Evaluating risk of injury to the lower extremity in collegiate football athletes using clinical screening tools and BMI

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A Thesis
titled
Evaluating Risk of Injury to the Lower Extremity in Collegiate Football Athletes using Clinical Screening Tools and BMI
by
William T. Yungtum
Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Master of Science Degree in Exercise Science

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The University of Toledo
May 2015
An Abstract of
Evaluating Risk of Injury to the Lower Extremity in Collegiate Football Athletes using Clinical Screening Tools and BMI

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Context: Pre-participation exams are conducted at the beginning of the respected sports seasons to help identify any biomechanical deficiencies of athletes before the upcoming season. There have been multiple ways to suggest if an athlete has any biomechanical deficiency but not one gold standard test to determine who is at a higher risk of injury due to these deficiencies. For this study, biomechanical deficiencies were assessed using four methods: the modified functional movement screen (MFMS), the weight bearing lunge test (WBLT), the anterior reach of the star excursion balance test (SEBT-A) and body mass index (BMI). Objective: To determine if the MFMS, WBLT, SEBT-A, and BMI can identify individuals at higher risk of a non-contact lower-extremity injury within the population of a division I collegiate football. Secondary objective is to determine if differences in scores were seen between injury groups (contact or non-contact) and player position (skilled or linemen) groups. Design: Prospective cohort study. Settings: University of Toledo football athletic complex. Participants: A total of 82 division I collegiate football players (82 males) participated in this study. Methods: Participants
underwent a pre-season screening which included the MFMS, SEBT-A and WBLT. A total of 3 acceptable MFMS trials were performed scored on a 0-3 scale, and then an averaged. The MFMS consists of the deep squat, hurdle step, inline lung, and active straight leg raise. For the WBLT, participants performed the test until maximum dorsiflexion range of motion distance of the ankle was met; they were progressed at 1cm increments until max reach distance was met. For the SEBT-A, 4 practice trials were performed followed by 3 successful recorded trials, test was done bilaterally. Normalized scores from each extremity were averaged together to determine maximum reach distance. Participants injured extremity reach distance side from the injured group were normalized and used for analysis. Following pre-season screening, injuries were tracked for the remainder of the season and defined as an injury to the ankle or knee resulting from participation in an organized, intercollegiate practice or competition, the injury requiring medical attention by a team-certified athletic trainer or physician, and the resulting in restriction of the student athlete’s participation or performance for one or more calendar days beyond the day of injury. Independent t-test was used to analyze all data with alpha set at 0.05. Results: 17 athletes who sustained a lower-extremity injury during practice or competition (ages 18.2±0.5, height = 185.24±4.62cm, weight=94.64±10.81kg) and 65 players who did not experience a lower-extremity injury (age 20.01±1.3 years, height=186.5±7.55cm, weight=106.35± 19.24kg.). There were no significant differences found using the MFMS, SEBT-A, and WBLT to indicate risk of injury or differences in scores. BMI of linemen (33.79 kg/m²±3.16 kg/m²) vs. skilled player (27.69kg/m²±2.45 kg/m²) was shown to be significantly greater (p-value ≥ 0.00). Conclusion: The data suggest it is still undetermined if the MFMS, SEBT-A, and the
WBLT are valid pre-participation screening tools to determine non-contact, lower-extremity injuries in collegiate football athletes. Further research is needed to determine the usefulness of these pre-participation screens.
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Chapter 1

Introduction

1.1 Background

Pre-participation exams (PPE) are completed before collegiate sports seasons to identify any health-related concerns for the athletes’ participation in the upcoming season. Ultimately, the PPE aims to decrease the risk of injury and illness, improve athletic performance, and improve overall quality of life during and after the athletes’ participation in the sport.¹ Despite the emphasis on these goals of PPE, individuals participating in highly competitive sports such as football are in danger at making these goals difficult.² In a systematic review conducted by Dick et al² he found injury rates throughout division I, II, and III college football teams have remained steady throughout the years even with these goals in mind. These injury rates ranged from 32.4-39.3 per 1000 athletic exposure during games throughout the 1988-2004 football seasons and 3.5-4.5 per 1000 athletic exposures during practices.² Studies have shown that ankle and knee injuries are the most common types of musculoskeletal injuries in football.³⁵ A 16% increase in participation has occurred during the past decade in intercollegiate sports, with the highest increase of participation in football.⁶ Due to the increase in the number
of athletes participating in football, the number of injuries are expected to increase as well.

Recently, greater emphasis has been placed on finding more comprehensive screening tools that can identify athletes’ risks for specific injuries.\textsuperscript{1,7,8} The functional movement screen (FMS), weight bearing lunge test (WBLT), and star excursion balance test (SEBT) have been used previously to identify lower-body biomechanical imperfections that may lead to injury with most differences seen between a healthy population and an injured population.\textsuperscript{7,9,10}

The FMS is an evaluation tool that attempts to analyze the quality of specific movement patterns. Cook et al.\textsuperscript{1} observed many individuals who perform at very high levels during activities such as collegiate sports are unable to perform some of the FMS tasks, which they attributed to compensatory movement patterns. An athlete’s risk of injury may increase due to poor biomechanics that are caused by these compensatory movements.\textsuperscript{1} In its original form, the FMS includes seven movement assessments encompassing upper and lower body movement requirements. Recent work from our laboratory suggests the Modified Functional Movement Screen (MFMS) is more effective and time efficient in indicating lower-extremity injury when focusing on the lower body.\textsuperscript{11} The MFMS, which only includes the four lower body tests (deep squat, in-line lunge, active straight leg raise, and hurdle step), may be more beneficial for determining injury risk to the lower extremity in football athletes, since the majority of musculoskeletal injuries occur in the lower extremity.\textsuperscript{4}

Another clinical outcome measure of importance to lower extremity injury risk may be ankle dorsiflexion.\textsuperscript{12} Triceps surae muscle tightness and arthrokinematic
restrictions in the ankle are commonly associated with a decrease in range of motion at the ankle. Previous studies have shown decreased range of motion at the ankle may alter an individual’s jogging pattern. This may lead to compensation at the knee and hip to make up for the restrictions at the ankle, which could ultimately cause unwarranted chronic injury to the ankle, knee, hips, or lower back. Decreased range of motion at the ankle, specifically dorsiflexion, can be assessed and identified during a PPE by using assessment tools such as the weight bearing lunge test (WBLT). The WBLT has the capability to indirectly examine the functional aspects of the ankle by quantifying closed kinetic chain ankle dorsiflexion. This test may be more beneficial than that of the basic goniometer reading because of functional aspect needed to perform the test. This may ultimately identify those individuals who are at a higher risk of injury to the lower body.

Performing at a high level of competition requires an individual to have good dynamic postural control; however, when this postural control is lacking, it may lead to a decrease in performance during competition. In addition to a hindrance in performance, individuals who lack dynamic control and have poor control of body segments may be at an increased risk of injury to areas of the body such as the ankles and knees. A positive relation between ankle dorsiflexion range of motion (DFROM) and dynamic balance measures in individuals with chronic ankle instability has been reported. A limitation in ankle dorsiflexion can also limit the amount of dynamic activities that can be performed, such as jogging and dynamic balance.

A common technique to assess dynamic balance deficits in patients is using the star excursion balance test (SEBT). It requires the participants to stand on one leg while reaching out as far as possible in specific directions with the opposite leg. It was found
that among all the reach directions of the SEBT, the strongest correlation to ankle
dorsiflexion was the anterior reach.\textsuperscript{12} The SEBT has had limited application for
identifying risk of injury. Plisky et al\textsuperscript{7} found high school basketball players who had
greater side-to-side anterior reach distance discrepancies were approximately 2.5 times
more likely to sustain a lower body injury. This demonstrates that the anterior reach of
the star excursion balance test (SEBT-A) could be used as an assessment tool during PPE
to assess dynamic balance deficits as an indicator of risk for injuries to the lower
extremities.

An area that has not been examined fully within division one collegiate football
players, yet may add importance to understanding of predisposition to injury, is body
mass index (BMI). Previous research has indicated that elevated BMI may increase an
athlete’s injury risk.\textsuperscript{16} A wide variety of body types exist in football in order to suit the
demands of various positions, which require different levels of height, weight, strength,
or speed. Thus, specific position groups, particularly ones that tend to have a greater
BMI, such as the linemen on the team, may be at greater risk of injury and may have
poorer performance on screening tests.

Injuries within player positions are another topic of interest with the sport of
football. Bradley et al.\textsuperscript{17} broke down NFL football player position, on both the offensive
and defensive side of the ball, and the percentage of ACL injuries that occurred over five
year span. On the offensive side of the ball running backs and linemen reported very
similar measures (30\% of player position) and on the defensive side of the ball secondary
and linemen reported similar measures (35\% of player position).\textsuperscript{17} We were interested in
the different position groups due to controversy within research related to injury to the lower extremity.

Many studies have been conducted to determine if risk injury of non-contact, lower-extremity injuries, such as anterior cruciate ligament (ACL) tears, can be decreased by implementing preventative programs.\textsuperscript{18-20} These clinical assessment tools in this study may have a potential to indicate biomechanical deficiencies that may contribute to these non-contact injuries. If these biomechanical imperfections can be identified, possible future implementation of preventative programs may be advantageous with decreasing non-contact injuries.

The above clinical assessments have potential for identification of risk of lower extremity. However, the application of these tests in football player populations is extremely limited, making it unclear if these tools may be useful for helping to alleviate some of the highest injury rates observed in competitive sports.

1.2 Problem Statement

Football has injury rates among the highest in all of collegiate athletics.\textsuperscript{21} Currently, most PPEs are not sufficient at identifying athletes predisposed to lower-body injuries. There is some evidence supporting the ability of assessments of functional movements to identify injury risk, but further research is needed. Identification of those at a higher risk of an injury using functional movements, while also considering BMI, at the beginning of the season could help determine the most effective preventions for these athletes.

1.3 Purpose Statement
The purpose of this study is to determine if there are prospective differences on the MFMS, WBLT, and SEBT-A, along with BMI, between individuals who sustain a lower extremity injury and those who do not. A secondary purpose of this study is to determine, within the injured population, if these clinical screening tools can detect differences between athletes who sustained a contact versus a non-contact injury. A tertiary purpose of this study is to determine if there are differences between player position and their scores on the MFMS, WBLT, and SEBT-A.

1.4 Hypothesis

H1: Participants with lower-extremity injuries during the season will have lower scores and measurements on the MFMS, WBLT, and SEBT-A, and a higher BMI during the PPE.

H2: Participants who are classified as having a non-contact injury will show to have worse scores on the MFMS, WBLT, and SEBT-A along with having a higher BMI than those classified as having a contact injury.

H3: The linemen position group will show a significant difference in scores on the MFMS, WBLT, and SEBT-A compared to the skilled group.
Chapter 2

Literature Review

2.1 Epidemiology of Lower-Extremity Football Injuries

Football is one of the most popular sports in the United States; over 60,000 collegiate male athletes and over 1 million high school male athletes played football in 2005. Football is also the leading cause of sports-related injuries in the United States, with an injury rate almost twice that of basketball, the second most popular sport in the United States. Football accounts for approximately 600,000-1.2 million injuries annually within the United States. Dick et al. tracked the rate of injury in NCAA college football players from 1988-2004. Over 16 years the rate of injury during games (35.9 per 1000 athletic exposures) was approximately 9 times higher than the practice injury rate (3.8 per 1000 athletic exposures). Rechel et al. found injury rates in high school football players of 12.09 per 1000 athletic exposures during competition and 2.54 per 1000 athletic exposures during practices. While injury rates are well-defined, evidence is lacking in the area of identifying possible relationships between pre-participation screens that could identify injury risk and injury rate.

2.1.1 Injury Distributions
The majority of sports-related musculoskeletal injuries occur in the lower extremity with children and young adults (ages 5-24) accounting for nearly two thirds of these injuries. Fernandez et al estimated that 807,000 lower-extremity injuries occur in high school athletes annually in the United States. Of all the sports analyzed by Fernandez et al, football had the leading injury rate of 2.01 for every 1000 athletic exposures. Nearly 60% of all injuries to collegiate football players are sustained to the lower extremities, and approximately half of the lower extremity injuries involve ligamentous sprains.

A vast majority of all injuries to the ankle are ligament injuries (75%), with inversion ankle sprains comprising 85% of those injuries. Football injuries affect mostly the ankle and knee joints, as well as their surrounding musculature; 20.5% of those injuries were to the lower leg/ankle, along with another 31.7% to the knee/thigh when compared to the rest of the joints in the body. The next most injured joint was found to be the shoulder with injuries occurring 13.2% of the time. Kaplan et al analyzed the incidence of foot and ankle injuries in elite college football players. They found the most common type of injury of the foot and ankle was the lateral ankle sprain, occurring in 31.3% of the participants. Syndesmotic sprains occurred in 14.7% of the participants, and turf toe/MTP dislocation was third, occurring in 10.9% of the participants.

One reason the ankle and lower leg are injured so frequently is due to the forces they withstand while supporting the body’s mass: supporting more of the body’s weight per unit area than any other joint. Mechanical and functional instability may predispose athletes to sprains of the knee and ankle. As many as 70% of athletes will have
lingering signs and symptoms of chronic ankle instability such as feelings of ankle instability, pain, swelling, and recurrent lateral ankle sprains after they have sustained a single lateral ankle sprain.\textsuperscript{26} Those who have had an anterior cruciate ligament (ACL) injury and ultimately surgical procedure, have a 50-80% chance of osteoarthritis developing.\textsuperscript{27} Due to the discomfort and pain knee osteoarthritis causes, the individual may not be able to perform daily tasks that were once pain free; this may ultimately affect the performance of an athlete.

2.1.2 Mechanism of Injuries

Mechanisms of injury can be categorized as non-contact and contact, which can be further broken down into object contact (i.e. balls, blocking dummies, and ground) and player-to-player contact.\textsuperscript{2} The majority of game (78%), fall practice (57%), and spring practice (69%) football injuries result from player contact.\textsuperscript{2} Non-contact injuries occur half as often as player contact injuries but were more common than object-contact injuries.\textsuperscript{2} Contact injuries during football do not appear to be predictable, due to the erratic occurrences of collisions. Non-contact, lower-extremity injuries may be caused by biomechanical imperfections and improper movement technique.\textsuperscript{1} Detrimental movement patterns may be identified by clinical tests; and thus, they could be predictors of non-contact injuries.

The most common mechanisms for lateral ankle sprain are excessive foot inversion or supination, extreme plantar flexion, or a combination of both inversion with plantar flexion.\textsuperscript{24} When considering the knee, any kind of increased varus alignment may result in extreme tensile force of the lateral capsular and ligamentous tissues while increasing medial tibiofemoral contact force, both of which may lead to structural
If a participant has valgus misalignments, the opposite structures would become damaged. The medial capsular ligaments would have excessive tensile forces placed on them, along with unwarranted compressive forces to the lateral tibiofemoral joint line. It was found by Dick et al that nearly 55% of ACL injuries occurring over a 15-year period happened due to rotational forces accompanied with a planted foot. This mechanism is often considered to be a non-contact type of injury.

2.1.3 Differences for positions

One modifiable risk factors that has a significant relationship to injury risk is BMI. BMI is defined as an indirect estimation of the percentage of body fat of an individual. The most commonly used threshold to define obesity is a BMI score of greater than 27.0 kg/m$^2$. Wilkerson et al found in those football players whom have a BMI $\geq$ 32.7 kg/m$^2$ had a better predictive value of sustaining a lower body injury. Due to the nature of the game of football the two player positions to have the highest BMI are offensive and defensive linemen. Considering the presence of high BMI in certain football positions and the elevated risk of injury for those with a higher BMI, assessment of BMI within a cohort may be an effective means for injury risk identification. However, the relationship between BMI and functional pattern deficits has never been addressed.

Knee injuries and their relation to position differ from the ankle. Research by Bradley et al found the three most common positions to sustain a knee injury were defensive linemen (68%), tight ends (64.3%), and offensive linemen (57.4%). The three positions with the lowest risk of knee were placekickers (27.3%), quarterbacks (29.2%), and defensive backs (51.2%). It was also
When considering player position groups within the sport of football, some may question whether a certain position will be injured more frequently than others. Kaplan et al\(^3\) studied the incidence of contact and non-contact injuries in the foot and ankle in college football players careers and discovered 82.8% of running backs had a foot/ankle injury, followed by 82.5% of wide receivers, and finally 80% of offensive linemen. The groups with the lowest rate of foot/ankle injury were linebackers (66.7%), tight ends (61.9%), and quarterbacks (52.0%).\(^3\) Conversely, Tyler et al\(^{33}\) found overweight players with a previous ankle sprain were 19 times more likely to sustain a non-contact ankle sprain than those with normal body weight and no previous ankle sprains. These investigators also discovered players classified as overweight were approximately four times more likely to sustain recurring ankle sprains.\(^{33}\)

### 2.1.4 Influence of Previous Injury

Some evidence suggests that previous history of injury has a role in the likelihood of suffering an injury. Arnason et al\(^{34}\) found that a previous strain or sprain on the same side of the body to the lower extremity was found to be a strong predictor for a new injury of the same type and location. A previous history of knee injury, ankle sprain, groin strain, and hamstring strain predisposes an athlete to a subsequent injury four to seven times more often than those without a previous injury.\(^{34}\) Hagglund et al\(^{35}\) learned elite football players suffering an injury during one season had a nearly three times greater risk of suffering an injury the following year.\(^{35}\) The risk of injury increased as the number of injuries a player sustained during the previous season increased.\(^{35}\) In congruence with Arnason et al\(^{34}\), Hagglund et al\(^{35}\) also learned previous hamstring injury,
Injury, and knee joint trauma were associated with a two to three times increased risk of an identical injury in the same leg.

Tyler et al\textsuperscript{33} found that football players with a previous ankle sprain were 6.5 times more likely to have another ankle sprain. McHugh et al\textsuperscript{36} found there was a significant correlation between previous ankle sprains and non-contact lateral ankle sprains. On the other hand McHugh et al\textsuperscript{36} found there to be no correlation of sustaining a lateral ankle sprain if the individual had a previous history along with having a high BMI. This is a controversial subject considering there have been multiple studies to suggest that an increase in BMI increases the risk of injury,\textsuperscript{16,31,33} and previous history increases the risk of injury\textsuperscript{33,34}.

2.1.5 Definition of Injury

For the purposes of this study, an athletic injury was defined as follows: an injury to the ankle or knee resulting from participation in an organized, intercollegiate practice or competition; requiring medical attention by a team-certified athletic trainer or physician, and resulting in restriction of the student athlete’s participation or performance for one or more calendar days beyond the day of injury.\textsuperscript{37} A non-contact injury is defined as an injury sustained by an athlete without extrinsic contact by another player or object on the field.\textsuperscript{18} A contact injury is defined as an injury sustained to the lower body as a result of direct contact to the body by another player or object during the course of practice or a game.\textsuperscript{18}

2.2 Prevention of injury

2.2.1 Identifying risk
One responsibility of many health care professionals is the prevention of injuries and illness. In order to prevent sports-related injuries, risk factors associated with the injuries must be identified. Once the level of risk has been identified, individualized interventions can be implemented to counteract their effects. In football, injuries to the lower body are more common than the upper body.\(^4,23\) The most common types of lower-body injuries are sprains, strains, and contusions to the ankle and knee joints.\(^4,23,24,38\)

It is common to classify risk factors into two separate categories: modifiable risk factors and non-modifiable risk factors.\(^16\) Modifiable risk factors are those that may be able to be changed through rigorous training or conditioning, such as strength, BMI, and flexibility.\(^16\) Non-modifiable risk factors are those that cannot be changed easily, if at all.\(^16\) Potential factors that may cause sports related injury are flexibility, muscle strength, joint stability, and neuromuscular control.\(^39\) When considering neuromuscular control, a study conducted by Hewett et al\(^40\) found that during a jump landing, knee abduction angle was greater in ACL injured athletes when compared to uninjured athletes. Athletes who went on to sustain an ACL injury had a 2.5 times greater knee abduction moment and 20% greater vertical ground reaction force than uninjured athletes.\(^40\) Therefore, athletes at higher risk of an ACL injury experience an increased dynamic valgus load during landing.\(^40\)

Another consideration to think about is the two types of risk factors associated with injury: intrinsic and extrinsic risk factors. Some examples of intrinsic risk factors are muscle weakness, bony deformities, and flexibility.\(^41\) Extrinsic risk factors are those caused by outside factors such as training patterns, poor technique, footwear, and training surfaces.\(^41\)
Calcaneal eversion, rotation, and muscle strength imbalances place individuals at a higher risk of inversion ankle sprain occurrences. Along with that, men are found to sustain more ankle injuries if they had an increase in tilt of their talus. Lateral ankle sprains and chronic ankle instability occur more often in individuals who have a hypermobile subtalar joint. It is also more common for an ankle sprain to occur in athletes with higher torque ratios between eversion and inversion, who have higher peak torque values during plantar flexion, and those with a lower peak torque ratio between dorsiflexion and plantar flexion. Postural control deficits have also been found to be a contributing factor in patients who have presented themselves to have chronic ankle instability. With the lack of research on the effectiveness of a PPE, the implementation of tests such as the FMS, SEBT, and WBLT could be implemented to determine which are the most useful tools to identify those with musculoskeletal imperfections.

2.2.2 Potential cost savings

There is an average of 2.6 million emergency room visits annually for lower-extremity, sports-related injuries for patients ages 5-24. These injuries account for more than 68% of the total 3.7 million sports injuries reported to emergency rooms. More specifically, sports-related, lower-body injuries occurring in this age range account for nearly 20% of all emergency department visits.

As an athlete advances through the levels of their respected sport the costs that accompany injuries during this time may start to accumulate. Half of the athletes who sustain an ACL rupture receive surgery to repair the rupture. The total cost for one ACL surgery with associated physical therapy can be as high as $17,000, leading to annual costs within the United States for ACL surgical procedures of nearly $1 billion.
ankle sprains, the most common way to treat this injury is with rest, ice, compression, and elevation (RICE). More severe injuries may require formal rehabilitation and may cost as much as $300-$900 per patient. The annual cost has been estimated to be upwards of 2 billion dollars for the treatment of ankle injuries. This cost is equivalent to the money spent for coronary artery bypass surgery. De Loes et al estimated the average cost of a football injury to be between $188-$500, depending on the severity and location of the injury. These costs may be preventable if an individual’s risk can be determined and an effective intervention can be applied.

2.3 FMS

2.3.1 FMS Overview

The FMS is an assessment of seven movement patterns incorporating postural control, flexibility, and mobility of the body segments. These movement patterns are the deep squat, hurdle step, in-line lunge, active straight leg raise (ASLR), shoulder mobility, trunk stability push-up, and rotary stability. These movement patterns provide the tester with a comprehensive performance test of basic locomotor, manipulative, and stabilizing movements. If a participant has inadequate stability and mobility, flaws and discrepancies are seen in the individual due to the performed testing positions.

The FMS is graded on a 0-3 scale for each individual test, with a maximum of 21 possible points. If pain occurs during the testing session, a score of 0 is given to the athlete. A score of 1 is given if the participant is unable to complete the task. The participant receives a 2 when the movement pattern is performed with compensation. A score of 3 indicates the participant is able to perform the movement pattern without compensation. Each movement is repeated three consecutive times, with the lowest score
given as a final score for each of the movement patterns. When scoring a test with bilateral movements (hurdle step, ASLR, in-line lunge, shoulder mobility, and rotary stability), the lowest score between both sides is the final score for that test.

2.3.1.1 Shoulder Mobility

The purpose of this test is to assess the bilateral range of motion of the shoulder. The ranges of motion which it will test are as follows: internal rotation with abduction and external rotation with abduction, scapular mobility, and thoracic spine extension. Overhead throwing athletes may perform poorly on this test due to the repetitive throwing mechanics causing excessive external rotation and decrease of internal rotation at the shoulder. Another reason for performing poorly on this test is due to rounded shoulders which may be caused by changes such as the shortening of the pectoralis minor or latisimus dorsi muscles. Scapulothoracic dysfunction may also cause an athlete to perform poorly, causing a decrease in glenohumeral mobility accompanied by improper scapulothoacic mobility and stability.

When performing this screening tool, the first thing in the protocol is to determine the length of the individual’s hand. This is done by measuring the distance between the end of the third phalange and the most distal crease in the participants’ wrist. This measurement is needed for scoring the test, which is later explained. Once this measurement is obtained, the participants are told to make a fist with both hands; the thumb needs to be inside the fist. They are then told to try to touch their fists together by reaching one hand behind their head by flexing, abducting, and externally rotating their shoulder and the other hand up their thoracic spine by extending, adducting, and internally rotating their shoulder. While performing the test the participant’s fists must
stay closed the entire time while making the movements in one fluid motion. If the participant tries to crawl their hands up or down their back, the trial is repeated. Once the participant has reached the point to where they can no longer bring their fists any closer to each other, the examiner measures the distance between the two closest bony eminences of each hand. This test is performed three times bilaterally.

To achieve a score of three on this test, the participant must have a distance measured of one hand length or less. To achieve a score of two, the distance measured must be between one and one and a half hand lengths, and to score a one, the participant’s measured distance between hands must be greater than one and a half their hand length.

2.3.1.2 Trunk Stability Push-Up

This test assesses the ability to stabilize the spine in one plane during a closed kinetic chain upper-body movement. If the individuals can perform this test, it shows they have balanced trunk stability in the sagittal plane during a symmetric upper-extremity movement. Many functional activities in sports require this type of movement, such as an offensive lineman blocking a defensive player. Performing this test poorly means the athlete has weak trunk stabilizers.

When first instructing participants to do this test, the first thing they should be told is to lay in a prone position on the ground with their feet together and their hands placed shoulder width apart with thumbs aligned with their forehead. The position of the thumbs will determine the score received; this will later be explained. Once the hands are in position, they are asked to perform a pushup. The examiner must watch to make sure the participants’ bodies are lifted all at once with no lag within the lumbar spine. If the
participants can’t perform a push up, their hand placement is moved lower to make the test easier.  
In order to score a three on this test, the participant must perform just one pushup while the thumbs are aligned with the top of the forehead.  If they cannot perform a push up in that position, their hands are lowered, so their thumbs are aligned with their chin.  If they can perform one pushup in this position, they will score a two on this test. If the participants is unable to perform a pushup with this hand position, they will receive a score of one.  

2.3.1.3 Rotary Stability

The purpose of this test is to assess the movement which requires an athlete to have proper neuromuscular coordination with both the upper and lower segments of the body through the torso.  The ability to perform this test requires the trunk be stable in both the sagittal and transverse planes.  Many functional activities in sports require the trunk stabilizers to transfer force asymmetrically from the upper to the lower extremity.  An example of this would be exploding out of a lineman’s stance and changing direction during competition.

To perform this screen, the participants must start off in the quadruped position. The examiner must make sure the participants’ shoulders, hips, and knees are positioned at 90 degrees of flexion, along with the ankles being dorsiflexed.  The participants are then instructed to raise the same side arm and leg until both are complexly straight and approximately six inches off the ground.  They then need to touch the raised arm elbow to the raised leg knee in one fluid movement. If they are unable to do this, the opposite
arm and leg are done with the same movements. This is performed three times bilaterally.

To score a three on this test, the participants must perform one correct unilateral repetition while keeping their spine parallel to the ground while touching their elbow to their knee. To score a two, the participants must able to perform one diagonal repetition while keeping their spine parallel with the ground and still being able to touch their elbow to their knee. If the participants are unable to perform the diagonal movement, they will receive a score of one.

2.3.1.4 Deep Squat

The squat is a movement needed in most athletic events, is mainly used as the ready position, and is required for most power movements involving the lower extremities. The deep squat allows the tester to assess bilateral, symmetrical, and functional mobility of the hips, knees, and ankles. In order to perform the deep squat, the body is required to flex and abduct the shoulders, extend the spine, flex at the knees and hips, and dorsiflexion the ankles through a closed kinetic chain movement. Inadequate glenohumeral and thoracic spine mobility may lead to decreased mobility in the torso which will cause the athlete to perform poorly on this test. In proper closed kinetic chain, dorsiflexion of the ankles or reduced flexion of the hips may also be a reason for poor performance of the deep squat.

This test is performed by squatting down into a deep squat position while a dowel is held over the participants’ heads. Scores will vary depending on the positioning of the knees, hips, trunk, and arms which will later be explained in full detail in the procedures portion.
2.3.1.5 Hurdle Step

The hurdle step is used to assess the bilateral functional mobility and stability of the hips, knees, and ankles. It is designed to challenge the body’s proper stride mechanics during a stepping motion. When performing this test, single leg stance stability is necessary while the contralateral limb steps over the hurdle which requires the body to have proper coordination and stability between the hips and torso.\(^1\) For the step-leg; open-kinetic chain, dorsiflexion of the ankle, and flexion of the knee and hip are also necessary to perform this test correctly.\(^1\) Along with all of these factors, the athlete shows excellent balance due to the test applying a need for dynamic stability.\(^1\)

Poor performance during the test can be a result of several factors. One of those factors may be due to poor stability of the stance leg or poor mobility of the step leg.\(^1\) Maximal hip flexion of one leg while maintaining hip extension of the opposite leg requires the athlete to have bilateral, asymmetric hip mobility.\(^1\)

This test is performed by resting a dowel on the shoulders of the participants and holding onto that dowel with both hands. They are then told to step over a hurdle set to the height of the participants’ tibial tuberosity. They then step over with one leg and bring back that leg over the hurdle. Scoring is dependent on trunk, ankle, knee, and hip movements and alignments which will be discussed in full detail later on in the procedures section.

2.3.1.6 In-line Lunge

Stresses of rotational and lateral movements along with deceleration during running and jogging are tested by the inline lunge by putting the athlete in a position that focuses on these stresses.\(^1\) The body segments are placed in a position so the lower
extremity is in a scissor-like position which will challenge the body’s trunk and extremities to resist rotation and maintain proper alignment. It tests hip, knee, and ankle mobility and stability along with quadriceps flexibility. In order to properly carry out this test, the stance leg must be stable through the ankle, knee, and hip segments along with closed kinetic chain abduction. It is also necessary for the anterior leg to have mobility of hip abduction, ankle dorsiflexion, and rectus femoris flexibility, while achieving proper balance from the intrusion of lateral stresses.

There are several reasons for performing poorly on the in-line lunge test. First, a lack of hip mobility in either the stance leg or step leg may be present. Second, stability of the stance leg knee or ankle may not be adequate, causing compensation of another limb. A third inhibitory factor includes a strength imbalance between the adductors and abductors in one or both of the hips. Lastly, a decrease in thoracic spine mobility can cause improper movements causing the athlete to perform poorly.

This test is performed while standing on the testing board with the distance between the participants’ feet equal to the height of their tibial tuberosity. The participants hold the dowel on their back so the dowel is perpendicular to their spine. They are then instructed to drop the posterior knee down and touch the board. Scoring is dependent on the movement and alignment of the ankles, knees, hips, and trunk. Further details will be discussed in the procedures section.

2.3.1.7 ASLR

Segregation between the lower extremity and the trunk while conserving stability within the torso is assessed by the ASLR. The ASLR associates the relationship of how flexible the hamstring and triceps surae complex are while managing a stable pelvis with
an active extension of the opposite leg.\textsuperscript{9} The athlete must demonstrate proper hip mobility of the contralateral leg throughout the entire movement along with lower abdominal stability.\textsuperscript{9}

Scoring poorly on this test may be indicative of a few things. One of the first indicators is the athlete has poor functional hamstring flexibility.\textsuperscript{9} Secondly, the athlete may have a tight iliopsoas complex causing inadequate mobility of the opposite hip.\textsuperscript{9} Due to the combination of these factors, the athlete may demonstrate relative bilateral, asymmetric hip mobility.\textsuperscript{9} This test is more specific to the limitations imposed by the muscles of the hamstrings and the iliopsoas.\textsuperscript{9}

This test is performed with the participants lying supine on the ground and the testing board underneath their popliteal fossa. They are instructed to lift one leg up as high as they can while keeping the contralateral popliteal fossa touching the board. Scoring is dependent on the movement of the ankles and hips which will be explained in full detail later on in the procedure section.

\textbf{2.3.2 FMS Reliability}

The FMS has been associated with high inter rater reliability and can confidently be applied by trained individuals.\textsuperscript{45,46} It has been shown the level of experience may play a minor part in the scoring, but it does not affect the final test scores to where there was a significant difference was seen.\textsuperscript{45} The intra rater reliability of the FMS has also been shown to have a moderate to good reliability.\textsuperscript{46,47} Minick et al\textsuperscript{45} found that those raters with two or more years of experience in rating the scores of the FMS have been shown to have a stronger inter rater reliability when compared to novice raters who are just learning how to rate the test. This suggests it is a good idea to find raters who may have a
background in rating the FMS. A study conducted by Gribble et al\textsuperscript{48} found that athletic trainers with at least 6 months or more of experience using the FMS showed to have very strong intrarater reliability. For this study all the raters had at least 6 months of experience using the FMS.

2.3.3 FMS Injury Prediction Capability

The FMS is one of the few functional assessment tools used that demands full utilization of the participants’ entire kinetic chain. When injuries occur to the body, altered motor programs may dictate how individuals may move, which may lead to further unwanted complications.\textsuperscript{1} The fact that the FMS incorporates the entire kinetic chain is important because it will allow the examiner to distinguish where there is a lack of mobility or stability within the kinetic chain. This will allow the examiner to incorporate an intervention program to improve that person’s stability or mobility imbalance.

The FMS was designed to distinguish which parts of the kinetic chain are lacking in stability or mobility. Stability is defined as the ability to control forces or movement while mobility is defined as the muscle and joint working together to achieve maximum range of motion.\textsuperscript{49} Multiple studies done on a wide variety of participants—including firefighters, female collegiate athletes, professional football players, and marine officers—have all shown if a participant scores < 14 they are at a higher risk of injury than those who score higher than a 14.\textsuperscript{50-53}

The study conducted on the firefighters found a significant relationship between injury and the deep squat of the FMS.\textsuperscript{53} In order to perform the movement of the deep squat correctly, the whole body needs to work together as a unit: similar to that of
The study conducted on female collegiate athletes found the participants’ were 4 times more likely to sustain an injury if scoring poorly on the FMS. However, there are many issues related to the original study’s definition of injury, on which subsequent studies have based their 14 point cut-off score for injury identification. This raises concerns on how universally the FMS may actually be applied for injury risk identification.

### 2.3.4 Modified Functional Movement Screen

The MFMS is composed of the four, lower-body functional tests instead of the entire seven tests. These tests include the deep squat, inline lung, hurdle step, and ASLR. These four tests were used because they focus specifically on the lower extremity and this study is interested in the lower body non-contact injuries only. Because the shoulder mobility, rotary stability, and trunk push up test are all targeting core and upper extremity movement patterns, these may not be not useful for investigating deficits in the lower extremity. In recent work from the laboratory at the University of Toledo, the four stations of the MFMS had a diagnostic odds ratio (DOR) of 3.6 compared to the seven station FMS DOR of 1.8 when distinguishing if a player is at a higher risk of a non-contact, lower-body injury specifically to the ankle and knee joints. This allows us to assume we are twice as likely to find those who are at a higher risk of a non-contact, lower-body injury specifically to the knee and ankle when using the more focused MFMS compared to the full version of the FMS.

### 2.4 Star Excursion Balance Test

#### 2.4.1 Test Overview
The SEBT is a simple clinical tool used to assess dynamic postural control. The SEBT is performed on a grid of eight lines laid on the ground using tape, separated by a 45 degree angle. The reach directions are known as anteromedial, anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, and medial. The reach directions are labeled in relation to the stance leg. Once the grid is placed on the ground the participant is instructed to stand at the center of the grid barefoot. The participant assumes a single leg stance while reaching out for maximum distance with the opposite leg in the direction of the lines on the floor. The participant brings the reach leg back to the center after each trial.

2.4.2 SEBT Reliability

The SEBT has been associated with strong interrater and intrarater reliability. Most recently, Gribble et al looked at 29 participants and had 5 different raters to assess the SEBT in the anterior, posterior medial, and posterior lateral directions. They conducted the study, so three different raters assessed each participant, but the assessments took place at two different locations to eliminate any kind of bias or discrimination. When the raters have been trained by an experienced rater the SEBT is a test with excellent reliability. In a study conducted by Hertel et al they determined both the inter and intra rater reliability were shown to be relatively high with an inter rater intraclass correlation coefficient (ICC) of 0.81-0.93 and intra rater ICC of 0.78-0.96. Both the Gribble et al and Hertel et al are evidence that multiple raters are effective when conducting the SEBT.

2.4.3 SEBT Injury Prediction Capability
Due to the simplicity of the SEBT and its ability to indicate those lacking in the area of dynamic postural control, it has the ability to assist clinicians in identifying those who are at a high risk of injury to the lower body, especially at the ankle. It has been shown when the lower extremity becomes fatigued through exercise, in combination with having chronic ankle instability, the participant is more likely to establish kinematic changes to the knee and hip. With compensations at the knee and hip occurring, it may predispose those participants to unwarranted further injury. Pathological indications may have an effect on the SEBT that may have the ability to distinguish which participants are at risk of injury. Participants with previous lower-body injury can be assessed using the SEBT because the test is measuring the level of dynamic postural control. If deficits are seen on the stance leg, this may indicate a deficiency in dynamic postural control which, indicating a pathological condition such as chronic ankle instability or complications from a previous surgical procedure.

2.4.4 SEBT-A

The variance in reach distance in the anterior direction proves mechanical impairments at the ankle which may cause faulty dynamic function. Thirty-one percent of the variance reach distance was explained by the anterior reach of the SEBT, which has the strongest relationship to ankle dorsiflexion range of motion (DFROM). A significant correlation was found between performance on the SEBT in the anterior direction and closed kinetic DFROM. Specifically, a decrease in weight-bearing DFROM may create limiting factors for maximal reach distance in the anterior direction of the SEBT for participants with chronic ankle instability. This is based on the positive correlation exhibited between weight-bearing DFROM and anterior reach distance in
healthy individuals.\textsuperscript{62} These are a few of the reasons why instead of using the more commonly known 8-direction SEBT we will just be using SEBT-A.

2.5 WBLT

2.5.1 WBLT Overview

The WBLT assesses ankle DFROM in a closed kinetic chain position by measuring the maximal movement of the tibia over the rearfoot.\textsuperscript{10} It is very important as a health care provider to distinguish improper arthokinematic and osteokinematics of the ankle during weight bearing dorsiflexion.\textsuperscript{63} With a weight bearing dorsiflexion movement, the tibia moves anteriorly over the foot along with an anterior glide over the talus.\textsuperscript{63} If this glide is limited, like it may be in those people with chronic ankle instability, it will decrease DFROM.\textsuperscript{63} Decreased range of motion in this closed packed position allows the ankle to be vulnerable to inversion and internal rotation forces of the ankle.\textsuperscript{63} Studies have shown there is a significant positive correlation between WBLT performance and peak ankle sagittal plane kinematics during walking and running, as well as reach distance on the SEBT.\textsuperscript{10}

The WBLT is performed with individuals standing facing the wall with hands on the wall: one foot touching the wall with their toes, with a tape measure taped to the ground, all while the rater is knelt over keeping track of lunge distance. The participants lunge forward touching their knee to the wall. If they are able to accomplish this task, the participants are instructed to move their foot back until maximum dorsiflexion distance is found. This distance is measured in centimeters. Further detail will be explained later within the procedures section about step by step instructions and scoring.
2.5.2 WBLT Reliability

The WBLT in uninjured participants can be performed reliably by therapists with varying clinical experience.\textsuperscript{64,65} Dennis et al\textsuperscript{66} determined strong inter rater reliability by asking raters to observe the performance of the WBLT then compared the recordings at the end of the data collection.

2.5.3 WBLT Injury Prediction Capability

The WBLT is a good test to do in combination with the SEBT-A due to the fact the WBLT measures maximum DFROM.\textsuperscript{10} If the WBLT shows a participant has very minimal DFROM scores, it may also have a negative effect on the SEBT-A.\textsuperscript{62} It is also believed those with functional ankle instability have a decreased DFROM.\textsuperscript{63} The WBLT has not been used to predict injury up to this point but is an optimal choice for assessing ankle DFROM in a closed kinetic chain movement.

2.6 Summary

Previous research suggests there is potential for the ability to predict lower-extremity injuries using function movement assessment. Specifically, the MFMS, WBLT, and SEBT-A have shown promise for injury risk identification.\textsuperscript{7,10,11,50,51,53} However, evidence of these tests’ abilities to predict injury in collegiate football players is limited. If risk can be determined, health care professionals may be able to implement individualized interventions based on the results of these assessments, leading to hopeful reductions in the lower extremity injury rates in this athletic population.
Chapter 3

Methods

3.1 Study design

Prospective Cohort study

3.2 Participants

Football players from the University of Toledo NCAA Division I Collegiate Football Team who were cleared for full participation prior the 2013-2014 season volunteered for this study and were screened one week prior to the beginning of pre-season camp. At the conclusion of the 2013-2014 competitive season, players were placed into groups that either did or did not sustain a lower extremity injury associated with football practice or game participation. We also analyzed the risk of injury between the positions on the field and divided players into two separate position groups: linemen and skilled. Within the linemen group were the offensive linemen, including the centers, guards, tackles, and tight ends and defensive linemen, including nose-guards, tackles, and defensive ends. Within the skilled group were the cornerbacks, safeties, linebackers, quarterbacks, running backs and wide receivers. Exclusionary criteria included vestibular dysfunction, lower-body injury within the past 30 days, disqualification from the team during the competitive season, and a history of concussion within the past three months.
Before participation, each participant signed an informed consent form (Appendix A) approved by the University of Toledo’s Institutional Review Board (IRB#106503). Participants completed a questionnaire about their age, position played, injury history, and brace/tape use for the knees and ankles.

3.3 Instrumentation

To evaluate the MFMS, a FMS kit was used (Functional Movement Systems Inc., Virginia). The kit included a 2x6x48in hard plastic board, adjustable hurdle, and measuring dowel. A metric tape measure was used for both the WBLT and the SEBT-A. BMI was measured from self-reported height and mass.

3.4 Independent Variables

Group
a. Injured
b. Non-injured

Group
c. Contact
d. Non-contact
e. Non-injured

Position
f. Lineman
g. Skilled

3.5 Dependent Variables

1. Modified Functional Movement Screening (score out of 12)
2. Anterior reach of Star Excursion Balance Test (score as a % of leg length)

3. Weight Bearing Lunge Test (measured in cm)

4. BMI (kg/m$^2$)

3.6 Procedures

Testing was completed on the day of preseason physical check in at the Larimer Athletic Complex on the University of Toledo campus one week prior to the beginning of the competitive season. The three tests were administered by five certified athletic trainers who were previously trained on how to correctly administer the tests based on established reliability procedures.$^{48,56}$ Listed in Appendix B is a consort flow chart of the data independent variables.

3.6.1 MFMS

Participants were instructed on how to perform the MFMS using the guidelines from Cook et al.$^{1,9}$ All assessors completed reliability training as previously discussed in Gribble et al.$^{48}$ Each movement was graded on a 0-3 scale, with a maximum of 12 possible points. If pain occurred during the testing session, a score of 0 was given to the participant. A score of 1 was given if the participant is unable to complete the task. The participant received a 2 when the movement pattern is performed with compensation. A score of 3 was given to the participant if he was able to perform the movement pattern without compensation. Each movement was repeated three consecutive times, with the lowest score given as a final score for each of the movement patterns.

3.6.1.1 Deep Squat

For the deep squat, the participants started by positioning their feet approximately shoulder width apart and facing forward. The participants then adjusted their hands on the
dowel so the angle of their elbow and shoulders were at 90 degrees while the dowel was resting on top of their head. Next, the dowel was pressed overhead allowing the dowel to be positioned slightly posteriorly to their head. The participants were then instructed to descend slowly into a deep squat position. When going into the deep squat, the participants’ heels should remain on the floor, head and chest should remain facing forward, and the dowel maximally pressed overhead slightly posterior to the head. This movement was repeated three times. The lowest score out of the three trials was the score achieved by the participants.¹

In order to receive a score of three, the upper torso must remain parallel with the tibia, the femur dropped below horizontal, knees were aligned over feet without passing over their toes, and the dowel must be aligned over the participants’ feet (figure 3.1). If the participants are unable to achieve any one of those criteria, a 2”x6” board was placed under their heels, and the trials were repeated. The only difference between scoring a two and three is the 2”x6” board was placed under their heels; otherwise the criterion that will be met when scoring a three is the same as scoring a two (figure 3.2). The participants scored a one if they were unable to achieve any one of the criteria listed above while the 2”x6” board is under the heels of the participant (figure 3.3).¹

Figure 3.1: Deep Squat score of 3
Figure 3.2: Deep Squat score of 2
3.6.1.2 Hurdle Step

The participants started by first placing their feet together along with aligning their toes by touching the base of the hurdle. The hurdle was then adjusted to the height of the participants’ tibial tuberosity. The athlete positioned the dowel across their shoulders and below their neck. The athlete was asked to slowly step over the hurdle and tap their heel to the floor while maintaining the stance leg in an extended position. The moving leg was slowly returned to the starting position. This movement will be repeated three times bilaterally.\(^1\)

In order to receive a score of three during the movement, the participants’ hips, knees, and ankles needed to remain aligned, minimal to no movement should have been noted in the lumbar spine, and the dowel needed to remain parallel with the string (figure 3.4). A two was scored when alignment was lost between the hips, knees, and ankles, movement was noted in the lumbar spine or the dowel did not stay parallel with the string (figure 3.5). If contact was made between the foot and string or loss of balance was noted a score of one was given to the athlete (figure 3.6).\(^1\)
3.6.1.3 Inline Lunge

The first thing needed to perform the inline lunge test was a measurement by the tester of the participants’ tibia length. This can be found by measuring from the floor to the tibial tuberosity or acquiring it from the height of the string during the hurdle step test. The participants were asked to place the toe of one foot on the zero mark of the board. They were instructed to step out on the board placing the heel of the contralateral foot to the distance of the tibial measurement. The dowel was placed behind the back touching the head, thoracic spine, and sacrum. The hand opposite to the front foot was the hand grasping the dowel at the cervical spine. The other hand grasped the dowel at the lumbar spine. The participant lowered the back knee enough to touch the board behind
the heel of the front foot then returned to the standing starting position. The lunge was performed three times bilaterally in a slow, controlled fashion. The front limb was the test limb for each trial.

The criteria for scoring a three for this test are as follows: 1) the dowel remained in contact with the head, thoracic spine, and sacrum; 2) no torso movement was noted in the sagittal or frontal planes; 3) the dowel and feet remained in sagittal plane; 4) the heel of the front foot did not raise off the board; and 5) the knee touched the board behind the heel of the front foot (figure 3.7). The participant received the score of two if the dowel did not remain in contact with the lumbar spine, movement of the torso was noted in the sagittal or frontal planes, dowel and feet did not remain in the sagittal plane, if the heel of the front foot raised off of the board, or the knee did not touch behind the heel of the front foot (figure 3.8). If a loss of balance occurred during the movement, a score of one was received (figure 3.9).
3.6.1.4 ASLR

The participants started by lying in the supine position with their arms positioned beside their body in an anatomical position and head flat on the floor. The rater slid the testing board underneath the popliteal fossas of the participant. Once this was done, the rater found the mid-point between the anterior superior iliac spine (ASIS) and mid-point of the patella by measuring the distance between these two landmarks and taking half of that measurement. A dowel was placed at this position perpendicular to the ground. Next, the athlete was instructed to lift the test leg with a dorsiflexed ankle and an extended knee. During the test, the contralateral popliteal fossa should remain in contact with the testing board, the toes should remain pointed upward, and the head should remain flat on the floor. Once the end range position was reached, the investigator took note of where the lateral malleolus resided. The score received by the participant was dependent on the location of the lateral malleolus. The ASLR was performed three times bilaterally.

To receive the score of three for the ASLR test, the lateral malleolus of the test limb must reside past the dowel, between the mid-thigh and ASIS (figure 3.10). To achieve a score of two, the lateral malleolus must reside between mid-thigh and mid-
patella/joint line (figure 3.11). For a score of one to be given to the participants their ankle must reside below mid-patella/joint line (figure 3.12).\(^9\)

![Figure 3.10: ASLR score of 3](image1.jpg) ![Figure 3.11: ASLR score of 2](image2.jpg) ![Figure 3.12: ASLR score of 1](image3.jpg)

3.6.2 SEBT-A

The SEBT-A was performed by standing on one leg with the hallux of the stance leg positioned at zero of the plastic tape measure which was taped to the floor. A successful trial required the hands to remain on the participants’ hips, the foot position of the stance leg needed to remain as originally positioned, and the heel of the stance leg had to stay in contact with the floor.\(^{67}\) Participants were instructed to make a maximum reach with the contralateral leg of the stance leg in the anterior direction, touch the floor lightly with the most distal part of the reaching foot, and then return to a double-leg stance without changing the base of support of the stance leg (figure 3.13). If this
criterion was not met, the trial was discarded, and an additional trial was performed. Reach distances were recorded by having one of the raters place a mark on the tape measure that corresponded to the touchdown point. Reach distance was measured in centimeters. The participants practiced this reaching motion four times before scores were taken; then, the following three reaches were recorded as scores. Once this is done on one leg, the steps were repeated on the contralateral leg.

Studies have shown that maximum excursion distance and stance-leg angular displacement values achieved stability within the first four practice trials. Reach scores were normalized as a percentage of leg length. The definition of leg length is the distance measured between the ASIS and medial malleolus.

![Figure 3.13: SEBT-A trial](image)

### 3.6.3 WBLT

For the WBLT, the participants’ were instructed to place the test-limb foot on the plastic tape measure that was taped to the ground, with their first toe and center of their heel inline and perpendicular to the wall. To promote upright balance during the test, the opposite limb was positioned behind the test foot in a comfortable tandem stance while their hands were placed on the wall. The participants were then instructed to lunge.
forward allowing the knee to flex with the goal of making contact between the knee and the wall. All of this was done while keeping the heel of the front foot firmly planted on the floor (figure 3.14).\textsuperscript{10} When the participant was able to do this movement, he was progressed back in 1cm increments until the heel came off the ground. If this occurred, the placement of the foot was adjusted in smaller increments back toward the wall until the maximum lunge distance is found. Maximum lunge distance is defined as the maximal distance from the great toe to the wall without the heel lifting from the ground while the knee was able to touch the wall.\textsuperscript{10}

![Figure 3.14: WBLT Trial](image)

**3.7 Injury Monitoring**

Injury monitoring was conducted by the certified athletic trainer (ATC) assigned to The University of Toledo football team. Daily exposure rates during practice and games along with injury occurrences including the extremity that is injured, type of injury, severity of the injury, type of activity (practice vs. game), number of injuries that occur to the area, whether or not the participant uses prophylactic support, and the number of previous incidences was also recorded. An exposure was defined as one athlete participating in one practice or game in which he was exposed to the possibility of
an athletic injury regardless of the time associated with participation. Only the first injury of the season was recorded. Additional injuries suffered by a participant were not used in the analysis.

3.8 Statistical Analysis

Independent t-tests were used to determine if there was a significant difference between athletes with an in-season injury and non-injured athletes on the MFMS, WBLT, SEBT-A scores, and BMI. Independent t-tests were used to determine if there was a significant difference between athletes suffering a contact vs. non-contact injuries to the lower extremity on the MFMS, WBLT, SEBT-A, and BMI. An independent t-test was used to determine if there was a significant difference between athletes within the skilled position and linemen position on the MFMS, WBLT, SEBT-A and BMI. All statistical analyses were conducted using SPSS. Statistical significance was set \textit{a priori} at \( P<0.05 \).
Chapter 4

Results

4.1 Injured vs Non-Injured

The purpose of this study was to determine if the MFMS, WBLT, and SEBT-A, along with BMI, can prospectively identify individuals who sustain a lower extremity injury. There were no significant differences between the injured and non-injured players for MFMS (p=0.62), SEBT-A (p=0.25), WBLT (p=0.80), or BMI (p=0.84) (Table 1).

Table 4.1: Means and Standard Deviation of Pre-participation screening scores and BMI for Injured vs. Non-Injured

<table>
<thead>
<tr>
<th>Pre-participation Screen</th>
<th>Group</th>
<th>N</th>
<th>Mean±SD</th>
<th>t-value</th>
<th>p-value (&gt;0.05)</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>Injured</td>
<td>17</td>
<td>29.7±4.39</td>
<td>-0.21</td>
<td>0.84</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Non-injured</td>
<td>65</td>
<td>30.0±3.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MFMS (score out of 12)</td>
<td>Injured</td>
<td>17</td>
<td>8.35±1.37</td>
<td>-0.50</td>
<td>0.62</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Non-injured</td>
<td>65</td>
<td>8.55±1.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEBT-A (% of leg length)</td>
<td>Injured</td>
<td>17</td>
<td>63.0±6.0</td>
<td>-1.01</td>
<td>0.25</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Non-injured</td>
<td>65</td>
<td>65.0±6.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBLT (cm)</td>
<td>Injured</td>
<td>17</td>
<td>6.76±3.38</td>
<td>-0.26</td>
<td>0.80</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Non-injured</td>
<td>65</td>
<td>6.97±2.84</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.2 Contact vs Non-Contact

A secondary purpose of this study was to determine, within the injured population, if these clinical screening tools can detect differences between athletes who sustained a contact versus a non-contact injury. There were no significant differences between the injured and non-injured players for MFMS (p=0.26), SEBT-A (p=0.36), WBLT (p=0.57), or BMI (p=0.95) (Table 2).

Table 4.2: Means and Standard Deviation of Pre-Participation screening scores and BMI for Contact vs Non-contact Injuries

<table>
<thead>
<tr>
<th>Pre-participation Screen</th>
<th>Group</th>
<th>N</th>
<th>Mean±SD</th>
<th>t-value</th>
<th>P-Value (≥ 0.05)</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>Contact</td>
<td>11</td>
<td>29.8±3.73</td>
<td>0.07</td>
<td>0.95</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Non-Contact</td>
<td>6</td>
<td>29.6±5.81</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MFMS (score out of 12)</td>
<td>Contact</td>
<td>11</td>
<td>8.64±1.43</td>
<td>1.17</td>
<td>0.26</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>Non-Contact</td>
<td>6</td>
<td>7.83±1.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEBT-A (% of leg length)</td>
<td>Contact</td>
<td>11</td>
<td>64.0±8.0</td>
<td>0.94</td>
<td>0.36</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>Non-Contact</td>
<td>6</td>
<td>61.0±4.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBLT (cm)</td>
<td>Contact</td>
<td>11</td>
<td>7.12±3.50</td>
<td>0.58</td>
<td>0.57</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>Non-Contact</td>
<td>6</td>
<td>6.10±3.40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3 Linemen vs Skilled

A tertiary purpose of this study was to determine if there are differences between player position and their scores on the MFMS, WBLT, and SEBT-A. BMI was significantly greater in linemen compared to skilled player positions (p-value ≤ 0.00) (Table 3). No significant differences were observed between the player positions for MFMS (p = 0.08), SEBT-A (p =0.48), or WBLT (p=0.38). (Table 3)
Table 4.3: Means and Standard Deviation of Pre-Participation screening scores and BMI between linemen and skilled players

<table>
<thead>
<tr>
<th>Pre-participation Screen</th>
<th>Group</th>
<th>N</th>
<th>Mean±SD</th>
<th>t-value</th>
<th>P-Value (≥ 0.05)</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>Lineman</td>
<td>30</td>
<td>33.8±3.16</td>
<td>9.75</td>
<td>≤ 0.00</td>
<td>1.93</td>
</tr>
<tr>
<td></td>
<td>Skilled</td>
<td>52</td>
<td>27.7±2.45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MFMS (score out of 12)</strong></td>
<td>Lineman</td>
<td>30</td>
<td>8.13±1.36</td>
<td>-1.80</td>
<td>0.08</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>Skilled</td>
<td>52</td>
<td>8.73±1.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SEBT-A (% of leg length)</strong></td>
<td>Lineman</td>
<td>30</td>
<td>64.0±6.0</td>
<td>-0.71</td>
<td>0.48</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>Skilled</td>
<td>52</td>
<td>65.0±6.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WBLT (cm)</strong></td>
<td>Lineman</td>
<td>30</td>
<td>7.30±3.26</td>
<td>0.88</td>
<td>0.38</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Skilled</td>
<td>52</td>
<td>6.70±2.74</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 5

Discussion

5.1 Introduction

The purpose of this study was to determine if the MFMS, WBLT, SEBT-A, and BMI can prospectively identify deficits in individuals who sustain a lower extremity injury during a competitive football season compared to those who did not sustain an injury. A secondary purpose of this study was to determine, within the injured population, if these clinical screening tools can detect differences between athletes who sustained a contact versus a non-contact injury. With the uniqueness of this study looking specifically at division I collegiate football players we were interested to see if positions played had a significant difference between the scores of the screening tools and BMI. The tertiary purpose of this study was to determine if there are differences between player position and their scores on the MFMS, WBLT, and SEBT-A. The only statistically significant relationship from our investigation was the linemen had higher BMI compared to the skilled players.

5.2 BMI

BMI was significantly greater in linemen compared to skilled player positions (p-value ≤ 0.00). As we hypothesized, we expected this due to the demands required to play
the positions within this group and the body type of each of those positions. Generally the larger athletes will play on the offensive and defensive line while the leaner athletes will play in the skilled positions. Wilkerson et al\textsuperscript{30} showed that individuals above the threshold of 32.7 kg/m\textsuperscript{2} had a better predictive value of sustaining a lower-extremity injury (DOR = 3.5). This did not agree with the findings in our studies. We found those who within the injury group had an average BMI of 29.7 kg/m\textsuperscript{2}. When analyzing within that injury group between contact and non-contact injuries it was found the average BMI of contact injuries to be 29.8 kg/m\textsuperscript{2} and non-contact injuries to be 29.6 kg/m\textsuperscript{2}. This also disagrees with the research done by Wilkerson et al\textsuperscript{30}. Furthermore, the average BMI for our lineman group was 33.8±3.16 kg/m\textsuperscript{2} which is above the 32.7 threshold; however, there was no difference in incidence of injury to the lineman compared to the skilled position players.

An explanation for the differences in findings between studies may have been the injuries being analyzed. Wilkerson et al\textsuperscript{30} reported injuries to the ankle, knee, hip, and lower back as lower-extremity injuries where we reported lower-extremity injuries as just injuries to the ankle and knee. Wilkerson et al\textsuperscript{30} contributed 17 of their 39 lower-extremity injuries to the hip and lower back. If they also would have just analyzed injuries to the ankle and knee this would have decreased the total number of injuries and may have influenced their threshold of 32.7 kg/m\textsuperscript{2}.

5.3 MFMS

This study found there to be no differences between any of the aims using the MFMS. To our knowledge, this is the first study to use the MFMS to determine which player position had lower scores. With this study, since the effect size was found to be
moderate and p-value close to being significant it shows the findings to be trending in the direction that the MFMS could potential be beneficial when testing a large population, specifically pertaining to lineman and skilled players. However, it is difficult to conclude that this would be a good screening tool to use because it only shows there is a difference between the skilled and lineman groups not a difference between injury groups or type of injury. The reason for these findings again may be because of the sample size. Division one football teams typically do not exceed numbers of 100-120 athletes. Even if the team was large enough every athlete would not be able to participate due to the exclusion criteria.

As previously discussed our reasoning for using the MFMS was the recent work conducted at the University of Toledo that found the four stations of the MFMS had a better DOR than the full FMS when distinguishing if a player is at a higher risk of a non-contact, lower-body injury specifically to the ankle and knee joints.\textsuperscript{11} This allowed us to assume we would find a risk twice as high of a non-contact, lower-body injury specifically to the knee and ankle when using the more focused MFMS compared to the full version of the FMS. However, prediction quality was still weak to moderate. Because of some of the published work using the FMS to predict injury, we felt it was important to implement this tool for risk identification. To our knowledge this is the first study to use the MFMS to indicate risk of injury within division I collegiate football players.

Our lack of strong injury prediction contradicts some of the previous published studies indicating the FMS as a prediction tool\textsuperscript{51,54}, but is consistent with more recent publications suggesting it may not be effective at prediction of injury among different
athletic populations\textsuperscript{70,71}. While in isolation, the FMS may not be a strong injury predictive tool, as Lisman et al\textsuperscript{71} suggest, in combination with other tests, perhaps prediction models can be improved.

5.4 SEBT-A

Unlike previous research for the SEBT, this study established there was no significance between the scores on the SEBT-A and injury to the lower extremity in football players.\textsuperscript{12,55,59,68} When comparing scores on the SEBT-A within the healthy population with previous research our scores are very similar.\textsuperscript{12,69,72} The normalized reach distances from previous studies ranged from 69.5\%\textpm7.1\% of leg length\textsuperscript{12,69,72} our study that ranged from 65.0\%\textpm6.0\% of total leg length. However our study showed there to be no difference between the injured and non-injured population where studies have shown a decrease in performance due to fatigue and chronic ankle instability.\textsuperscript{12,58}

When looking between the populations of lineman and skilled player positions no significant difference was found between scores. This may be explained by the insufficient amount of participants that were used in this study. Another possible explanation for the differences seen between this study and previous studies\textsuperscript{12,55,59,68} with the SEBT is the definition of a non-contact injury used. Due to the definition of a non-contact injury and the nature of the sport, football is an extremely high contact sport, this may have limited the number of participants who met the requirements of this study.

A possible variation of definition that could be used in future studies to assist in this limitation is the definition used by Boden et al.\textsuperscript{73} The definition used for a non-contact injury by Boden et al were classified as sudden deceleration prior to a change of direction or landing motion.\textsuperscript{73} Another definition of non-contact injury that could
potential be used is modeled after the definition used by Gilchrist et al\textsuperscript{18} but simply an injury sustained by an athlete without extrinsic contact by another player. This could potentially add those injuries where participants land on an object after jumping in the air and injuring themselves or simply just injuring themselves while doing drills using blocking dummies, pads, or miniature hurdles.

5.5 WBLT

As discussed previously, to our knowledge, the WBLT has not been used to predict injury within the collegiate football population. From the findings in this particularly study it suggests this tool would not be useful to show who is at a higher risk of injury. An explanation for these findings may be due to the insufficient amount of non-contact, lower-extremity injuries. As previously stated a possible change to the definition of a non-contact injury may be appropriate for future studies. Our rationale for using this screening tool in our study was because of the previous research conducted by Basnett et al\textsuperscript{12} who reported poor DFROM at the ankle was most associated with poor performance on the SEBT-A. With previous research showing those who perform poorly on the SEBT-A had a higher risk of injury, we were interested in seeing if decreased DFROM showed which individuals were at a higher risk of injury due to the relationship between the two variables\textsuperscript{12,57,59,68}. Because, the WBLT assesses ankle DFROM in a closed kinetic chain position by measuring the maximum movement of the tibia over the rear foot we wanted to determine if the WBLT was capable of determining risk of injury to the ankle and knee.\textsuperscript{10} However from the findings in our study we found no relation between poor performance of scores on the WBLT and risk of injury.
5.6 Clinical Significance

Overall, the data from this study suggests it is unlikely these screening tools in this study would be beneficial in implementing into a pre-participation screen to indicate who is at a higher risk of a non-contact, lower-extremity injury within this population. However; if the definition of injury and non-contact injury were to be changed along with a longitudinally conducted study relating to this area it could possibly show more promising significant findings. Due to the nature of football, being an intensive contact sport, it may be more difficult to come to a good conclusion for indicating who may be at a higher risk of a non-contact, lower-extremity injury using these pre-participation screens. Ultimately, further research is needed in this area to determine the effectiveness of these particular screening tools and usefulness within the clinical settings.

5.7 Limitations

Limitation within this study did exist even though we tried to minimize them. One of the main things that hindered the results of the study was our sample size. This study may be found to be more effective if it was conducted longitudinally over a multiple seasons to increase the sample size. Our injury definition of a non-contact injury limited us in the number of recorded non-contact injuries. Due to the definition some of the injuries that were sustained were reported as contact injuries. With this definition some injuries may have been left up to interpretation of whether the injury came from an object or human being or if it was a non-contact injury. One last limitation to this study is the nature of the sport; football is a highly competitive contact sport. The injury rate for
football is much greater than those of other sports which may cause the number of non-contact injuries compared to contact injuries to be greater than other sports\textsuperscript{6,23,36}.

5.8 Conclusion

With the results from this study only showing to have one statistically significant finding, BMI between lineman and skilled players, it is difficult to conclude if these screening tools should be implemented as a PPE. It is still undetermined if the MFMS, SEBT-A, WBLT are valid pre-participation screening tools to determine non-contact lower-extremity injuries. Further longitudinal studies should be conducted to determine if the results would continue to trend in the same direction as this particular study. More research is needed to determine the usefulness of these pre-participation screens and BMI to indicate who may be at a higher risk of a non-contact, lower-extremity injury.
References


Appendix A

Informed consent form

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

Principal Investigator: Phillip Gribble, 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)
Masafumi Terada, 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 Yungtum, ATC (research assistant)

Contact Phone number(s): (419) 530-2744, (419)-530-2691

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.
- You have the right to refuse to take part in this research, or agree to take part now and change your mind later.
- If you decide to take part in this research or not, or if you decide to take part now but change your mind later, your decision will not affect your routine care.
- Please review this form carefully. Ask any questions before you make a decision about whether or not you want to take part in this research. If you decide to take part in this research, you may ask any additional questions at any time.
- Your participation in this research is voluntary.
PURPOSE (WHY THIS RESEARCH IS BEING DONE)

You are being asked 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 take part in a research study that will examine the relationship between dynamic balance and function and ankle injury among high school football, basketball, volleyball, soccer, baseball, softball, and cross country athletes. The purpose of the study is to determine if performance on simple balance tests 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 this test 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.

You are being selected as someone who may want to take part in this study because you have 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.

You are 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 test 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 to participate, you will be asked to come to your school on the designated testing day with this form signed by you. 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 you for participation in basketball, football, soccer, volleyball, baseball, softball, and cross country for the upcoming school year. If you cannot make this
designated testing date, another date will be arranged to conduct this testing prior to the first
day of schedule team practice.

After receiving the necessary signed forms, a brief medical questionnaire will be
administered by a member of the research team asking about your previous leg injuries (ankles,
knees, hips). This will ensure correct inclusion criteria.

Next, you will move to a station where your age, height and weight will be measured.
Additionally, you will be assigned an identification number in this paperwork so that your 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 perform the test. Then they are given
give 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 the participant by the investigator and the participant may ask any clarification questions to
ensure they are comfortable with the test they wish before attempting to perform the test. For
each test, 3 trials will be performed for a total of 21 trials. Participants 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 your ankle and hip joints. Hip motion will be assessed with a simple plastic measuring
device while you are lying 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 you stand facing a wall and bend your ankle and knee.
You will put their hands on the wall and move slowly into a squatting position until your heel
starts to lift off the floor. At the point, the member of the research team will have you 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 hips. While lying on a treatment table, the member of the research team will gently place a small handheld device that measures force against your leg, and then ask you to move your 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 you hold each position for approximately 5 seconds. You will be allowed as much time as you would like between each of the 4 movements on each leg.

After this session is complete, you 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 you suffer an ankle injury during practice or competition during the season. If you suffer an ankle sprain, tendon injury or a fracture to the ankle, the “incident” will be recorded in a notebook. However, no personal information about you will be provided to the research team members. The “incident” will be recorded using the assigned identification number, as described above, assuring that your name is not used. This information will be kept confidential, only accessible to the research team. You 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 preseason SEBT performances to determine a score that can predict the ankle injury “incidents”.

This study is examining the ability of dynamic balance and functional movement performance to predict ankle injury in high school and college football, basketball, volleyball, soccer baseball, softball, and cross country athletes. You 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 you are unable to participate in the study or you are uncomfortable with 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, you may experience one or more of the following:

1. There is a slight chance of falling during the balance and functional testing. However, you will be given instruction on how to perform each task and adequate practice to become comfortable with the task. An investigator will be standing nearby in the unlikely event that you do need assistance.
2. You may experience slight soreness or tiredness during the balance and functional tasks. Having the rest periods between the tasks should help to minimize this risk.
3. You 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 you are pregnant, it is advised that you do not participate in this study. Due to balance changes during pregnancy you 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 you 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 you are not able to make the designated testing date, an alternative time will be arranged to test you when you 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 you 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. By 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) 530-2691

**Voluntary Participation**

Taking part in this study is voluntary. You may refuse to allow participation or discontinue participation at any time without penalty or a loss of benefits to which you are otherwise entitled. If you decide not 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 Grible, PhD, ATC (419) 530-2891.

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 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 authority or Legal Guardian)  a.m.  Time  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

Consort Flow Chart of subjects

Numbers Enrolled

(82)

Screened

(82)

Injured

(17)

Non-Injured

(65)

Skilled

(52)

Linemen

(30)

Contact Injury

(11)

Non-Contact Injury

(6)