injury history
Table 3: Sensitivity and Specificity of the CAIT Using Cut-off Scores of ≤25 and ≤27 – Group 2

<table>
<thead>
<tr>
<th>Group 2</th>
<th>≤25, SR</th>
<th>≤27, SR</th>
<th>≤25, OD</th>
<th>≤27, OD</th>
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</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.5</td>
<td>0.727</td>
<td>0.444</td>
<td>0.7</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.533</td>
<td>0.4378</td>
<td>0.5</td>
<td>0.412</td>
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<tr>
<td>(+) Likelihood Ratio</td>
<td>1.071</td>
<td>1.293</td>
<td>0.889</td>
<td>1.19</td>
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<tr>
<td>(-) Likelihood Ratio</td>
<td>0.938</td>
<td>0.623</td>
<td>1.111</td>
<td>0.729</td>
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</tbody>
</table>

***SR = self-report method of injury history; OD = official sports medicine documentation method of reporting injury history
Table 4: Sensitivity and Specificity of the CAIT Using Cut-off Scores of ≤25 and ≤27 – Group 3

<table>
<thead>
<tr>
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<th>≤25, SR</th>
<th>≤27, SR</th>
<th>≤25, OD</th>
<th>≤27, OD</th>
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<tr>
<td>Sensitivity</td>
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<td>0.444</td>
<td>0.889</td>
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<tr>
<td>Specificity</td>
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<td>0.333</td>
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<tr>
<td>(+) Likelihood Ratio</td>
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<td>1.154</td>
<td>1.422</td>
<td>1.422</td>
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<tr>
<td>(-) Likelihood Ratio</td>
<td>0.843</td>
<td>0.6923</td>
<td>0.808</td>
<td>0.296</td>
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</tbody>
</table>

***SR = self-report method of injury history; OD = official sports medicine documentation method of reporting injury history
Table 5 – Spearman’s Rho Comparison of Initial and Follow-up CAIT Scores, All Subjects and Groups

<table>
<thead>
<tr>
<th></th>
<th>All Subjects</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Spearman's rho</em></td>
<td>.492</td>
<td>.397</td>
<td>.662</td>
<td>.455</td>
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<tr>
<td><em>P-value</em></td>
<td>&lt;.001</td>
<td>0.01</td>
<td>&lt;.001</td>
<td>0.022</td>
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Table 6 – Spearman’s Rho Comparison of Initial CAIT Scores With Subsequent LAS, All Subjects and Groups

<table>
<thead>
<tr>
<th></th>
<th>All Subjects</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self Report of Injury</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spearman’s rho</td>
<td>-0.267</td>
<td>-0.353</td>
<td>-0.103</td>
<td>-0.121</td>
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<tr>
<td>P-Value</td>
<td>0.01</td>
<td>0.024</td>
<td>0.608</td>
<td>0.566</td>
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</table>

<table>
<thead>
<tr>
<th><strong>Official Documentation</strong></th>
<th>All Subjects</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spearman’s rho</td>
<td>-0.245</td>
<td>-0.27</td>
<td>-0.13</td>
<td>-0.248</td>
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<tr>
<td>P-Value</td>
<td>0.018</td>
<td>0.087</td>
<td>0.518</td>
<td>0.231</td>
</tr>
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</table>
Figure 1: Electronic Ankle History Questionnaire Instructions
Figure 2: Electronic CAIT Instructions
Figure 3: Subject Flow Chart – Inclusion and Exclusion

66 Surveys Returned = 132 ankles

- 93 ankles used for data analysis
- 6 ankles excluded
- 33 ankles excluded

Group 1 = 41 ankles
Group 2 = 27 ankles
Group 3 = 25 ankles

History of fracture or surgery
No history of LAS

Surveys Returned = 132 ankles
66 Surveys Returned = 132 ankles
93 ankles used for data analysis
6 ankles excluded
33 ankles excluded
Group 1 = 41 ankles
Group 2 = 27 ankles
Group 3 = 25 ankles
History of fracture or surgery
No history of LAS
Figure 4: Self-Reported History of Previous Injury as Reported With Initial Ankle History Questionnaire
Figure 5: Sensitivity and Specificity Across Groups Over a 3-year Time Period – Self-Report, $\leq 25$

![Sensitivity and Specificity Across Groups and Time: Self-Report, 25 Cut-off](image)
Figure 6: Sensitivity and Specificity Across Groups Over a 3-year Time Period – Self-Report, ≤27
Figure 7: Sensitivity and Specificity Across Groups Over a 3-year Time Period – Official Documentation, ≤25

<table>
<thead>
<tr>
<th>Group</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>0.5556</td>
<td>0.6875</td>
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<tr>
<td>Group 2</td>
<td>0.4444</td>
<td>0.4444</td>
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<tr>
<td>Group 3</td>
<td>0.8125</td>
<td>0.5</td>
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Figure 8: Sensitivity and Specificity Across Groups Over a 3-year Time Period – Official Documentation, ≤27

<table>
<thead>
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<th>Group</th>
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<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>0.7</td>
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</tr>
<tr>
<td>3</td>
<td>0.8889</td>
<td>0.375</td>
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Sensitivity and Specificity Across Groups and Time: SMC, 27 Cut-off
REFERENCES


Appendix A

SPECIFIC AIMS

Lateral ankle sprains (LAS) are one of the most commonly occurring injuries amongst the general population, accounting for upwards of 20% of all joint-related injuries. \(^1\) It has been reported that 32 - 74% of individuals with a previous history of LAS will suffer from residual or chronic symptoms and go on to develop chronic ankle instability (CAI). \(^1\) Chronic ankle instability has been classified as a condition involving ankle pain and swelling with activity, recurring episodes of “giving-way”, repetitive ankle sprains, and restriction of or a failure to return to levels of previous activity. \(^4\) Additionally, these injuries that are often considered insignificant, have not only been linked to CAI but also to long-term consequences such as ankle osteoarthritis, articular degeneration and an overall decreased quality of life. \(^20\) The high prevalence of CAI paired with the condition’s negative long-term effects advocates for further investigation into clinical interventions to aid healthcare providers in the treatment and prevention of this condition.

Previous studies have used healthy controls as a comparison group to assess the differences between those with and without CAI. Unfortunately, this research model has been inconclusive as to why a portion of the population experiencing LAS does not recover. Recently, researchers have begun using an alternative comparison group of
controls that includes individuals who have sustained LAS in the past, but have successfully recovered without any recurrent injury. These individuals have been termed “copers” and offer researchers a different model for comparison. \(^4\) Wikstrom et al. has offered the following as an operational definition for defining copers: “those individuals that have a history of at least one LAS that occurred at least 12 months ago and do not complain of disability and/or “giving-way” episodes since their injury.”\(^4\) Other researchers have generally used the same criteria, although inclusion into coper groups is still quite variable throughout the current literature.\(^1,5,25\)

For the purpose of this study and the application of the Cumberland Ankle Instability Tool (CAIT) as a clinical tool we will use the following in defining a potential coper: an individual who has sprained their ankle and have returned to full function with no subsequent re-injury. The precise coping mechanism that allows some individuals to suffer LAS without any residual symptoms or recurring injury is still unknown. Insight into this coping mechanism may help healthcare providers in their attempts to explain why some individuals are unable to cope following an ankle sprain.\(^25\) These successful coping mechanisms may potentially be useful in treating CAI once they have been identified.\(^25\) However, prior to addressing coping mechanisms, researchers must first develop a reliable “‘gold standard’” for identifying copers and distinguishing them from individuals with CAI; then, and only then, can researchers begin to confidently identify how and why copers differ from individuals with CAI. In the past, the CAIT has been used as an instrument to determine the presence and severity of CAI.\(^7\)
The CAIT is a 9-item, 30-point questionnaire that is utilized without comparison to the contralateral ankle. With a maximum score of 30 points, a lower score is more indicative of increasing ankle instability whilst scores increasing to 30 indicate greater ankle stability. The reliability and validity of this subjective, perception-based clinical tool has been tested in the past, but not in regards to its use as a predictor of potential copers and non-copers and/or subsequent re-injury. The primary goal of this study is to determine the effectiveness of the CAIT in predicting ankle re-injury following one or more LAS in a group of collegiate athletes over time.

**Specific Aim 1:** To determine sensitivity and specificity of the CAIT in predicting ankle re-injury in a sample of collegiate athletes using a cutoff score of 25 and 27.

**Hypothesis 1:** We hypothesize that the CAIT will prove to be an effective tool in correctly identifying subsequent ankle re-injury.

**Hypothesis 1.1:** Further, we hypothesize that using a cut-off score of 25 will result in greater accuracy for correctly identifying subsequent ankle re-injury versus a cut-off score of 27.

**Specific Aim 2:** To determine the agreement between initial and follow-up CAIT scores derived from three different injury exposure periods.

**Hypothesis 2:** We hypothesize that the CAIT scores derived from each of the three injury exposure periods will strongly agree, thus validating the use of the CAIT as an accurate predictor ankle re-injury

**Specific Aim 3:** To examine the relationship between CAIT scores and subsequent injury history in a group of collegiate athletes.
Hypothesis 3: We hypothesize that there will be a positive correlation between lower initial CAIT scores and subsequent ankle re-injury.

Hypothesis 3.1: We hypothesize that as initial CAIT scores decrease, subjects will sustain more ankle sprains during the exposure period that follows.
Appendix B

LITERATURE REVIEW

An appreciation and understanding of the complexity of the pathomechanics and pathophysiology related to acute lateral ankle sprains and chronic ankle instability is critical to clinicians in effectively evaluating, treating and preventing LAS. In the past, CAI has been primarily attributed to two potential causes: mechanical instability and functional instability. In 1965, Freeman et al first described functional ankle instability (FAI) when they attributed CAI to proprioceptive deficit following ligamentous injury. Later, Tropp et al. described mechanical ankle instability (MAI) as a cause of CAI due to pathologic laxity following ankle injury. Although both concepts of mechanical and functional instability have evolved quite a bit since their introduction, these two potential causes of CAI alone do not offer an adequate explanation to the growing spectrum of conditions leading to CAI.

In 2002, Hertel proposed a paradigm of the mechanical and functional insufficiencies that contribute to chronic ankle instability (illustrated below in figure 9). This paradigm illustrates the idea that mechanical and functional instabilities likely are not mutually exclusive of one another but rather form a continuum of pathologic contributions to CAI. Hertel explains not only the concepts mechanical and functional instability but further clarifies the potential insufficiencies leading to each type of instability. Within this model, recurrent sprain will only occur in the event that both
mechanical and functional instabilities exist. However, anecdotal evidence refutes this idea in that individuals who have reported residual feelings of instability or ankle laxity have not re-injured their ankles. Additionally, previous research has demonstrated that functional instability and recurrent sprain may be present without the presence of mechanical instability. Not only do inconsistencies such as these exist, but the proposed relationship between these two variables varies widely. Some suggest that functional instability is a direct consequence of mechanical instability while others believe it to be a cause of mechanical instability. Until recently, this has been the widely accepted model in our understanding of chronic ankle instability.

Figure 9 - Hertel’s Model of Chronic Ankle Instability
In 2011, Hiller\textsuperscript{24} proposed a modification of the Hertel model where not just two, but three basic components may exist independently or in combination with one another. The Hiller model, unlike that of the model proposed by Hertel, consists of 3 main components of CAI which may exist independently or all in combination with one another creating 7 possible subgroups (illustrated below in figure 10).\textsuperscript{24} With the additional component of one’s “perceived instability” Hiller has introduced a new concept into the CAI classification scheme that may indeed offer answers to many questions that have been left unanswered with Hertel’s previous classification scheme. This proposed expansion of the Hertel model was created with the intended purpose to allow classification of all ankles with CAI and not just some particular cases. The Hertel model describes CAI as existing only when functional and mechanical instability both exist together.\textsuperscript{20} This classification scheme likely left many individuals with recurrent sprain and ankle instability out of the unstable group due to such narrow restrictions for group membership.
Recently, in a study conducted by Wikstrom et al\textsuperscript{5} in 2012, multiple outcome measures proved to be successful in identifying and discriminating between unstable and stable individuals. This finding further supports both ideas presented by Hertel and Hiller in that CAI, along with the mechanism through which some individuals are able to cope following LAS, is certainly multifactorial in nature. Additionally, in a 2007 study conducted by Hubbard et al. that investigated correlations within and between various measures of both FAI and MAI, of the 35 significant correlations that were found, only 3 were found between the groups with the rest primarily residing within each of the groups. Again, these findings further support the platform presented by both Hertel and Hiller that CAI is indeed an extremely complex pathology and all components must be accounted for. With such inconsistencies amongst various laboratory test measures in
distinguishing between these two groups, researchers should begin to investigate more thoroughly the implications of an individual’s perception of ankle instability. A focus on an individual’s perception of ankle instability, without regard to the presence or absence of MAI and FAI may offer clinicians a much simpler way to determine the presence of CAI.

Unlike copers in ACL research, the term “coper” in regards to ankle injury is relatively new and still lacking a widely accepted definition for inclusion into this group. Additional research in this area is highly indicated due to such a high rate of injury and re-injury when it comes to LAS in both the general and athletic populations. In 2013, Wikstrom offered the following as a minimal operational definition for defining copers in research: “those individuals that have a history of at least one LAS that occurred at least 12 months ago and do not complain of disability and/or giving way episodes since their injury”. Although the most important difference to be considered between the coper and non-coper groups is the presence of ankle re-injury.

Previous studies have utilized uninjured healthy controls as a comparison group to assess the differences between those with and those without CAI. Unfortunately, this research model has not shed any light on why or why not a portion of the population experiencing LAS does not recover. Recently, researchers have begun using copers as an alternative comparison group and likely a much more appropriate model to compare to. At this point in the research it is paramount that we determine two things in regards to copers in CAI research: the mechanism through which some individuals “cope” following an initial LAS while others do not, in addition to common standards in
definitions and terminology used for inclusionary/exclusionary criteria. Before we can even attempt to find a solution to either of these problems, we must first develop a reliable measure that can be used by clinicians to accurately identify copers or individuals that will not suffer from re-injury. Then, and only then can we move forward in determining the coping mechanism by which some individuals are able to return to full activity while others are not. Additionally, this finding may lead us to a better explanation of the underlying cause of CAI.

Researchers have made similar observations, in terms of the ability to cope following injury, amongst individuals with an ACL-deficient knee. These observations have led to the development of a classification scheme that now allows us to discriminate among copers and non-copers in the ACL-deficient population. Additionally, these observations amongst both populations suggest that copers do indeed exhibit some sort of mechanism that likely leads to a better functional outcome.  

If a reliable measure that is capable of accurately predicting whether or not an individual will be more or less likely to develop CAI (or go on to suffer subsequent re-injury) following an LAS can be found, the clinician will be allowed the opportunity to better tailor a rehabilitation program that will meet the specific needs of that individual. To date, researchers have not been able to identify any differences in functional performance scores (such as hop tests) between copers and individuals with CAI.  

However, differences in perceptual, mechanical and sensorimotor measures have been identified between these two groups. In a study conducted by Wikstrom et al. to quantify the diagnostic utility of these three measures, results indicated that perceptual
outcome measures had the greatest ability to accurately predict people who became copers after their initial injuries. Furthermore, the greatest diagnostic utility scores were achieved by self-assessed disability questionnaires. Various differences have been found between coper and non-coper groups, most of which being found in laboratory measures. A clinically relevant tool to discriminate between groups and predict subsequent re-injury is needed so that clinicians can improve treatment and prevention strategies.

The Cumberland Ankle Instability Tool, although not one used in the aforementioned study, is a self-assessed disability questionnaire that has been used in the past to identify the presence and severity of CAI, and might also be useful in predicting subsequent re-injury and potentially identifying copers following LAS. Although mechanical ankle instabilities can be easily assessed and measured through clinical tools, functional ankle instability has proven to be much more difficult to measure. This inability to accurately diagnose functional ankle instability has made it difficult to correctly use instability as an outcome measure both in the clinic and in research as well as the selection of homogeneous groups of participants for research. In current literature, self-reported subjective questionnaires are the most widely accepted methodology utilized to “diagnose” an individual with functional ankle instability.

Prior to the Cumberland Ankle Instability Tool (CAIT) two questionnaires had been developed in attempt to assess functional ankle instability: the Functional Ankle Instability Questionnaire (FAIQ) and the Ankle Joint Functional Assessment Tool (AJFAT). The FAIQ contained eleven questions with dichotomous responses likely
making it insensitive to gradations of severity and only useful in identifying instability. Although the AJFAT was able to offer gradations of severity, it required comparison to the contralateral ankle making this tool useful only in the case of unilateral instability. Following the development of these two questionnaires, researchers looked to develop the CAIT, a tool to accurately identify FAI in addition to the severity of the instability without comparison to the contralateral ankle.

The original CAIT was first devised after researchers identified questions used in previous studies \(^{30,31}\) on ankle injury in addition to questions from focus group interviews with people suffering from chronic instability. This initial 12-item questionnaire was administered to a pilot group of subjects with a mix of uninjured, sprained, and unstable ankles. For each of the 12 items a range of 4 or 5 responses was possible. After all subjects involved in the study responded with the same answer to 2 questions on the survey, researchers chose to remove them and re-distribute in hopes that the new CAIT would offer more useful discrimination between subjects. The second pilot group consisted of 49 subjects with a mix of uninjured, unilateral and bilateral sprained ankles. At this point the CAIT consisted of ten questions with a maximum score of 37. After responses were collected and examined, the range of responses for three questions was modified and one question was discarded. Nine questions remained with a maximum score of 30 points, with a lower score indicating a more severe instability. These remaining nine items were retained for further study, and are what have been used within the literature that has utilized the CAIT to date.
In 2006, Hiller et al.\textsuperscript{7} conducted a study to examine the validity and reliability of
the CAIT. Results of this study revealed that there was a strong correlation between the
CAIT and visual analog scores (VAS) of subjects’ perception of ankle stability or
instability. Additionally, statistical analysis revealed that there was in fact a distinct
scoring scale that could be used to determine whether or not a subject had experienced an
ankle sprain, indicating ankle instability. Subjects with a score greater than 28 were
unlikely to have functional ankle instability whereas scoring 27 or below indicated that a
subject was more likely to suffer from functional ankle instability. Sensitivity and
specificity of the CAIT, using a discrimination score of 27.5 were found to be 82.9% and
74.7% respectively. Not only did the CAIT prove to be valid, it also proved exhibit
excellent test-retest reliability in agreement between subject scores on two different
occasions.

Since the introduction of the CAIT and it’s proposed cut-off score of 27, many
researchers have opted to use this tool with a cut-off score less than 27 due to concerns
that a score of 27 may be suboptimal for use within this population. In 2014, Wright et al.
proposed a recalibration of the CAIT using a cut-off score of at least less than 25 to allow
individuals membership in the CAI population. Findings of this study ultimately
supported the Wright et al. hypothesis that a lower cut-off score would enhance the
usefulness of the CAIT, which also supports the recommendation put out by the
International Ankle Consortium.\textsuperscript{1} Additionally, Wright and colleagues propose that the
use of a cut off score of 27 could potentially result in copers falling into the CAI
grouping, which would ultimately invalidate the results of any study using such a high
score to determine inclusion criteria. With the proposed score of 25 or less the CAIT may be more effective in accurately discriminating between copers and non-copers. Wright et al. have further suggested that studies working intentionally with copers should utilize an even lower cut-off score of 23.

To date, no studies have been done to evaluate the true effectiveness of either of these scores in determining copers from non-copers over time or predicting re-injury. The primary goal of this study is to determine the effectiveness of the Cumberland Ankle Instability Tool in correctly predicting ankle re-injury following one or more lateral ankle sprains (LAS) in a group of collegiate athletes over time.

The CAIT has been used in many studies to detect the presence of CAI, but injury follow-up has yet to be completed on all subjects within a study. A diagnosis of CAI suggests that an individual will likely go on to sustain further ankle injury. It is reasonable to suggest that those subjects meeting the scoring requirements to be considered “unstable” will likely sustain one or more future ankle sprains. A retrospective look at injury history during various exposure periods following distribution of the CAIT could provide the information necessary to confirm that a diagnosis of CAI, definition of CAI, and subsequent injury history are all in agreement.

If a reliable measure that is capable of accurately predicting whether or not an individual will be more or less likely to sustain subsequent ankle injury following a LAS can be found, the clinician will be allowed the opportunity to better tailor a rehabilitation program that will meet the specific needs of that individual in preventing further injury. The CAIT may be of large value to clinicians due to it’s simplicity and easily
distributable design, not only in identifying individuals that might be at risk for future re-
injury but also in monitoring rehabilitation programs following LAS if taken multiple
times. CAIT results might potentially change throughout a rehabilitation program as an
individual’s perception of their ankle’s stability changes similar to the way in which
scores for a concussion symptom checklist will progressively improve if the protocol is
working properly. Thus, essentially utilizing the CAIT as screening tool for injury risk,
specific to the ankle joint.

Furthermore, the CAIT has the potential to be of great importance amongst CAI
and coper researchers. If the CAIT can be used to accurately predict subsequent ankle
injury, it is only logical that it would also be useful in predicting the development of CAI
dependent upon the presence of re-injury. Currently, there is no widely used “gold
standard” in determining the presence of CAI. Due to this lack of a “gold standard”,
heterogeneous groupings have likely been created within the literature that exists today;
and so by using the CAIT, or another similar tool, may aid researchers in creating
homogeneous groupings for research. This lack of a “gold standard” has likely been a
large part of the reason why no largely conclusive evidence has been found in
distinguishing the mechanism through which some individuals are able to return to full
function whereas others do not.
Appendix C

ANKLE HISTORY QUESTIONNAIRE

Ankle History Questionnaire
The first form that you have been given is entitled "Ankle History Questionnaire". Please do not leave any blanks and respond to all questions honesty and to the best of your ability.

Survey Powered By Quatrics
Appendix D

CUMBERLAND ANKLE INSTABILITY TOOL

The second form that you have been given is the Cumberland Ankle Instability Tool. This form consists of 9 questions, each with multiple answers. Please choose only ONE response to each question in regards to EACH ankle. Please be honest and truthful in all of your responses.
I have pain in my ankle:
LEFT Ankle
RIGHT Ankle

My ankle feels UNSTABLE:
LEFT Ankle
RIGHT Ankle

When I make SHARP turns my ankle feels UNSTABLE:
LEFT Ankle
RIGHT Ankle

When going down the stairs my ankle feels UNSTABLE:
LEFT Ankle
RIGHT Ankle

My ankle feels UNSTABLE when standing on ONE leg:
LEFT Ankle
RIGHT Ankle

My ankle feels UNSTABLE when:
LEFT Ankle
RIGHT Ankle
My ankle feels UNSTABLE when:

- LEFT Ankle
- RIGHT Ankle

TYPICALLY when I start to roll over (or "twist") on my ankle I can stop it:

- LEFT Ankle
- RIGHT Ankle

Following a TYPICAL incident of my ankle rolling over, my ankle returns to "normal":

- LEFT Ankle
- RIGHT Ankle
Appendix E

CAIT SCORING GUIDELINES

Please tick the ONE statement in EACH question that BEST describes your ankles.

<table>
<thead>
<tr>
<th>Question</th>
<th>LEFT</th>
<th>RIGHT</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I have pain in my ankle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>☐</td>
<td>☐</td>
<td>5</td>
</tr>
<tr>
<td>During sport</td>
<td>☐</td>
<td>☐</td>
<td>4</td>
</tr>
<tr>
<td>Running on uneven surfaces</td>
<td>☐</td>
<td>☐</td>
<td>3</td>
</tr>
<tr>
<td>Running on level surfaces</td>
<td>☐</td>
<td>☐</td>
<td>2</td>
</tr>
<tr>
<td>Walking on uneven surfaces</td>
<td>☐</td>
<td>☐</td>
<td>1</td>
</tr>
<tr>
<td>Walking on level surfaces</td>
<td>☐</td>
<td>☐</td>
<td>0</td>
</tr>
<tr>
<td>2. My ankle feels UNSTABLE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>☐</td>
<td>☐</td>
<td>4</td>
</tr>
<tr>
<td>Sometimes during sport (not every time)</td>
<td>☐</td>
<td>☐</td>
<td>3</td>
</tr>
<tr>
<td>Frequently during sport (every time)</td>
<td>☐</td>
<td>☐</td>
<td>2</td>
</tr>
<tr>
<td>Sometimes during daily activity</td>
<td>☐</td>
<td>☐</td>
<td>1</td>
</tr>
<tr>
<td>Frequently during daily activity has no mention</td>
<td>☐</td>
<td>☐</td>
<td>0</td>
</tr>
<tr>
<td>3. When I make SHARP turns, my ankle feels UNSTABLE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>☐</td>
<td>☐</td>
<td>3</td>
</tr>
<tr>
<td>Sometimes when running</td>
<td>☐</td>
<td>☐</td>
<td>2</td>
</tr>
<tr>
<td>Often when running</td>
<td>☐</td>
<td>☐</td>
<td>1</td>
</tr>
<tr>
<td>When walking</td>
<td>☐</td>
<td>☐</td>
<td>0</td>
</tr>
<tr>
<td>4. When going down the stairs, my ankle feels UNSTABLE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>☐</td>
<td>☐</td>
<td>3</td>
</tr>
<tr>
<td>If I go fast</td>
<td>☐</td>
<td>☐</td>
<td>2</td>
</tr>
<tr>
<td>Occasionally</td>
<td>☐</td>
<td>☐</td>
<td>1</td>
</tr>
<tr>
<td>Always</td>
<td>☐</td>
<td>☐</td>
<td>0</td>
</tr>
<tr>
<td>5. My ankle feels UNSTABLE when standing on ONE leg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>☐</td>
<td>☐</td>
<td>2</td>
</tr>
</tbody>
</table>
On the ball of my foot  □ □  1
With my foot flat  □ □  0

6. My ankle feels UNSTABLE when
   Never  □ □  3
   I hop from side to side  □ □  2
   I hop on the spot  □ □  1
   When I jump  □ □  0

7. My ankle feels UNSTABLE when
   Never  □ □  4
   I run on uneven surfaces  □ □  3
   I jog on uneven surfaces  □ □  2
   I walk on uneven surfaces  □ □  1
   I walk on a flat surface  □ □  0

8. TYPICALLY, when I start to roll over (or “twist”) on my ankle, I can stop it
   Immediately  □ □  3
   Often  □ □  2
   Sometimes  □ □  1
   Never  □ □  0
   I have never rolled over on my ankle  □ □  3

9. After a TYPICAL incident of my ankle rolling over, my ankle returns to “normal”
   Almost immediately  □ □  3
   Less than one day  □ □  2
   1–2 days  □ □  1
   More than 2 days  □ □  0
   I have never rolled over on my ankle  □ □  3
Appendix F

IRB APPROVAL AND INFORMED CONSENT

University of Delaware Human Subjects
Informed Consent Form

RESEARCH STUDY TITLE: Ankle Injury Assessment and Tracking in an Athletic Population

INVESTIGATORS: Thomas W. Kaminski, PhD (Dept. of Kinesiology & Applied Physiology); Geoff Gustavsen, MD (Team Physician - UD Sports Medicine)

PURPOSE OF STUDY AND INTRODUCTION
The purpose of this research project is to better understand factors that could lead to an ankle sprain. You are being asked to participate because you're a student-athlete at the University of Delaware. You must be 18 years or older to participate in this study. We will examine different aspects of ankle function (strength, balance, looseness, ligament status, etc...) and track any changes that may occur over your athletic career at the University of Delaware. Your participation is voluntary and you are in no way obligated to take part in this project.

PROCEDURES
The initial testing will take about 75 minutes to complete. You will be asked to complete a questionnaire and several tasks to evaluate your ankle. You will be asked wear workout clothing (e.g. shorts/sweatpants and t-shirt) for all testing and perform each task either barefoot or wearing running shoes. All testing will take place in the Human Performance Lab.

Questionnaire: You will be asked about your age, height, weight, and gender and will complete a questionnaire about physical activity. You will complete two questionnaires about your ankle health and past history of lower leg injuries.

Body Composition Testing: Your Lean Body Mass (LBM) will be determined using a device called a Bod Pod®. Wearing a pair of shorts, you will sit in the device, which is a small egg shaped apparatus with a window. You will remain quiet, still and breathe normally for about 10 minutes. During this time, the device makes a series of calculations based on your weight.
**Warm-up:** You will be provided with a 5-minute warm-up on a stationary bike with lower body stretching activities before and after each set.

![Image of warm-up](image1)

**Strength Testing:** Ankle strength will be measured using an isokinetic dynamometer; a device that you will sit on that easily measures ankle force. Strength measurements will be performed on both ankles at a slow and fast speed for all four ankle motions (up, down, in, and out). You will wear running shoes during this test and will perform 3 warm-up reps followed by 3 maximal repetitions at each speed and motion (see image below)

![Image of strength testing](image2)
**Stability:** You will be asked to perform hopping tasks onto a force platform built into the floor. The four hopping tasks will be from the left, right, backward, and forward directions. For the left, right, and backward hopping tasks, you will be standing next to the force platform, single-legged and barefoot, and have your hands on your waist. After you hear the command “go”, you will hop over a 2” hurdle to the center of the force platform. Your task is to stabilize yourself as quickly as possible (see image below). You will hold the position for 5 sec. This procedure will be repeated using the other foot. For the forward hops, we will measure your leg length (from hip to ankle) and place a rubber hurdle 6” high between you and the force platform. We will demonstrate the “step-step-hop” method to hop over the rubber hurdle. You are to land one-footed on the force platform (barefoot), and again stabilize for 5 sec. You will perform this procedure separately on both the left and right foot. You will be asked to perform three trials of each hopping task.

**Balance Assessment** (using the Balance Error Scoring System (BESS))

We will assess your balance while standing quietly on either a firm or foam surface using the three stances shown above. Balance will be evaluated using the Tekscan MobileMat™ BESS while the mat surface shown above is connected to a laptop computer, which performs all scoring. You are to remain as motionless as possible during each test trial. Each trial is timed for 20 sec. You will perform one trial of each with the basketball shoes in place.

**Ankle Arthrometer:** Ankle looseness will be measured using a device that is strapped to your foot and tests motion in an up, down, and rotary manner (see image below). This procedure will take about 5 minutes to complete.

**Ultrasound Imaging:** We will take ultrasound images of both of your ankles using some gel and an ultrasound wand (see image below). The gel will be applied directly to your skin and the wand will be slowly moved over the inside and outside of your ankle to capture an image on a computer screen. You will experience no pain with this test. A total of 6 images will be taken for each ankle: 1) outside ankle in neutral position, 2) inside ankle in neutral position, 3) outside ankle with your toes pointed all the way down, 4) inside ankle with your toes pointed all the way down, 5) outside ankle with your toes...
pointed all the way in, and 6) inside ankle with your toes pointed all the way out.

**Follow-Up Questionnaire:** At 1 year intervals you may be asked to complete the identical 2 survey questionnaires you’ve completed today at the baseline test session. The link to the “on-line” questionnaires will be sent to the e-mail address you have provided us today. The questionnaires require about 5 minutes to complete.

**Functional Movement Screen (FMS) Scores:** As part of your annual baseline evaluation/testing with the UD Strength and Conditioning staff, you have an FMS score that has been calculated as a result. We work closely with the UD Strength & Conditioning staff in scheduling participation for this project and so they will handle the transfer of those scores to us. We intend to compare that score with results of some of the testing performed in this battery of tests involving the ankle.

**CONDITIONS OF SUBJECT PARTICIPATION**

All of the data will be kept confidential. Aggregate (cumulative) data from this study will be shared with the sports medicine staff here at the University of Delaware. In addition, records of any athletic-related injuries that you experience while participating as an intercollegiate athlete will be shared with the research team. Your information will be assigned a code number. The list connecting your name to the code number will be kept in a locked file. When the study is completed and the data have been analyzed, that list will be destroyed, but the coded data will be kept indefinitely on a secured electronic file device. Your name will not be used in conjunction with this study. In the event of physical injury during participation, you will receive first aid. If you require additional medical treatment, you will be responsible for the cost. You will be removed from the study if you experience any injury that interferes with the results or prevents you from completing it. There are no consequences for withdrawing from the study and you can do so at any time.

**RISKS AND BENEFITS:** Potential risks in this project are minimal. As with any exercise or challenging movements, risks include fatigue, localized muscle soreness, and the potential for strains and sprains of muscles and joints of the lower leg. There is a slight risk to you of suffering bone, muscle, or joint injuries during the exercise protocol. If you are injured during research procedures, you will be offered first aid at no cost to you. If you need additional medical treatment, the cost of this treatment will be your
responsibility or that of your third-party payer (for example, your health insurance). By signing this document you are not waiving any rights that you may have if injury was the result of negligence of the university or its investigators. If you become too fatigued or uncomfortable, you may stop the test at any time. Potential benefits include the better understanding of why some people sprain their ankle more than others. In addition, this study can lead to identify predisposing factors to an ankle injury and therefore help prevent future ankle injuries.

CONTACTS: Questions regarding the research study can be directed to Dr. Thomas W. Kaminski (302) 831-6402 or kaminski@udel.edu. For questions of concerns about the rights to the individuals who agree to participate in the study: Human Subjects Review Board, University of Delaware (302) 831-2137.

ASSURANCE: Participation in this study is completely voluntary. You may stop at any time during the testing without penalty. Refusal or choosing to discontinue participation in this study is the right of the individual, with no loss of benefits to which the subject is otherwise entitled.

CONSENT SIGNATURES

______________________________
Subject Consent Signature        Date

______________________________
Principal Investigator Signature Date

Signed consent forms will be retained by the researcher for three years after completion of the research.

UD IRB Approval from 03/09/2015 to 08/25/2015

Initial_______________________