ROLE OF THE FUNCTIONAL MOVEMENT SCREEN IN THE EVALUATION OF NEUROMUSCULAR DEFICITS ASSOCIATED WITH CHRONIC ANKLE INSTABILITY

by

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
CAI	Chronic Ankle Instability
FMS	Functional Movement Screen
DF	Dorsiflexion
PF	Plantar flexion
AROM	Active Range of Motion
ASLST	Athlete Single Leg Stability Test
OSI	Overall Stability Index
FADI-S	Foot and Ankle Disability Index-Sport

ABSTRACT

Context: In the United States, lateral ankle sprains account for an annual healthcare cost that has been estimated at $3.8 billion. The term "chronic ankle instability" (CAI) is used to identify insufficiencies in the ankle following an ankle sprain as well as recurring ankle sprains or "giving way". Chronic ankle instability has been observed in 54% to 72% of first-time ankle sprain patients. The risk factors for developing CAI are not well understood. Previous research identified CAI risk factors such as diminished postural control, decreased range of motion (ROM), increased ligament laxity, muscle weakness, delayed neuromuscular reaction, and decreased functional ability. **Objective:** To determine the extent to which the Functional Movement Screen™ (FMS) is an effective tool for discriminating between healthy individuals and patients with CAI with neuromuscular deficits. A secondary aim was to identify risk factors that predispose individuals to CAI. **Design:** Case-Control. **Setting**: Laboratory setting. **Participants or Other Patients:** 60 physically active individuals (age range, 18-35 yrs; mean age, 21.9 $\pm$ 3.11 yrs) participated in this study. Of our 60 participants, 20 met our operational definition of having CAI. **Interventions:** We employed a 2:1 ratio of persons without a previous history of ankle injury to those with CAI, and triple matched them on sex, age ($\pm$ 5 years) and BMI category (underweight, normal, overweight, obese). **Main Outcome Measure(s)**: Foot and Ankle Disability Index (FADI-Sport), Overall FMS Score, Lower Extremity (LE) and Core Stabilization FMS sub-scores, ankle plantar flexion and dorsiflexion active range of motion (AROM), subtalar eversion and inversion AROM, Y-Balance Test, Athlete Single Leg Stability Test (ASLST). **Statistical Analyses:** A Group (2) x Limb (2) ANOVA approach was used to identify differences on 8 outcome measures between the Case and Control groups, and the involved/uninvolved limbs of the participants with CAI ($\alpha \leq 0.05$). To investigate the extent to which the risk factors played a role in increasing risk for CAI, we calculated odds ratios using conditional logistic regression in an effort to identify independent risk factors for chronic ankle instability. We used paired t-tests to differentiate possible risk factors between involved and uninvolved sides. **Results**: The FADI-S scores were significantly different between the case and control groups ($F = 43.4$, $p = 0.001$, $\eta^2 = 0.428$). The average score for the case group for the FADI-S (78.3 ± 17.9) was significantly less than the mean score for the control group (97.8 ± 4.3). While the overall logistic regression analysis result was statistically significant ($p = 0.001$), none of the 5 variables was a significant predictor of the risk of developing CAI. **Conclusion:** The FMS did not identify risk pertaining to this specific injury, but for injury risk overall. The FADI-S may assist in determining risk for CAI. Future studies should be prospective in nature, involve larger sample sizes, and employ multifactorial statistical approaches (MANOVA) in effort to identify risk factors for developing chronic ankle instability.

1. INTRODUCTION

Lateral ankle sprains account for up to 40% of all athletic injuries and are most commonly seen in basketball, soccer, running, dance and volleyball. [1,2] Recent epidemiological studies indicate that 45% to 53% percent of all high-risk sports such as basketball. As many as 54% of volleyball injuries, and 29% to 61% of soccer injuries are ankle sprains [1-3]. Between 2002 and 2006, the incidence rate reported for ankle sprains was estimated at 2.15 per 1000 persons admitted to emergency departments, with a peak rate of 7.2 per 1000 persons between the ages of 15 and 19 years of age. [4] The estimated aggregate healthcare cost attributed to acute ankle sprains ranges from $2 to $3.8 billion per year in the United States.[4,5]

Ankle sprains result in a considerable time loss acutely and can result in long-term disability in 60% of patients. [4,6] Fifty-four to 72% of patients may report residual symptoms between 6 to 18 months after an acute ankle sprain. [3,7,8] It is important to identify those who are at risk for residual and perceived symptoms of CAI after an acute ankle sprain.

More than 60 years ago in 1955, Bosien et al. reported a rate of ankle re-injury to be 36%. Persistent abnormal changes such as increased and excessive ROM in inversion and eversion were found in 60% of the population studied, and 55% of the [3,7,8] population was found to have an increase in talar lateral and rotary mobility.[9] Following this study, Freeman et al. showed an increased rate of perceived or recurrent symptoms in 40% of persons with a lateral ankle sprain[10], a rate which has not decreased in over 50 years, despite the sizeable amount of awareness to the issue. More recent research shows 30% to 40% of all acute ankle sprains will result in chronic ankle instability with a recurrence rate of re-injury of up to 54%. [4,6,8]

The term "chronic ankle instability" (CAI) is used to identify insufficiencies in the ankle following an ankle sprain such as recurring ankle sprains or "giving way". [1,11,12] Along with residual symptoms, patients with CAI typically experience a balance deficit or decrease in postural control. [5,12,13] One possible cause to CAI may be mechanical instability due to ligament laxity following trauma to the ankle. [11] Freeman et al.[14] first described the concept of "functional instability" and attributed CAI to proprioceptive deficits after ligamentous injury in 1965. [11] The diminished neuromuscular coordination commonly after ligamentous injury had been suggested to stem from partial and permanent deafferentation. [10,11,14]

The International Ankle Consortium endorses a standard of minimum inclusion and exclusion criteria to categorize patients that fall within the category of CAI in controlled research. The standard inclusion criteria for CAI clinical research volunteers are: (a) a history of at least one ankle sprain within the past 12 months, and (b) a history of the previously injured ankle "giving way" and/or recurrent sprains and/or "feelings of instability". The standard exclusion criteria for volunteers are as follows: (a) a history of previous surgeries to the musculoskeletal structures in either limb of the lower extremity, (b) a history of a fracture in either limb of the lower extremity requiring realignment, and (c) acute injury to musculoskeletal structures of other joints of the lower extremity in the previous 3 months, which impacted joint integrity and function, resulting in at least 1 interrupted day of desired physical activity.[15]

An ankle sprain typically involves, but is not limited to, damage to the lateral ligaments of the ankle and results in increased laxity, decreased or excessive ROM, decreased strength, and proprioceptive or neuromuscular control deficits. [2,3,6,16] Waterman et al.[4] demonstrated that age, sex, race, and involvement in athletics are all risk factors for an ankle sprain in the general United States population with an incidence rate of 2.15 per 1000 person-years with peak incidence between 10 and 19 years of age. Black and white races had higher rates compared to Hispanic races, and males between the ages of 15 and 24 had higher rates than females. A high rate of recurrent sprains puts these athletes in danger of deficits and time away from sports or work in early high school to early college years. Extrinsic risk factors such as shoe type, bracing technique and the playing surface are commonly identified prior to competition by a medical professional over-seeing the event. For example, many cross-country racing trails will mark larger roots, stumps and rocks or sudden changes in elevation or surface before a race. Intrinsic risk factors will separate an athlete at high vs low risk for an ankle injury. Murphy et al.[17], in a review of literature, identified many intrinsic risk factors including aerobic status, body size or mass, which leg is dominant. These authors reported that “left leg dominant collegiate athletes participating in soccer, field hockey, and lacrosse were more likely to incur ankle sprains than right leg dominant athletes”. [17]

There are multiple patient-reported self-assessments to determine the presence of CAI. Two such assessments are the Functional Ankle Disability Index (FADI) and the Foot and Ankle Ability Measures (FAAM). The FAAM and FADI self-assessment tools have shown a significantly greater amount of reported disability from those with CAI than uninjured patients. [18] The variation of the FADI, the FADI-Sport, assesses more functional movements which are essential to sport.[19] The FADI-Sport has been shown to detect functional limitations in recreationally active patients with CAI as well as be sensitive to differences in subjects with and without CAI. [19] The FADI-S is generally considered the most appropriate self-assessment tools for patients to use in order to obtain objective data about functional limitations in patients with CAI. [7,19-21]

Previous studies have also shown that patients with CAI experience balance and postural control deficits, especially in a single leg stance.[12,13] Patients with CAI will present with decreased postural stability during dynamic tasks, such as hoping in place or transitioning from double to single leg stances, including an increase in center of pressure (COP) displacement.[12] Wikstrom et al. [22] showed COP, Time-to-Boundary (TTB), and COP-Center of Mass (COM) measures can successfully discriminate between patients with CAI and those who are unaffected or classified as copers.

Munn et al. reported that sensorimotor deficits occur not only in postural control, but also with joint position sense (JPS) in patients with CAI. [13] In subjects with CAI, passive JPS was decreased by 0.7° and active JPS was decreased by 0.6°.[13] JPS is a precise sensorimotor function that if decreased in the ankle and surrounding areas, could lead to an increased risk of sustaining an ankle sprain. [23] Due to the damage to mechanoreceptors in the ligaments, tendons and other connective tissue sustained during and ankle sprain, the use of JPS measures is appropriate to determine a level of proprioception deficits associated with the injury.[16]

Patients with CAI may demonstrate decreased dynamic postural control due to altered ankle motion and decreased JPS.[13,23,24] Results from Hoch et al. [24] demonstrated a significant decreased in ankle dorsiflexion range of motion (DFROM) as compared to healthy individuals as another internal risk factor for experiencing and ankle sprain. Similar results were noted between patients with and without CAI during the Weight-Bearing Lunge Test (WBLT) and the Star Excursion Balance Test (SEBT) in the anterior direction. [24] Hertel et al.[25] reported that the SEBT could be abbreviated into 3 motions—anteromedial, medial, and posteromedial—without loss of precision.[25]

Other objective measures using clinical devices such as the NeuroCom and Biodex Stability System have been used to detect postural stability deficits associated with CAI. The Biodex Stability System produces an Overall Stability Index (OSI) that may be correlated with proprioceptive status of the ankle. A higher stability index indicates more difficulty the patient had in balancing during the test.[26] In a pilot study, Testerman et al.[26] suggested that this is a tool useful in quantifying ankle proprioceptive deficits. The researchers found differences between injured and uninjured ankles in 6 of 10 participants. This initial study raised questions as to the cause(s) of the deficit measured, and if a stability index is clinically relevant.

Cook and Burton[27] developed the Functional Movement Screen™ (FMS) to capture injury risk factors throughout the entire body. Seven different tests require the patient to enter and maintain extreme positions where weaknesses and imbalances are visible if the patient cannot maintain stability while performing the mobility tasks. [27,28] The concept of the tests is based on proprioceptive and kinesthetic awareness with each position or test requiring the adequate function of the body's kinetic chain. [27] Two "clearing" tests are also included in the FMS in order to determine if the patient has pain or restriction with a required motion for the tests; these include the shoulder impingement clearing screen and the ankle mobility screen. [27,28] The 7 tests that comprise the FMS are: the deep squat, the active straight leg raise (ASLR), the hurdle step, inline lunge, rotary stability test, the shoulder mobility test, and the trunk stability pushup.

Choi et al. [29] evaluated the postural control during two movements of the FMS, the deep squat and hurdle step, in patients with and without CAI. To measure postural control, COP data were obtained. Differences in the COP path length and velocity during the hurdle step were identified as significant identifiers of CAI patients and decreased postural stability as compared to healthy (non-injured) subjects. [29]

Completion of the 7 FMS tests requires strength, flexibility, range of motion, balance, proprioception and good neuromuscular control. [27,30] The FMS was created to quantify deficits in these categories. [27] Choi et al. [31] reported that the lower extremity screens in the FMS instrument (deep squat, hurdle step, inline lunge) could be used reliably to detect functional limitations in patients with CAI. The FMS may do so through determining a loss in somatosensory function due to the damaged ligamentous mechanoreceptors and interruptions in arthrokinematics of the ankle. [31] The authors did not use the ankle clearing test in the examination as a lower extremity FMS™ evaluation.

This study was designed to identify risk factors associated with CAI due to deficits in postural stability and postural sway, neuromuscular control and joint position sense that are not present in patients who do not experience CAI. The purpose of this study was to determine the ability of the FMS to identify neuromuscular deficits. The specific aims of this study were to identify risk factors in the lab to categorize CAI based on neurologic deficit. A second specific aim was to use the FMS tool as a way to identify a person at risk for ankle sprains, especially leading to CAI. The results of this study will provide insight on the functional and neurologic limitations of patients with CAI, and evaluate the ability of the FMS screen to identify patients with CAI with associated neurologic deficits.

Following the successful completion of this master's thesis, abstracts of the findings will be submitted for presentation at the 69^{th} annual meeting of the National Athletic Trainers' Association in New Orleans, Louisiana in June 2018, and at the 64^{th} annual meeting of the Southwest Athletic Trainers' Association in Arlington, Texas in July 2018. The primary manuscript from this thesis will be submitted for publication to the *Journal of Athletic Training*.

2. MANUSCRIPT

ROLE OF THE FUNCTIONAL MOVEMENT SCREEN™ IN THE EVALUATION OF NEUROMUSCULAR DEFICITS ASSOCIATED WITH CHRONIC ANKLE INSTABILITY

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ABSTRACT

Context: In the United States, lateral ankle sprains account for an annual healthcare cost that has been estimated at $3.8 billion. The term "chronic ankle instability" (CAI) is used to identify insufficiencies in the ankle following an ankle sprain as well as recurring ankle sprains or "giving way". Chronic ankle instability has been observed in 54% to 72% of first-time ankle sprain patients. The risk factors for developing CAI are not well understood. Previous research identified CAI risk factors such as diminished postural control, decreased range of motion (ROM), increased ligament laxity, muscle weakness, delayed neuromuscular reaction, and decreased functional ability. **Objective:** To determine the extent to which the Functional Movement Screen^{TM} (FMS) is an effective tool for discriminating between healthy individuals and patients with CAI with neuromuscular deficits. A secondary aim was to identify risk factors that predispose individuals to CAI. **Design:** Case-Control. **Setting**: Laboratory setting. **Participants or Other Patients:** 60 physically active individuals (age range, 18-35 yrs; mean age, 21.9 $\pm$ 3.11 yrs) participated in this study. Of our 60 participants, 20 met our operational definition of having CAI. **Interventions:** We employed a 2:1 ratio of persons without a previous history of ankle injury to those with CAI, and triple matched them on sex, age ($\pm$ 5 years) and BMI category (underweight, normal, overweight, obese). **Main Outcome Measure(s)**: Foot and Ankle Disability Index (FADI-Sport), Overall FMS Score, Lower Extremity (LE) and Core Stabilization FMS sub-scores, ankle plantar flexion and dorsiflexion active range of motion (AROM), subtalar eversion and inversion AROM, Y-Balance Test, Athlete Single Leg Stability Test (ASLST). **Statistical Analyses:** A Group (2) x Limb (2) ANOVA approach was used to identify differences on 8 outcome measures between the Case and Control groups, and the involved/uninvolved limbs of the participants with CAI ($\alpha \leq 0.05$). To investigate the extent to which the risk factors played a role in increasing risk for CAI, we calculated odds ratios using conditional logistic regression in an effort to identify independent risk factors for chronic ankle instability. We used paired t-tests to differentiate possible risk factors between involved and uninvolved sides. **Results**: The FADI-S scores were significantly different between the case and control groups ($F = 43.4$, $p = 0.001$, $\eta^2 = 0.428$). The average score for the case group for the FADI-S (78.3 ± 17.9) was significantly less than the mean score for the control group (97.8 ± 4.3). While the overall logistic regression analysis result was statistically significant ($p = 0.001$), none of the 5 variables was a significant predictor of the risk of developing CAI. **Conclusion:** The FMS did not identify risk pertaining to this specific injury, but for injury risk overall. The FADI-S may assist in determining risk for CAI. Future studies should be prospective in nature, involve larger sample sizes, and employ multifactorial statistical approaches (MANOVA) in effort to identify risk factors for developing chronic ankle instability.

Key Words: Ankle injury, risk factors, injury prevention

Word Count: 479

INTRODUCTION

Lateral ankle sprains account for an estimated aggregated healthcare cost of $2 billion to $3.8 billion per year in the United States.[4,5] Recent epidemiological studies indicate that ankle sprains account for 45% to 53% of all basketball injuries, with higher incidences observed in volleyball (54%) and soccer (61%). [1-3] From 40% to 60% percent of patients with ankle sprains will experience significant time loss from activity, sport or work, or long-term disability. [4,6]

Identification of those who are at risk for persistent residual symptoms after an acute ankle sprain is important. As many as 72% of patients report symptoms between 6 and 18 months following their initial ankle sprain.[3,7,8] The incidence rates of ankle re-injury, has increased in the past 60 years. In 1955, Bosien et al.[9] reported ankle re-injury rates to be 36%. [9] In 1965, Freeman et al.[10] reported an increased rate of 40% of patients with ankle sprains reporting re-injury.[14] More recent studies have reported that between 30% and 40% of all acute ankle sprains will result in CAI, and 54% of all individuals who have sprained their ankle will have a recurrent injury in their lifetime. [4,6,8]

Chronic ankle instability (CAI) has been operationally defined as frequent and repetitive ankle sprains, combined with feeling unstable following an initial ankle sprain. [1,11,12] The 2014 International Ankle Consortium definition of CAI employs inclusion criteria to categorize a patient as having CAI. Their CAI criteria are: (a) a history of at least one ankle sprain within the past 12 months, and (b) a history of the previously injured ankle "giving way" and/or recurrent sprains and/or "feelings of instability." [15]

Previous research has identified risk factors for developing CAI. A lateral ankle sprain typically will result in increased ligament laxity, decreased active dorsiflexion ROM or excessive inversion, decreased strength, and proprioceptive and neuromuscular deficits. [2-4,6,16,32] The neurologic dysfunctions that result from ankle sprains are known to play a role in the rate of ankle sprain recurrence. [8,10,14] Research on this topic since 1955, and especially in the last 5 years has focused on a priori screening for these dysfunctions, as well as discovering other factors that contribute to CAI including significant balance and postural control deficits. [1,3,9,13,16,18,20,22,29,31-39]

Patient-oriented questionnaires are an important and cost-effective method of cataloging symptoms that assist in determining whether or not the ankle sprain patient has developed CAI. The results of patient-oriented questionnaires such as the Functional Ankle Disability Index (FADI) and Foot and Ankle Ability Measure (FAAM) have revealed significant disability differences between uninjured individuals and those with CAI. [18] The FADI-Sport is an abridged version of the FADI that focuses on functional limitations with CAI, and more appropriate outcome measure for physically active population.[19] Hale et al.. suggested that the FADI-Sport may be more sensitive at detecting deficits and more practical for use with high-functioning individuals due to the questions relating to higher-level activities.[19]

Functional screening tools are needed to assist in the identification of patients at risk for CAI or those that do have CAI. Functional screens can be administered in a short amount of time and do not require expensive machines. This would allow for identification of those at risk at an earlier age or level of competition, as high school, for example, may not have access resources such as a NeuroCom or Biodex machine. Functional performance tests require the use of multiple body regions and systems to execute a movement pattern. This integration of systems may allow for an advantage over more clinical measures that cannot assess components such as ROM, neuromuscular control, postural stability, coordination, strength simultaneously.[31]

One such screen is the Star Excursion Balance Test (SEBT), which assesses dynamic balance, postural control and ROM. Hoch et al.[31] found significantly less anterior reach on the SEBT among patients with CAI compared to than healthy individuals classifying the test as useful in identification of CAI in patients with a previous ankle injury. Gonell et al. revealed that soccer players with a difference of 4 cm or more between each leg in the posteromedial direction were 3.9 times more likely to sustain a lower extremity soft tissue injury. [40] The excursions (distances reached) in the anterior, posterolateral and posteromedial directions of the SEBT have shown good to excellent intrarater (ICC range, 0.85 to 0.96) and interrater (ICC range, 0.81 to 0.93) reliability. [25] Testing using the combination of these 3 directions is known as the Y-Balance test, an abbreviated version of the SEBT. [25,41,42] Research on which directions identify statistically significant differences between limbs with and without CAI initially identified the anteromedial, posteromedial directions.[25] Olmsted et al.[43] found that participants with unilateral CAI reached significantly less far on their involved limb with CAI than their uninvolved limb, and to the side-matched limbs of a control group.

Functional tests that indicated deficits in areas such as ROM and postural control may be helpful in indicating which clinical measurements required an objective measurement. If a patient has a deficit during the SEBT, a clinician may decide to measure ROM to rule out the possibility that ROM is limiting the patient's ability to perform on the test. Changes in range of motion (ROM) after ankle injuries may play a role in postural deficits and recurring injury, especially a decrease in dorsiflexion.[13,23,24] Open-chain active dorsiflexion ROM and weight-bearing dorsiflexion ROM deficits have revealed a significant correlation with the anterior reach portion of the Y-Balance test ($r = 0.41$, $p = 0.014$).[24] Reach deficits in the SEBT associated with a decreased active dorsiflexion and weight-bearing dorsiflexion ROM are accompanied by reduced hip and knee motions, suggesting that CAI to be related to performance deficits in the entire affected extremity.[44]

The Functional Movement Screen™ (FMS) was developed to identify injury risk factors associated with neuromuscular control, postural and strength deficits, as well as ROM deficits. [27,28] O'Connor et al.[41] used 874 marine officer candidates to demonstrate a cutoff score of 14. A score of 14 of 21 or less meant that the individual was at a greater risk for injury than those who were above 14.[45] The FMS has been suggested as able to differentiate between patients with and without CAI.[29,31] Choi and Shin[21] recently reported a very strong positive correlation ($r = 0.818$, $p < 0.01$) between lower extremity FMS (FMS-LE) scores and scores on the FADI–Sport questionnaire. Research lacks in determining the ability of the FMS to identify risk factors associated with a joint, instead focusing on injury risk as a whole.[31]

The primary purpose of this study was to determine if the FMS is able to discriminate between healthy individuals and patients with CAI. A secondary aim was to identify risk factors that predispose individuals to developing CAI.

We hypothesized that the FADI-S, FMS LE score, dorsiflexion ROM, and Y-Balance scores will be significantly decreased in patients with CAI compared to healthy controls. Additionally, we hypothesized that the Athlete Single Leg Stability Test scores will be increased in patients with CAI compared to those without ankle injury ($p \leq 0.05$)

METHODS

Design

This study was a case-control observational study, using a triple matching procedure to aid in determining which of 5 risk factors play a significant role in developing CAI. This study obtained both disease-oriented and patient-oriented evidence as it relates to chronic ankle injury.

Participants

We used an IRB-approved recruitment email as our primary method of attracting participants to this study. Over a period of 3 months during 2017, more than 36,500 emails were sent to undergraduate and graduate students at a large university, inviting them to participate in this study. We were able to recruit a total of 64 physically-active male and female participants (age range, 18 to 35 yrs; mean age, 21.9 $\pm$ 3.1 yrs) to this study. Twenty-one of the participants met our operational definition of CAI, while 43 individuals who had no history of significant lower extremity injury involving time lost from activity served as members of our control group.

Volunteers qualified for membership in the case (CAI) group if a medical history of ankle instability that is associated with an initial injury, and if they have re-injured that same ankle in the past 6 months. Volunteers for the CAI group were excluded from this study if they had any of the following: (a) bilateral ankle instability, (b) sustained an ankle injury in the past 3 months, (c) a history of anterior cruciate ligament (ACL) reconstruction or meniscal repair, (d) history of ankle fracture, or (e) a history of a balance (vestibular) disorder. (Table 1)

To be considered for membership in the Control group, a volunteer must have had no history of significant lower extremity injury resulting in time lost from activity, no history of ankle injury in the past 18 months, nor resulting in a recurrent injury or residual symptoms, and be physically active. Our operational definition of a "physically-active individual" is based on the Centers for Disease Control and Prevention's categorization of 30 minutes of moderate physical activity per day for 5 days per week or a total of 150 minutes.[46]

Healthy volunteers were excluded from participation in this study if they had previously sustained any injury to their lower extremity requiring surgery, or time away from work, sports or activity. (Table 1) The participants in the CAI group were matched in a 1:2 ratio with healthy individuals. Three-way matching was accomplished using the participant's sex (male, female), age ($\pm$ 5 years), and body mass index (BMI) category (underweight, normal, overweight, obese). [6]

Table 1. Participant Inclusion/Exclusion Criteria.

Group	Inclusion	Exclusion
Chronic Ankle Instability	Ipsilateral ankle injury only Re-injury of ankle >3 months ago	Bilateral Ankle Instability Ankle Injury < 3 Months History of ACL reconstruction, meniscal tear, ankle fracture or balance disorder
Control	No history of ankle sprains resulting in residual symptoms or recurrent sprains, and not in the past 18 months Physically active for 30 minutes/day, 3-4 days/week Matched on sex, age, and BMI criteria to a CAI participant	Injury resulting in time from work/activity History of ankle injury resulting in residual symptoms or recurrent sprains, and not in the past 18 months

Instrumentation

The FADI-Sport questionnaire [47] consisting of 8 questions with a maximum of 100 points was used to determine the level of dysfunction for each participant, and to confirm categorization the participants into one of the test groups: CAI Instability or Control (healthy physically-active individuals).

A digital goniometer with 2 bubble levels (Baseline™ Absolute Axis, model 32613) was used to measure and record each participant's dorsiflexion, plantar flexion, eversion and inversion AROM on both ankles.

The Biodex Stability System (Biodex Medical Systems, Shirley, NY) was used to obtain objective measures for postural control in static and dynamic positions through the Athlete Single Leg Stability Test (ASLST). Two different stability level settings, "4" and "12", were used to quantify the participant's postural control ability. We measured the amount of tilt the platform could provide at each level with an iPhone based inclinometer. The instrumented Biodex platform allows for 19 degrees of tilt in any direction. Level 4 is the least stable of the two, compared to level 12, the more stable level.

A Functional Movement Screen™ testing kit (Functional Movement Systems, Inc., Chatham, VA) was used to determine the scores for each participant for overall FMS assessment. Additional subscores of the FMS-LE component (Hurdle Step, Deep Squat, In-Line Lunge)[31], and for the Rotary Stability Test were also recorded.

Lastly, the Y-Balance test kit (Perform Better, West Warwick, RI) was used to measure each participant's performance of the Y-Balance Test. The participants completed the test on both legs, using the unaffected leg first if the participant was in the CAI group. The participants were asked to stand on their dominant leg first to perform the test, followed by their non-dominant leg.

The experimental parameters and outcomes measures associated with this study are summarized in Table 2.

Table 2. Experimental Parameters and Outcome Measures

Experimental Parameter	**Outcome Measure**
Functional Movement Screen™ (FMS)	1. Overall FMS Score
	2. Lower Extremity-FMS Score
	3. Rotary Stability Score
Ankle Range of Motion	1. Dorsiflexion AROM Measured with Goniometer
	2. Inversion AROM Measured with Goniometer
	3. Eversion AROM Measured with Goniometer
	4. Plantarflexion AROM Measured with Goniometer
Dynamic Postural Stability	1. Y-Balance Test
	2. Athlete Single Leg Stability Test at Level 12 - Overall Stability Index (OSI)
	3. Athlete Single Leg Stability Test at Level 4 - Overall Stability Index (OSI)
Patient Oriented Outcome Measure of Current Ankle Disability	1.Foot and Ankle Disability Index – Sport Score

Experimental Procedures

All data collection sessions were conducted in the Biomechanics/Sports Medicine Laboratory at Texas State University. All data were collected by the principal investigator (WPD) from each participant during one experimental session that lasted approximately 45 to 60 minutes. Informed consent was obtained prior to any physical testing. Prior to testing, the volunteers who met the inclusion criteria for this study completed a demographic questionnaire to obtain self-reported data for use in participant matching.

Once volunteers qualified for inclusion and provided written consent to participate in the study, they began testing by completing the Foot and Ankle Disability Index (FADI)-Sport™ questionnaire taking approximately 5 minutes to complete.

Each patient completed a 5-minute warm up on the stationary bicycle at a self-selected pace between 60 to 90 rpm to begin the physical testing component of the session. Each participant then had his or her ankle active range of motion (AROM) measured with a digital goniometer (Baseline™ Absolute Axis, model 32613) within (time frame) of the warm-up period has concluding.

Ankle dorsiflexion and plantar flexion AROM was measured with the participant sitting at the edge of an examination table with knee bent to 90 degrees. The digital goniometer fulcrum was centered over the lateral malleolus, the moving arm parallel with the base of the 5th metatarsal, and the stationary arm pointed toward the head of the fibula. The participant was asked to maximally dorsiflex his or her ankle and the resulting angle of the goniometer was recorded. The participant then was asked to plantar flex his or her ankle and the resulting angle was measured with the goniometer and recorded. This procedure will be repeated for both ankles.

Subtalar inversion and eversion AROM were measured with the participant in a long sitting position on a standard examination table, with the bare foot positioned in subtalar neutral and centered on a 24” (length) x 18” (width) x ½” thick rigid ceramic tile surface that is overlaid with a blank sheet of paper. A 12” x 12” x ½” thick ceramic tile was be placed against the plantar aspect (“bottom”) of the foot, and a line was drawn on the paper to indicate the subtalar neutral (starting) position. (Figure 1.) The participant was asked to maximally invert his/her subtalar joint, and this position was recorded using the tile to trace the end position onto the sheet of paper. The participant then was asked to maximally evert his/her subtalar joint, and that position was also obtained using the tile to trace the end position onto the sheet of paper. This procedure was repeated for both ankles. After data collection has concluded, the primary researcher (WPD) used a digital goniometer to measure the inversion and eversion AROM values from the lines drawn on the paper.

Figure 1. Measurement Procedure for Inversion and Eversion.

The participants were evaluated using the Athlete Single Leg Stability Test (ASLST) available with the Biodex Stability System (Biodex Medical Group, Shirley, NY). Each participant was asked to perform the ASLST at 2 levels of platform stability (Levels 12 and 4) with their eyes open and barefoot. Three trials of the most stable level (Level 12) ASLST testing was completed first, followed immediately by ASLST testing repeated using Level 4. This protocol was repeated for both the right and left legs of all participants. For participants in the Case group, the uninjured ankle was tested first, followed by testing of their injured ankle. For participants in the Control group, the dominant limb was tested first, followed by the testing of the nondominant limb.

Participants were instructed to stay as balanced as possible, while keeping the contralateral knee at 90 degrees of flexion, and their arms comfortably crossed across their chest. The patient was instructed to keep the black dot representing their center of balance in the middle of a bull's eye target on the screen. [26] (Figure 2) A 3-trial average Overall Stability Index (OSI) representing the variance of foot-platform displacement from a level surface was calculated from anterior/posterior and medial/lateral sway motions to represent a single measure of dynamic postural stability. [26,48]

Figure 2. Athlete Single Leg Stability Test (ASLST) on Biodex Stability System.

Each participant completed all 7 of the FMS tasks in the order as determined by the creators of the screen (Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Pushup, Rotary Stability). Each participant was scored on a scale of “0” to “3” on each 4 of the FMS movements. For each movement, the participant was asked to make 3 attempts. The participant received a score of “3” if the movement could be completed correctly, without errors. If not, the participant received 3 more attempts with a modification of the movement. If he or she could complete the movement then, the participant received a score of “2”. If the participant could not complete the movement with modification, he or she received a score of “1”, and if pain was elicited during the movement, the participant received a 0. The sub-scores we calculated using the for the LE-FMS using totals of the Hurdle step, deep squat and inline lunge test.

To complete the FMS deep squat test (Figure 3), the participants stood with their feet shoulder width apart, holding a dowel in their hands above and resting on their head. The participant’s elbows will be placed at a 90-degree angle before the individual is instructed to press the dowel above their head and perform the deepest squat possible. A score of “3” was given to those who complete the test with their heels on the floor, no valgus collapse at the knee and correct posture maintaining the dowel in the shoebox extended vertically. A score of “2” was given if the participant can complete the movement with their heels raised onto the provided board. A score of “1” was given if the criteria cannot be met once the heels have been raised, and a score of “0” was given if the individual had pain during the movement. [27,28]

Figure 3a. FMS Deep Squat, frontal view. Figure 3b. FMS Deep squat, lateral view.

The FMS hurdle step (Figure 4) test began with the examiner measuring the height of the participant’s tibial tuberosity. The FMS test kit was then set to create a hurdle, with the height of the obstruction at the height previously measured. The participant was instructed to hold a dowel on their posterior shoulders similar to a back squat. The participant was instructed to lift one leg, reach up and over the hurdle, tap their heel on the floor, and return to starting position. A score of “3” was given if the participant could complete the movement without compensation and pain. The hips and shoulders should remain level, with no rotation of the femur, and the participant must clear the hurdle. A score of “2” as given if the individual must compensate to complete the movement and a score of “1’ if the participant could not complete the movement. If pain is elicited, the participant was given a “0”. [27,28]

Figure 4. FMS Hurdle step task.

The FMS inline lunge test (Figure 5) uses the participant's tibial tuberosity height to determine foot position. The toes of the back foot are placed on the start line, and the heel of the front foot is placed at the line that correlates with the height of the tibial tuberosity. The participant held a dowel vertical behind his or her back touching the back of the head, thoracic spine and sacrum. The hand opposite the front foot grasped the dowel at the cervical spine level while the other hand grasped the dowel at the level of the lumbar spine. The participant was instructed to lunge, touching the back knee to the ground and return to starting position. The dowel should remain its vertical position and its contact with the participant. If the movement is completed without errors, a score of "3" was given. If the movement is completed with errors, a "2" was given, and if the movement cannot be completed a score of "1" was given. If pain is elicited, the score was automatically a "0". [27,28]

Figure 5. FMS Inline Lunge task.

The FMS rotary stability test was evaluated for core stabilization. The participant began in the quadruped position with the FMS board between his or her hands and knees. The participant was instructed to flex the shoulder and extend the hip and knee on the same side, bringing the knee and elbow together and then back to starting position. The participant received a “3” if the movement is completed without error. He or she received a “2” if the participant can complete the movement using the opposite arm and leg, a “1” was given if the participant could not complete the movement, and if pain is elicited the participant received a “0”. [27,28]

The participants performed the Y-Balance Test by beginning in a single leg stance on the centerboard (Figure 6). Leg length was measured from the ASIS to the distal pole of the medial malleolus. To normalize the data, the participant’s leg length was used to determine the percentage maximum reach, e.g., ((Excursion distance/leg length) x 100). He or she then reached with the contralateral foot to push the 3 measuring boxes as far as possible while the heel of the ipsilateral foot remains in contact with the centerboard. The distance that the boxes were pushed were measured in centimeters and recorded for later analysis. Participants were allowed a maximum of 5 attempts to complete 3 successful trials of each of the 3 directions.

Figure 6. The Y-Balance Test.

The testing order was completed on the uninvolved and then involved leg for each direction before moving to the next direction. The control group began with their dominant leg. The direction order was anterior, posteromedial, then posterolateral. Each participant had the 3 successful trials averaged together for each excursion direction to create a composite score. [41]

To control for the effects of neuromuscular fatigue and test order, we counterbalanced the order of the FMS, ASLST, and the Y-Balance tests using a Latin square 3 x 3 matrix.

Statistical Analysis

To determine if multicollinearity ($r \geq 0.80$) existed among our 18 original outcome measures, we created an 18 x 18 Pearson product moment intercorrelation matrix. This analysis resulted in the removal of 3 outcome measures from further consideration.

An ANOVA approach was then used to identify differences between participants with CAI and healthy control participants, and between the involved and uninvolved limbs ($\alpha \leq 0.05$) of the participants with CAI. A total of 11 outcome measures—ankle dorsiflexion, plantar flexion, inversion and eversion AROM, FMS-LE score, Y-Balance Test scores , postural stability (ASLST results, specifically OSI), and FADI-Sport questionnaire score—were analyzed for significant main effects and interactions.

The increased risk of chronic ankle instability associated with the 5 selected outcome measures, the FMS-LE score, FADI-Sport score, Y-Balance Anterior Reach, Average Dorsiflexion, and Average ASLST level 4 score, was estimated by calculating odds ratios with the use of a conditional logistic regression analysis. This procedure describes the odds that a participant with CAI has been exposed to the risk factor that is identified as significant, e.g., reduced dorsiflexion AROM, divided by the odds that 2 triple-matched control participants had been exposed to that same risk factor, after adjusting for all other variables in the model.

We used IBM SPSS software (version 23) for all statistical tests.

RESULTS

Pilot Study

Prior to formal data collection, we conducted a pilot study with 10 physically active volunteers (6 men, 4 women; mean age = 24.6 $\pm$ 2.6 yrs) to establish the intra-rater reliability of the principal investigator (WD) for all the clinical outcome measures. According to Shrout and Fleiss [49] intraclass correlation coefficients ($ICC_{3,1}$) values $\geq$ 0.75 indicate "excellent" intra-rater reliability. Values between 0.40 and 0.74 are considered "good and fair" reliability, while values $\leq$ 0.39 reflect "poor" reliability. As reported in table 3, intraclass correlation coefficients ($ICC_{3,1}$) values of greater than 0.75 were obtained for all outcomes measures except Right Y-Balance medial reach and Left Athlete Single Leg Stability Testing at level 12. Measures for the individual FMS tests "Hurdle Step" and "Rotary Stability Test" were not calculated by SPSS due to zero variance in scores among the volunteers. To determine the intra-rater reliability with our clinical measures obtained by one examiner (WD), the intraclass correlation coefficient formula $ICC_{3,1}$ was used due to the 3 trial averages that were calculated during data collection (Table 3).

Cross-Sectional Study Results

A total of 77 volunteers between the ages of 18 and 35 were screened for eligibility to participate in this study. Of those, 13 volunteers failed to meet the inclusion requirements due to previous history of lower extremity surgery or bilateral ankle injury. Sixty-four volunteers matched all requirements for participation and completed all measures.

Table 3. Pilot Study Results for Intra-rater Test-Retest Reliability for All Clinical Measures				
Outcome Measure	*Right ($ICC_{3,1}$)*	*Left ($ICC_{3,1}$)*	*Side N/A ($ICC_{3,1}$)*	*Intraclass Correlation Coefficients Category*
FADI - S			*1*	Excellent
Ankle Dorsiflexion AROM	0.905	0.874		Excellent
Ankle Plantarflexion AROM	0.929	0.969		Excellent
Ankle Inversion AROM	0.902	0.948		Excellent
Ankle Eversion AROM	0.949	0.882		Excellent
ASLST Level 12	0.82	0.692		Excellent and Good and Fair
ASLST Level 4	0.795	0.885		Excellent
Y-Balance Anterior Reach	0.819	0.845		Excellent
Y- Balance Medial Reach	0.655	0.815		Good and Fair and Excellent
Y-Balance Lateral Reach	0.779	0.789		Excellent
FMS Deep Squat			1	Excellent
FMS Hurdle Step				No Variance, Excluded from Data Analysis
FMS Inline Lunge			1	Excellent
FMS Shoulder Mobility			1	Excellent
FMS Active Straight Leg Raise			1	Excellent
FMS Trunk Stability Pushup			1	Excellent
FMS Rotary Stability Test				No Variance, Excluded from Data Analysis

The data from 4 participants who met all the qualification criteria and completed the study were not used in conditional logistic regression analysis. Three participants who qualified for the control group did not match with a participant in the case group, and 1 participant who qualified for the case group did not match with any participants in the control group.

The Case group was comprised of 20 individuals with a history of ankle sprains within the last 12 months, but not the last 3 and recurring symptoms from (or related to) their initial sprain. A summary of participant demographic information is provided in Table 4.

Table 4. Descriptive Statistics for Participants with CAI (N = 20)				
Sex	*Male*	*Female*		
	9	11		
	Minimum	*Maximum*	*Mean*	*Std. Deviation*
Age	19	33	21.9	3.1
	Normal	*Overweight*	*Obese*	
BMI Category	13	4	3	

The Control group was made up of 40 individuals who were triple matched with a case group participant at a 2:1 ratio. These participants were free of ankle sprain symptoms and had not had a sprain within the last 18 months, a history of lower extremity surgery, or broken bones within the last year. All participants reported being physically active for an equivalent of 1 hour per day, 3-4 days per week. A summary of both group's statistics based on the matching criteria is provided in Table 5.

Table 5. Summary of Participant Demographic Data							
Group	*N*	*Age*	*BMI Category*			*Sex*	
			Normal	*Overweight*	*Obese*	*Male*	*Female*
Case	20	21.9 ± 3.1	13	4	3	9	11
Control	40	21.8 ± 2.7	26	8	6	18	22
Total	60	21.9 ± 2.8	39	12	9	27	33

ANOVA Results

To determine the presence of multicollinearity among our outcome measures, we created a Pearson product moment correlation matrix. The table revealed a statistically significant correlations between the ASLST levels 12 and 4 ($r = 0.865$, $p = 0.001$) and a statistically significant correlation between Y-balance medial and lateral directions ($r = 0.888$, $p = 0.001$) To decrease the chances of making a Type 1 error, the ASLST level 12 was removed to keep the more challenging level, and the Y balance lateral reach were removed from the analysis based on previous research supporting[33] the anterior and medial directions in the use of differentiating between individuals with and without CAI.

An ANOVA was performed on the variables that were not excluded. The results indicated a statistically significant difference between the case and control group for the FADI-S scores ($F = 43.38$, $p = 0.001$, $\eta^2 = 0.428$). The average score for the case group on the FADI-S (78.3 ± 17.9) was less than the average score of the control group (97.8 ± 4.3).

Conditional Logistic Regression Results

A block method Cox survival analysis approach was used with IBM SPSS software to complete a conditional logistic regression analysis. A total of 5 outcome variables were included in this model to determine their relationship(s) with chronic ankle instability. The order of input of the variables chosen was based on the study's hypothesis (FMS-LE, FADI-S, Average Dorsiflexion ROM, Y-Balance (Anterior), ASLST level 4).

The results of the overall logistic regression revealed an overall statistically significant model ($p = 0.001$), with the FADI-S as the only significant variable in the model ($p = 0.012$, $Exp(B) = 0.816$) indicating that for every point a participant does not score on the FADI-S, he or she was 18.4% more likely to have CAI.

DISCUSSION

Our study differs from numerous studies looking for risk factors for chronic ankle instability that have searched for correlations between having the condition and the measure or measures taken, or between a known risk factor and a new proposed risk factor. Our study matched 2 healthy individuals for every 1 participant with CAI to create a stronger analysis of the proposed risk factors that are present in those subject to CAI. Hertel[33] reported a significant deficit in anterior reach of the Y-balance in 48 participants with CAI and 39 who did not.[25] Similarly., Choi et al.[31] evaluated 3 portions of the FMS and found statistical significance in identifying functional limitations in patients with CAI.[31] Both studies results rely on the correlations of the scores obtained by the participants.

Our results from this study show that the FADI-S score is a significant factor in CAI. Unlike Choi et al.[31], we did not find the LE-FMS score (x/9) to have a significant difference between participants with CAI (mean = 6.1 $\pm$ 1.4) and those with healthy controls (mean = 6.5 $\pm$ 1.2). We also did not find a strong correlation between the two ($r = 0.251$, $p = 0.053$). Choi et al.[31] also found a strong relationship between the FADI-S score and the Inline Lunge score from the FMS ($r = 0.896$), which our results also did not concur with ($r = 0.163$)

The conditional regression was done in a step by step process, evaluating each risk factor individually, and as a model based on the order which they were entered. We started with the LE-FMS score as this was the focus of our study. The model was not significant based on this score ($p = 0.232$). Based on previous research and the ANOVA results, the FADI-S score was entered next which changed the model to be significant ($p = 0.001$) and the FADI-S score was significant individually ($p = 0.004$).

Block 3 included the LE-FMS score, the FADI-S and the average dorsiflexion. The model overall remained significant, and again, the FADI-S score was the only significant individual variable ($p = 0.006$). Block 4 included the Y-Balance anterior direction which did not chance the model as a whole, and the FADI-S score remained the only individual variable that was significant ($p = 0.005$).

Choi et al. concluded that the FMS tool could reliably detect functional limitations in patients with CAI.[31]The overall intent of the FMS is the identify individuals at risk for injury overall. The Functional Movement Screen needs to quantify not only physical deficits, but neurologic as well, with decreased postural stability recognized as a risk factor. The FMS does not seem to be specific to any one injury. O'Connor et al.[41] determined an FMS cutoff score of 14 with the use of 874 marine officer candidates. The score of 14 out of 21 or less meant that the individual was at a greater risk for an injury than those above 14.[41] Currently, each individual movement of the FMS does not have a cutoff score for injury risk. Choi and Shin[21] only looked at 3 of 7 parts of the FMS. To score a 14, a participant may score a 2 on each of the individual screens. The increased risk for injury does not guarantee injury, and especially not a specific type of injury. A decrease in ankle function does not mean that the ankle is at an increased risk for injury, but simply that the individual is at an increased risk. Poor ankle mechanics that lead to falling, for example, may lead to an upper extremity injury, rather than a lower one. The FMS scoring is not specific enough to truly single out a specific injury.

Hoch[31] compared weight bearing dorsiflexion with SEBT anterior reach and found a significant correlation between the two groups, suggesting limits in dorsiflexion is correlated with limited anterior reach (30 participants per group) ($r = 0.404$, $p = 0.015$). We found a weak to moderate positive relationship with dorsiflexion AROM correlated with Y-Balance anterior reach ($r = 0.351$, $p = 0.006$) in the entire participant pool ($n = 60$).

Additionally, dorsiflexion is known to have a very important role in the functional movement chain. We found that dorsiflexion was positively correlated with the FMS deep squat (r

= 0.322, p = 0.012), the FMS hurdle step (r = 0.312, p = 0.015), and the FMS total score (r = 0.290, p = 0.025). While these 3 correlations were statistically significant, the clinical meaningfulness of these correlations is low, as the amount of explained variance (r^2) between these respective outcome measures ranges only from 8.4% to 10.3%.

Both the FMS Hurdle Step and the Deep Squat require DF of the ankle, while many of the other screening movements such as the shoulder mobility do not. It is not surprising that though the FMS total score is correlated with dorsiflexion that is a relatively low correlation due to the inclusion of all 7 movements. This small of a correlation, however, may not be clinically meaningful, supporting FMS as an overall assessment movement dysfunction, and not concentrated on a single dysfunctional piece of movement.

Fong measured ground reaction forces and knee flexion in landing mechanics.[47] Their study found that increased dorsiflexion resulted in less ground reaction forces and greater knee flexion in landing. The study also noted the landing posture that was consistent with reduced ACL injury risk. Based on the results of the present study and previous research, dorsiflexion has been shown to be a key part of the kinetic chain that allows for proper motion in the entire lower extremity.

The FMS is a 3-dimensional test that assesses all 3 cardinal planes of motion as well as balance, core strength and muscle activation. We were not surprised that the FMS total score in our study was correlated with the medial reach (r = 0.407, p = 0.001) and the Y-balance anterior reach (r = 0.507, p = 0.001) values obtained with the Y-Balance Test. The Y-balance test will give a more objective measure, a reach distance or percent excursion, instead of a general score for a whole movement which may need to be investigated further. The information from the Y-balance test will allow a clinician to narrow down the ankle dorsiflexion as the issue much more quickly. For example, the FMS deep squat may be scored a “1” for inability to perform the movement, even after it has been modified. The inability may be from more than one reason though, examples include valgus collapse at the knees, lack of dorsiflexion, poor core strength or shoulder flexion, or poor core strength. When used, however, the FMS will give an assessment and break down of the entire body, while the Y-balance test is generally limited to the lower extremity. Given the multifactorial nature of injury risk, a screen that can be applied efficiently and cover the entire body should be considered. While the FMS may not be a tool specifically for CAI, there is value in assessing overall function, and identifying individuals with an increased risk for injury. The clinician would then know who to exam further to determine the cause for risk.

We also found two statistically significant negative (inverse) correlations between the FMS total score and the Athlete Single Leg Stability Test (ASLST) level 4. ($r = -0.300$) Once again, it is not surprising that it is a small correlation due to the multifactorial nature of the FMS. The ASLST is a unipedal test of dynamic balance, and the FMS has 7 separate components, not all of which involve closed kinetic chain movements.

At this time, the FMS scores may be associated with multiple risk factors that have been identified as synonymous with CAI, but a single cut-off score cannot be suggested with this study. It may be that the FMS is not sufficiently specific to chronic ankle instability, due to a more general goal of singling out a participant as having increased overall risk for injury. A recent study by Welveart[48] used the FMS in an attempt to identify hamstring injury in 28 recreationally active participants. They found no significant difference in scores between the groups of healthy individuals and those with hamstring conditions.[49] O'Connor et al. [48] were not able to single out any one injury despite the number of participants involved. A score of 14 indicated risk for an injury, but did not indicate the type of injury, to what part of the body, or severity of injury that would happen. Instead it seems that the FMS included pieces of all the known risk factors involved, but further investigation and break down of the individual movements would be required to determine the root cause of the dysfunction if a participant was unable to score perfectly.

Examples of this might be seen with the FMS-hurdle step. This movement combines a balance component, a hip flexion component, a component of rotational core stability, and of ankle stability. The screen may indicate that there is dysfunction in the individual's ability to complete it. The investigator may infer that the participant has a risk for injury based on the score but cannot entirely determine the cause of the dysfunction from the score. The investigator needs to examine the movement again, either live or on film, and determine why the participant was scored in this way and figure out which of the components impacted the participant's ability to complete the movement.

Other parts of the FMS screening process involve the ability to do a pushup from the floor and to have full ROM of the shoulders in the FMS-shoulder mobility test. We had hoped to see some sort of correlation of these tests with risk factors of CAI, linking together the full kinetic chain. Our study suggests that these portions of the screen are not related to CAI. The FMS does not seem to possess the ability to focus on a singular injury or injury type. When scored, a participant receives a "3" for doing the movement perfectly, a "2" for completing the movement with a modification or single error, a "1" for being unable to complete the movement even with modification or with more than a single error, and a "0" is given if there is any pain in the movement. Those who are picked out by the screen to be at risk for injury should have further movement analysis done to further identify causes of dysfunction and better assist in prevention of injury.

Increased ROM has also been identified as an injury risk factor in previous research.[2,3,6,16] In our study, active inversion ROM was positively correlated with the Y-Balance anterior reach ($r = 0.356$, $p = 0.005$) and the total FMS score ($r = 0.403$, $p = 0.001$). This is the opposite of what we would expect to see if the FMS was sensitive to CAI. The most common mechanism of an ankle sprain is known to be in forced plantar flexion and inversion, spraining ligaments in the lateral ankle. We would then expect an increase in inversion ROM to be correlated with a decrease in FMS scores. However, it is important to note that plantarflexion and inversion are not key factors during the FMS movements, as the ankle is typically in a closed-packed position during the movements involving the ankle.

Interestingly, our study did not see correlation with dorsiflexion and the ASLST tests. The ASLST tests may not correlate to dorsiflexion because of the way the test is set up and the unstable surface. Each participant is positioned on the computerized force plate so that their center of balance is directly over the center of the board. This center of pressure may be different in each participant, some may balance on their forefoot, some on their rear foot, and some may have an equal weight distribution. The participants in our study were instructed to stand normally on the foot that was being tested. The platform for the Biodex stability system would lean with the weight shift of each participant. One thing observed by the researcher was the different strategies of balancing or coping with weight shifts while on the platform. Some patients used an ankle strategy where the movement to keep the dot in the center of the bull's eye target came from the ankle, and the rest of the body stayed fairly still. Other participants used hip strategies where the compensation to keep the dot in the center would come from the participant leaning from his or her hips. Research has shown that smaller surface perturbations, will require less body movement, and less correction from a patient, and so that individual will use an ankle strategy. For those participants who experience a greater perturbation, and a greater amount of body movement, a hip strategy is required to compensate.[45] Less available motion in the ankle would create a scenario where an individual may encounter less ground perturbation, and require a hip strategy to compensate, than an individual with a greater relative ankle motion. Versteeg discovered an inverse relationship between peak trunk orientation and peak COM excursion in a simulation study with a human mechanical model.[47] The smaller the center of mass, the larger the movement of the trunk sway. This may explain the differences in strategies used. Further research is needed to determine the effects of dorsiflexion ROM on the balance strategies used. The strategies chosen may have been based on the interpretation of the instructions to "keep the dot in the center of the bullseye", instead of asking the patient to keep a straight knee.

This study targeted a broad population, we searched for a population that was at least mildly physically active, and between 18 and 35 years of age, like that of Choi et al.[25] We used BMI to match the participants as well as sex and age ($\pm$ 5 years). BMI ranges are fairly large, and not perfectly descriptive of a person's true body type. BMI in athletes and young adults may not provide the correct classification of obese or overweight.[45] This is the case especially in athletes where a large male, while being a very good athlete, in extremely good physical condition, may be marked as Obese, and in our study, paired with an individual who may be obese but possessed a larger amount of body fat than the athlete. Matching on height and weight similar to the Choi et al. study may have proven a more effective method.

CONCLUSIONS

Chronic ankle instability is a largely overlooked issue that has cost billions of dollars in healthcare bills for people living in the United States; CAI has become more, not less prevalent over the last 6 decades. Not one single risk factor has been able to be pinned down as leading to an increased risk. The FMS, while not focused on CAI, has been shown to predict an overall risk for injury. Our results show that a lower FADI-S score puts an individual at risk for CAI. Using the FMS in conjunction with other screening tools such as the FADI-S may provide a better indicator of what injury an individual is at risk for. FMS may be better suited alone for overall performance, as even being at risk, does not necessarily mean an individual will get injured.

3. SUMMARY AND RECOMMENDATIONS FOR FUTURE RESEARCH

The purpose of this study was to determine which risk factors, both known and hypothesized, were most predictive of ankle injury. Recent research shows that 30% to 40% of all acute sprains will result in chronic ankle instability with a sprain recurrence rate of up to 54%.[4,6,8] Chronic ankle instability (CAI) includes symptoms such as feelings of instability or giving way, making it a broad term and therefore, common. Reports of 54% to 72% of patients will have residual symptoms between 6 to 18 months after an acute sprain. [3,7,8] To understand the risks for developing CAI studies have looked at correlations between CAI and reduced postural stability [5, 12,13], increased ankle ligament laxity, a decreased or increased overall ROM, and decreased strength.[3,6,16] Despite the increase in prevalence of ankle re-injury increasing over the past 60 years, risk factors for CAI are not well understood and the list of possible factors grows continually in research. Waterman et al.[4] noted age, involvement in athletics, race and sex as risk factors for ankle sprains, while Murphy et al.[17] identified aerobic status, body size and dominant leg as risk factors. In contrast, Wikstrom showed COP, TTB and COM measures to differentiate between those with and without CAI[22]. Munn et al. demonstrated that joint position sense decreases in patients with CAI.[24]

The FADI-S score was statistically significantly different between those with CAI and the control participants with no ankle injury. It is noted that the greatest predictor of re-injury has been previous injury, which may be why this measure was the only significant factor.

Recommendations for Future Research

To provider stronger evidence in populations, future research should be conducted to examine the relationship between these risk factors and chronic ankle instability in specific populations using a larger sample with a longitudinal, prospective experimental design to order to establish cause and effect relationships when ankle injury occurs and when an individual develops CAI.

We need to encourage more research on competitive athletes to assist in the recovery and treatment of athletes who suffer from these symptoms. Additional investigation is also warranted into roles that leg dominance, gender, height, and weigh play in increasing risk for CAI. There are other functional screens such as the weight bearing lunge test that have been suggested to differentiate between individuals with and without CAI. Further examination into other screens of this nature is needed.

APPENDIX SECTION

REVIEW OF LITERATURE

Introduction

Boisen et al. reported a 36% ankle re-injury rate in 1955.[9] More than 60 years later, in 2015, Hershkovich et al. reported a 54% ankle re-injury rate.[6] Recurrent ankle sprains is a characteristic of chronic ankle instability (CAI). After an initial sprain, 54% to 72% of patients will report feelings of instability [3,7,8] An estimated aggregate healthcare cost of lateral ankle sprains per year in the United States is reported to be as high as $3.8 billion.[4,5,49] Factors such as deficits in postural stability, ROM and neuromuscular control have been reported as risk factors for CAI.[50] Not until recently have functional movement screens been identified as useful in recognition of risk factors for CAI after injury.[29,31] The purpose of this research is to identify the role of the Functional Movement Screen™ and its sub-components (Core and LE-FMS) in detecting risk factors associated with CAI and add to the current research on risk factors for the condition.

Deficits Associated with Ankle Injury

Subjective feelings of giving way are common symptoms among patients with CAI. Mechanical instability may play a role in creating the feelings of instability.[34] Hiller et al. identified a subgroup of CAI that consists of mechanical laxity and perceived instability. [51] Injury to the ligaments will cause deafferentation of the ankle joint, leading to a slower response from the muscles during excess inversion of the ankle. [10,14] The injury to the ligaments will not allow the mechanoreceptors to properly, if at all, communicate with the brain to indicate a rapid change in stress applied to the ankle structures. Freeman et al. was the first to suggest that injury to the ligaments of the foot and ankle results in severance of nerve fibers and damage to mechanoreceptors controlling muscles of the lower leg responsible for dynamic stabilization of the ankle.[14] Participants with instability of the ankle have demonstrated more rapid ankle inversion compared to healthy uninjured participants during a simulated injury task.[34,52]. Gehring et al. demonstrated the delayed sensory ability of an injured ankle leading to mechanical laxity to be an indicator of poor dynamic instability in the ankle. Brown et al. found that individuals with both perceived instability and mechanical laxity demonstrated dynamic postural stability deficits during a single leg jump landing.[34]

Both dynamic and static ankle stabilizers are necessary to control landing forces. [36,52] Stability deficits will arise when one of the stabilizing groups is compromised. It appears that mechanical laxity and damage to the non-contractile structures will contribute to dynamic postural instability, a symptom of CAI.[34,53] According to the 2016 International Ankle Consortium, lateral sprains should be treated as a noteworthy musculoskeletal injury.[49]

Stability of the ankle joint is due to the bony configuration oat the ankle mortise and talar dome making up the talocrural joint, the ligamentous structures, capsule, tendons and syndesmosis. The lateral ankle ligaments are the most commonly sprained. These ligaments are the anterior talofibular, the calcaneofibular, and posterior talofibular ligaments. The anterior talofibular is the most commonly sprained of all the ankle ligaments, due to a forced combination of plantarflexion and inversion.[18] Damage to the structures of the joint includes damage to mechanical receptors in the joint capsule and the ligaments. These mechanical receptors are responsible for relaying signals to the brain of excess forces being place on the structures in which each receptor is in. Without the proper communication, an individual is more apt to re injure his or her ankle, as responses of dynamic stabilizing muscles in the lower leg will respond slower to changes in ankle posture.[14,15]

Chronic Ankle Instability (CAI)

An estimated 55% of individuals who sustain an ankle sprain do not seek out treatment or advice from a health care professional.[15] More than 628,000 ankle injuries are treated per year in the United States and a recurrence rate as high as 80% in high-risk sports has been reported.[15] The

2014 position statement of the International Ankle Consortium determined that chronic ankle instability (CAI) is the most commonly used term to describe an individual that reports ongoing symptoms after an initial ankle sprain base on the definition provided by Gribble et al.[15]

Gribble et al. operationally defined CAI as having a history of at least 1 significant ankle sprain, a history of the previously injured ankle giving way and/or recurrent feelings of instability.[15] Not all individuals with CAI have these homogenous symptoms, which creates the need for broad inclusion criteria.

The criteria are based on injury history, function, and disability. To begin determining if an individual has CAI, the person must report an initial sprain that he or she credits the resulting symptoms of pain, recurring sprains or feelings of instability to. An acute ankle sprain often negatively affects ligamentous integrity, presenting with an increase in laxity, hypermobility or hypomobility. Patients with CAI have not consistently presented with mechanical instability, and a definitive association of increased laxity and CAI has not been found.[15] Hiller et al. suggested that mechanical instability provided the weakest contribution in developing CAI, and rather hypomobility is a more noteworthy risk factor. [15,51] More recent research has focused on functional impairments and neuromuscular control in identifying patients with CAI. [15] Prevention of re-injury and development of CAI must start with reliable identification of risk factors that may predispose an individual to the condition.

Validated Patient-Oriented Questionnaires for CAI Patients

Common measures of risk factors for CAI include self-report of symptoms. There are 2 questionnaires identified as the most appropriate instruments by Eeuchaute et al. to quantify functional disabilities in individuals with CAI: the Foot and Ankle Ability Measure (FAAM) and the Foot and Ankle Disability Index (FADI). [4,20] Relative to uninjured controls, individuals with CAI report a greater amount of disability.[18]Disability refers to difficulty performing daily activities, or sports specific movements, and varies from no difficulty, to unable to do.

The FADI is a 26-item questionnaire created by Martin et al. [47] containing 4 items related to pain and 22 related to activity. Each question is scored on a 5 point Likert scale (0-4). An abbreviated version of the FADI, the FADI-Sport, contains 8 activity related questions and is scored the same way. The FADI-Sport can be scored a total of 32 points and then turned into a percentage with 100% representing no dysfunction. Hale et al. determined CAI normative scores on the FADI-Sport to be 79.5%+12.7 in recreationally active individuals. [19] Gribble et al. reported similar normative values for classifying CAI to be 74.8%_+ 4.1 in a population that participated in 30 minutes of activity, 3 times per week.[50]

Hale et al. suggested that the abridged version of the FADI, the FADI-Sport may be more appropriate for the physically active population[19]. Hale et al.also reported a greater sensitivity to impairments associated with CAI in the FADI-Sport than in the full FADI, showing lower scores on the FADI-sport for the involved ankles.[19] Further supporting the use of the FADI-S, Wikstrom et al. studied the in the FADI-Sport and postural stability measures between participants with CAI and those who have returned to high-level activity without loss of function (copers). Copers were participants who had initially sprained their ankle but did not result in recurring symptoms of the ankle sprain. Researchers demonstrated the FADI (p=0.004) and FADI-Sport (p=0.001) revealed greater disability in those with CAI relative to uninjured controls, and that the FADI (p= 0.047) and the FADI-Sport (p=0.014) were able to reveal a greater disability in those with CAI than in copers. [22] FADI-Sport was used in this study to evaluate the physically active population that we worked with.

Ankle Joint Position Sense

Freeman et al. (1965) suggested that receptors in the damaged ligaments following an ankle sprain contribute neural signaling deficits found in CAI, identifying CAI as a neurological disorder.[10,13] Joint position sense (JPS) has been measured to account for this deficit in sensory information, showing that patients with CAI will have decreased JPS measures, and that JPS is appropriate to use in determining an objective level of proprioceptive dysfunction associated with ankle injury. [13,16,23,32]

The most common way to evaluate ankle JPS is to determine the threshold for detection of passive movement (TTDPM) by stabilizing the lower extremity (typically in a seated position), removing visual and auditory input, and moving the ankle at 0.5 to 2.0 deg/sec through the normal arc of motion, and asking the patient to react as soon as he or she detects movement. [23]

The patient may also be asked to reproduce a passive or active position within the ankle's range of motion, and then measure the difference (error) between the target angle and the patient's reproduction of that target angle in degrees. This JPS evaluative technique is known as either the reproduction of active positioning (RAP) or reproduction of passive positioning (RPP). [23]

Konradsen et al. found that patients with acute ankle inversion sprains demonstrated a near 100% increase in target angle replication error. A follow-up measure 12 weeks post-injury without formal rehabilitation determined that a 33% increase in error remained. [23,54] In contrast, Holme et al. discovered no side-to-side differences in JPS 6 weeks after an acute injury, but did note postural control and peroneal muscle strength deficits.[55] The evidence remains mixed regarding whether JPS is decreased in individuals with CAI; however, most studies suggest a deficiency in proprioceptive function is present among persons with CAI.[23,54] Proprioceptive function may refer to closed chain scenarios where the patient is balancing and having to keep their foot flat on the ground. Although JPS has not been able to definitively identify CAI, balance tests have shown better promise.

Evans et al. observed postural control deficits in both the injured and uninjured limb after an acute ankle injury. [56] The participants in their study were reported as having significant deficits in the injured ankle over the healthy ankle ($p < .05$).[56] Postural control deficits support the concept of neuromuscular contribution to CAI.[56]

Clinical Measures of Postural Control

Researchers have found postural control measures useful in identification of neuromuscular deficits in the ankle. Center of pressure (COP) and center of mass (COM) measures have successfully distinguished patients with and without CAI. [12,22,32,56]

The Star Excursion Balance Test (SEBT) challenges an individual's dynamic stability and postural control by placing them in a single leg stance and requiring the individual to reach in 8 different directions with the opposite leg. [44] The SEBT has shown sensitivity in screening for functional deficits related to musculoskeletal injuries, such as CAI in the recreationally active population.[44]

Participants with lateral ankle sprains have been shown to have a curved COP path during the anterior, posteromedial, and posterolateral (the 3 components of the Y-Balance Test), associated with a significant reach distance in all three directions.[24] This may coincide with having hypermobility in more than one direction of the ankle, or the latent time to detect stress in the ankle joint. The results of this study and previous research suggest the Y-Balance or "abbreviated SEBT' to be a measure for postural control in individuals with ankle injury.[13,25,32,40,50,57] Gonell et al. concluded that individuals with a difference between limbs of 4 cm or greater have almost a 4 times greater likelihood of a loss of time from activity due to any non-contact injury than those with equal excursion bilaterally.[40] The functional aspect of this test makes it more applicable to the active population. The SEBT can also be administered easily, as it requires a tape measure and tape laid out in the directions on the floor.

Hoch et al.[24] used the Star Excursion Balance Test (SEBT) to reveal decreased postural control in 20 participants with CAI. The participants had a significant correlation between active and weight-bearing dorsiflexion ROM and anterior reach test of the SEBT, indicating a decreased postural control secondary to a decrease in functional movements of the ankle[24]. These results suggest that deficits in active dorsiflexion ROM may negatively impact other movements such as a jump landing, or squat, as well as other motions dependent on the ability of the ankle to move through the entire dorsiflexion range of motion. [24] This assumption is supported by other research, which has identified greater contributions from the proximal lower extremity joints during the SEBT in participants with CAI. [5,24,32,37,58]

Terada et al. revealed a significant correlation between the SEBT-Anterior, decreased weight-bearing dorsiflexion ($p=0.014$) perceived stiffness ($p=0.014$), and decreased open-chain dorsiflexion ($p=0.015$) in participants with CAI.[37] There is additional evidence emphasizing the importance of dorsiflexion range of motion in landing mechanics, describing participants with CAI as having less knee flexion during a jump landing, which may be attributed to a limited dorsiflexion ROM. [24,50,59]

The Biodex Stability System has been shown to be a useful tool in objectively measuring proprioceptive function. [26] The individual and composite stability indices generated from the Biodex Stability System have been correlated with the proprioceptive status of the ankle. [26] Bączkowicz et al. observed correlations among Biodex Stability System measures of overall stability, mediolateral, and anteroposterior indices, and participants with CAI, but not in controls, suggesting the sensitivity of the Biodex Stability System as clinical tool for evaluating single leg dynamic balance in individuals with CAI.[60]

Lower Extremity Kinematics in Patients with CAI

Landing from a jump on a single leg requires multiple joints to work in unison to absorb the forces exerted on the body. Deficits in measures of jump landing kinematics and the ability to create stability after a jump have been associated with CAI. [50] Studies show that knee and hip-joint kinematics become altered with ankle instability. [50] Gribble et al. demonstrated that Time to Stability (TTS) in a single-leg landing identifies the functional deficits in proximal lower extremity joints associated with CAI. [50] Recreationally active participants in the study revealed significantly less knee flexion than the healthy control group. The study also supported previous research on the SEBT[24,57] in identification of the diminished ability to stabilize the lower extremity in the anteroposterior direction. [50] Participants with CAI exhibit decreased sagittal knee-flexion at ground impact[50], which has been suggested to be due to result of limited ankle dorsiflexion ROM.[37]

Functional Tests for Recognition of CAI and General Injury Risk

Functional movement and balance deficits are factors that may increase risk for injury.[27-29] Functional movement has been defined as the ability to produce and maintain mobility and stability in the whole kinetic chain while completing a movement pattern [29] Functional performance tests require the use and integration of multiple body segments.[27,31] Functional movement test can assist in evaluation of range of motion, flexibility, strength, endurance, coordination, balance, as well as motor and postural control.[27,31,61] If an individual does not have an adequate amount of balance, mobility and stability, the ability to perform a simple skill is decreased. The individual may perform the skill using a compensatory movement pattern to overcome any deficiencies.[27] This may be true in other functional testing such as the Weight-Bearing Lunge test or the hop test where hip movement may compensate for lack of ankle motion.

The development of a poor kinematic relationship between joints (poor movement pattern) secondary to deficiencies can also be explained by previous injury. Poor movement patterns may be viewed as improper mechanics during a motion e.g. a squat. A disruption in proprioceptive input results in altered mobility, stability, and asymmetry.[13,14,18,21,22,24,27,29,56,61] Altered proximal control of the lower extremity indicates that patients with CAI may have impairments involving the sensorimotor system, exhibiting decreased functional performance and diminished postural control. [37]Functional performance tests have been used to identify impairments in relation to ankle injury and to determine whether or not an athlete is ready to return to competition.[31]

The Functional Movement Screen™ (FMS) is a group of 7 movement patterns identified as fundamental to function, which can be used to measure dysfunction and identify risk for injury. [27,29,31,61] The 7 movement patterns in the FMS are shoulder mobility, trunk stability pushup, rotary stability, deep overhead squat, active straight leg raise, hurdle step and in-line lunge. [27,31,61] Each movement pattern assessed using the FMS tool was identified based on kinesthetic awareness principles, requiring appropriate function of all the body's segments. [27] Regional interdependence has been used to describe the relationship between regions of the body, describing how injury or dysfunction in one part of the body will affect and contribute to dysfunction in another.[61] The FMS tool looks to identify the causes of dysfunction in the kinetic chain.

The FMS uses a simple scoring system to create an objective measurement. Each movement pattern is scored on a scale of 0-3. A score of "3" is given if the individual can perform the movement without error, a score of "2" is given if the individual performs the movement in an ineffective way, and a score of "1" indicates that the individual cannot complete the movement. A score of "0" is given if the individual has pain during the movement. During the movements requiring both sides to be tested separately, the lowest score from either side is taken, but both sides are recorded. The FMS™ scores are then totaled, with a maximum score of 21. [27,31,61]

Research has shown that an FMS score of 14/21 or lower indicates an increased risk of injury. [30,62] Garrison et al. reported that college athletes with a self-reported past history of injury and a FMS score of 14 or below were at a 15 times greater risk for injury.[62] CAI is due to a history of ankle injury, causing feelings of instability or recurrent sprains. A history of ankle injury, coupled with a score from select FMS movements may increase a clinician's ability to identify those at risk for CAI.

Choi et al.[31] investigated 20 participants with CAI and 20 without CAI to determine if the lower extremity (LE) involved parts of the FMS could identify deficits associated with CAI. The researchers used the hurdle step; deep squat and in-line lunge, allowing a maximum FMS score of 9. The research concluded that the LE-FMS may be used to detect functional deficits related to CAI between healthy and affected individuals. However, no score has been identified for each individual part of the FMS scores to identify a patient at risk for injury. To determine an increased risk for injury using the FMS screen, the full screen needs to be completed.

Murphy et al.[17], in a review of the current literature at the time, identifies previous injury, muscle strength, muscle imbalance, range of motion and dynamic and postural stability as intrinsic risk factors for lower extremity injury, supporting the use of the functional movement screen. The FMS creators claim that the screen can determine if a patient is at risk for injury due to these factors.[43,44] The FMS does not discern which of these factors is the culprit for a smaller score on the screen. In order to identify the underlying causes of the dysfunctions, each movement must be individually assessed, not by FMS scoring criteria, but by biomechanical analysis of the movement.

Functional screening requires more evidence to determine the instrument's ability to identify risk factors in a patient susceptible to CAI. Research shows risk factors to be neuromuscular control, ROM, and postural control deficits.[63] The screen may be beneficial, but the ability to be implemented is just as important. Further research has shown the ease of application of the screen. Minick et al. found the inter-rater reliability between novice and expert raters to be excellent or substantial on all 17 aspects of the FMS.[63] This study compared novice raters to the creators of the FMS tool as the experts. The study went on to conclude that the FMS may assist in identifying athletes at risk for injury.[63] A clinical measure designed to recognize deficits and risk factors such as the FMS may be useful in recognizing those at risk for CAI prior to development of symptoms. CAI has been prevalent in research since 1965 yet remains a problem today. The purpose of this study is to determine if FMS can be used to identify the risk factors associated with CAI and furthers the current knowledge on the topic, increasing the ability to prevent recurrent ankle injury associated with CAI.

In future correspondence please refer to 2017538

February 23, 2017

William DeCraene
Texas State University
601 University Dr.
San Marcos, TX 78666

Dear Mr. DeCraene:

Your application 2017538 titled, “Role of the Functional Movement Screen and FMS Subscores in the Evaluation of Neuromuscular Deficits Associated with Chronic Ankle Instability,” was reviewed by the Texas State University IRB and approved. It has been determined there are: (1) research procedures consistent with a sound research design and they do not expose the subjects to unnecessary risk. (2) benefits to subjects are considered along with the importance of the topic and that outcomes are reasonable; (3) selection of subjects is equitable; and (4) the purposes of the research and the research setting is amenable to subjects’ welfare and producing desired outcomes; that indications of coercion or prejudice are absent, and that participation is clearly voluntary.

1. In addition, the IRB found that you need to orient participants as follows: (1) signed informed consent is required; (2) Provision is made for collecting, using and storing data in a manner that protects the safety and privacy of the subjects and the confidentiality of the data; (3) Appropriate safeguards are included to protect the rights and welfare of the subjects.

This project is therefore approved at the Expedited Review Level until January 31, 2018

2. Please note that the institution is not responsible for any actions regarding this protocol before approval. If you expand the project at a later date to use other instruments, please re-apply. Copies of your request for human subjects review, your application, and this approval, are maintained in the Office of Research Integrity and Compliance. Please report any changes to this approved protocol to this office. A Continuing Review protocol will be sent to you in the future to determine the status of the project.

Sincerely,

Monica Gonzales

Monica Gonzales
IRB Regulatory Manager
Office of Research Integrity and Compliance
Texas State University

CC: Dr. Rod Harter

Recruitment Email Message Template

Replace the red and bracketed [ ] text below, with text appropriate for your approved research.

To: [Use this line for individual addresses or your own address if BCC line is used]
From: wpd6@txstate.edu
BCC: [Use this line when sending the same email message to multiple addresses]
Subject: Research Participation Invitation: Identifying Risk Factors for Repeated Ankle Sprains

This email message is an approved request for participation in research that has been approved or declared exempt by the Texas State Institutional Review Board (IRB).

Researchers in the Biomechanics/Sports Medicine Laboratory at Texas State University are seeking physically-active adult volunteers between the ages of 18 and 35 who: (a) are completely healthy with no history of serious lower extremity injuries, or (b) have previously sustained two or more sprains to the same ankle, with one of those sprains occurring during the last year.

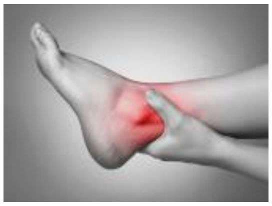
During this study, both of your ankles will be evaluated with a series of standard orthopedic and neuromuscular clinical measurements. The study will require only one (1) visit to our laboratory that will last approximately 60 to 90 minutes. Your participation will be kept confidential.

Every person who qualifies for participation and completes this study will receive a $10 gift card from HEB.

Questions about this research should be addressed to William DeCraene, Graduate Student Researcher, at wpd6@txstate.edu or Dr. Rod Harter, Professor and Thesis Supervisor, at rod.harter@txstate.edu. William DeCraene can also be reached via cell phone at 630-863-5419.

This project 2017538 was approved by the Texas State IRB on February 23, 2017. Pertinent questions or concerns about the research, research participants' rights, and/or research-relatedinjuries to participants should be directed to the IRB chair, Dr. Jon Lasser 512-245-3413 – (lasser@txstate.edu) or to Monica Gonzales, IRB Regulatory Manager 512-245-2334 -(meg201@txstate.edu).

TEXAS STATE
APPROVED: *2/23/2017*
Expedited Review
EXPIRES: *1/31/2018*



TEXAS STATE UNIVERSITY

The rising STAR of Texas

VOLUNTEERS WANTED!!!

Have you injured or reinjured your ankle in the last 6 months?

Or, are you physically active and haven't had any injuries?

We are conducting an ankle injury risk study and need your help! This study requires a one-time visit to the Texas State Biomechanics/Sports Medicine Lab for approximately 1 hour to measure your strength, balance and ankle range of motion.

Participants will receive valuable knowledge of the status of their ankles and general functional ability. The goal of our study is to identify new strategies for preventing ankle injury.

Volunteers who qualify and complete all aspects of this study will receive a $10 gift card from HEB.

If interested, please contact graduate student researcher William DeCraene, ATC, LAT using the contact information below.

This study is being conducted under the direction of Dr. Rod Harter (IRB number: 2017538)

William DeCraene wpd6@txstate,edu (630)863-5419	William DeCraene wpd6@txstate,edu (630)863-5419	William DeCraene wpd6@txstate,edu (630)863-5419	William DeCraene wpd6@txstate,edu (630)863-5419	William DeCraene wpd6@txstate,edu (630)863-5419	William DeCraene wpd6@txstate,edu (630)863-5419	William DeCraene wpd6@txstate,edu (630)863-5419	William DeCraene wpd6@txstate,edu (630)863-5419	William DeCraene wpd6@txstate,edu (630)863-5419

TEXAS STATE

Consent Form to Be in a Research Study

(In this form "you" means a person 18 years of age or older who is being asked to volunteer to participate in this study. In this form "we" means the researchers and staff involved in running this study at Texas State University.)

Study Title: Role of the Functional Movement Screen™ in the Evaluation of Neuromuscular Deficits Associated with Chronic Ankle Instability

Principal Investigator: William DeCraene, ATC, LAT

Co-Investigator/Faculty Advisor: Rod A. Harter, PhD, ATC, LAT, FNATA

Sponsor: College of Education Faculty-Mentored Graduate Student Research Grant.

This form will help you decide if you want to participate in the research study. You need to be informed about the study, before you can decide if you want to be involved. You do not have to be in the study if you do not want to. You should have all your questions answered before you give your permission to be involved in the study.

Please read this form carefully. If you choose to participate in the study, you will need to sign this form. You will receive a copy of this signed form.

Purpose and Background

The primary purpose of this study will be to determine if the **Functional Movement Screen™** (FMS), a battery of 7 physical tests, is useful in identifying risk factors that are associated with **chronic ankle instability**. A person is said to have chronic ankle instability when they have injured ("sprained") their ankle on one or more occasions within the past 12 months, and have experienced "giving way" or feelings of ankle instability that may or may not resulted in another ankle sprain/injury.

We are seeking volunteers between the ages of 18 and 35 who are currently physically-active for approximately 30 minutes a day during 3 to 4 days per week and are interested in helping us answer this research question.

Procedures

Your participation in this study will require one (1) laboratory visit lasting approximately 60 to 90 minutes. After you have read and signed this consent form, your participation in the study will begin at Texas State University's Biomechanics/Sports Medicine Laboratory. You will be asked to complete a participant demographic questionnaire that asks questions about your age, activity level and previous lower extremity injuries. If you qualify for inclusion in this study, you will then be asked to perform a variety of functional tasks that are described in detail in the next section.

What will happen if you are in the study?

If you volunteer to participate in this study, you will be screened for eligibility by completing a screening form that will ask questions about your general health and ankle conditions. If you meet all of the inclusion criteria and agree to participate, you will need to sign this Consent Form before any study procedures take place.

Once you sign the Consent Form, you will be asked to complete a paper-and-pencil questionnaire known as the ***Foot and Ankle Disability Index - Sport*™**. You should be able to complete this 6 item questionnaire in about 5 minutes.

Next you will first be asked to step on the scale so that we can measure your weight. We will also measure your height, and use these two values to calculate your body mass index (BMI).

You will then be asked to warm up on a stationary bike for 5 minutes, pedaling at a pace that you select that is between 60 and 90 rpm. Next, we will measure your ankle range of motion by having you lie on your back on an examination table so that three different ankle range of motion measurements—dorsiflexion, inversion and eversion—can be obtained for both ankles.

You will be asked to complete the 7 tasks of the **Functional Movement Screen™**, specifically a deep squat **(Figure 1)**, a hurdle step, an inline lunge, a rotary stability test, an active straight leg raise, a shoulder mobility test, and a trunk stability push-up. Each movement will be explained to you using the manufacturer's standard instructions. You may be asked to attempt each of the movements 3 times. The movement will be modified if you are unable to complete it. Any pain during each movement should be reported to the researcher.

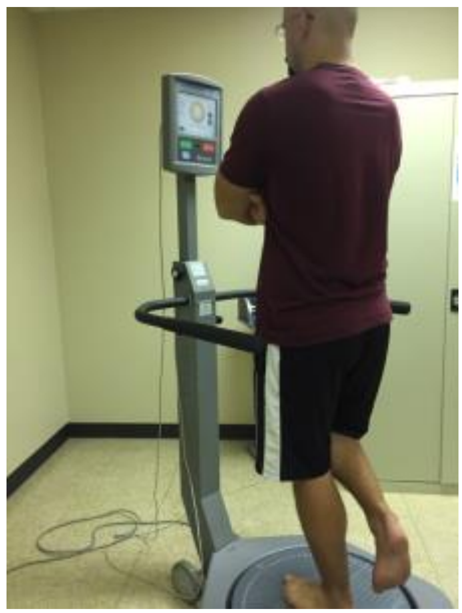
Figure 1. Deep Squat Test within the Functional Movement Screen™

You will also be asked to complete the **Y-Balance Test (Figure 2).** While standing on one foot on the device's elevated base, you will be asked to slide each of 3 blocks as far as possible in 3 different directions using your opposite leg. You will be given 5 attempts to complete 3 successful slides in each direction. This test will be completed on both legs.

Figure 2. Y-Balance Test

The final component of this study in the **Ankle Single Leg Stability Test** using a Biodex Stability System **(Figure 3)**. You will be asked to stand on one leg for 3 trials that each last 20 seconds, and be tested at 2 different levels of difficulty. When the test begins, the device's platform will "unlock" and you will be required to maintain your balance while watching the computer monitor screen in front of you. On the screen you will see a "bull's eye target" and a black dot that represents your center of balance. Your challenge is to try and keep your "dot" in the middle of the target. This test will be completed on both legs.

Figure 3. Ankle Single Leg Stability Test



Risks/Discomforts

The physical tasks in this study are low risk and require very low levels of physical exertion.

To minimize the already low risk of injury to the muscles or ligaments of your body, you will be required to warm up on a stationary bike prior to completing any physical tests.

During this study you will be subjected to the risk of falling during balance exercises and testing. To minimize this risk, the examiner will be close by and ready to support you, should you start to fall. If you lose your balance while standing on one foot, put your other foot on the ground/testing platform. If you are being tested on the Biodex Stability System and lose your balance, grab onto the device's handles so that you can quickly catch yourself.

What if you are hurt in this study?

Please be advised that medical treatment is available upon the event of physical injury resulting from the study. Medical treatment will be limited to first aid and ice for any pain and swelling. In the event that you sustain an injury needing medical treatment beyond that, you will need to seek appropriate medical attention. Texas State University students may choose to go to the Student Health Center free of charge. Students should call 512-245-2161 to schedule an appointment or speak to a health care provider at the Student Health Center. We will report any adverse events per institutional policy. In the event that you believe you have suffered injury not apparent immediately after testing, please contact the IRB chairperson Dr. Jon Lasser at 512-245-3413, who will review the matter with you and identify any other resources that may be available to you.

Benefits/Alternatives

There are minimal benefits associated with participation in this study. However, you will learn about your current body mass index, as well as other clinical orthopedic information about your ankle, functional ability and balance.

Will you be compensated/helped for being in this study?

If you complete all aspects of this study during your one visit to our laboratory, you will receive a $10 gift card to HEB.

Extent of Confidentiality

Your participation in this study is confidential. Only the investigators will have access to your personal identifiers and to any information that may be linked with your identity. All information that you provide will be assigned an identification number rather than your name to ensure your confidentiality. All coded data will be stored in a locked filing cabinet in Texas State University's Biomechanics/Sports Medicine Laboratory for up to 3 years following the conclusion of this study before being destroyed. The members of the research team, and the Texas State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

In the event of this study being published, none of your personal identifying information will be disclosed.

If you want to know about the results before the study is done:

We cannot disclose any information about your results to you until the end of the study, after all results have been analyzed. At that point, we will be happy to discuss and interpret your individual clinical findings, and the overall results of this study with you.

Payment/Compensation

If you complete all aspects of this study during your one visit to our laboratory, you will receive a $10 gift card to HEB.

Voluntary Participation

Your participation in this study is completely voluntary. You may withdraw from this study at any time without any negative consequences from anyone associated with this study or loss of benefits to which you are otherwise entitled.

Questions

You may ask questions about the research procedures at any time and will receive immediate responses. If you have any further questions, please direct these to William DeCraene (Graduate Student Researcher) or Dr. Rod Harter (thesis supervisor).

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This project 2017538 was approved by the Texas State IRB on February XX, 2017 . Pertinent questions or concerns about the research, research participants' rights, and/or research-related injuries to participants should be directed to the IRB chair, Dr. Jon Lasser (512-245-3413 - lasser@txstate.edu) or to Monica Gonzales, IRB Regulatory Manager , Research Integrity & Compliance (512-245-2334 – meg201@txstate.edu).

What does your signature mean?

Before you sign this form, please ask questions about any part of this study that is not clear to you. Your signature below means that you understand the information given to you about the study and in this form. If you sign the form, it means that you agree to participate in the study.

You have been given an opportunity to ask any questions that you may have and all have been answered to your satisfaction.

You must be 18 years of age or older to consent to this study. If you consent to participate in this study and to the terms above stated, please sign your name and date below.

You will be given a copy of this consent form for your records.

____

______Participant Name (please print in all caps)

___________________________ ____________

Participant Signature Date

I, the undersigned, verify that the above informed consent procedure has been followed.

___________________________ ____________

Investigator Signature Date

FMS

THE FUNCTIONAL MOVEMENT SCREEN

SCORING SHEET

NAME ______ DATE ______ DOB ______

ADDRESS ______

CITY, STATE, ZIP ______ PHONE ______

SCHOOL/AFFILIATION ______

SSN ______ HEIGHT ______ WEIGHT ______ AGE ______ GENDER ______

PRIMARY SPORT ______ PRIMARY POSITION ______

HAND/LEG DOMINANCE ______ PREVIOUS TEST SCORE ______

TEST		RAW SCORE	FINAL SCORE	COMMENTS
DEEP SQUAT				
HURDLE STEP	L			
	R			
INLINE LUNGE	L			
	R			
SHOULDER MOBILITY	L			
	R			
IMPINGEMENT CLEARING TEST	L			
	R			
ACTIVE STRAIGHT-LEG RAISE	L			
	R			
TRUNK STABILITY PUSHUP				
PRESS-UP CLEARING TEST				
ROTARY STABILITY	L			
	R			
POSTERIOR ROCKING CLEARING TEST				
TOTAL				

Raw Score: This score is used to denote right and left side scoring. The right and left sides are scored in five of the seven tests and both are documented in this space.

Final Score: This score is used to denote the overall score for the test. The lowest score for the raw score (each side) is carried over to give a final score for the test. A person who scores a three on the right and a two on the left would receive a final score of two. The final score is then summarized and used as a total score.

380

www.orthopaedicscores.com

Date of completion
July 19, 2017

The Foot & Ankle Disability Index (FADI) Score - Sports Module

Clinician's name (or ref) ....

Patient's name (or ref ....

Please answer every question with one response that most closely describes your condition within the past week. If the activity in question is limited by something other than your foot or ankle, mark N/A

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
1. Running	○	○	○	○	○
2. Jumping	○	○	○	○	○
3. Landing	○	○	○	○	○
4. Squatting and stopping quickly	○	○	○	○	○
5. Cutting, lateral movements	○	○	○	○	○
6. Low-impact activities	○	○	○	○	○
7. Ability to perform activity with your normal technique	○	○	○	○	○
8. Ability to participate in your desired sport as long as you would like	○	○	○	○	○

Thank you very much for completing all the questions in this questionnaire.

Print page Close Window Reset

The Foot & Ankle Disability Index (FADI) Score is 0

To save this data please print or Save As CSV

Nb: This page cannot be saved due to patient data protection so please print the filled in form before closing the window.

Reference for Score:
Martin RL, Burdett RG, Irrgang JJ. Development of the Foot and Ankle Disability Index (FADI) J Orthop Sports Phys Ther. 1999;29:A32â€"A33

Web Design London - James Blake Internet

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