A Thesis
entitled
Using Functional Performance Assessment Tools to Predict Ankle Injuries in High School Football and Basketball Athletes
by
Sarah E. Wilhelm, ATC
Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Master of Science Degree in Exercise Science.

Dr. Phillip Gribble, Committee Chair

Dr. Brian Pietrosimone, Committee Member

Dr. Abbey Thomas, Committee Member

Dr. Patricia R. Komuniecki, Dean
College of Graduate Studies

The University of Toledo
May 2014
An Abstract of

Using Functional Performance Assessment Tools to Predict Ankle Injuries in High School Football and Basketball Athletes

by

Sarah E. Wilhelm, ATC

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Masters of Science Degree in Exercise Science

The University of Toledo
May 2014

Context: There are many different risk factors that have been suggested to predict those at risk of sustaining an ankle injury. These risk factors include previous history of ankle injury, dynamic balance measured using the star excursion balance test (SEBT), decrease in ankle dorsiflexion measured using the weight-bearing lunge test (WBLT) and active and passive dorsiflexion range of motion (DF-ROM), increase in BMI, decrease in functional movement using the Functional Movement Screen (FMS), and self-assessed functional disability utilizing the FAAM and FAAM Sport. Injury history, the SEBT, and active and passive DF-ROM have been assessed in the high school football and basketball players previously, the remaining potential risk factors have little research done in the same setting. Mechanism of injury (MOI) may influence the prediction capability of these screening tools. Additional information is needed to further substantiate the predictability of these tests while considering the MOI, such as contact or non-contact. Objective: Examine the capability of the functional performance assessment tools to predict ankle injuries in high school football and basketball athletes while taking MOI into consideration as well. Design: Prospective cohort. Setting: High school athletic training facilities. Patients or Other Participants: Two hundred-eight high
school football and basketball players (15.48±1.15 yrs; 176.11±9.55 cm; 73.83±16.80 kg; 23.69±4.57 kg/m$^2$) volunteered. **Interventions:** Prior to the 2013-2014 football and basketball seasons, participants completed a single session in which the anterior reach of the SEBT (SEBT-A), WBLT, active and passive DF-ROM, and modified version of the FMS (deep squat, hurdle step, in-line lunge, and active straight leg raise) were evaluated bilaterally. A health history questionnaire, FAAM and FAAM Sport were completed prior to the respective season as well. **Main Outcome Measures:** The mean of three SEBT-A trials (cm) from each leg was normalized to stance leg length (cm) and presented as a percentage. The furthest distance completed for the WBLT was recorded (cm). Active and then passive DF-ROM were measured in degrees. Each of the four stations of the modified FMS was scored on a 0-3 scale, with a total possible score of 12 points indicating a perfect performance. The lowest score of three attempts in each station was used to create the total score. Certified Athletic Trainers tracked and reported ankle injuries and the MOI (non-contact, contact). After the season, athletes were placed in a injured (n=31) or uninjured (n=177) group. Group differences were assessed using a t-test, one-way ANOVA, and chi-squared analysis. ROC Curves were utilized to find the optimal sensitivity and specificity, which were used to create positive and negative likelihood ratios. Diagnostic odds ratios (DOR) were created separately for each outcome measure using the likelihood ratios found. **Results:** For all ankle injuries (non-contact: n=17, contact: n=14), the only group difference was found with BMI, with those having a higher BMI sustaining more non-contact ankle injuries (contact: 22.72±3.10; non-contact: 27.58±4.71; non-injured: 23.40±4.50; p=0.001). Active DF-ROM trended toward significance (p=0.078). A BMI of 25.07 kg/m$^2$ was associated with moderate sensitivity
(0.688) and moderate specificity (0.68), with a DOR of 4.69 for those who played football. The DOR decreased to 2.45 for those who played basketball but was still the highest of the variables. **Conclusions:** The ankle injury prediction models from the included variables improved when focused on non-contact injuries. High school football players with a high BMI and a decrease in active DF-ROM appear to have the highest risk of ankle injury. These functional assessment tools provide a strong capability to assess high school football players at risk for a non-contact ankle injury and are easily performed by clinicians in the high school athletic training facilities.
Acknowledgements

There are so many people who have helped me along this crazy journey. I would like to start out by thanking my committee members – Dr. Brian Pietrosimone, Dr. Abbey Thomas, and especially Dr. Phillip Gribble. Also a special thank you to Masafumi Terada who helped me with this process. Whether it was reading drafts upon drafts, helping with data collection, or simply encouragement, without your help this process would not have gone as smoothly.

To all whom helped with preseason data collection at the various high schools as well as the athletic trainers who helped with injury surveillance and exposure tracking during the football and basketball seasons, I appreciate the dedication to help with research and add to your already busy schedules working at a high school.

Thanks are also due to the athletic directors, coaches, players, and parents at the schools utilized for testing this year. Without your cooperation, this thesis would not have been possible.

Finally, I would like to thank my friends and family who listened when I was frustrated, encouraged me to push on, and helped in ways I would never have imagined. I am very blessed to be surrounded by such wonderful people who never batted an eye when asked to help.
Table of Contents

Abstract.......................................................................................................................iii
Acknowledgements....................................................................................................vi
Table of Contents......................................................................................................vii
List of Tables...............................................................................................................x
List of Figures...........................................................................................................xi

1 Introduction..............................................................................................................1
  1.1 Introduction........................................................................................................1
  1.2 Statement of Problem/Purposes.........................................................................4
  1.3 Specific Aims......................................................................................................5
  1.4 Statement Hypotheses.......................................................................................5
  1.5 Significance.......................................................................................................6
  1.6 Operational Definitions....................................................................................7

2 Literature Review...................................................................................................9
  2.1 Ankle Injuries...................................................................................................9
  2.2 Associated Risk Factors..................................................................................14
  2.3 Star Excursion Balance Tests..........................................................................16
  2.4 Weight Bearing Lunge Test.............................................................................18
  2.5 Functional Movement Screen™......................................................................19
2.6 Foot and Ankle Ability Measure.........................................................22
2.7 Gaps in Literature..............................................................................22

3 Methods..............................................................................................24

3.1 Study Design.....................................................................................24
  3.1.1 Independent Variables.................................................................24
  3.1.2 Dependent Variables....................................................................25

3.2 Participants.......................................................................................25

3.3 Instrumentations...............................................................................26

3.4 Procedures.........................................................................................26
  3.4.1 Star Excursion Balance Test – Anterior Reach...............................27
  3.4.2 Weight Bearing Lunge Test............................................................28
  3.4.3 Active and Passive Dorsiflexion Range of Motion.........................28
  3.4.4 Functional Movement Screen™....................................................29
  3.4.5 BMI..............................................................................................32
  3.4.6 Self Reported Function.................................................................32

3.5 Statistical Analysis............................................................................32
  3.5.1 Specific Aim 1.............................................................................33
  3.5.2 Specific Aim 2.............................................................................33

4 Results..................................................................................................35
  4.1 Demographics..................................................................................35
  4.2 History of Ankle Sprain.................................................................36
4.3 Group Comparisons ................................................................. 37
4.4 Mechanism of Injury ............................................................... 37
4.5 ROC Curves ........................................................................... 40

5 Discussion .................................................................................. 41
5.1 Previous Injury History .......................................................... 42
5.2 Group Differences ................................................................... 43
5.3 ROC Curve .............................................................................. 46
5.4 Limitations .............................................................................. 48
5.5 Future Applications ............................................................... 50
5.6 Conclusion ............................................................................... 50

References .................................................................................... 52

Appendices
A. Parental Consent Form ............................................................. 62
B. Assent Form .............................................................................. 70
C. Health History Questionnaire .................................................. 72
D. FAAM and FAAM Sport ............................................................. 74
E. Data Collection .......................................................................... 77
F. Athlete Exposure Tracking ......................................................... 85
G. Injury Tracking ........................................................................... 86
List of Tables

Table 4.1  Demographics: All Athletes. .................................................................35
Table 4.2  Demographics: Football Athletes. .........................................................36
Table 4.3  Demographics: Basketball Athletes. ......................................................36
Table 4.4  2x2 Contingency for injured/non-injured football and basketball athletes. ...36
Table 4.5  2x2 Contingency for injured/non-injured football athletes. .......................36
Table 4.6  2x2 Contingency for injured/non-injured basketball athletes. ....................37
Table 4.7  T-Test Comparisons for injured/non-injured football and basketball athletes.
                                                     .................................................................37
Table 4.8  ANOVA for ankle injuries in football and basketball athletes. .................39
Table 4.9  ANOVA for ankle injuries in football athletes. ......................................39
Table 4.10 ANOVA for ankle injuries in basketball athletes. .................................39
Table 4.11 ROC Cut off, Sensitivity, Specificity, Positive and Negative Likelihood
        Ratios, and Diagnostic Odds Ratios by Sport. ..............................................41
Table 4.12 ROC Combining of Factors with Sensitivity, Specificity, Positive and
        Negative Likelihood Ratios, and Diagnostic Odds Ratios. ............................41
List of Figures

Figure 1  Star Excursion Balance Test – Anterior Reach. ..............................................27
Figure 2  Weight-Bearing Lunge Test. .............................................................................28
Figure 3  DF ROM – Active and Passive. .......................................................................29
Figure 4a Deep Squat. .....................................................................................................31
Figure 4b Modified Deep Squat. ....................................................................................31
Figure 5  Hurdle Step. .....................................................................................................31
Figure 6  In-line Lunge. ..................................................................................................31
Figure 7  Active Straight Leg Raise. ................................................................................32
Chapter One

Introduction

1.1 Introduction

Participation in high school sports has increased in the past three decades from 5 million to 7 million participants.\(^1\) Although it is important for adolescents’ healthy lifestyle, participation in high school sports is associated with an inherent risk of lower extremity injury. High school athletes sustain over 2 million injuries annually and over 53% of these injuries occur in the lower extremity.\(^2,^3\) Specifically, among high school athletes participating in football and basketball, lower extremity injuries accounted for 47 to 69% of all injuries.\(^3\) Furthermore, ankle injuries accounted for 22.6% of all injuries among United States high school athletes participating in nine sports, with a total ankle injury rate of 5.23 injuries per 10,000 athlete-exposures.\(^4\) High school football and basketball accounted for 47.9% of all ankle injuries among nine sports, with this being the highest incidence rate of ankle injury (football = 6.52; boys’ basketball = 7.74; girls’ basketball = 6.93).\(^4\) Ankle injuries have a major impact on healthcare costs and may lead to long-term complications and disability.\(^5,^6\) As high school sport participation continues to grow with proportional increases in ankle injuries, development of prevention
programs is needed to reduce the occurrence of ankle injuries and to maximize the health benefits of high school participation.

One of the most important steps in preventing ankle injuries is to predict high school athletes who are at risk for ankle injuries. Identifying high school athletes who may be at risk for sustaining an injury will allow for clinicians to better care for athletes and work toward preventing injury.

Previous studies have examined injury prediction capabilities of various functional assessment tools and self-reported functional questionnaires. Recent functional testing includes the star excursion balance test (SEBT), the weight-bearing lunge test (WBLT), and the functional movement screen™ (FMS™). The SEBT is a reliable and valid functional examination that is used to evaluate dynamic balance. It has become a widely used dynamic test in both clinical and laboratory settings. Preliminary data have established the anterior reach of the SEBT (SEBT-A) as having potential predictive capability of a lower extremity injury occurrence. However, additional data are necessary to support the use of the SEBT-A for injury prediction.

The WBLT is a functional and reliable way to assess functional dorsiflexion (DF) range of motion (ROM) that has been an accepted as a risk factor for lower extremity injuries. While the test has not been reportedly used as an injury predictor, it has been shown to have a moderate relation between the WBLT and the SEBT. The addition of this test could potentially help to develop the prediction model for ankle injury. The assessment of passive and active open chain DF also is needed as it is not yet known if DF during functional movements, or the total available amount of ankle DF is more indicative of ankle sprain risk. The FMS™ is a functional screening process that is
completed by performing seven different stations.\textsuperscript{31} The stations of FMS™ include deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability test. Preliminary data from our lab have shown that the FMS™ may have a potential capability to predict ankle injury, specifically in collegiate football players.\textsuperscript{14-16,19} Athletes who scored below a cut-off score of 15.5 were three times more likely to have a lower extremity injury during the season.\textsuperscript{15} However, it is still unknown if using the FMS™ can successfully and consistently predict ankle injury in high school athletic populations. Additionally, the current FMS™ utilizes upper body tests that might not be relevant to lower extremity prediction. A previous study assessed FMS™ scores for lower extremity injury using all seven movements as well as movements excluding shoulder mobility and the trunk stability push up.\textsuperscript{16} Additionally, recent work in our laboratory suggests that a modified version of the FMS, using only four lower extremity tests, had a diagnostic odds ratio almost two times higher than the 7 station version for predicting lower extremity injury in collegiate football players (unpublished data). By modifying the FMS to be lower extremity-oriented and focusing on the deep squat, hurdle-step, active straight leg raise and the in-line lunge, clinicians can potentially make the testing more sensitive and time efficient.

Finally, body mass index (BMI) has been suggested to have predictive capabilities. There have been data to support an increase in ankle sprains in those with a higher BMI.\textsuperscript{32,33} Not all research has supported this through statistical significant findings but there have been trends in the way that those with an increase in BMI do in fact have a higher incidence of injury.\textsuperscript{33}
A factor that also may be important to injury prediction would be the mechanism of injury (MOI). A non-contact ankle injury is most likely due to intrinsic factors of the participant opposed to those who sustain a contact injury caused by extrinsic factors. It is than a question of which risk factors – intrinsic or extrinsic – leave an individual more at risk and which have a higher capability of predicting incidence rates for football and basketball athletes. Non-contact injuries may be more easily predicted using functional measures as you are assessing the intrinsic factors such as strength, range of motion, and balance of the participant.

1.2 Statement of Problem/Purposes

There are different functional testing options that are made available to clinicians, but no gold standard has been set to predict ankle injury in athletes. Many studies have examined the predictability of isolated functional exams; however, no investigations have compared their ability to predict injury. Furthermore, perceived instability has been suggested as a predictor of ankle injuries; however, findings of the strength of predicative capability of a self-reported functional questionnaire for ankle injuries are inconsistent among previous studies. Additionally, a previous history of ankle sprains has been suggested as a potential risk factor for ankle injuries. Previous prospective studies have consistently identified the history of ankle sprain as a predictor of future ankle sprain. Therefore, the overall objectives of our study are to examine the strength of predictive capability of the SEBT, WBLT, active and passive measures of DF, modified four-station FMS™, BMI, self-reported function, and a history of ankle sprain for acute ankle injuries in high school football and basketball athletes as
well as to determine which of these identified factors can best predict acute ankle injuries while taking MOI into consideration as well.

1.3 Specific Aims

**Purpose:** To determine if SEBT-A, WBLT, active and passive measures of DF, a four station modified FMS™, BMI, self-reported function, and a history of ankle sprain can be used effectively in the prediction of an ankle injury in high school football and basketball players while taking the MOI into consideration as well. The specific aims of the study are:

**Aim 1:** To determine if there will be a significant difference in investigated variables between the athletes who experience an ankle injury and the athletes who do not.

**Aim 2:** To determine the strength of the predicative capability of functional performance assessment tools, BMI, self-reported function, and history of ankle sprain and if there is a difference between contact and noncontact injury.

1.4 Statement Hypotheses

1. Participants who suffer from an ankle injury during the competitive season will have a shorter normalized anterior reach distance during the SEBT, reduced ankle DF ROM assessed by the WBLT, reduced ankle active and passive DF ROM, a lower score on the modified FMS™, a higher BMI, lower self-reported function, and have a previous history of ankle sprains during pre-participation screening at the beginning of the competition season compared to those who do not from an ankle injury during the season.
2. The SEBT will provide the strongest capability to predict acute ankle injuries among the selected functional performance assessment tools.

3. Participants with a previous history of ankle sprains will be more likely to suffer traumatic ankle injuries during a competitive season.

4. Participants with a previous history of ankle sprains will have a lower baseline score on the SEBT, WBLT, active and passive DF, and FMS™ with a higher BMI than when compared to those without a history of ankle sprains.

5. Participants who sustain a non-contact injury during a competitive season will have a shorter normalized anterior reach distance during the SEBT, reduced ankle DF ROM assessed by the WBLT, reduced ankle active and passive DF ROM, a lower score on the modified FMS™, a higher BMI, lower self-reported function, and have a previous history of ankle sprains during pre-participation screening at the beginning of the competition season compared to those who suffer a contact injury or do not suffer from an ankle injury during the season.

1.5 Significance

The completion of this study will provide a foundation for continued work to identify the most effective injury prevention program as well as determine a cut-off score that can maximize injury prediction among high school athletes. It will also provide insight for a higher injury rate for those who have a history of an ankle sprain.
1.6 Operational Definitions

• Acute Injury: an injury that occurred during a practice or competition, required medical attention by ATCs or physicians, and resulted in restriction of sport participation for one or more days beyond the day of injury.\(^4\)

• Ankle Sprain: injury to the ligaments of the ankle joint that can be classified in three different grades of severity and the location. Usually caused by sudden inversion or eversion, often in combination with plantar flexion or dorsiflexion.\(^40\)

• Athlete Exposure: one athlete participating in one practice or competition.

• Chronic Ankle Instability (CAI): altered mechanical joint stability due to repeated disruptions to ankle integrity with resultant perceived and observed deficits in neuromuscular control.\(^41\)

• Dorsiflexion (DF): motion of the ankle joint that is completed by the tibialis anterior, extensor digitorum longus, extensor hallucis, and peroneus tertius muscles.\(^40\)

• Dynamic Postural Control: attempting to maintain a stable base of support while completing a prescribed movement.\(^41\)

• Postural Control: the act of maintaining, achieving or restoring a state of balance during any posture or activity.\(^42\)

• Range of Motion (ROM): degrees of motion in which the joint in question can be moved either actively through voluntary muscle contraction or passively by external means such as by a clinician.\(^40\)
• Star Excursion Balance Test (SEBT): battery of lower extremity maximal reach tests while the contra-lateral limb attempts to maintain single-limb balance.\textsuperscript{43}

• Weight-Bearing Lunge Test (WBLT): test to indirectly assess DF by measuring maximal advancement of the tibia over the rearfoot in a weight bearing position.\textsuperscript{25}
Chapter Two

Literature Review

This literature review will discuss ankle injuries, the rate of occurrence, associated risk factors, and the prediction capabilities of various functional assessment tools as well as self-reported functional questionnaires.

2.1 Ankle Injuries

In 2009, there were 119,815 lower extremity injuries reported in the United States. Of those 119,815 injuries, 19.8% occurred in the ankle. The most common injury reported was an ankle sprain with an incidence rate of 206 per 100,000 per year for the general population.

Waterman et al. examined the incidence rate of ankle sprains presented in emergency departments. Over a four-year time frame, 82,971 ankle sprains were identified throughout emergency rooms in the United States for what was an estimated total of 3,140,132 ankle sprains. It was reported that the highest peak incidence of ankle sprains occurred between fifteen and nineteen years of age (7.2 per 1000 persons-years). Overall, there was no comparable difference between males and females. However, when taking into account age as well, males between fifteen and twenty-four years old had a higher incidence of ankle sprains (incidence rate ratio, 1.53), whereas females over thirty
had a higher rate of incidence, 2.03. In regards to race, those who were black or white experienced higher rates of ankle sprains when compared to Hispanics (3.55 and 2.49, respectively). It was also noted that nearly half of all reported ankle sprains occurred during athletic activity (49.3%), with basketball being the most common (41.1%). This is only a snapshot of the total ankle sprains that occur, as there are individuals who will not seek medical treatment in an emergency department. Because of this, we cannot have a fully accurate description of all grades of ankle sprains that occur: from the mild sprains that may last only a day in regards to a decrease in function to those where a fracture has to be ruled out.

There have also been studies that looked to athletics specifically. Nelson et al. investigated the incidence rates of ankle injuries by sex, type of exposure, and sport during the 2005-2006 high school sports season. Certified athletic trainers (ATC) throughout the school year collected data from a sample that was representative of the nation. The sports that were included were boys’ football, boys’ and girls’ soccer, girls’ volleyball, boys’ and girls’ basketball, boys’ wrestling, boys’ baseball, and girls’ softball. Injury and injury event information were compiled along with athlete exposure (A-Es) rate. For this study, one A-E was defined as 1 athlete participating in 1 practice or competition. The authors found an ankle injury rate of 5.23 ankle injuries per 10,000 A-Es, equating with 326,396 ankle injuries occurring nationally each year. Injury rates were higher in competition than in practices. This was consistent throughout all sports, excluding volleyball. Gender did not appear to have any significant difference, except for when injuries occurred. The highest occurrence rate of ankle injuries was associated with football with 24.1% followed by both boys’ and girls’ soccer.
Similar epidemiological studies have been completed at the collegiate level. Hootman et al.\textsuperscript{46} summarized 16 years worth of injury surveillance data for 15 National Collegiate Athletic Association (NCAA) sports across all divisions. Lower extremity injuries accounted for the largest portion of injuries sustained with 53% of the total injury count. Ankle sprains accounted for 14.8% of all injuries. More than 27,000 ankle sprains were reported, which averages to approximately 1,700 per year.\textsuperscript{46} These injuries accounted for one quarter of all injuries in men’s and women’s basketball as well as volleyball. Spring football and men’s basketball had the highest rates of injury when A-\textsubscript{Es} were taken into account with 1.34 per 1,000 A-\textsubscript{Es} and 1.3 per 1,000 A-\textsubscript{Es}, respectively.\textsuperscript{46}

These large numbers of ankle injuries can lead to a high cost in health care for not only those who participate in athletics, but for the general population as well. In the United States alone, an annual aggregate cost of $2 billion is spent on acute ankle sprains.\textsuperscript{47} These costs come from diagnostic testing and initial treatments. Depending on the severity of the injury, the treatment for ankle injuries varies from basic first aid involving rest, ice, compression, and elevation to potential surgeries.\textsuperscript{47} An ankle injury can cause pain, swelling, and a decrease in range of motion of the ankle, and in some cases the lower leg and foot dependent on the severity of the injury. Those who suffer from ankle injuries can exhibit symptoms for at least two years after the injury.\textsuperscript{48} These in turn can lead to a lack in functional ability. Even if the individuals are put through a thorough ankle rehabilitation protocol, there is still a risk of long-term complications. The long-term complications that have come to be associated with ankle sprains include
recurrent ankle sprains and posttraumatic osteoarthritis of the ankle. These long-term complications that follow can increase the amount spent for healthcare costs.

Chronic ankle instability, often defined by a tendency toward repeated ankle sprains and associated recurring symptoms, is a long-term complication that often occurs in those who sustain an ankle sprain. A new model of CAI has allowed us to better understand the various contributing factors: mechanical instability, perceived instability, and recurrent sprain. Hiller et al. looked to create a model in which the current data fit. Using the model by Hertel, the previously accepted model, 56.5% of ankles fit the model, while with the new model, all 108 ankles fit. While held back by many limitations, the clinical implications are important in that the new model may provide a basis for improved patient care as well as help lead to a clinical-prediction rule to assist the clinician in best treating their patients. Surveys conducted in Australia during 2009 inquired about long-term complications with the ankle. Of the total 751 responses, 459 (61.1%) reported a history of an ankle sprain. One quarter of these individuals reported long-term problems. These chronic ankle disorders were due in majority to musculoskeletal disorders, which is caused most commonly by injury, followed by arthritis.

Sefton et al. analyzed the capability of sensorimotor function as a predictor for CAI. Sensorimotor function is made up of different measures, and the purpose of the study was to determine which variables, when combined, create the optimal capability to discriminate between CAI and healthy ankles. Joint kinesthesia, static and dynamic balance, and motoneuron pool excitability were all included as the four sensorimotor constructs. Significant differences were found with static balance as well as motoneuron
pool excitability. This study demonstrates that CAI is not a simple problem with a simple answer and is something that deserves further research. By preventing an initial ankle sprain, CAI is in turn prevented.

While we do not know the true mechanism of CAI, it is suggested through research such as the one completed by Sefton et al. that there is not just one factor, but many. The laxity associated with ankle sprains, while the most obvious and the factor often focused on, will not fix the issue of instability. An aspect often overlooked, loss of relevant sensory information from the ligament and associated tissue is connected with the disability connected with ankle sprains. If not addressed properly, the instability of CAI will cause a cascade of events subsequently leading to the development of post-traumatic ankle osteoarthritis (OA). By altering the position of the ankle joint, most likely due to poor ligament stability and the factors discussed, the joint articulation becomes altered, thus not allowing the joint to function properly and predisposing the joint to the development of ankle OA. This variation in joint position, varus malalignment, is thought to correlate with ankle OA.

A previous history of ankle sprains might potentially lead to future proximal limb injuries as well. Backman and Danielson showed that a small ankle dorsiflexion range of motion is a risk factor for developing patellar tendinopathy, specifically in basketball players. The authors also found that limbs that had 2 or more ankle sprains had a smaller range of dorsiflexion compared with limbs without a history of an ankle sprain, indicating that a history of ankle sprain might contribute to a lower range of ankle dorsiflexion. Therefore, a history of ankle sprains might potentially increase a risk for patellar tendinopathy. Furthermore, a potential association between a history of ankle sprains and
the occurrence of ACL injuries was also reported. The correlation between ACL rupture and general knee laxity and a decrease in iliotibial band flexibility was stronger.\textsuperscript{54} These factors are also related to a history of an ankle sprain, thus creating a stronger kinetic chain relationship between a history of ankle sprain and ACL rupture.\textsuperscript{54} Finally, low back pain has been shown to have a connection with overuse injuries such as patellar tendonitis as well as ligamentous laxity such as ankle instability and postoperative ACL reconstruction.\textsuperscript{55} Looking at these various studies, the importance of prevention and proper care of ankle injuries should be reinforced.

2.2 Associated Risk Factors

It is important to understand different mechanisms of injury as well as the different risk factors that are associated with sustaining an ankle injury. An injury may appear that it occurred due to the specific event, but in fact may be a result of various interactions of both internal and external risk factors.\textsuperscript{7} To better understand the injury and what factors increase the risk for injury, it is important to understand the different risk factors that can play a role in the incidence of the injury in question: ankle injuries.

There are two different categories of risk factors: extrinsic and intrinsic. Extrinsic risk factors include the environment (i.e. weather, the playing surface, and maintenance), sports equipment (i.e. shoes, skis), protective equipment (i.e. helmet, shin guards), and sports factors (i.e. coaching, rules, referees).\textsuperscript{7} Different sports will have different incidence rates dependent on these factors. For instance, a volleyball player’s most important extrinsic risk factor is landing after a jump.\textsuperscript{34} If where the athlete is landing is compromised in that the floor is slick or there is something in the athlete’s way such as another athlete’s foot. These various types of extrinsic risk factors listed above can be
controlled for to an extent, but not fully eliminated. Better fitting protective equipment, choosing correct sports equipment, and better controlling for the playing environment, these extrinsic risk factors can be better controlled, but there is no specific recommendations that can be made based on current research.\textsuperscript{34}

While intrinsic risk factors can include but are not limited to age, sex, body composition, health, physical fitness, anatomy, and skill level, it has been suggested that the following risk factors for ankle injuries should be considered for targeted prevention strategies: strength, proprioception, range of motion, and balance.\textsuperscript{34} An alteration in any of these risk factors has been indicated to put the individual at an increased risk of sustaining an ankle injury. Intrinsic risk factors are more difficult to alter, as there are some that cannot be changed, such as their health history, sex, and age. Although these cannot be altered, if it can be determined which individuals are at a higher risk of injury, dependent on combination of risk factors, preventative measures can be implemented in hopes to limit the occurrence of ankle injuries. A history of ankle sprains has been shown to increase an individual’s risk of suffering another ankle sprain, thus strengthening the resolve to prevent the first ankle injury if possible. Previous investigations have reported that sex may not have an important role in increasing an individual’s injury/re-injury rate.\textsuperscript{45} In fact, both males and females have been shown to have a similar rate of injury. It has been suggested that adolescent athletes are more likely to sustain an ankle injury due to the maturation period that occurs, as there is a greater development of body mass and strength during this time frame.
2.3 Star Excursion Balance Test

The star excursion balance test (SEBT) is a series of single limb squats using the non-stance leg to reach to a maximal distance along different directions designated on the ground.\(^43\) There have been improvements to the methods of this test, such as minimizing the number of directions used as well as changing the position of the stance foot.\(^22\) Originally, there were 8 different directions used: anterior, posterior, medial, lateral, anterior medial/lateral, and posterior medial/lateral. As progressions have been made to utilize the SEBT as functional assessment tool, the directions now include only 3: anterior, posterior medial, posterior lateral.\(^56\)

The SEBT has been shown to be a reliable and valid measurement of dynamic balance.\(^21,57\) Kinzey et al.\(^57\) was the first study completed assessing the reliability of the SEBT for 4 diagonal reach directions (anteromedial, anterolateral, posteromedial, and posterolateral). The intraclass correlation coefficient (ICC) ranged from 0.67 to 0.87 for the different directions.\(^57\) A intratester and intertester reliability study was completed by Munro et al.\(^21\) for all 8 directions. Three trials were completed in each direction on two separate days. Intratester reliability (ICC) varied from 0.78 to 0.96 while intertester reliability ranged from 0.35 to 0.84 on day 1 and 0.81 to 0.93 on day 2. The variation was attributed to the learning effect that most likely occurred during the first day.\(^21\)

Gribble et al.\(^58\) examined which method is the best to normalize the measures of the SEBT. Foot type, height, leg length, and range of motion were used to normalize the reach distance of the SEBT. A strong correlation for structural leg length was found, and the researchers concluded that leg length normalization should be used. This is done by
measuring the patient’s leg length, dividing it by the reach distance, and then multiplying the number by 100 to get the percentage to be recorded.\textsuperscript{58}

Hertel et al.\textsuperscript{59} performed a study to evaluate ways to simplify the SEBT. Based on the results of a factor analysis, a large amount of redundancy was found in the completion of the 8 different reach directions. Participants with CAI had a significant decrease in the anterior medial, medial, and posterior medial directions.\textsuperscript{59} Subsequently, the suggested number of reach directions to be performed was narrowed down to 3 with further research performed by Hertel\textsuperscript{56}.

As with any movement, there is a learning curve that needs to be accounted for. Robinson and Gribble looked to determine how many practice trials are necessary for the individual to complete before collecting data when using the SEBT. The data collected show that the stance limb stabilized by the fourth trial. It was recommended then that a total of 4 practice trials are completed when measuring reach distance for clinical outcomes or when completing research.\textsuperscript{60} Munro and Herrington found similar results in that performance stabilized after 4 practice trials with healthy individuals.\textsuperscript{21}

Plisky et al.\textsuperscript{11} examined the utility of the SEBT for injury prediction. Prior to the season, the normalized reach distance of the SEBT in the anterior, posteromedial, and posterolateral directions were measured in 235 high school basketball athletes bilaterally. Coaches and ATCs were trained in injury surveillance, keeping track of injuries as well as time loss. A questionnaire was completed at the end of the season to ensure all injuries and time loss was accounted for. A total of 54 lower extremity injuries were reported, fifty of which were of a traumatic nature. Using a receiver operation characteristic (ROC) curve, a cutoff score of 4 cm was associated with 2.5 times increase of an injury.\textsuperscript{11} While
this is an important study in that it was the first to suggest using the SEBT to predict injury, there were limitations to the study, the largest of which was the fact that there was no accounting for the rate of athlete exposures. The comparisons made were also specific to each athlete, which makes the application of the cutoff score limited.

Previous research completed in our laboratory has assessed the use of the SEBT as a predictor of lower extremity injury in both basketball and football high school athletes.\textsuperscript{10,12,13,17} These studies all showed a decrease in normalized SEBT scores in athletes that suffered an injury during the season, but the differences were not all statistically significant. For all three, the anterior reach differences were nearly significant with a moderate effect size. The composite score of the three reach directions also had a moderate effect size.\textsuperscript{10,13,17} Using a ROC curve analysis, an anterior cut off score of 66.725 and a composite cut off score of 69.95 were associated with odds ratios between 3 and 5. This data compilation supports the use of the anterior direction as a single measurement for lower extremity injury prediction. This would decrease the amount of time it would take to test individual athletes as well as save resources.

\textbf{2.4 Weight-Bearing Lunge Test}

The weight-bearing lunge test (WBLT) is a closed chain measure of ankle dorsiflexion range of motion (DF-ROM). Ankle DF-ROM has been suggested as a risk factor for lower extremity injury.\textsuperscript{29} Reliability of the WBLT appears to be strong, with ICC’s reported by O’Shea and Grafton\textsuperscript{24} between 0.98-0.99, and similarly By Bennell et al.\textsuperscript{25} between 0.97-0.99.

This functional test has been used to evaluate a deficit where an asymmetry of 1 or 2 cm difference is considered clinically relevant. However, it is important to determine
if this is a normal occurrence and if there needs to be a form of normalization as there is with the SEBT. Hoch and McKeon\textsuperscript{26} looked to answer this question using healthy adults. Results indicated that there was a 0.1 cm bias on the right limb with a 95\% reference interval of $\pm$ 2.8 cm. This in turn indicates that right limb asymmetry could range from -2.7 to 2.9 cm. There was no signification relations between the performance of either limb and the subject’s age, height, mass, leg or foot length, or talar displacement.\textsuperscript{26} Therefore, there does not appear to be a need for normalization.

Hoch et al.\textsuperscript{61} examined if there was a relationship between the WBLT and the SEBT. A significant correlation between the anterior reach direction of the SEBT and the WBLT supports the idea that dorsiflexion measured by the WBLT is related to the anterior reach of the SEBT.

Taking the correlation found between the anterior reach of the SEBT and the WBLT, Hoch et al.\textsuperscript{62} assessed the relationship of dorsiflexion and dynamic postural control deficits in participants with CAI. Significant difference was found in both the WBLT and the anterior reach of the SEBT between participants with and without CAI. They also identified a moderate relationship between the two tests in both participants with and without CAI.

As the anterior reach of the SEBT has been found to have promising results in injury prediction, it is possible that the WBLT would as well. However, there have been no published studies assessing this potential use.

2.5 Functional Movement Screen™

The Functional Movement Screen (FMS)™ is an emerging evaluation tool that attempts to analyze functional movement patterns of individuals. The goal of the FMS™
is to determine if an individual has the necessary movement to participate in sport without increasing the risk of injury. Evidence is currently inconsistent in showing the capability of predicting injury or helping to reduce injury risk.\textsuperscript{14,15,19,31} It is important first to understand what exactly the FMS™ is comprised of. There are seven different movement patterns creating seven different stations that are thoroughly discussed in a two-part publication by Cook et al.\textsuperscript{63,64} The stations of FMS™ include deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability test.\textsuperscript{63,64} A scoring method of zero to three is introduced in which three is when the movement is performed perfectly while zero indicates that pain was experienced. It is suggested that the reasoning for scoring is noted including the compensatory movement and where it observed.\textsuperscript{65}

Because the scoring of the FMS™ movements is highly reliant on the rater’s ability to pick up on the completed movement and any compensatory movements that occur, the question of reliability is raised. Gribble et al.\textsuperscript{66} assessed intrarater reliability where the assessor was assigned to one of three groups based on clinical background with the FMS™. The groups included athletic training students, ATCs without experience using the FMS™, and ATCs with at least six months of experience using the FMS™. Moderate intra-rater reliability was observed when all groups of clinical background were included. The group of athletic trainers with at least six months of experience had the strongest reliability with an ICC of 0.946.\textsuperscript{66} These findings are indicative of the fact that ATCs with at least six months of experience have the highest intra-rater reliability with a value of 1 being a perfect correlation. Butler et al.\textsuperscript{67} looked at inter-rater reliability using a newly proposed 100-point scoring system and suggested that this scoring system would
increase the sensitivity of FMS. Middle school age students participated, completing the movements while being videotaped. The assessors then completed the scoring while reviewing these tapes. The analysis revealed a high reliability with the overall ICC value equaling 0.99. While shown to be reliable, it is important to note that the assessors were able to watch the movements multiple times so as to evaluate all aspects of the 100-point scale while real time analysis can only be done at the initial time of the movement.67

Kiesel et al.31 looked at using the FMS™ to predict injuries in professional football athletes. Players completed the FMS™ during training camp. The scores were then recorded and stored through the season. An ATC kept track of injury rates where injury was defined as membership on the injured reserve with a loss of three or more weeks of playing time. A cutoff score of 14 was found using a ROC curve.31 The actual injuries were not recorded so there is no way to say if the injury was an ankle sprain, a concussion, or a broken hand. Each of these relates to the FMS™ movements in very different ways, making it difficult to say if the predictive value with athletes scoring under 14 is clinically significant.

Previous work in our laboratory15,16,19 has considered the use of the FMS as an injury predictive tool in collegiate athletes, but found the FMS to be relatively poor at predicting these injuries. Some of this work examined using a modification of the FMS to focus on lower extremity stations only, but the sensitivity and specificity were still suggest effective prediction.16 Similarly, work from our lab suggests the FMS is not a strong predictor of injury in high school basketball players.14 The inconsistency of the cut off score as well as the associated sensitivity and specificity data reported across these studies demonstrates the need for more research on the FMS and its injury prediction.
Since this current research project will focus on ankle injury prediction, it is logical to only assess the movements that involve the ankle.

2.6 Foot and Ankle Ability Measure

While there is no universally accepted instrument to assess self-reported function related to foot and ankle injury, the Foot and Ankle Ability Measure (FAAM) is often considered a valid assessment tool of disability. This questionnaire looks to assess the individual’s functionality and the involvement of the leg, ankle, and foot.68 There are two subscales to the FAAM: activities of daily living (ADL) with 21 items and a sports scale with 8 items.

Martin et al.68 created the FAAM and completed a study to support the new questionnaire in regards to reliability and validity. Determination of the final items included in the FAAM was based off the responses of 1027 subjects. Upon completion of the study, test and retest reliability was 0.89 and 0.87 for the ADL and sport subscales respectively.68 However, this tool has never been used to assess injury risk, only the existence of self-reported disability after injury. It is hoped that this research will help support the use of self-reported questionnaires during pre-participation exams to potentially predict those who are at a higher risk of injury.

2.7 Gaps in Literature

Currently, there is no model for injury prediction with the use of screening tools such as those previously discussed for lower extremity injuries in high school athletes, much less ankle injuries in football and basketball high school athletes specifically. The study completed by Plisky11 had a limited population in which to pull data from. The lack of athlete exposures being accounted for affects the capability of putting the methods into
practice as well as applying the predicted scores to a more general athletic population. This in turn limits the external validity of the study. Also, the study completed by Plisky included only the SEBT. There is yet to be a published study looking at the ability of the WBLT in injury prediction. With the FMS™, there are studies with an injury prediction model, but the agreement of a cutoff score between studies is weak. It shows a promising thought process and with a more specific scoring system and focusing on fewer movements, perhaps a relationship can be found that leads to the prediction of ankle injuries.

It is the hope of this study that by compiling the functional assessments of the anterior reach of the SEBT, the WBLT, a modified 4 station FMS™, and the FAAM a foundation for continued work to identify the most effective form of injury prediction and in turn injury prevention for high school athletes. By compiling the information from these various assessments, weaknesses or risk factors that may be missed when using just one will be addressed. There will also be insight provided in regards to how the history of an ankle sprain influences the recurrence rate of ankle injuries in high school football and basketball athletes.
Chapter Three

Methods

3.1 Study Design

This study was a prospective cohort study to determine the strength of the anterior direction of the SEBT (SEBT-A), WBLT, active and passive measures of DF, four stations of FMS™, BMI, and self-reported disability as a predictor of acute noncontact and contact ankle injuries in high school athletes with and without a history of ankle sprains.

3.1.1 Independent Variables

1. Group
   a. Ankle injury during the season
      i. contact
      ii. non-contact
   b. Non-injured

2. History
   a. Previous ankle sprain (LAS)
   b. No previous ankle sprain (NAS)
3.1.2 Dependent Variables

1) SEBT – normalized anterior reach distance (%MAXD)
2) Ankle DF ROM using the WB Lunge Measurement (cm)
3) Active and Passive DF ROM using a goniometer
4) Total of four stations of FMS™
5) BMI
4) FAAM scores
5) FAAM-Sport scores

3.2 Participants

Football and basketball players were recruited from local area high schools in Toledo, OH and Petersburg, MI. Participants were included if they: (1) participated in an interscholastic football or basketball program in varsity or junior varsity level under the supervision of a coach during the 2013-14 seasons, (2) were cleared for full sport participation by a physician at the time of the study, (3) had no history of lower extremity surgery and fractures in the previous 12 months, (4) were free of any diagnosed balance or vestibular disorders, and (5) had no history of concussion in the previous one month. Participants were grouped into those that had a previous history of ankle sprains at the time of pre-season screening (LAS) or had never experienced ankle sprains previously at the time of pre-season screening (NAS).

Prior to participation in this study, all participants and their parent/guardian (if participants are under the age of 18) read and signed an informed consent form approved by the University Institutional Review Board.
3.3 Instrumentation

Tape measures, goniometers, as well as a Functional Movement Screen™ kit were used to assess participants’ functional performance.

3.4 Procedures

At the beginning of the competitive season, participants completed a health-related questionnaire as well as the Foot and Ankle Ability Measure (FAAM) and FAAM-sport. After completion of questionnaires, the participant’s leg length was measured from the anterior superior iliac spine to the distal aspect of the medial malleolus with the participant in a supine position. This measurement was used in the normalizing process to calculate the maximum reach distance in the anterior direction during the SEBT.58 Next, dorsiflexion range of motion was assessed using goniometry. Participants bilaterally performed the SEBT-A, WBLT, and four stations of FMS™. The participants were not allowed to use ankle taping or a prophylactic ankle brace during the testing session.

During the season, Certified Athletic Trainers (ATCs) tracked and reported acute ankle injury occurrences, MOI, time lost from these injuries, the total number of exposures from practice and games, and the use of external support for the ankle and knee. An athletic exposure was defined as one athlete participating in one practice or competition. An acute ankle injury was defined as one that occurred during a practice or competition, required medical attention by ATCs or physicians, and resulted in restriction of sport participation for one or more days beyond the day of injury.4 Furthermore, the following information regarding an acute lower extremity injury was recorded: 1) if the injury occurred during practice or competition, 2) the mechanism of injury (contact vs.
non-contact) 3) if the injured athlete used external ankle support at the time of injury, and 4) if the injury is a first-time injury or recurrent injury. These factors had the possibility of being considered as potential co-variates in follow-up analyses.

At the end of the competitive season, high school student athletes in each group (LAS, NAS) were dichotomously stratified into an injured or non-injured group for data analysis. The injured group was further divided by mechanism of injury – contact vs. non-contact.

3.4.1 Star Excursion Balance Test – Anterior Reach. Participants performed the SEBT-A to assess dynamic postural control. Participants stood barefoot with their toe at the edge of the tape measure. Participants were instructed to reach as far as they can with the opposite limb, tap their toe on the line, and then return to the starting position. Maximum reaching distance was then recorded (Figure 1). Participants were given four practice trials to minimize the learning effect. Three testing trials were performed. The trials were repeated if the participant did not keep their hands on their hips, they lost their balance, their heel lifted from the floor, or their foot moved from the starting position. The number of failed trials was also recorded. The average of the three maximum reach distances (cm) was normalized by leg length (cm) and reported as a %MAXD.

Figure 1: Star Excursion Balance Test – Anterior Reach
3.4.2 Weight Bearing Lunge Test. Participants performed three trials of the WBLT by the knee-to-wall principle\textsuperscript{70} (Figure 2) to assess the availability of weight-bearing ankle DF (WB-DF) ROM. A measuring tape was placed on the floor, and the participant placed their heel firmly on the floor and flexed their knee to the wall. The participant was progressed backwards in 1cm increments until they were unable to keep their heel on the ground or touch the wall with their knee. After the participant failed a lunge attempt, foot placement was adjusted in smaller increments to achieve the maximum distance from the wall. The distance from their great toe to the wall (cm) was measured as reaching maximum DF to the closest 0.1 cm. The participant was given practice trials on the testing limb in which they keep their stance heel on the ground while their knee is flexed to the wall.

![Figure 2: Weight-Bearing Lunge Test](image)

3.4.3 Active and Passive Dorsiflexion Range of Motion. Participants sat at the end of a table with their knee bent and lower limb and feet off the table. This put the participant in position to assess open kinetic chain DF. The goniometer was placed with the following landmarks. The axis point was placed at the lateral malleolus, the stationary arm along the lower leg with the fibula as a landmark, and the moving arm along the base of foot with the 5\textsuperscript{th} metatarsal as a landmark. The participant was then instructed to
dorsiflex as much as possible. Active DF was than recorded. The participant was than passively put into DF by the researcher. Passive DF was than recorded as well.\textsuperscript{71}

![Figure 3: DF ROM – Active and Passive](image)

3.4.4 Functional Movement Screen\textsuperscript{TM}. To assess the participant’s functional performance, participants performed four stations of the FMS\textsuperscript{™}, including Deep Squat, Hurdle Step, In-Line Lunge, and Active Straight Leg Raise, as previously described.\textsuperscript{63,72} The grading system described by Cook et al.\textsuperscript{63,65,72} was used. A score of 3 was given for performing the movement perfectly, a 2 was given when the movement was completed with some compensatory movements, a 1 was given if the subject could not complete the movement, and a score of 0 was given if there is pain present during the movement.

*Deep Squat*– The participant was instructed to stand tall with their feet shoulder width apart and toes pointing forward. The dowel was held in both hands and horizontally on top of their head so that their shoulders and elbows were at 90 degrees. The dowel was then pressed so that it was directly above their head. While maintaining an upright torso, and keeping their heels and the dowel in place, they completed the squat as deeply as possible (Figure 4a). This position was held for a count of one after which the participant returns to the starting position. The movement was scored. The participant
performed the motion up to a total of three total times if necessary. If the participant was not able to complete the movement achieving a score of 3, a 2” × 6” block was placed under the participant’s heels (Figure 4b) and the movement was repeated.

*FMS™: Hurdle Step*—The participant was instructed to stand tall with their feet together and toes touching. They then grasped the dowel with both hands and placed it behind their neck and across the shoulders. While maintaining an upright posture, they raised their right leg and stepped over the hurdle, making sure to raise their foot toward the shin and maintaining foot alignment with the ankle, knee, and hip (Figure 5). They then touched the floor with their heel and returned to the starting position while maintaining foot alignment with the ankle, knee, and hip. The moving leg was scored. The participant was able to repeat the motion two times per side if necessary.

*FMS™: In-line Lunge*—The participant was instructed to place the dowel along the spine so that it touched the back of their head, upper back, and middle of the buttocks. While grasping the dowel, their right hand was against the back of their neck and the left hand was against their lower back. They then stepped on to the 2” × 6” block with a flat right foot and toe on the zero mark. The left heel was placed in front, a distance equal to that of their right tibia. Both toes were pointing forward and their feet flat. While maintaining an upright posture so that the dowel remains in contact throughout the movement, the participant then descended into a lunge position so that their right knee touched the 2” × 6” block behind their left heel (Figure 6). They then returned to the starting position. The movement then scored. The participant was able to repeat the motion two times per side if necessary.
**FMS™: Active Straight Leg Raise**– The participant was instructed to lay flat with the back of their knees against the 2” x 6” block with their toes pointing up. Both arms were placed next to their body with their palms facing up. They were then told to pull the toes of their right foot toward their lower leg. With their right leg remaining straight and the back of their left knee maintaining contact with the 2” x 6” block, they were instructed to raise their right foot as high as possible (Figure 7). The movement was then scored and repeated on the opposite side.

![Figure 4a: Deep Squat](image)

![Figure 4b: Modified Deep Squat](image)

![Figure 5: Hurdle Step](image)

![Figure 6: In-line Lunge](image)
Figure 7: Active Straight Leg Raise

**3.4.5 BMI.** The participant’s height and weight were recorded and used to calculate the BMI as body mass/height\(^2\) (kg/m\(^2\)).

**3.4.6 Self-Reported Function.** The FAAM and FAAM-sport were used to assess the level of self-reported function. The FAAM is a self-reported functional assessment questionnaire that comprehensively assesses physical function of the leg, ankle, and foot. The FAAM contains two subscales, including the FAAM activities of daily living (ADL) subscale and Sports subscale (Appendix A). The FAAM and FAAM-sport have been shown to be valid and reliable measures of function of the lower extremity as well as responsive to change in a population with previous lower extremity injuries. Scores for the FAAM and FAAM-Sport were reported in percentages, with a lower score indicating increased self-reported disability.

**3.5 Statistical Analysis:**

The sides of the uninjured group were averaged and compared to the injured side of the injured group. The injured group was then further divided into non-contact and contact injuries. The level of statistical significance was set a priori at \(p<0.05\) using SPSS 22.0 for Windows (SPSS, Inc. Chicago, IL.).
3.5.1. **Specific Aim 1.** Independent t-tests were used to determine injured group differences in each dependent variable (%MAXD, WB-DF, active and passive DF, FMS scores, BMI, and FAAM and FAAM-Sport scores). Cohen’s $d$ effect sizes with associated 95% confidence interval (CI) were calculated using mean and pooled standard deviations to determine the magnitude of difference in dependent variables between injured and uninjured groups. The magnitude of effect sizes will be interpreted as small ($d < 0.4$), moderate ($0.40 \leq d < 0.8$), and large ($d \geq 0.8$).\(^{74}\)

A Chi-Square analysis was used to determine if there was a relationship in the distribution of previous history of ankle sprains and in-season ankle injuries. This was done using a 2x2 contingency table categorizing participants into having a 1) previous history of ankle sprains with in-season injury, 2) previous history of ankle sprains with no in-season injury, 3) no history of ankle sprains with in-season injury or 4) no history of ankle sprains with no in-season injury.

Finally, a one-way ANOVA was calculated to determine differences between mechanism of injury groups – contact, non-contact, and non-injured – for each dependent variable. As an exploratory analysis, these comparisons were completed for each sport separately to examine any potential differences for football and basketball.

3.5.2 **Specific Aim 2.** To examine the strength of predictive capability of each functional performance assessment tool, FAAM and FAAM-Sport scores, and a history of ankle sprain, sensitivity (rate of true positive) and specificity (rate of true negative) of each predictor to rule in and out the injured and non-injured participants and create a cut-off score was calculated using a receiver operating characteristic (ROC) curve analysis. For each dependant variable, positive likelihood ratios $[(\text{sensitivity}/(1-\text{specificity}))$ and
negative likelihood ratios [(1-sensitivity)/specificity] were calculated, from which diagnostic odds ratios (DOR) (+LR/-LR) could be created.
Chapter Four

Results

4.1 Demographics

Participant demographics for the 208 participants are reported in Table 4.1 which includes sex breakdown, age, height, and mass from the data collected representing the two high school football programs (n=87) and three high school basketball programs (n=121). There were a total of 31 ankle injuries sustained – 16 football athletes and 15 basketball athletes.

Not all participants completed all measures. Only those who played football had active and passive DF measures completed. FAAM and FAAM sport scores were missing from 32 of the basketball players as well.

Table 4.1 – Demographics: All Athletes

<table>
<thead>
<tr>
<th></th>
<th>Male (n=178)</th>
<th>Female (n=30)</th>
<th>Total (n=208)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>15.44±1.13</td>
<td>15.67±1.24</td>
<td>15.48±1.15</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.79±8.85</td>
<td>166.20±7.39</td>
<td>176.11±9.55</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>75.06±16.37</td>
<td>66.56±17.77</td>
<td>73.83±16.80</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.65±4.38</td>
<td>23.94±5.65</td>
<td>23.69±4.57</td>
</tr>
</tbody>
</table>
### Table 4.2 – Demographics: Football Athletes

<table>
<thead>
<tr>
<th>mean±SD</th>
<th>Total (n=87)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>15.44±1.16</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>175.03±8.43</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>76.00±17.67</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.69±4.81</td>
</tr>
</tbody>
</table>

### Table 4.3 – Demographics: Basketball Athletes

<table>
<thead>
<tr>
<th>mean±SD</th>
<th>Male (n=91)</th>
<th>Female (n=30)</th>
<th>Total (n=121)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>15.45±1.13</td>
<td>15.67±1.22</td>
<td>15.50±1.15</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180.42±8.53</td>
<td>166.20±8.53</td>
<td>176.90±10.24</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>74.16±14.77</td>
<td>66.56±20.47</td>
<td>72.28±16.05</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.66±3.52</td>
<td>23.94±6.03</td>
<td>22.98±4.27</td>
</tr>
</tbody>
</table>

### 4.2 History of Ankle Sprain

The distribution between those who sustained an injury and those who had a previous history of injury can be found in tables 4.4, 4.5 and 4.6 for all athletes, football athletes, and basketball athletes, respectively. The majority of athletes who sustained an ankle injury during their respective competitive season did not have a previous history. The chi-square analysis was not statistically significant ($X^2_1 = 2.157, p=0.142, \text{ odds ratio}=0.475, 95\% \text{ CI}=0.173 \text{ to } 1.306$). Therefore, history of ankle sprains was not included as an influential factor for the remaining analyses of the outcome measures for predicting ankle sprain injury, as planned.

### Table 4.4 – 2x2 Contingency for injured/non-injured football and basketball athletes

<table>
<thead>
<tr>
<th></th>
<th>Previous History of Injury</th>
<th>No Previous History of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injured</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>Non-injured</td>
<td>51</td>
<td>126</td>
</tr>
</tbody>
</table>

### Table 4.5 – 2x2 Contingency for injured/non-injured football athletes

<table>
<thead>
<tr>
<th></th>
<th>Previous History of Injury</th>
<th>No Previous History of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injured (FB)</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Non-injured (FB)</td>
<td>18</td>
<td>53</td>
</tr>
</tbody>
</table>
Table 4.6 – 2x2 Contingency for injured/non-injured basketball athletes

<table>
<thead>
<tr>
<th>Previous History of Injury</th>
<th>No Previous History of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injured (BB)</td>
<td>1</td>
</tr>
<tr>
<td>Non-injured (BB)</td>
<td>33</td>
</tr>
</tbody>
</table>

4.3 Group Comparisons

Group comparisons for all outcomes between injured and non-injured athletes may be found in Table 4.7. BMI was the only variable that was significantly different when comparing injured (25.39±4.69 kg/m²) to non-injured (23.40±4.50 kg/m²) athletes (p=0.025), with a moderate associated effect size (d=0.44). The remaining group comparisons were not statistically significant (p > 0.05), with small effect sizes.

Table 4.7 – T-Test Comparisons for injured/non-injured football and basketball athletes

<table>
<thead>
<tr>
<th></th>
<th>N=</th>
<th>Mean±SD</th>
<th>t</th>
<th>df</th>
<th>P</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>31</td>
<td>25.39±4.69</td>
<td>2.255</td>
<td>206</td>
<td>0.025</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>177</td>
<td>23.40±4.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEBT-A</td>
<td>31</td>
<td>65.27±7.59</td>
<td>-0.471</td>
<td>206</td>
<td>0.638</td>
<td>-0.09</td>
</tr>
<tr>
<td></td>
<td>177</td>
<td>65.96±7.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FMS</td>
<td>31</td>
<td>6.62±2.18</td>
<td>-0.885</td>
<td>206</td>
<td>0.377</td>
<td>-0.17</td>
</tr>
<tr>
<td></td>
<td>177</td>
<td>6.90±1.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBLT</td>
<td>31</td>
<td>8.76±3.93</td>
<td>-0.233</td>
<td>206</td>
<td>0.816</td>
<td>-0.05</td>
</tr>
<tr>
<td></td>
<td>177</td>
<td>8.92±3.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF Passive</td>
<td>16</td>
<td>13.19±6.08</td>
<td>-0.389</td>
<td>85</td>
<td>0.698</td>
<td>-0.11</td>
</tr>
<tr>
<td></td>
<td>71</td>
<td>13.79±5.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF Active</td>
<td>16</td>
<td>9.94±6.55</td>
<td>-1.173</td>
<td>85</td>
<td>0.244</td>
<td>-0.32</td>
</tr>
<tr>
<td></td>
<td>71</td>
<td>11.80±5.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAAM</td>
<td>27</td>
<td>97.88±5.49</td>
<td>-0.094</td>
<td>174</td>
<td>0.926</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>149</td>
<td>97.96±3.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAAM Sport</td>
<td>27</td>
<td>94.84±11.78</td>
<td>-0.090</td>
<td>174</td>
<td>0.928</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>149</td>
<td>95.04±10.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.4 Mechanism of Injury

The influence of MOI was compared for each of the pre-season measures using one-way ANOVA models, comparing the contact injured, non-contact injured and non-
injured athletes. This analysis was repeated for all athletes, and then separated for football athletes and basketball athletes (Tables 4.8, 4.9, and 4.10 respectively). When all athletes were included, the only variable found to be statistically significant was the BMI (contact: 22.72±3.10 kg/m$^2$; non-contact: 27.58±4.71 kg/m$^2$; non-injured: 23.40±4.50 kg/m$^2$; p=0.001). Active DF, while not statistically significant (p=0.078), did have reduced performance scores in the non-contact injury groups (Table 4.8). All other measures did not have relations of interest.

When considering football athletes only, there was interesting difference found when comparing BMI and active DF. Larger BMI values were found in individuals who sustained a non-contact injury (28.53±5.01 kg/m$^2$, p = 0.026) compared to those who sustained a contact injury (24.15±3.73 kg/m$^2$) or were non-injured (24.19±4.68 kg/m$^2$). Active DF was nearly significant (p=0.078), with the lowest values found in the non-contact group (7.80±6.86°) compared to the contact (13.50±4.42°) and non-injured groups (11.80±5.53°).

There was no statistical difference among all the various dependent variables when analyzing basketball player data. Observable differences in BMI suggested a potential relation for non-contact injuries, but this relation only approached significance (p=0.08).
Table 4.8 – ANOVA for ankle injuries in football and basketball athletes

<table>
<thead>
<tr>
<th></th>
<th>Contact (n=14)</th>
<th>Non-contact (n=17)</th>
<th>Non-injury (n=177)</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>22.72±3.10</td>
<td>27.58±4.71</td>
<td>23.40±4.50</td>
<td>7.247</td>
<td>0.001</td>
</tr>
<tr>
<td>SEBT-A</td>
<td>66.43±8.94</td>
<td>64.30±6.38</td>
<td>65.96±7.55</td>
<td>0.414</td>
<td>0.661</td>
</tr>
<tr>
<td>FMS</td>
<td>7.23±2.62</td>
<td>6.11±1.64</td>
<td>6.90±1.53</td>
<td>2.205</td>
<td>0.113</td>
</tr>
<tr>
<td>WBLT</td>
<td>8.2±3.60</td>
<td>9.23±4.23</td>
<td>8.92±3.34</td>
<td>0.371</td>
<td>0.690</td>
</tr>
<tr>
<td>DF Passive*</td>
<td>15.50±4.14</td>
<td>11.80±6.81</td>
<td>13.79±5.47</td>
<td>0.908</td>
<td>0.407</td>
</tr>
<tr>
<td>DF Active*</td>
<td>13.50±4.42</td>
<td>7.80±6.86</td>
<td>11.80±5.53</td>
<td>2.634</td>
<td>0.078</td>
</tr>
<tr>
<td>FAAM†</td>
<td>97.62±4.48</td>
<td>98.07±6.22</td>
<td>97.96±3.67</td>
<td>0.045</td>
<td>0.956</td>
</tr>
<tr>
<td>FAAM Sport†</td>
<td>95.13±10.14</td>
<td>94.64±13.11</td>
<td>95.04±10.25</td>
<td>0.011</td>
<td>0.989</td>
</tr>
</tbody>
</table>

* (n=6,10,71 respectively)
† (n=11,16,149 respectively)

Table 4.9 – ANOVA for ankle injuries in football athletes

<table>
<thead>
<tr>
<th></th>
<th>Contact (n=6)</th>
<th>Non-contact (n=10)</th>
<th>Non-injury (n=71)</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>24.25±3.73</td>
<td>28.53±5.01</td>
<td>24.19±4.68</td>
<td>3.823</td>
<td>0.026</td>
</tr>
<tr>
<td>SEBT-A</td>
<td>67.65±5.62</td>
<td>64.56±8.01</td>
<td>67.98±6.22</td>
<td>1.254</td>
<td>0.291</td>
</tr>
<tr>
<td>FMS</td>
<td>6.00±1.41</td>
<td>5.30±0.95</td>
<td>6.37±1.54</td>
<td>2.337</td>
<td>0.103</td>
</tr>
<tr>
<td>WBLT</td>
<td>7.08±2.53</td>
<td>8.07±4.82</td>
<td>8.26±3.80</td>
<td>0.258</td>
<td>0.773</td>
</tr>
<tr>
<td>DF Passive</td>
<td>15.50±4.14</td>
<td>11.80±6.81</td>
<td>13.79±5.47</td>
<td>0.908</td>
<td>0.407</td>
</tr>
<tr>
<td>DF Active</td>
<td>13.50±4.42</td>
<td>7.80±6.86</td>
<td>11.80±5.53</td>
<td>2.634</td>
<td>0.078</td>
</tr>
<tr>
<td>FAAM</td>
<td>97.42±4.48</td>
<td>97.38±7.87</td>
<td>98.07±3.78</td>
<td>0.149</td>
<td>0.862</td>
</tr>
<tr>
<td>FAAM Sport</td>
<td>93.45±12.86</td>
<td>94.64±15.73</td>
<td>95.37±10.51</td>
<td>0.091</td>
<td>0.913</td>
</tr>
</tbody>
</table>

Table 4.10 – ANOVA for ankle injuries in basketball athletes

<table>
<thead>
<tr>
<th></th>
<th>Contact (n=8)</th>
<th>Non-contact (n=7)</th>
<th>Non-injury (n=106)</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>21.57±2.08</td>
<td>26.23±4.23</td>
<td>22.87±4.32</td>
<td>2.571</td>
<td>0.081</td>
</tr>
<tr>
<td>SEBT-A</td>
<td>65.51±11.12</td>
<td>63.94±3.47</td>
<td>64.60±8.07</td>
<td>0.073</td>
<td>0.929</td>
</tr>
<tr>
<td>FMS</td>
<td>8.15±3.02</td>
<td>7.27±1.78</td>
<td>7.25±1.41</td>
<td>1.204</td>
<td>0.304</td>
</tr>
<tr>
<td>WBLT</td>
<td>9.04±4.19</td>
<td>10.89±2.73</td>
<td>9.36±2.93</td>
<td>0.909</td>
<td>0.406</td>
</tr>
<tr>
<td>FAAM†</td>
<td>97.86±4.79</td>
<td>99.21±1.44</td>
<td>97.86±3.58</td>
<td>0.400</td>
<td>0.672</td>
</tr>
<tr>
<td>FAAM Sport†</td>
<td>97.14±6.39</td>
<td>94.64±8.38</td>
<td>94.73±10.06</td>
<td>0.142</td>
<td>0.867</td>
</tr>
</tbody>
</table>

† (n=5,6,78 respectively)
4.5 ROC Curves

In order to determine the predictive capability of the many variables dependent on sport, ROC curve analyses were performed (Table 4.10). When looking at football athletes, BMI had the strongest predictive capability with a cut off score of 25.07 kg/m² associating with a sensitivity of 0.688 and specificity of 0.68 and a diagnostic odds ratio of 4.69. This is the highest DOR of all variables for both sports. Its predictive capability drops when applied to basketball (DOR =2.45). All other predictive models produced diagnostic odds ratios of less than 2.5. However, it is interesting to note that there was an overall stronger predictive capability with football player ankle injuries than when compared to basketball as is evident by higher DOR for each variable in the football players.

The combining of variables – one with strength in sensitivity and the other in specificity – was also completed for each sport. This allowed for a greater DOR in both football and basketball participants. Combining active DF and SEBT-A for football athletes produced a DOR of 5.96. For basketball, SEBT-A and FAAM Sport combined for a DOR of 9.78 (Table 4.12).
Table 4.11 – ROC Cut off, Sensitivity, Specificity, Positive and Negative Likelihood Ratios, and Diagnostic Odds Ratios by Sport

<table>
<thead>
<tr>
<th></th>
<th>Cut-Off</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>+ LR</th>
<th>- LR</th>
<th>DOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>football</td>
<td>25.07</td>
<td>0.688</td>
<td>0.68</td>
<td>2.15</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>basketball</td>
<td>21.89</td>
<td>0.667</td>
<td>0.55</td>
<td>1.48</td>
<td>0.61</td>
</tr>
<tr>
<td>SEBT-A</td>
<td>football</td>
<td>63.64</td>
<td>0.438</td>
<td>0.73</td>
<td>1.62</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>basketball</td>
<td>65.44</td>
<td>0.667</td>
<td>0.43</td>
<td>1.17</td>
<td>0.77</td>
</tr>
<tr>
<td>FMS</td>
<td>football</td>
<td>5.5</td>
<td>0.5</td>
<td>0.69</td>
<td>1.61</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>basketball</td>
<td>7.5</td>
<td>0.6</td>
<td>0.43</td>
<td>1.05</td>
<td>0.93</td>
</tr>
<tr>
<td>WBLT</td>
<td>football</td>
<td>8.25</td>
<td>0.625</td>
<td>0.49</td>
<td>1.23</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>basketball</td>
<td>9.45</td>
<td>0.4</td>
<td>0.54</td>
<td>0.87</td>
<td>1.11</td>
</tr>
<tr>
<td>DF Passive</td>
<td>football</td>
<td>12.25</td>
<td>0.5</td>
<td>0.58</td>
<td>1.19</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>basketball</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DF Active</td>
<td>football</td>
<td>10.25</td>
<td>0.688</td>
<td>0.56</td>
<td>1.56</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>basketball</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FAAM</td>
<td>football</td>
<td>98.8</td>
<td>0.313</td>
<td>0.7</td>
<td>1.04</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>basketball</td>
<td>97.02</td>
<td>0.182</td>
<td>0.72</td>
<td>0.65</td>
<td>1.14</td>
</tr>
<tr>
<td>FAAM Sport</td>
<td>football</td>
<td>96.42</td>
<td>0.25</td>
<td>0.78</td>
<td>1.14</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>basketball</td>
<td>87.5</td>
<td>0.182</td>
<td>0.83</td>
<td>1.07</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table 4.12 – ROC Combining of Factors with Sensitivity, Specificity, Positive and Negative Likelihood Ratios, and Diagnostic Odds Ratios

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>+ LR</th>
<th>- LR</th>
<th>DOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active DF + SEBT-A</td>
<td>0.688</td>
<td>0.73</td>
<td>2.54</td>
<td>0.43</td>
<td>5.96</td>
</tr>
<tr>
<td>Basketball:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEBT-A + FAAM Sport</td>
<td>0.667</td>
<td>0.83</td>
<td>3.92</td>
<td>0.40</td>
<td>9.78</td>
</tr>
</tbody>
</table>
Chapter Five

Discussion

The purpose of this study was to determine if SEBT-A, WBLT, active and passive measures of DF, a modified four station FMS™, BMI, self-reported function, and a history of ankle sprain could be used effectively in the prediction of an ankle injury in high school football and basketball players while taking the MOI into consideration as well. This adds to limited studies examining predictive factors in ankle sprains that are focused specifically at high school football and basketball athletes.

5.1 Previous Injury History

Previous ankle injury as a risk factor has been an important part of many different previous studies.\textsuperscript{20,33,39} It was consistently found and supported that individuals who had sustained an ankle injury previously were more likely to sustain a subsequent injury. The chi square analysis revealed that the ankle injuries sustained during the football and basketball seasons occurred predominately in individuals who did not have a history of ankle injury. We found that previous history of ankle sprain is not likely an influential factor to increase risk for ankle injury in the adolescent population. Out of the 208 participants of the study, only 56 (27%) of the high school athletes reported a previous injury.
This is one of the first studies to consider previous ankle injury history in combination with the physical performance measures to create prediction of injury in adolescent athletes. While previous injury has demonstrated the ability to predict ankle sprains in football athletes, the information on basketball players is limited.\textsuperscript{33,75} Continued work in this area is needed, including further dividing the athletes by age or class (i.e. freshman vs. seniors) to fully illustrate the role that previous injury history may have in the prediction of acute ankle sprains. Nonetheless, our analysis did not warrant the use of previous injury history as a factor in the rest of our analyses.

\textbf{5.2 Group Differences}

When comparing group differences, only BMI was statistically significant between the injured and non-injured athletes. Those who sustained an ankle injury had a larger BMI (25.39±4.59 kg/m\textsuperscript{2}) compared to non-injured participants (23.40±4.50 kg/m\textsuperscript{2}). When further divided by MOI, individuals who sustained a non-contact ankle injury had a BMI greater than those with a contact ankle injury. When considering sport we observed football athletes to have larger BMI compared to basketball players. These observations indicate that football players, possessing a higher BMI, possibly have more risk of sustaining a non-contact ankle injury. These findings support previous research by Waterman et al.\textsuperscript{32} and Tyler et al.\textsuperscript{33} in which individuals with an increased BMI had a greater risk of sustaining ankle injuries. Tyler et al.\textsuperscript{33} also differentiated between contact and non-contact injuries in that there was an increase in non-contact injury rate as BMI increased. As BMI is an indicator of one's body fat in relation to height, with increased mass, even with the same acceleration, forces experienced during sport will increase (F=ma). The increase in non-contact injuries in those with a higher BMI may be due to
the fact that these individuals have a larger amount of force that stabilizers in the ankle may be insufficient in dissipating. The forces created by a possible inversion moment, if not matched by dynamic stabilizers will in turn lead to injury. It appears that BMI may help guide injury predictive models for high school athletes, specifically those who play football. This should be accepted with caution as BMI assesses body mass and not body composition. Differences could be found between individuals who have the same BMI, but have different body compositions in fat or muscle make up. Clearly, more specific analyses in larger data sets are needed as we are basing these statements on observations within our data. The inclusion of a body composition measure in future studies could be important as well.

While we expected athletes with ankle injury would exhibit reduced dynamic postural control compared to those without ankle injury, there was no difference in SEBT-A performance between groups. The lack of difference between groups with this functional measure contrasts previous work by Plisky et al.\textsuperscript{11} as well as previous research completed in our laboratory\textsuperscript{10,12,13,17}. The main difference between previous studies and the current study was the elimination of two directions and the composite score in the hope to focus on one direction, further simplifying the test for clinical application during pre-participation exams. The decision to use the anterior reach was based on previous research conducted within our laboratory supporting the SEBT-A as a useful predictive tool for ankle sprains.\textsuperscript{12,17} Other studies have shown a poor performance with the posterolateral direction as a risk factor for ankle sprain,\textsuperscript{9} suggesting that additional reach directions of the SEBT may need to be utilized for a more complete assessment of ankle injury risk.
We also assessed high school athletes’ functional performance using four of the seven stations of the FMS focused on the lower extremity. However, there was no difference between athletes who suffered an ankle injury during the competitive season and those who did not, which conflicts with previous reports.\textsuperscript{15,16,19,31} Kiesel et al.\textsuperscript{31} did not evaluate group differences, but the predictive capability showed strong support when used with professional football athletes. Previous work in our laboratory\textsuperscript{15,16,19} demonstrates the FMS to be a poor tool for ankle injury risk assessment. While it may be due to the subjectivity of the investigator completing the scoring, intra-rater reliability has been shown to be high.\textsuperscript{66} Continued work with the FMS is needed to determine its utility in assessing ankle sprain risk in different sport and age group populations.

The WBLT was also selected as a tool for identifying risk of ankle injuries, but did not present as a useful screening tool in our data. While previous research has shown the WBLT can assess deficits in those with CAI,\textsuperscript{62} there may be no correlation in acting as a potential risk factor assessment for acute injury. However, dorsiflexion has been assessed in previous research and its place as a potential risk factor has been presented.\textsuperscript{27,28}

While DF assessed functionally with the WBLT did not yield important results, the predictive capability of DF ROM measurements in other positions did have interesting results. Due to logistic issues during data collection, both active and passive DF measures were only assessed in football athletes. While neither active nor passive DF ROM was statistically different between the non-injured and injured groups, when further sub-divided by MOI, active DF ROM approached significance (p=0.078), with a large effect size supporting the relation between a decrease in active DF ROM and non-contact
injuries sustained. While both the WBLT and active DF measure ROM, it may be that the manner in which it is assessed makes a difference. WBLT is considered to be more functional as it is a closed kinetic chain activity while active DF was assessed in an open kinetic chain position. However, many injuries occur before the ankle is in a full weight bearing position when it is in an open packed position. The isolation of ankle function with active DF can help to focus on other indications than Achilles flexibility while the WBLT incorporates knee and hip ROM as well. Further work is needed to determine how DF measured actively in an open chain position may influence the risk of ankle sprains, especially in football players.

The last variable thought to provide some insight toward potential risk factors for ankle injuries and in turn potentially predicting ankle injuries was the use of self-reported functional questionnaires. However, no group differences were observed in the FAAM scores. We believe this is the first study to include the FAAM in the assessment of acute ankle injury risk. These questionnaires gather information on the individual’s ability to perform ADLs and are more commonly used to determine progress post injury and the individual’s perception of their ankle stability. Based on previous research perceived instability is a possible risk factor of ankle injury. From the results of our study, it may be that the use of FAAM and FAAM Sport is simply best used as it was intended to assess disability after sustaining an injury.

5.3 ROC Curve

BMI was found to have the strongest predictive capability for both football and basketball athletes, with a DOR of 4.69 and 2.45 respectively. This, in combination with results examining group differences, indicates that BMI may be a strong indicator of
ankle sprain risk, especially for prediction of non-contact injuries. Individuals with a high BMI could experience more momentum with a change direction, leaving the ankle joint unable to transfer weight and provide the dynamic stability required to protect the joint.\textsuperscript{33} This is only speculative for now and requires additionally laboratory studies to help illustrate these potential relationships.

From the current study, results indicate that SEBT-A did not have a strong predictive capability, with a DOR of 2.11 Plisky et al.\textsuperscript{11} as well as previous studies conducted within our laboratory\textsuperscript{10,12,13,17} have focused on assessing the predictive capabilities of additional aspects of the SEBT and have found contrasting results to our current data set. Previous data from our laboratory\textsuperscript{10,12,13,17} when focused on the anterior reach yielded cut off scores ranging from 64.8-67.3\%, greater than the one for the current study, with DORs ranging from 1.17 to 4.83 for prediction of ankle injury. There is no strong consistency yet with this measure, but with small to moderate effect sizes the differences seen follow the trend from previous work. While lessening the time of the functional measure would be ideal, using only the anterior direction may not have a strong enough predictive capability to make the decrease in time worth it, but further research is needed to make this decision.

The FMS does not appear to have strong ankle injury predictive capabilities for either adolescent football or basketball players based a DOR of 2.23 for football and 1.13 for basketball, respectively. As stated previously, Kiesel et al.\textsuperscript{31} showed strong predictive capabilities, while studies done in the past in our laboratory have not. These studies utilized the full FMS and not a modified version. The methodology for the study of Kiesel et al.\textsuperscript{31} is questionable as the definition of injury was not well defined. Further
research is necessary to further assess if FMS could be used as an injury predictor for high school athletes.

The remaining three variables, WBLT, active and passive DF, and the FAAM, did not have previous studies to compare to in regards to the assessing their predictive capabilities. While the WBLT and FAAM did not show much promise due to DORs of 1.6 or less, active DF assessment of the football athletes has the second highest DOR at 2.81 indicating individuals who play football with poor active DF are almost 3 times more likely to sustain an ankle injury. A decrease in DF has been reported as a potential risk factor for ankle injuries.\textsuperscript{27,28} The use of active DF ROM as a functional measure should be further evaluated for predictive capabilities in regards to ankle injuries in high school athletes.

It has been suggested that combining variables (one with a high sensitivity and one with a high specificity) could increase the DOR and in turn help to increase the predictive capability by using a battery of tests. For football athletes, the combination of SEBT-A and active DF, and for basketball athletes, SEBT-A and FAAM Sport, showed an increase in DOR, which supports the idea of combining factors to in turn increase predictive capability. Further studies are needed to determine if these combinations are the optimal or if there are other batteries of tests better suited towards ankle injury prediction.

5.4 Limitations

Our sample size is potentially small for a study aimed to assess risk factors and their predictive capabilities. The majority of effect sizes when calculated were small. Furthermore, when comparing sports, this further limited the sample sizes. There were
also inconsistencies during data collection that prevented some information from being collected. Active and passive DF ROM was only measured in football athletes, eliminating a large group of participants. There was also a school whose basketball team did not complete the FAAM and FAAM Sport that additionally constrained the sample size for this variable.

As previously mentioned, the reliability of high school students when filling out either health history or self reported function, FAAM and FAAM Sport, questionnaires is questionable in that the participants did not honestly respond or did not see the importance of truthful responses. It may be necessary to go through a brief health history questionnaire with the athlete individually and perhaps emphasizing that if they ever sustained an injury it should be reported.

There were also several different days in which the functional measures were assessed and the same individual did not always assess the same variable. All researchers who collected outcome measures did undergo reliability testing for SEBT, WBLT, and FMS. Reliability studies have been completed for these measures, all of which were shown to be strong when the investigator is properly instructed as to the protocols. \textsuperscript{24,57,66,76} However, these studies also state that investigators with more experience have a stronger measure of reliability and many researchers had just learned these measures.

Finally, there is an innate difference between the sports assessed. Football is played outdoors on grass or turf and at the high school level, and field conditions can be poor at times. There are 11 players on the football field with contact encouraged. Participants also have more equipment that must be worn when participating. Basketball
is played indoors on a flat court with only 5 players active at one time. There is less
equipment worn and contact is a much less common occurrence. The length of season
and subsequent exposures may also be a limitation in that football has a much shorter
season when compared to basketball as well. Therefore, interpretations of results from
sports comparisons should be taken with caution.

5.5 Future Applications

Based on the data obtained during this study there may be a need to look towards
other functional performance assessment tools in the future or further specifying MOI
due to the fact many variables measured were lacking in predictive capability. Active
dorsiflexion measured in an open kinetic chain position may be implemented in
preseason physical examination as an injury screening tool. While the SEBT seemed to
have a promising predictive capability based on previous research, the anterior reach had
a low DOR of 2.11. In addition, based on this study and previous studies focusing on
prediction of non-contact injuries may be more useful and successful with these pre-
participation examinations. In sport we cannot always account for the large hit a running
back sustains or landing on an opponent’s foot when coming down from a rebound so the
contact injuries will be difficult to account for in a prediction model. Clinicians should
look to focus on things we can effectively change by encouraging healthy lifestyles in
athletes to help lessen BMI in potentially overweight athletes and promote work towards
increasing active DF ROM in athletes.

5.6 Conclusion

In conclusion, individuals with higher BMI were more at risk of sustaining an
ankle injury. Future research should consider focusing on predictive capabilities on non-
contact injuries as these injuries have a higher likelihood of being modified by potential rehabilitation and preventative measures that clinicians would be able to put into use. By focusing on and identifying modifiable risk factors we can further aid in enhancing prevention techniques in reducing the ankle injury risk.
References


10. Nelson B. *Using the star excursion balance test as a predictor of lower extremity injury among high school basketball athletes:* Kinesiology, University of Toledo; 2012.


12. Pollock K. *The star excursion balance test as a predictor of lower extremity injury in high school football players:* Kinesiology, University of Toledo; 2010.

13. Sato A. *Using the star excursion balance test as a predictor of lower extremity injuries in high school basketball players:* Kinesiology, University of Toledo; 2010.


15. Ford A. *Functional movement screening as a predictor of injury in division one collegiate football athletes:* Kinesiology, University of Toledo; 2011.
16. Cuson M. *FMS scores as a predictor of acute lower extremity in division 1 intercollegiate basketball players*: Kinesiology, University of Toledo; 2010.

17. Stout M. *Predicting lower extremity injury in high school football players using the star excursion balance test*: Kinesiology, University of Toledo; 2012.

18. Moss J. *An epidemiological study of lower extremity injury rates based on age, sex, and timing of injury*: Kinesiology, University of Toledo; 2010.


Appendix A

Parental Consent Form

Department of Kinesiology
Mailstop #119
Toledo, Ohio 43696
Phone: (419) 530-2744
Fax: (419) 530-2477

RESEARCH SUBJECT INFORMATION AND CONSENT FORM
USING DYNAMIC POSTURAL CONTROL AND FUNCTIONAL TESTING TO PREDICT ANKLE INJURY IN ADOLESCENT ATHLETES

Principal Investigator: Philip Girbibo, Ph.D., ATC
Other Staff (identified by role): Abbey Thomas, R.N., ATC (Co-Investigator)
Adam Lepley, M.S., ATC (Research Assistant)
Hayley Erchum, M.S., ATC (Research Assistant)
Michele McCrumb, M.S., ATC (Research Assistant)
Maureen Tweada, M.S., ATC (Research Assistant)
Megan Quinnan, M.S., ATC (Research Assistant)
Samantha Bowler, ATC (Research Assistant)
Lauren Welch, ATC (Research Assistant)
Sarah Wilkman, ATC (Research Assistant)
Dustin Bilups, ATC (Research Assistant)
William Yang, ATC (Research Assistant)

Contact Phone number(s): (419) 530-2744, (419) 530-291

What you should know about this research study:

- We give you this consent/authorization form so that you may read about the purpose, risks, and benefits of this research study.
- Your son/daughter/legal change has the right to refuse to take part in this research or agree to take part now and change his or her mind later.
- If you decide to allow your son/daughter/legal change to take part in this research or not, or if you decide to allow your son/daughter/legal change to take part now but change your mind later, your decision will not affect his or her routine care.
- Please review this form carefully. Ask any questions before you make a decision about whether or not you want your son/daughter/legal change to take part in this research. If you decide to allow your son/daughter/legal change to take part in this research, you may ask any additional questions at any time.
- Your son/daughter/legal change participation in this research is voluntary.
PURPOSE (WHY THIS RESEARCH IS BEING DONE)

As the authorized legal representative, you are being asked to allow your son/daughter/legal charge to take part in a research study that will examine the relationship of performance on a simple dynamic balance test and functional movement tests on the rate of ankle injury.

You are being asked to allow your son/daughter/legal charge to take part in a research study that will examine the relationship between dynamic balance and functional movement and ankle injury among high school football, basketball, volleyball, soccer, baseball, softball, and cross country athletes. The purpose of the study is determine if performance on a simple balance test and functional movement tests can help predict the risk of ankle injuries that are suffered by high school football, basketball, volleyball, soccer, baseball, softball, and cross country athletes. If we are able to determine that these tests can predict these injuries effectively, in the future, researchers and clinicians may be able to screen and identify high school football, basketball, volleyball, soccer, baseball, softball, and cross country athletes that may be at risk for suffering an ankle injury and give those athletes some appropriate interventions for preventing the injuries. This study is the first step in helping to reduce the high rate of ankle injury and stability that occurs during the sports of football, basketball, soccer, volleyball, baseball, softball, and cross country.

Your son/daughter/legal charge is selected as someone who may want to take part in this study because he or she has met the following criteria:

Volunteer participant
Inclusion criteria:
- Physically active individuals medically cleared by a physician for participation in either football, basketball, volleyball, soccer, baseball, softball, and cross country. Between the ages of 14 and 24 years

Exclusion criteria:
- Lower extremity injuries (other than to the ankle), concussions or any other neurological conditions within the last 6 months prior to participation in the study.
- Previous history of any lower extremity fracture
- Previous history of surgical procedures that have caused major structural changes in the lower extremities.

Your son/daughter/legal charge is enrolling in the study as one of approximately 2300 participants from 3 high schools in the Toledo area and student athletes at the University of Toledo. This research study will be conducted by faculty and graduate students affiliated with the Athletic Training Research Laboratory in the Health Science and Human Services building at The University of Toledo. The performance of the balance and functional testing will be performed at the athletic facilities of schools that are participating.

DESCRIPTION OF THE RESEARCH PROCEDURES AND DURATION OF YOUR INVOLVEMENT

If you give consent for your son/daughter/legal charge to participate, he or she will be asked to come to his or her school on the designated testing day with this form and the Assent form that has been provided signed by you and the participating child. The testing days will coincide with arranged physical exam days at the schools where physicians and athletic trainers...
will be present to examine and clear the children for participation in basketball, football, soccer, volleyball, baseball, softball, and cross country for the upcoming school year. If your son/daughter/legal charge cannot make this designated testing date or do not have the required consent and assent forms with them, another date will be arranged to conduct this testing prior to the first day of schedule team practice.

After receiving the necessary forms and checking for completed signatures, a brief medical questionnaire will be administered by a member of the research team asking about the child’s previous leg injuries (ankles, knees, hips). This will ensure correct inclusion criteria.

Next, he or she will move to a station where the age, height and weight will be measured. Additionally, the child will be assigned an identification number in this paperwork so that their identity is kept confidential throughout the duration of this research study. Finally, a brief health history questionnaire will be administered.

At the next station, a member of the research team will demonstrate the dynamic balance test, called the Star Excursion Balance Test (SEBT). The SEBT requires the participant to stand on one leg in the middle of a grid on the floor and then try to reach with the other leg to touch a spot on the floor as far as they can along a line on the grid. If the participant loses their balance, puts too much weight on the reaching foot or moves the foot of the leg they are standing on, the reaching trial is repeated. After the demonstration, the participants will practice the SEBT standing on their right leg four times and then on their left leg four times so that they can become familiar with how to do perform the test. Then they are given five minutes to rest.

Following the practice trials and the five minute rest, the participant will move to the next station. Here the same function grid will be on the floor. The participant will perform three reaches in three different directions while standing on the right leg and three reaches in three different directions while standing on the left leg. So, the participant will perform a total of 18 reach trials at this station.

At the next station, a member of the research team will demonstrate the functional testing procedures, called the Functional Movement Screen (FMS). The FMS consists of seven different functional movements commonly performed in athletic participation. These will include 1) a deep squat test, 2) a hurdle step over test, 3) a lunge test, 4) a shoulder mobility test, 5) a push-up test, 6) a leg flexibility test test, and 7) a core stability test. All 7 will be demonstrated to your son/daughter/legal charge by the investigator and the participant may ask any clarification questions to ensure they are comfortable with the test before attempting to perform the test. For each test, 3 trials will be performed for a total of 21 trials. Your son/daughter/legal charge will be given as much time as they would like between each trial and between each of the 7 movements.

At the next station, a member of the research team will measure the amount of motion in the ankle and hip joints of your child. Hip motion will be assessed with a simple plastic measuring device while your child is laying a treatment table and the member of the research team will measure how many degrees of movement are available as the hip is rotated in and out gently. Ankle motion will be assessed while your child stands facing a wall and bends their ankle and knee. They will put their hands on the wall and move slowly into a squatting position.
until their heel starts to lift off the floor. At the point, the member of the research team will have your child pause and the measurement of the ankle position will be recorded.

At the final station, a member of the research team will measure the strength of your child’s hips. While laying on a treatment table, the member of the research team will gently place a small handheld device that measures force against the leg of your child, and then ask the child to move their leg in different directions while the member of the research team offers some mild resistance. The handheld device will provide the measure of strength as your child holds each position for approximately 5 seconds. Your child will be allowed as much time as they would like between each of the 4 movements on each leg.

After this session is complete, your son/daughter/legal charge will have no more responsibilities to perform for the study. However, a part of providing consent for participation is to give permission to the certified athletic trainer (ATC) that is providing medical coverage for the football, basketball, volleyball, soccer, baseball, softball, and cross country teams to record if your son/daughter/legal charge suffers an ankle injury during practice or competition during the season. If your son/daughter/legal charge suffers an ankle sprain, tendon injury or a fracture to the ankle, the "incident" will be recorded in a notebook. However, no personal identification information about your son/daughter/legal charge will be used by the research team members. The "incident" will be recorded using the assigned identification number, as described above, assuring that the names of the student athletes are not used. This information will be kept confidential, only accessible to the research team. Your son/daughter/legal charge will not be contacted by research team for any additional questions or performances related to this study.

The number of injury incidents will be analyzed by the research team along with the pre-season SEBT performances to determine a score that can predict the ankle injury "incidents".

This study is examining the ability of performance on dynamic balance and functional movement testing to predict ankle injury in high school and college football, basketball, volleyball, soccer, baseball, softball, and cross country athletes. Your son/daughter/legal charge will come for the single testing session described above and participate for approximately 40 minutes.

The researchers encourage you to ask any questions you have prior to or during the study. If at any time you feel your son/daughter/legal charge is unable to participate in the study or you are uncomfortable with their participation, for whatever reasons, please tell the researcher and you will be kindly dismissed from the study.

RISKS AND DISCOMFORTS YOU MAY EXPERIENCE IF YOU TAKE PART IN THIS RESEARCH
When participating in any research study, you may encounter some risks. Although the risk for taking part in this study is very low, your son/daughter/legal charge may experience one or more of the following:

1. There is a slight chance of falling during the balance and functional testing. However, he or she will be given instruction on how to perform the task and adequate practice to become comfortable with the task. An investigator will be standing nearby in the unlikely event that your son/daughter/legal charge does need assistance.
2. Your son/daughter/legal charge may experience slight soreness or tiredness during the
tasks. Having the rest periods between the tasks should help to minimize this risk.
3. Your son/daughter/legal charge may experience minor muscle soreness for two or three
days following the study similar to what is felt after a day of exercising or playing sports.
   Having the rest periods between trials should help to minimize this risk.

If your daughter/legal charge is pregnant, it is advised that she not participate in this study.
Due to balance changes during pregnancy she may have an increased risk of falling. There are
no known additional risks for pregnant women taking part in this study.

POSSIBLE BENEFIT TO YOU IF YOU DECIDE TO TAKE PART IN THIS RESEARCH

We cannot and do not guarantee or promise that your son/daughter/legal charge will
receive any benefits from this research. The benefit of participating in this study is to help further
research regarding ankle injury prevention.

COST TO YOU FOR TAKING PART IN THIS STUDY

You are not directly responsible for making any type of payment to take part in this study.
However, you are responsible for providing the means of transportation to and from the testing
site. You will not be compensated for gas for travel or any other expenses to participate in this
study. If your son/daughter/legal charge is not able to make the designated testing date, an
alternative time will be arranged to test them when they will be at the testing site.

PAYMENT OR OTHER COMPENSATION TO YOU FOR TAKING PART IN THIS RESEARCH

No compensation including money, free treatment, free medications, or free
transportation will be provided for this study.

PAYMENT OR OTHER COMPENSATION TO THE RESEARCH SITE

The University of Toledo is not receiving money or other benefits from the sponsor of this
research as reimbursement for conducting the research.

ALTERNATIVE(S) TO TAKING PART IN THIS RESEARCH

There is no alternative to taking part in this research. Exclusion from the study, however,
will not affect the quality of care you may receive at the sports medicine/physical therapy facility,
doctor’s office, or other medical facilities.

CONFIDENTIALITY

The researchers will make every effort to prevent anyone who is not on the research
team from knowing that you provided this information, or what that information is. The consent
forms with signatures will be kept separate from the information we collect, which will not include
names and which will be presented to others only when combined with other responses.
Although we will make every effort to protect your confidentiality, there is a low risk that this
might be breached.

IN THE EVENT OF A RESEARCH-RELATED INJURY

In the event of injury resulting from your son/daughter/legal charge taking part in this
study, treatment can be obtained at a health care facility of your choice. You should understand
that the costs of such treatment will be your responsibility. Financial compensation is not
available through The University of Toledo or The University of Toledo Medical Center.
signing this form you are not giving up any of the legal rights of your son/daughter/legal charge
as a research subject.

In the event of an injury, contact Phillip Gribble, PhD, ATC (419) 530-2091

**VOLUNTARY PARTICIPATION**
Taking part in this study is voluntary. You may refuse to allow participation or discontinue
participation by your son/daughter/legal charge at any time without penalty or a loss of benefits
to which he or she are otherwise entitled. If you decide not to allow your son/daughter/legal
charge to participate or to discontinue participation, your decision will not affect your future
relations with the University of Toledo or The University of Toledo Medical Center.

**NEW FINDINGS**
You will be notified of new information that might change your decision to be in this study
if any becomes available.

**OTHER IMPORTANT INFORMATION**
There is no additional information

**ADDITIONAL ELEMENTS**
There are no additional elements to the study.

CONTINUED NEXT PAGE
OFFER TO ANSWER QUESTIONS

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. If you have questions regarding the research at any time before, during or after the study, you may contact Phillip Gribble, PhD, ATC (419) 530-2691.

If you have questions beyond those answered by the research team or your rights as a research subject or research-related injuries, please feel free to contact the Chairperson of the University of Toledo Biomedical Institutional Review Board at 419-383-6796.

SIGNATURE SECTION (Please read carefully)

YOU ARE MAKING A DECISION WHETHER OR NOT TO ALLOW PARTICIPATION IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES THAT YOU HAVE READ THE INFORMATION PROVIDED ABOVE, YOU HAVE HAD ALL YOUR QUESTIONS ANSWERED, AND YOU HAVE DECIDED TO ALLOW YOUR SON/DAUGHTER/LEGAL CHARGE TO TAKE PART IN THIS RESEARCH.

BY SIGNING THIS DOCUMENT YOU AUTHORIZE US TO USE OR DISCLOSE YOUR PROTECTED HEALTH INFORMATION AS DESCRIBED IN THIS FORM.

The date you sign this document to enroll in this study, that is, today’s date, MUST fall between the dates indicated on the approval stamp affixed to the bottom of each page. These dates indicate that this form is valid when you enroll in the study but do not reflect how long you may participate in the study. Each page of this Consent/Authorization Form is stamped to indicate the form’s validity as approved by the UT Biomedical Institutional Review Board (IRB).

Name of Subject (please print)  Signature of Subject or Person Authorized to Consent  Date

Relationship to the Subject (Healthcare Power of Attorney or Legal Guardian)  Time a.m. p.m.

Name of Person Obtaining Consent (please print)  Signature of Person Obtaining Consent  Date

Name of Witness to Consent Process (when required by ICH Guidelines) (please print)  Signature of Witness to Consent Process (when required by ICH Guidelines)  Date

YOU WILL BE GIVEN A SIGNED COPY OF THIS FORM TO KEEP.
Appendix B

Assent Form

Protocol # 16663
Version Date: 10/11/2013
Department of Kinesiology
Mailstop #110
Toledo, Ohio 43606
Phone (419) 530-2741
Fax (419) 530-2744

RESEARCH SUBJECT ASSENT FORM

USING DYNAMIC POSTURAL CONTROL AND FUNCTIONAL TESTING TO PREDICT ANKLE INJURY IN ADOLESCENT ATHLETES

Principal Investigator: Phillip Grizzle, Ph.D., ATC
Other Staff (identified by role): Abbey Thomas, PhD, ATC (Co-Investigator)
Adam Lepley, MS, ATC (research assistant)
Hayley Erickson, MS, ATC (research assistant)
Michelle McLeod, MS, ATC (research assistant)
Manahiti Teraa, MS, ATC (research assistant)
Megan Quinlan, MS, ATC (research assistant)
Samantha Bowker, ATC (research assistant)
Lauren Welsch, ATC (research assistant)
Sarah Wilhelm, ATC (research assistant)
Dustin Billups, ATC (research assistant)
William Yangum, ATC (research assistant)

Contact Phone number(s): (419) 530-2091, (419) 530-2744

- You are being asked to be in a study to help understand injury better.
- You should ask any questions you have before making up your mind. You can think about it and discuss it with your family or friends before you decide.
- It is okay to say "No" if you don't want to be in the study. If you say "Yes" you can change your mind and then quit the study at any time without any problems.

We are doing a research study about ankle injuries during sports and how we can prevent them. A research study is a way to learn more about people. If you decide that you want to be part of this study, you will be asked to come to your school before football, basketball, volleyball, soccer, baseball, softball, and cross country practice starts for the year and do a balance and functional test. The researchers will measure how far you can reach with one leg while standing on the other leg. How far you can reach will tell them how good your balance is. Also, we will look at flexion of your hips and ankles are, and how strong your hips are. During the football, basketball, volleyball, soccer, baseball, softball, and cross country seasons at your school, we will be working with the Athletic Trainer to find out how many ankle injuries happen. Then we will try to use the balance scores to help understand the ankle injuries happen.

There are a few small risks if you participate. There is a small chance you could fall over during the balance test. But, we will give you practice to make sure you feel good about doing the balance test before you do it. Also, we will make sure there is someone standing close by in case you feel unstable. Finally, even though the test doesn't take very long, we will make sure you have a chance to rest in case...
Not everyone who takes part in this study will benefit. A benefit means that something good happens to you. We think these benefits might be that it will help doctors, athletic trainers, and coaches prevent ankle injuries in the future. We want to use balance and functional tests that athletes can do at their schools to help find out who may need extra help in preventing an ankle injury before they start playing football, basketball, volleyball, soccer, baseball, softball, and cross country.

Before you do the balance tests, we will ask you some questions about any injuries to your ankles, knees, hips or head you've in the past. After that, we will measure how tall you are and how much you weigh. Then, we will measure how long your legs are, which is used to calculate your balance score after you do the balance test.

Finally, after your football, basketball, volleyball, soccer, baseball, softball, and cross country seasons starts, we will be talking with your school's athletic trainer about how many ankle injuries happened each week. He or she will tell us if you or any other teammate got hurt. They will not tell us your name if you get hurt. You and all of your teammates will be given a code number so that we can know who got hurt and compare it to your balance score, but we won't actually know your name. We will only know the code number.

When we are finished with this study we will write a report about what was learned. This report will not include your name or say that you were in the study.

If you have any questions about the study, you can ask Dr. Phillip Gribble or one of the investigators. You can call the investigator listed at the top of this page if you have a question later.

You do not have to be in this study if you do not want to. You can decide later if you want to think about it for awhile. If you decide to be in this study, please print and sign your name below.

I__________________________, want to be in this research study.

(Print your name here)

Sign your Name: ________________________ Date: __________
Appendix C

Health History Questionnaire

Subject # ______
Name ______________________________________________
Date of Birth _______ Height _______ Weight _______
Team ______________________________________________
Sex: M F Dominant Leg: R L

1. Have you ever experienced a head injury? Y N
   If Yes, number of injuries? ____________
   If Yes, when was the most recent? ____________

2. Have you ever suffered a significant back injury causing you to interrupt your
   sport activity? Y N
   If Yes, when was the most recent incident? ____________
   What was the cause of the back injury/pain? ____________

3. Have you ever suffered a fracture to any part of your leg, ankle or foot? Y N
   If yes, which bone(s) was fractured? _______________________
   When did the fracture occur? _______________________

4. Have you ever suffered a significant knee injury causing you to interrupt your
   sport activity? Y N
   a. If Yes, when was the most recent incident? ____________
      What was the cause of the knee injury/pain?
   b. Did the injury require surgery? Y N
      If yes, when was the surgery? ____________
   c. Did the injury require rehabilitation with an athletic trainer or physical
      therapist? Y N
      If yes, how long did the rehab last? ____________
      How long ago did you stop rehab? ____________
   d. Do you currently wear a brace for your knee during physical activity? Y N
      If yes, how long have you been wearing the brace? ____________
      If yes, do you wear the brace during all physical activity, or just during
      competitions? ____________
      If no, how long ago did you discontinue wearing the brace? ____________
5. Have you ever suffered a significant ankle injury causing you to interrupt your sport activity? Y N
   a. If Yes, when was the most recent incident? __________
      What was the cause of the ankle injury/pain? __________
   b. Did the injury require surgery? Y N
      If yes, when was the surgery? Y N
   c. Did the injury require rehabilitation with an athletic trainer or physical therapist? Y N
      If yes, how long did the rehab last? __________
      How long ago did you stop rehab? __________
   d. Do you currently wear a brace for your ankle during physical activity? Y N
      If yes, how long have you been wearing the brace? __________
      If yes, do you wear the brace during all physical activity, or just during competitions? __________
      If no, have you ever worn an ankle brace during physical activity? Y N
      If you have worn an ankle brace before but are not currently, how long has it been since you discontinued using the brace? __________
      If you have worn an ankle brace before but are not currently, do you currently have your ankles taped for physical activity? Y N

6. Have you ever suffered a significant hip injury causing you to interrupt your sport activity? Y N
   a. If Yes, when was the most recent incident? __________
      What was the cause of the hip injury/pain? __________
   b. Did the injury require surgery? Y N
      If yes, when was the surgery? Y N
   c. Did the injury require rehabilitation with an athletic trainer or physical therapist? Y N
      If yes, how long did the rehab last? __________
      How long ago did you stop rehab? __________
## Appendix D

### FAAM and FAAM Sport

<table>
<thead>
<tr>
<th>Foot and Ankle Ability Measure (FAAM)</th>
<th>Activities of Daily Living Subscale</th>
</tr>
</thead>
<tbody>
<tr>
<td>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 “Not Applicable” (N/A).</td>
<td>No Difficulty</td>
</tr>
<tr>
<td>Walking on even ground</td>
<td>![ ]</td>
</tr>
<tr>
<td>Walking on even ground without shoes</td>
<td>![ ]</td>
</tr>
<tr>
<td>Coming up on your toes</td>
<td>![ ]</td>
</tr>
<tr>
<td>Walking 5 minutes or less</td>
<td>![ ]</td>
</tr>
<tr>
<td>Walking 15 minutes or greater</td>
<td>![ ]</td>
</tr>
</tbody>
</table>
Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living Subscale
Page 2

Because of your foot and ankle how much difficulty do you have with:

<table>
<thead>
<tr>
<th></th>
<th>No Difficulty at all</th>
<th>Slight Difficulty</th>
<th>Moderate Difficulty</th>
<th>Extreme Difficulty</th>
<th>Unable to do</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home responsibilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activities of daily living</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal care</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light to moderate work (standing, walking)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy work (push/pulling, climbing, carrying)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreational activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How would you rate your current level of function during your usual activities of daily living from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities.

__ __ __. 0 %

### Foot and Ankle Ability Measure (FAAM) Sports Subscale

Because of your foot and ankle how much difficulty do you have with:

<table>
<thead>
<tr>
<th>Activity</th>
<th>No Difficulty at all</th>
<th>Slight Difficulty</th>
<th>Moderate Difficulty</th>
<th>Extreme Difficulty</th>
<th>Unable to do</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jumping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting and stopping quickly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutting/lateral Movements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to perform Activity with your Normal technique</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to participate In your desired sport As long as you like</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How would you rate your current level of function during your sports related activities from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities?

__ ___ . 0% 

Overall, how would you rate your current level of function?

- [ ] Normal
- [ ] Nearly Normal
- [ ] Abnormal
- [ ] Severely Abnormal

Appendix E

Data Collection

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Age</th>
<th>Gender</th>
<th>Height (in)</th>
<th>Height (cm)</th>
<th>Weight (lbs)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arm Dominance (1R, 2L)</th>
<th>Leg Dominance (1R, 2L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant</td>
<td>Previous Inj Hx</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Prev head injury? (&lt;V/N&gt;)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FRACTURE</th>
<th>Which bone(s)?</th>
<th>Date of fx</th>
<th>Prev sig knee injury? (&lt;V/N&gt;)</th>
<th>Date of most recent knee injury</th>
<th>Cause of knee injury or pain?</th>
<th>Require surgery? (&lt;V/N&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Date of surgery</th>
<th>Require rehab? (Y/N)</th>
<th>Length or rehab? (days)</th>
<th>Last date of rehab?</th>
<th>Currently wear a knee brace during PA? (Y/N)</th>
<th>How long been wearing knee brace? (days)</th>
<th>Wear during all PA or only competition? (all or comp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>When discontinue wearing knee brace? (days)</th>
<th>Prev sig ankle injury? (Y/N)</th>
<th>Date of most recent injury</th>
<th>Cause of ankle injury or pain?</th>
<th>Require surgery? (Y/N)</th>
<th>Date of surgery</th>
<th>Require rehab? (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANKLE</td>
<td>HIP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-----</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length or rehab? (days)</td>
<td>Date of most recent injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last date of rehab?</td>
<td>Cause of hip injury or pain?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Currently wear a ankle brace during PA? (Y/N)</td>
<td>Require surgery? (Y/N)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How long been wearing ankle brace? (days)</td>
<td>Date of surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wear during all PA or only competition? (all or comp)</td>
<td>Require rehab? (Y/N)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When discontinued wearing ankle brace? (days)</td>
<td>Length of rehab? (days)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prev sig hip injury? (Y/N)</td>
<td>Last date of rehab?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### FADI/FAAM

<table>
<thead>
<tr>
<th>Participant Code</th>
<th>FAAM - ADLs</th>
<th>FAAM - Sport</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Ankle ROM

<table>
<thead>
<tr>
<th>Participant Code</th>
<th>WBLT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant Code</td>
<td>Trial 1</td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hurdle Step</th>
<th>Left</th>
<th></th>
<th></th>
<th>Min.</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IN-Line</th>
<th>Right</th>
<th></th>
<th></th>
<th>Min.</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LUNGE</td>
<td></td>
<td>ACTIVE STRAIGHT LEG RAIS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------------------------</td>
<td>-------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial</td>
<td>Left</td>
<td>Min.</td>
<td>Right</td>
<td>Min.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>Trial 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>Trial 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>FINAL SCORES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RIGHT</td>
<td>LEFT</td>
<td>TOTAL</td>
</tr>
<tr>
<td>Trial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix F

Athlete Exposure Tracking

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Number of athletes</th>
<th>Practice or Game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>11/18/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td>11/19/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td>11/20/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thursday</td>
<td>11/21/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friday</td>
<td>11/22/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturday</td>
<td>11/23/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunday</td>
<td>11/24/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monday</td>
<td>11/25/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td>11/26/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td>11/27/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thursday</td>
<td>11/28/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friday</td>
<td>11/29/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturday</td>
<td>11/30/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunday</td>
<td>12/1/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monday</td>
<td>12/2/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td>12/3/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td>12/4/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thursday</td>
<td>12/5/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friday</td>
<td>12/6/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturday</td>
<td>12/7/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunday</td>
<td>12/8/2013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix G

**Injury Tracking**

<table>
<thead>
<tr>
<th>JMV</th>
<th>Name</th>
<th>Injury Date</th>
<th>Specific Diagnosis</th>
<th>Body Location</th>
<th>Type (Traumatic or Overuse)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mechanism
(Contact or Non-Contact)  Specific MOI

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Specific MOI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active with pain (AWP), Activity modified with pain (AMWP), Activity stopped (ASTOP)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Days (#): active with pain, modified activity with pain, or rest.</th>
<th>Wearing ankle brace? (Y or N)</th>
<th>Practice or game? (P or G)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
