

A Thesis
entitled
The Star Excursion Balance Test as a Predictor of Lower Extremity Injury in High
School Football Players
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Submitted to the Graduate Faculty as partial fulfillment of the requirements for the
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May 2010

An Abstract of
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It is reported that one million high school athletes participate in interscholastic football annually, resulting in 350,000 injuries, most of them occurring to the lower extremity. This has lead researchers to examine ways to predict lower extremity injury in high school athletes. The Star Excursion Balance Test (SEBT) has been shown to be a predictive measure of lower extremity injury in high school basketball players. However, this test has yet to be determined as a predictive measure in high school football athletes. By utilizing this screening tool, I have found the SEBT to be a predictive measure of lower extremity injury. Therefore, the results of this study suggest that the SEBT can be used as a predictive tool to identify high school football athletes at risk to suffer a lower extremity injury.

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Chapter 1

Introduction

For the high school age population, participation in athletics continues to be one of the most popular extracurricular activities. The National Federation of State High School Associations states that in 2007 more than one million high school students participated in football alone¹. With this high amount of participation comes an increase in musculoskeletal injury, primarily to the lower extremity. In a review of high school football injuries conducted in 2003, 62% of injuries that occurred involved the lower extremity³⁸. Ankle sprains are consistently the most common musculoskeletal injury that occurs accounting for 10% to 28% of total injuries⁵. Ankle sprains also are the most common lower extremity injury in athletes at the high school level, with high school football demonstrating the most²⁵. According to an injury surveillance study conducted by the National Athletic Trainers Association in 2007, ankle sprains were also the most common injury seen in collegiate athletics followed by injury to the anterior cruciate ligament¹⁷.

The high amount of injuries results in high medical and insurance costs. According to the 2003 Product Safety Commission the estimated cost of treating ankle sprains in high school alone was more than \$70 million with indirect costs of up to \$1.1 billion³⁹. Along with this, it is predicted that 40% of individuals suffering from an ankle sprain will develop long term ankle

dysfunction commonly referred to as Chronic Ankle Instability(CAI)²⁹. The cost of repairing injury to the anterior cruciate ligaments annually has been estimated at 665 million, and many athletes who suffer from this injury have been shown to develop osteoarthritis, leading to long term disability and further medical costs¹⁶. While a large amount of information is known on how to effectively treat and rehabilitate lower extremity injury, little has been done in the clinical setting to prevent this common injury from occurring.

Many different measurement tools have been utilized to identify individuals at risk for lower extremity injury. These tools require expensive and not easily portable computerized tests that are time consuming and not practical for the clinical setting. Over the past few years an effort has been made to utilize functional balance testing as a predictive measure for ankle injury. McGuine et al¹⁹ assessed balance through single leg stance measures and found that subjects who displayed poor balance had nearly seven times more ankle injuries than subjects with good balance. The Balance Error Scoring System(BESS) has also been proposed as a way to screen athletes who are predisposed to ankle injury. In a study by Docherty et al⁸ in 2006, significant differences were seen in scores between subjects with functional ankle instability and healthy individuals. However, single leg stance testing does not assess the dynamic stability that is commonly linked to lower extremity injury in research.

The Star Excursion Balance Test (SEBT) was first introduced as an inexpensive, quick method for measuring dynamic postural control. The SEBT consists of a series of lower extremity reaching tasks in eight directions that challenge subjects' postural control, strength, range of motion, and proprioceptive ability¹². Research suggests that the further the reach distance, the better the athlete's functional performance. The ability to reach farther with a limb

requires a combination of better balance, strength, and motion on the contralateral stance limb¹⁴. The test is conducted bilaterally and reach distances are then normalized to leg length and compared to determine the subject's dynamic postural control.

Research has proven the SEBT to be a reliable and valid measuring tool for assessing dynamic postural control^{15, 18}. Decreased reach distances have been associated with different pathologies including chronic ankle instability, anterior cruciate ligament sprains, and patellofemoral pain^{13, 28}. The SEBT has also been recommended as an effective exercise to utilize in rehabilitation for CAI¹². Plisky et al³⁰ first introduced the test as a possible method for predicting lower extremity injury in high school basketball players. The results of the study demonstrated that SEBT was a reliable and predictive measure of lower extremity injury in basketball players. However, this testing has yet to be determined as a predictive measure of injury in football players.

1.1 Statement of the Problem

Due to the high amount of ankle and knee injuries sustained by high school football players, the ability to identify individuals at risk for lower extremity injury is needed. The SEBT is proven to be a reliable and predictive assessment tool for lower extremity injury in high school basketball players³⁰. By utilizing this screening tool on high school football players, clinicians will be able to identify at risk individuals and recommend proper prevention. Recognition and prevention may help to reduce the amount of medical costs annually and reduce the number of athletes suffering from the long term effects associated with lower extremity injury.

1.2 Statement of the Purpose

The purpose of this study is to examine the relationship between the reach distance on the SEBT and lower extremity injury in high school football players. By identifying normalized values and tracking injury rates throughout the season, we will be able to identify at risk athletes and recommend prevention for those individuals.

1.3 Significance of the Study

As demonstrated above, the most common injury in high school football is injury to the lower extremity. By providing clinicians with an effective and inexpensive assessment tool they will be able to identify at risk individuals and implement proper injury intervention for at risk individuals.

1.4 Hypothesis

H1: Athletes that suffer a lower extremity injury will display a significantly lower composite SEBT score when compared with athletes who do not suffer from an injury.

H2: Similar to the previous study in high school basketball players, an ideal cut -off point of the SEBT normalized composite score will predict increased risk of lower extremity injury in high school football players³⁰.

Chapter 2

2.1 Anatomy

The ankle is a complex joint that consists of four primary bones and a large amount of ligaments and tendons. The three primary bones of the ankle include the tibia and fibula which are connected together by ligaments to the talus and calcaneus. The ankle has ligaments that join these bones together at the most proximal aspect of the joint on the medial and lateral aspects of the ankle. The ligaments on the lateral aspect of the ankle include the anterior talofibular ligament, calcaneofibular ligament, and the posterior talofibular ligament. The anterior and posterior talofibular ligaments connect the fibula to the talus on the anterior and posterior aspect respectively. The calcaneofibular ligament runs in between these two ligaments and connects the calcaneus and the fibula. The ligament on the medial aspect of the ankle is commonly referred to as the deltoid ligament. At the more proximal aspect of the joint lie the anterior and posterior tibiofibular ligaments which connect the tibia and fibula together.

The most commonly injured ligaments in the ankle include the anterior and posterior talofibular ligaments and the calcaneofibular ligament in a lateral ankle sprain. These ligaments are responsible for preventing ankle inversion and translation of the talus. The deltoid ligament is responsible for preventing excessive ankle eversion and is injured in a medial ankle sprain. A syndesmosis sprain, more commonly referred to as a high ankle sprain, is an injury to the

anterior and posterior tibiofibular ligaments which prevent excessive motion between the proximal tibiofibular joint. The most common mechanism of the injury involves a sudden change in direction or improper technique when landing from a jump. After injury to the ligament changes in strength, range of motion and proprioception occur. Along with the substantial medical costs of treating this injury, decreased function and dynamic stability also occurs.

The knee is a complex joint that consists of four bones and a large amount of ligaments and tendons. The femur is attached to the tibia and fibula by ligaments to form tibiofemoral joint and the patella and femur together form the patellofemoral joint. The two primary ligaments of the knee are the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL), which are the primary stabilizers of the knee, preventing translation of the tibia on the femur during dynamic activity. The medial collateral and lateral collateral ligaments provide protection to the knee against valgus and varus forces during dynamic activity. The menisci are fibrocartilaginous structures that lie between the articulating surfaces of the tibia and femur to provide stability and shock absorption. Injury to these ligaments most commonly occurs during a sudden change in direction or when the athlete sustains a direct blow to the knee.

2.2 Lower Extremity Injury Prevalence

Research consistently demonstrates that ankle and knee injuries are the most common injury suffered in the athletic population. Ankle injuries are also among the most prevalent injuries that occur in high school athletics. According to the National Federation of State High

School Associations, more than one million high school students participated in high school football, with participation rapidly increasing each year¹. Football has also been shown to be the leading cause of sport related injury³⁶. With this increased participation in athletics comes an increase risk for injury. Turberville et al³⁸ reported that 62% of all high school football injuries sustained during the 2003 season occurred to the lower extremity with 27% of injuries occurring to the ankle and 20% occurring at the knee joint. Nelson et al²⁵ reported that 67.3% of football players had sprained their ankle during a single season. Another study found that ankle injury was the most prevalent injury in high school football, resulting in 24.2% of all injuries³⁶. Of the 24.2% of ankle injury, 88% of them were ankle sprains. The financial impact associated with these injuries is substantial, resulting in \$70 million dollars being spent in 2003 and the indirect costs adding up to \$1.1 billion³⁹. This high prevalence for injury causes the need for researchers to examine ways to reduce lower extremity injuries in high school athletics.

2.3 Predictive Factors

Due to the high rate of injury, a large amount of research has been conducted to determine the intrinsic and extrinsic factors associated with ankle and knee injury. Some of the most common intrinsic factors include previous history, sex, height, weight, limb dominance, foot type, foot size, joint laxity, range of motion, strength, proprioception, and muscle reaction time. Some proposed extrinsic risk factors include ankle bracing and taping, shoe type, playing surface, and duration and intensity of competition⁷. Most of these proposed factors are considered inconclusive as predictive factors for ankle injury in research including, sex, joint

laxity, limb dominance, foot type, and muscle reaction time, while others have displayed some promising results⁷.

Decreased strength has been proposed as one of the most common predictors for ankle injury. One of the most common deficits examined in research is the relationship between ankle inversion and eversion strength with limited success. Wang et al⁴⁰ found no significant results between ankle inversion and eversion strength and ankle injury in high school basketball players. Other studies have found that higher ratios between inversion and eversion peak torques suggest increased risk for ankle injury in soccer, lacrosse, and field hockey⁶. Decreased hip strength has also been proposed as an indicator for increased incidence of ankle sprain^{21, 27}. Nicholas et al²⁷ found that subjects who demonstrated hip abduction and adduction weakness suffered from an ankle sprain, making the argument of the importance of proximal stability in preventing distal injury. In contrast, McHugh et al²² found that hip abduction and adduction strength were not associated with increased ankle injury in high school football players. Therefore more studies to determine the role of hip strength in lower extremity injury.

Other proposed indicators for ankle injury in high school football players include previous history and high body mass index²². McHugh et al²³ found that football players who were classified as overweight were 19 times more likely to sustain an ankle sprain than a healthy athlete with no previous history of ankle sprain. They also found that previous history was a significant factor in the risk of ankle injury. Similar results have shown that previous history of ankle sprain increases the risk in high school football^{4, 38}. Additionally studies have shown that increased height and weight are predisposing factors for ankle injuries in soccer⁴¹ and military training²⁴.

Although there is high amount of knee injuries in football, little research has been conducted to determine the predictive factors for these injuries. Some of the most common risk factors that have been identified are decreased valgus/varus moments, decreased landing forces, and increased muscle activation². Therefore, prevention programs have been introduced to improve technique and muscle activation recruitment during cutting maneuvers, when the ACL is most commonly injured. Other proposed risk factors include knee joint laxity, small and narrow intracondylar notch width, and decreased core strength and proprioception². Along with this, most research around preventing knee injuries to date has been focused on gender. In a study by Zebis et al⁴² on female high school athletes found that decreased hamstring muscle activation during side to side cutting were more likely to suffer an ACL injury during the season. However, there is no information to support how this applies to male athletes.

2.4 Instrumented Stabilometry Testing and Injury Prediction

Although these risk factors are all possible causes for injury, many are unable to be modified prior to or during athletic activity. One of the most effective interventions for reducing ankle and knee injury has been balance training. The relationship between ankle injury, proprioceptive, and balance deficits was first proposed by Freeman in 1965⁹. Since this time altered proprioception has been proposed as a predisposing factor to ankle injury when deficits exist. Additionally, balance deficits have been shown to be a predictive factor for ankle injury with instrumented testing^{19, 40 37}, and balance training protocols have been used to reduce ankle injury in football and basketball players^{20, 23, 39}. While this suggests that the use of balance

training may provide the most successful outcome for reducing lower extremity injury, more research needs to be conducted.

Due to the influence of balance on lower extremity injury, researchers have increased the amount of studies examining the ability to predict lower extremity injury in high school athletes. One of the more common trends being utilized in research is the role of stabilometry to try and predict athletes who are more susceptible to ankle injury^{19, 37, 40}. Stabilometry is a valid and reliable technique to measure balance²⁶. One of the more common stabilometry predictions made is postural sway through the use of force plates and instrumented balance systems. Postural sway commonly is an assessment of the center of the pressure and the amount of distance that is moved away from the center. Postural sway deficits consistently have been proposed in research as an intrinsic factor for athletes to sustain an ankle injury^{37, 40}. One of the preliminary studies that have utilized stabilometry for ankle injury prediction was conducted in 1985 by Tropp et al³⁷. Examining Finland soccer players, they found that players with a standard deviation of their postural sway two times the group mean were more likely to sustain an ankle injury.

Further research has been conducted to determine the association between postural sway and ankle injury. In a study by McGuine et al in 2000, the relationship between postural sway measures and ankle injury demonstrated that higher composite sway scores on the NeuroCom New Balance System was associated with ankle injury risk¹⁹. In this study, they had the subjects perform a single leg balance test with their eyes open and closed for twenty seconds. The assessment was performed three times and tests were conducted on both legs. They found that high school basketball players who had higher postural sway measurements were seven times

more likely to sustain an ankle injury. Similar results were found by Wang et al in 2006 when they measured single leg stance performance on a force plate in basketball players⁴⁰. They found that increased postural sway in the mediolateral and anteriorposterior direction were associated with increased ankle injury. Due to these results, both researchers encouraged conducting balance testing in preseason as an intervention to identify athletes who are more susceptible to lower extremity injury.

Although positive research is displayed with these studies, questions arise about the practicality of stabilometry in the clinical setting. Although stabilometry produces predictive and reliable measures, it is also an assessment tool that is not a practical expense for most high school and collegiate settings and requires time and staff that often are not readily available in these settings. Additionally, instrumented testing of static postural control does not assess the athlete's function during sport specific activity which causes its validity to be questioned. These concerns therefore raise questions about the clinical applicability of postural sway measures and lower extremity injury. This has caused researchers to seek other balance assessments in research for lower extremity injury prediction.

2.5 Clinical Balance Testing and Injury Prediction

To predict lower extremity injury, researchers have explored different clinical balance tests to provide a clinical application to the results seen with instrumented balance testing. A common balance test that is utilized today is the single leg stance test or Rhomberg test. This test, which correlates well with instrumented balance testing, may be used in a clinical setting and uses the number of errors observed during the test to calculate a balance deficit. The test is

commonly referred to as the Balance Error Scoring System(BESS) first utilized by Riemann et al³³.

During the test, the amount of errors are calculated while trying to maintain balance using combinations of different testing surfaces and with different stance positions, each for twenty seconds. An error is calculated if the subject takes a step, stumbles, opens their eyes, lifts their heel, takes their hands off their hips, or hips move more than thirty degrees. The test typically increases in difficulty by moving from a bilateral to unilateral or tandem stance, or changing from a firm to foam surface. This test provides clinicians with a much more practical assessment tool that can be conducted in any setting. It also requires limited staff and can be an easy assessment tool to implement into preseason of high school athletes.

Although this test provides clinicians with a much simpler and cost effective assessment, only one study to date has used the BESS to predict ankle injury⁸. Docherty et al⁸ found that patients with functional ankle instability scored more errors on the test when compared to healthy subjects. However, this is the only research to date that supports the correlation between a low score on the BESS and ankle injury. McHugh et al examined the relationship between the Rhomberg test and ankle injury²¹. For the study they tested high school athletes during preseason and tracked injury rates throughout the season. For balance assessment they conducted the Rhomberg test on a wobble board and instructed the athletes to maintain balance for one minute with their arms across their chest. A switch was placed on the foot that counted the amount of times that the nonstance foot was used to correct balance. The researchers in the study found no correlation between the amount of errors during the testing and an ankle injury.

One of the primary problems with clinical balance testing is the lack of reliability due to

the subjective nature of the testing. As demonstrated in the research presented above, the inability to subjectively measure balance hinders the clinician's ability to predict injury. Therefore, a balance test that more objectively measures balance ability is needed. Also, similar to instrumented testing, many researchers argue that static balance testing does not assess function and consequently cannot be translated into identifying at risk athletes during sport specific activity. This demonstrates the need for, a balance assessment that simulates sport specific activity and function.

2.6 The Star Excursion Balance Test (SEBT)

The Star Excursion Balance Test (SEBT) is a clinical test that was first designed to detect functional performance deficits commonly associated with lower extremity pathology. The test consists of a series of reaching tasks with the lower extremity in eight directions. During the testing, the subject is encouraged to reach as far as possible with the nonstance leg while maintaining balance on the stance leg. The SEBT is a test proposed to challenge the subject's postural control, range of motion, strength, and proprioceptive abilities¹⁴. The further the subjects reach distance during the test, the better functional performance of the athlete being tested.

The SEBT is a test that is designed to assess and challenge the subject's dynamic postural control. Postural control can be defined in research as either static or dynamic in nature. Static postural control is often described as the ability to maintain a position with minimal movement of the body occurring. Static postural control is most commonly measured through the use of

force plates while maintaining a stationary position. The most common test utilized by researchers is the Romberg test where the patient maintains a unilateral stance. Although this type of testing is commonly utilized in the clinical setting, it tells the clinician very little information about the athlete's functional ability. Dynamic postural control is described as the ability of the body to maintain a stable base of support while in motion ¹¹. It is commonly linked to sports specific activities and other activities of daily living. Dynamic activity is also defined as any activity that causes the body's center of gravity to change in response to muscular activity¹⁸. This muscular activity in sports can be due to an internal or external disturbance. This type of activity is commonly seen in football when an athlete is forced to make a sudden change of direction to avoid a tackle or comes into contact with another player during a tackle. Testing that is able to assess an athlete's ability dynamically is needed to help predict injury risk as well as determine the return to play and functional status of the athlete.

The SEBT has been proven to be a reliable method for assessing dynamic balance ^{15, 18}. Kinzey and Armstrong¹⁸ reported intraclass correlation coefficients between .67 and .87 for intersession reliability assessments of the SEBT. After six practice repetitions were completed, the range was increased to above .86, prompting researchers to recommend that subjects should be encouraged to perform practice repetitions before formalized testing occurs.

The SEBT has also displayed strong intratester and intertester reliability in research ¹⁵. When controlling for learning effects, the interclass correlation coefficients ranged from .81 to .93 for intertester reliability and .85 to .96 for intratester reliability ¹⁵. These findings have provided the foundation for the SEBT to begin to become one of the gold standards in measuring dynamic postural control.

As stated above, the SEBT consists of reaching with one lower extremity limb into eight different reaching directions while maintaining a unilateral base of support in the middle of the testing grid with the testing leg. This task can be a time consuming and repetitive process for both the researcher and subject, so researchers have made attempts to simplify the task into a smaller amount of reaching distances that will still provide adequate assessment. Hertel¹⁴ found that three of the eight measurements, the anteriomedial, medial, and posteromedial were the most representative of functional performance in patients with and without chronic ankle instability. Since that time, most researchers have simplified the SEBT to the posteromedial, posterolateral, and anterior reach directions³⁰. Additionally, the ability to normalize the data across all subjects was introduced to provide comparisons between subjects¹¹. This is done by measuring the subject's leg length from the anterior superior iliac spine to the medial malleolus. Once the leg length is obtained, the measured reach distance can be divided by the leg length and multiplied by 100 to provide the normalized measurement for comparison.

Current studies have evaluated the effectiveness of the SEBT as a rehabilitation tool for improving dynamic stability patients with chronic ankle instability(CAI)¹² and healthy individuals³². Rasool and George³² used the SEBT as a balance training intervention in healthy males to determine if it improves dynamic stability. The subjects performed the training for four weeks and measurements were made at baseline, two, and four weeks post intervention. The results of the study indicated that SEBT scores in the trained leg increased by 11 -36% at two and four weeks when compared to the control leg in healthy subjects. From these results, they concluded that the SEBT improves dynamic stability rapidly and therefore has practical implications for preseason training. Similar results have been demonstrated when subjects with

CAI utilized the SEBT as a rehabilitation tool to improve dynamic stability. Hale et al¹² found that subjects with CAI improved their reaching distances when compared with the control group. The subject's also demonstrated lower self reported scores on the functional ankle disability index when compared to baseline measurements.

Along with improvements in rehabilitation, the SEBT is also an effective tool for identifying patients with functional deficits due to CAI²⁸. For this study, the SEBT measurements were recorded in all eight reaching directions for healthy patients and patients who suffer from CAI. In this study Olmsted reported that patients with CAI demonstrated decreased reach distances when standing on the injured leg in comparison with the patients in the healthy population (78.6 cm vs. 82.8 cm). She also noted that the CAI subjects reached a significantly less distance when standing on their injured limb when compared to their uninjured limb(78.6 cm vs. 81.2 cm). This demonstrates that the SEBT is an effective assessment tool for identifying at risk individuals who are suffering from chronic ankle instability. Similar results have been seen in a study conducted by Gribble and Hertel et al^{10, 14}. These studies support the conclusion that CAI subjects display deficits during the SEBT.

Decreased reach distances on the SEBT have also been identified in subjects with knee pathology^{3, 13}. Herrington et al¹³ found that subjects with anterior cruciate ligament deficient knees displayed decreased reach distances in the anterior, posteromedial, and medial reach directions. Similar results were also displayed in a study conducted by Aminaka and Gribble³ in patients suffering from patellofemoral pain syndrome.

Since the SEBT is a proven test for identifying functional deficits, Olmsted proposed the use of this test as a cost -effective method for injury screening²⁸. Only one research study to

date has used the SEBT as a preseason screening assessment for injury prediction³⁰. In a study by Plisky et al in 2003, male and female high school basketball players performed the SEBT prior to the season. Throughout the season, the researchers documented lower extremity injuries and used the measurements from the SEBT to determine any correlations existed. They found that basketball players with an anterior right/left reach difference of more than four cm were 2.5 times more likely to sustain a lower extremity injury. They also found that females with a composite reach score of less than 94% of their limb length were 6.5 times more likely to sustain a lower extremity injury.

Based on these results, Plisky et al³⁰ demonstrated that the SEBT was a reliable and predictive measure of lower extremity injury in high school basketball players. To date, this is the only study that has used the SEBT for injury prediction. Based on these results, Plisky et al³⁰ encouraged the SEBT to be utilized as a preseason assessment tool to identify at risk individuals and encourage early intervention for these individuals. We know that training with the SEBT will cause improvements in reach distances over time^{28, 32}. Therefore, more studies need to be conducted to prove the correlation between lower extremity injury and the reach distance on the SEBT exist. To prove this, the SEBT during preseason screening needs to be expanded to other sports which are at high risk for lower extremity injury including football.

In conclusion, the ability to predict and identify at risk individuals is needed due to the high amount of lower extremity injuries sustained by high school football players. The SEBT is proven to be a reliable and predictive assessment tool for lower extremity injury in high school basketball players³⁰. By utilizing this screening tool on high school football players, clinicians will be able to identify at risk individuals and recommend proper prevention for these

individuals. This could reduce the amount of medical costs annually and prevent athletes from suffering from the long term effects associated with lower extremity injury. The purpose of this study is to examine the relationship between the reach distance on the SEBT and lower extremity injury in high school football players. By identifying normalized values and tracking injury rates throughout the season, we will be able to identify at risk athletes for lower extremity injury. This may lead to the standards for recommending prevention and intervention for those individuals in the future.

Chapter 3

3.1 Subjects

The subjects for this study included 121 (age= 15.9 ± 1.1 years; height= 175.6 ± 7.9 cm; mass= 80.5 ± 14.7 kg) high school male football players. The subjects were recruited from the local area high schools in Toledo, Ohio. The subjects included players on the junior varsity and varsity level football teams who participated during the 2009 - 2010 season. All participants participated with an interscholastic football program under the supervision of a coach, and were willing to perform the SEBT, and signed an informed written consent prior to enrolling in the study. Potential subjects were excluded if they had any previous lower extremity surgeries, fractures in the previous 12 months, history of concussion or balance disorders in the previous six months, or required the use of external support during football activity. Of the 121 subjects that were tested, 21 were excluded for the use of external reports during the season. Participants were healthy and cleared for full participation in football activity by a physician at the time of the study.

Subjects were recruited by the certified athletic trainers(ATC) at the local high schools that provide onsite care through the University of Toledo Medical Center. The researchers informed the subjects of the purpose of the study through the coaches and ATC prior to the first day of practice. Prior to any participation in the study, all subjects and their guardians if under

18 signed an informed consent form approved by the University of Toledo Institutional Review Board. Subjects also completed an injury history questionnaire prior to data collection to ensure inclusion and exclusion criteria were accurate. Copies of the consent and assent forms can be seen in Appendices C, D, and E.

3.2 Baseline Measurements

During the preseason screening subjects completed an injury history questionnaire providing baseline characteristics including age, previous injury history, use of external support during activity including tape or brace, and participation in any balance training programs. Prior to testing, the researcher measured the athlete's height, weight, and limb length bilaterally to allow for normalization of the data to occur. To assess limb length, the athlete was placed in a supine position and the researcher measured the distance from the anterior superior iliac spine to the distal aspect of the medial malleolus. To assess true leg length, the subject lifted their hips in a bridge position off the table three times and the researcher passively straightened the legs for the subject. The subject's leg length was recorded in centimeters bilaterally.

3.3 SEBT Protocol

After completion of the survey, the subjects performed the SEBT protocol. The protocol utilized by Plisky et al²⁶ was replicated for this testing. The SEBT requires the subject to stand in the middle of the testing grid and reach as far as possible with the nonstance limb in eight marked directions on the grid. For this test, the subject was required to reach in the anterior,

posteromedial, and posterolateral direction. Prior to data collection, the SEBT protocol included four practice trials in the three reach directions prior to testing. The practice trials control for the learning effect examined by Robinson et al³⁴ after four practice trials. After the practice trials were completed in all three directions, the subjects rested for five minutes before the formal testing. Then, the subjects performed three test trials in each of the three reaching directions on each stance limb for a total of nine trials per limb.

During testing, the researcher instructed the subjects to stand on one leg in the center of the grid with the most distal aspect of the toe at the beginning of the line. The researcher encouraged the subject to reach as far as possible with the non stance leg, lightly touch their toe on the line, and return their foot back to the stance leg. The researcher also instructed the subject to keep their hands on their hips throughout the entire test. The subjects reached in the anteromedial, posteromedial, and posterolateral directions in relation to the stance foot in a randomized order. The subject repeated the trial if they failed to maintain a unilateral stance, lifted or moved the stance foot, touched down with the reach foot, or failed to return the foot to the starting position. The subjects repeated the protocol on the opposite leg for bilateral comparisons. The order of testing limb was randomized.

The researcher recorded the reach distance by marking the tape with ink on the grid. At the end of the three trials, the researcher measured the three marks with a standard tape measure. The averages of the reach distances were recorded in centimeters and normalized to leg length.¹¹ This was done by dividing the reach distance by the subject's leg length and converting to a percentage for each of the three reach directions.

To improve efficiency during the testing, the subjects completed four testing stations. At

the first station the subjects completed the consent form and injury history questionnaire. The second station measured the subject's height, weight, and limb length. The third station was set up as a demonstration and practice station. The fourth station was where the three testing trials were measured and recorded. A copy of the SEBT Data Collection Form can be seen in Appendix F.

3.4 Injury Data Collection

All injury data collection was conducted by the ATC at the assigned high school site. The ATC at the high school recorded and monitored any ankle or knee injury that occurred during the 2009-2010 football season. The ATCs collected injuries and athletic exposure data from the high schools on a weekly basis and transferred the data into a data collection form kept in each high school athletic training room. The information was then collected by the researchers and transferred to an Excel spreadsheet to be processed. Copies of these data collection forms can be seen in Appendices A and B.

The ATCs followed the guidelines for reporting injury incidence and athletic exposures described by Nelson et al²⁵. An athletic exposure was defined as one athlete participating in one practice or competition. A reportable injury was defined as one that occurred as a result of an organized practice or competition, required medical attention by the ATC or a physician, and resulted in restriction of the athlete's participation for one or more days beyond the day of injury²⁵. The ATC also categorized the injuries based on the following choices: 1) if the injury occurred during practice or competition, 2) the use of external ankle support (tape or brace), 3) if

the injury was a "first time" injury or if there was a previous history of the same injury.

The athletic exposure data did not have any identifying information. When an injury occurred, the subject's name was recorded so that it could be matched to the preseason SEBT performance. Permission for this information to be released was clearly explained in the informed consent form signed by the athlete and the parent or guardian during preseason. All injury surveillance information was locked and secured in the athletic training rooms.

3.5 Statistical Analysis

At the end of the preseason screening, the researcher calculated the means and standard deviations for the three reach directions. The reach distances were normalized with leg length to standardize the data among all the subjects. The normalized score was calculated by dividing the reach distance by leg length and multiplying the score by one hundred to determine a percentage. Then a composite reach distance was calculated as the average of the three reaching distances.

To determine if lower composite reach score is associated with ankle or knee injury, the subjects were grouped into an injured and uninjured group. The injured group consisted of those who suffered a lower extremity injury during the football season. Independent t -tests were utilized to compare the anterior, posterolateral, posteromedial, and composite normalized reach score between the two groups to determine significant differences between those who did or did not suffer a lower extremity injury.

Once the normalized values were calculated, the cutoff points for the left and right reach distance were determined using a receiver operating characteristic(ROC) curve analysis using the

calculated lower extremity injury rates. This analysis is similar to that used in the study by Plisky et al³⁰. The ROC is a plot of sensitivity versus specificity of the SEBT. The ROC determines what value of a test is considered positive by different point on the curve corresponding to different cut-off points^{31, 35}. Once a cut-off score on the SEBT was determined, a 2x2 contingency table was created to dichotomize which athletes suffered a lower extremity injury and which did not and which athletes were above or below the cut -off score. This information was used to calculate likelihood ratios and sensitivity and specificity of the SEBT in predicting lower extremity injury. The alpha level for the statistical analysis was set at $p < .05$ to determine significant differences. All data analysis was analyzed using SPSS 15.0 (SPSS Inc, Chicago, IL).

Chapter 4

Results

At the end of the football season, athletes were classified into two groups based on if they sustained a time loss lower extremity injury. Of the 148 junior varsity and varsity football players tested, 43 were excluded for the use of external supports, 2 for previous history or lower extremity injury, and 3 did not finish the season. Of the 100 high school football players who were included in the analysis, 22 (age= 16.8 ± 1.23 years; height= 177.5 ± 8 cm; weight= 91.3 ± 1.2 kg) subjects sustained a lower extremity injury and 78 (age= 15.7 ± 1.1 years; height= 175.1 ± 7.8 cm; weight= 79 ± 14.4 kg) were placed in the uninjured group. Of the 22 lower extremity injuries, 12 injuries occurred at the ankle and 10 at the knee joint.

4.1 Comparison of Means

Independent t tests were then conducted to determine group differences comparing the four normalized reach scores between the injured and uninjured group. The means and standard deviations are provided in Table 4.1.

Table 4.1: This table displays the means and standard deviations in all four reach directions. Subjects were categorized in the injured or uninjured groups based on if they suffered a lower extremity injury during the football season. Statistical significance was set at $p \leq .05$. Statistical significance is denoted with a *

Direction	Injured	Uninjured	
* Anterior	66.0 \pm 9.11	79.97 \pm 7.79	p= .013
Posteromedial	81.67 \pm 8.13	84.94 \pm 10.26	p= .172
Posterolateral	66.47 \pm 11.54	70.83 \pm 11.55	p= .121
* Composite	71.39 \pm 7.71	75.71 \pm 9.05	p= .044

For the four normalized reach scores, significant differences were observed between the injured and noninjured groups in the anterior (70.97 \pm 7.79 vs. 66 \pm 9.11 cm, P=.013) and composite (75.71 \pm 9.05 vs. 71.39 \pm 7.71, P=.044) scores. No significant differences were noted in the posterolateral (70.83 \pm 11.55 vs. 66.47 \pm 11.54 cm, P=.121) and posteromedial (84.94 \pm 10.26 vs. 81.67 \pm 8.13 cm, P=.172) scores.

4.2 Receiver Operating Curve (ROC) Analysis

The ROC analysis was used to determine cutoff scores that demonstrate increased risk for suffering a lower extremity injury in each of the four reach directions. A separate ROC curve was produced for each of the 4 SEBT scores and subsequently, a performance score for each of the four measures was produced that maximized sensitivity and specificity scores. Sensitivity was defined as a measure of how many subjects who scored below the cutoff score on each of the reach directions actually suffered a lower extremity injury. Specificity was defined as a measure of how many subjects who scored above the cutoff point did not suffer a lower extremity injury. To determine these scores, 2x2 contingency tables were constructed for each of the four reach directions. The injured and noninjured subjects were placed into categories based on if they demonstrated a positive or negative test on the ROC analysis. A positive test was described as a subject who scored below the cutoff score in the ROC analysis. A negative test

would then be defined by subjects who scored above the cutoff score on the ROC analysis. For each of the four reach directions, the cutoff score was calculated as the data point in the analysis where the highest sensitivity score and lowest 1 -specificity score was calculated. The scores are represented in Table 4.2 below.

Table 4.2: This table demonstrates the results of the ROC curve analysis. For each direction, the cutoff, sensitivity, and specificity scores are denoted. Statistical significance in comparison of means from Table 4.1 is denoted with a *.

Direction	Score	Sensitivity	1-Specificity
* Anterior	66.725	0.591	0.231
Posteromedial	82.40	0.636	0.410
Posterolateral	65.15	0.545	0.269
* Composite	69.95	0.455	0.167

The results of the 2x2 contingency tables for each reach direction are demonstrated below in Tables 4.3-4.6.

Table 4.3: This table demonstrates the 2x2 contingency table for the anterior reach direction. A subject was placed in the injured or uninjured category based on if they suffered a lower extremity injury during the football season. A positive or negative test is based on if they scored above or below the ROC cutoff score.

	Injured	Uninjured
Positive Test	13	18
Negative Test	9	60

Table 4.4: This table demonstrates the 2x2 contingency table for the posteromedial reach direction. A subject was placed in the injured or uninjured category based on if they suffered a lower extremity injury during the football season. A positive or negative test is based on if they scored above or below the ROC cutoff score.

	Injured	Uninjured
Positive Test	14	31
Negative Test	8	47

Table 4.5: This table demonstrates the 2x2 contingency table for the posterolateral reach direction. A subject was placed in the injured or uninjured category based on if they suffered a lower extremity injury during the football season. A positive or negative test is based on if they scored above or below the ROC cutoff score.

	Injured	Uninjured
Positive Test	12	21
Negative Test	10	57

Table 4.6: This table demonstrates the 2x2 contingency table for the composite reach direction. A subject was placed in the injured or uninjured category based on if they suffered a lower extremity injury during the football season. A positive or negative test is based on if they scored above or below the ROC cutoff score.

	Injured	Uninjured
Positive Test	11	14
Negative Test	11	64

4.3 Likelihood Ratios

To determine the value of the sensitivity and specificity scores, positive and negative likelihood ratios were also calculated. A positive likelihood ratio was represented as sensitivity over 1-specificity with negative likelihood ratios demonstrating the opposite. For the SEBT, a positive likelihood ratio would demonstrate how much the odds of suffering a lower extremity increase if the subject scores below the cutoff score. A negative test would tell you how much the odds of a lower extremity decrease when scoring below the cutoff score. These ratios were calculated for all four reach directions. The results of these ratios are depicted in Table 4.7 below.

Table 4.7: This table demonstrates the positive and negative likelihood ratios for the anterior, posteromedial, posterolateral, and composite sensitivity and specificity scores.

Direction	Positive Likelihood Ratio	Negative Likelihood Ratio
Anterior	2.56	0.53
Posteromedial	1.07	0.77
Posterolateral	2.00	0.63
Composite	2.78	0.61

4.4 Effect Size

Effect sizes were calculated from the means and standard deviations presented in Table 4.1. These relationships allow a comparison of the magnitude of differences between the mean scores while considering the variability in the samples. The results of these calculations are listed in the Table 4.8 below.

Table 4.8: The effect sizes for the anterior, posteromedial, posterolateral, and composite reach scores are listed below. These differences are based on the comparison of means between the injured and uninjured groups.

Direction	Effect Size	95% Confidence Interval	Effect
Anterior	0.61	(0.13, 1.09)	moderate
Posteromedial	0.33	(-0.15, 0.80)	small
Posterolateral	0.38	(-0.10, 0.85)	small
Composite	0.49	(0.01, 0.97)	moderate

The posteromedial, posterolateral, and composite scores all had small effect sizes (<0.50) and the 95% confidence interval of the posteromedial and posterolateral crossed zero. For the anterior and composite reach directions, a moderate effect size was observed with a 95% CI that did not cross zero.

Chapter 5

Discussion

According to the results of the data collection, significant group differences in means existed between the injured and uninjured subjects in the anterior and composite normalized reach scores. This supports our hypothesis that states that differences in means between the injured and noninjured group would be found. No significant differences existed in the posterolateral and posteromedial reach direction. Along with this, cut-off scores in the anterior reach and composite were identified that could produce moderate sensitivity (0.59) and moderate to strong specificity (0.77) scores, allowing creation of likelihood to produce injury prediction models. This also supports our hypothesis that we would be able to identify an ideal cutoff score to predict lower extremity injury in high school football players.

5.1 Anterior Normalized Reach Score Results

In the anterior reach direction, significant group mean differences existed between the injured ($66 \pm 9.11\%$) and noninjured ($70.97 \pm 7.79\%$) groups. The sensitivity and specificity scores from the ROC analysis indicated that 60% of athletes who score below a 66.73 normalized reach

score in the anterior reach direction will suffer a lower extremity injury, while 23% of athletes who score above this score will suffer a lower extremity injury.

The results of this data demonstrate to us that high school football players who score statistically lower on the SEBT in the anterior reach direction are more likely to suffer a lower extremity injury than athletes who do not suffer a lower extremity injury. While the sensitivity scores are not as strong, we see stronger specificity scores in the anterior reach direction. The 1 - specificity scores tell us that only 23% of athletes who scored above the ROC cutoff score suffered a lower extremity injury. This demonstrates to us that while athletes who score below the ROC cutoff score of 66.73% may not be injured, we can rule out the risk of lower extremity injury significantly if the athletes score above this number. We can then identify with moderate confidence athletes who will not suffer a lower extremity injury and possibly recommend neuromuscular training for the athletes who score below this normalized reach score in the anterior reach direction.

5.2 Posteromedial Normalized Reach Score Results

The results of the data analysis in the posteromedial reach direction revealed no statistically significant differences in group comparison of means between injured ($81.67 \pm 8.13\%$) and uninjured groups ($84.94 \pm 10.26\%$). The sensitivity and 1-specificity scores of the ROC curve analysis also did not reveal any significant findings. For the sensitivity scores, the ROC analysis indicated that 64% of athletes who score below a cut-off score of 82.4% on the SEBT will suffer a lower extremity injury. While this is similar to what was found for the

anterior reach direction, strong results specificity scores were not found. The 1 -specificity scores demonstrated to us that 41% of athletes who score above the cutoff score will suffer a lower extremity injury, which were worst 1 -specificity results of any of the four normalized reach directions. The results of this analysis demonstrate to us that the posteromedial normalized reach distance is not as strong as the anterior reach direction in predicting lower extremity injury in high school football players.

5.3 Posterolateral Normalized Reach Score Results

The results of the posterolateral normalized reach scores also revealed no statistically significant differences in group comparison of means between the injured ($66.47 \pm 11.54\%$) and uninjured ($70.83 \pm 11.55\%$) groups. There were also no significant predictive qualities from the sensitivity and specificity scores from the ROC curve analysis. The sensitivity scores indicated that 54% of athletes who score below 65.15% on the SEBT will suffer a lower extremity injury, which demonstrated the worse sensitivity of all four normalized reach directions. The 1 -specificity scores indicated that 27% of athletes who score above the cut off score will suffer a lower extremity injury. The results of this assessment also are not as strong as the anterior normalized reach direction, indicating that the posterolateral normalized reach direction is also not as effective in predicting lower extremity injury in high school football players.

5.4 Composite Normalized Reach Score Results

Similar to the anterior reach direction, the results of the composite score revealed significant differences between the injured ($71.39 \pm 7.71\%$) and uninjured ($75.71 \pm 9.05\%$) groups. Since the composite score is based on an average of the other three reach directions, we can assume that this is primarily due to the anterior normalized reach direction. The sensitivity and specificity scores from the ROC analysis also indicate similar results to the anterior normalized reach direction. The sensitivity scores from the ROC analysis indicated that 45.5% of athletes who scored below a cut-off score of 69.95% suffered a lower extremity injury. The 1-specificity score however displays the strongest ability to rule out lower extremity injury, indicating 17% of athletes who score above the cut-off score will suffer lower extremity injury. This score has the best ability to rule out lower extremity injury of all the specificity scores; however based on the three normalized reach scores discussed above, can primarily be attributed to the anterior reach direction.

5.5 Support for Anterior Normalized Reach Direction

Upon examination of proposed risk factors for lower extremity injury, we hypothesize that the anterior reach direction is sensitive to lower extremity pathology based on the combination of proprioceptive, strength, and postural control challenges that the anterior reach direction presents. For increased reach distance in the anterior reach direction, ankle dorsiflexion and knee flexion are necessary. The ability to maintain balance and postural control while changing the center of gravity is also measured. Also in the anterior reach direction, co-activation of the hamstring and quadriceps occurs while maintaining balance on the stance limb.

All of these factors have been hypothesized by researchers as possible contributions to lower extremity injury.

Other statistical support also exists for testing the anterior normalized reach direction. When compared to the posterolateral and posteromedial normalized scores, the anterior reach direction also demonstrated the strongest likelihood ratios and effect size calculations. For the anterior normalized reach scores, the positive likelihood ratio was 2.56 and negative was .53. The anterior reach direction also displayed the strongest effect size score (.61) when compared to the posterolateral (.38) and posteromedial (.33) normalized reach scores.

The anterior normalized reach direction has also been supported in other studies that looked at the SEBT and injury prediction. Plisky et al³⁰ found that decreased performance in the anterior reach direction increased the risk of lower extremity injury in female basketball players. Additionally, they reported that athletes who demonstrated side to side differences in the anterior reach direction were more likely to suffer lower extremity injury. Even though these are slightly different results, poorer anterior reach differences are still linked to lower extremity injury when compared to the three other reach scores. However to date these are the only studies to examine the SEBT as a predictor for lower extremity injury. More information is needed to examine injury prediction abilities of the SEBT between male and female athletes, across age groups, and across different sports.

5.6 Clinical Relevance

Based on the results above, clinicians may only need to examine the anterior reach direction in preseason testing to predict lower extremity injury in high school football athletes. This will save time and resources for the clinician. This makes the SEBT a much more practical test to be conducted in the athletic training room setting, especially for the testing of teams with larger participation such as football. We know how this test applies to football players, but future directions need to focus on other sports and populations such as the collegiate setting to determine if level of training and age are factors. Also, larger sample sizes are needed over multiple seasons to improve external validity. Since an ideal cutoff score has been determined, future studies need to implement neuromuscular training interventions for athletes who score below the normalized anterior reach direction score to determine if lower injury rates occur. We know that improvements in score occur when healthy³² and subjects with CAI¹² perform the SEBT as a rehabilitative tool, but we have yet to determine if injury rates decrease.

5.7 Limitations

A limitation to the study, as with any other epidemiology study, is accuracy in injury data reporting and collection. The ATCs at the assigned high schools were responsible for reporting injuries and athletic exposures to the researcher on a weekly basis. However, since the athletic trainers involved in this study only traveled for varsity away games, some of the injury data may not have been given to the home athletic trainer. Another limitation with football is that not all of the subjects that were tested recorded the same amount of time in practice and game

participation which may have affected injury rates. Some factors that also could not be controlled for is participation in balance training during the season or use of external supports throughout the season. Although subjects were excluded if they stated they used external support during practice and game activity, some may not have been honest or may not have planned on using them at the time of testing. Finally, although subjects were encouraged to give their best effort on the test, some may have not which is a factor that cannot be controlled for. These are all factors that may have also affected injury rates and performance on the SEBT.

5.8 Summary

Based on our findings, we have concluded that the SEBT is a predictive measure of lower extremity injury in the anterior and composite direction for high school football athletes. We recommend that clinicians can simplify the SEBT to the anterior reach direction for preseason injury screening due to the lack of significant results in the posterolateral and posteromedial direction. More research needs to be conducted to determine how these results are influenced by different sports, settings, and larger sample sizes. Future studies should focus on determining if neuromuscular training reduces lower extremity injury for athletes who score below the ROC cutoff score. If so, the SEBT may be utilized as a simple and extremely effective training tool that will prevent many athletes from suffering from time loss injuries.

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Appendix A

Ankle Injury Data Collection Form

Date of Injury: _____ Practice or Competition

Sex: M F Age: _____

Sport: Football Soccer Volleyball Basketball

Injury

Lateral Ankle Sprain: Grade I Grade II Grade III

Medial Ankle Sprain: Grade I Grade II Grade III

Dislocation: Indicate Joint _____

Achilles Tendon: Grade I Grade II Grade III (rupture)

Peroneal Tendon: Grade I Grade II Grade III

Fracture: Indicate Bone _____

Describe Mechanism of Injury:

Was Ankle Protected: No Yes-Taped Yes-Braced

Was this the first time this injury was experienced: Y N

If no, how many times had this injury been experienced? _____

Appendix B

Knee Data Collection Form

Date of Injury: _____ Practice or Competition

Sex: M F Age: _____

Sport: Football Soccer Volleyball Basketball

Injury

Medial Collateral Sprain: Grade I Grade II Grade III

Lateral Collateral Sprain: Grade I Grade II Grade III

Anterior Cruciate Sprain: Grade I Grade II Grade III (rupture)

Posterior Cruciate Sprain: Grade I Grade II Grade III (rupture)

Meniscal Injury: Medial Lateral

Patellar Dislocation: Medial Lateral Superior Inferior

Patellar/Quadriceps Tendon Rupture

Quadriceps Strain: Grade I Grade II Grade III

Hamstrings Strain: Grade I Grade II Grade III

 Indicate muscle: SM ST BF

Fracture: Indicate Bone _____

Describe Mechanism of Injury:

Was Knee Protected: No Yes-Braced

Was this the first time this injury was experienced: Y N

If no, how many times had this injury been experienced? _____

Appendix C

ADULT RESEARCH SUBJECT INFORMATION AND CONSENT FORM

USING DYNAMIC POSTURAL CONTROL TO PREDICT ANKLE INJURY IN ADOLESCENT ATHLETES

Principal Investigator: Phillip Gribble, Ph.D., ATC

Other Staff (identified by role): Kristen Pollock, ATC (research assistant)

Naoko Aminaka, ATC, MS (research assistant)

Junji Shinohara, ATC, MS (research assistant)

Kathryn Webster, ATC, MA (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 allow to take part in a research study that will examine the relationship of performance on a simple dynamic balance test 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 ankle injury among high school football and basketball athletes. The purpose of the study is determine if performance on a simple balance test can help predict the risk of ankle injuries that are suffered by high school football and basketball 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 and basketball players 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 instability that occurs during the sports of football and basketball.

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 or basketball
- Between the ages of 14 and 18 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 400 participants from 4 high schools in the Toledo area. 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 test will be performed at the high schools that are participating.

DESCRIPTION OF THE RESEARCH PROCEDURES AND DURATION OF YOUR INVOLVEMENT

If you give consent to participate, he or you will be asked to come to your school on the designated testing day with this form signed by you and the participating child. The testing days will coincide with arranged physical exam days at the schools where physicians and athletic trainers will be present to examine and clear you for participation in basketball or football 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 their identity is kept confidential throughout the duration of this research study.

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

Following the practice trials and the five minute rest, the participant will move to the last 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.

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 and basketball 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 pre-season SEBT performances to determine a score that can predict the ankle injury “incidents”.

This study is examining the ability of dynamic balance performance to predict ankle injury in high school football and basketball athletes. You will come for the single testing session described above and participate for approximately 20 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 testing. However, you will be given instruction on how to perform the task and adequate practice to become comfortable with the task. An investigator will be standing nearby in the unlikely event that you do need assistance.
2. You may experience slight soreness or tiredness during the single -leg standing balance task. 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 high school. 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 on the high school campus.

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.

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.

Name of Subject (please print)	Signature of Subject or Person Authorized to Consent	
Relationship to the Subject (Healthcare Power of Attorney authority or Legal Guardian)		Time
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

Appendix D

RESEARCH SUBJECT INFORMATION AND CONSENT FORM

USING DYNAMIC POSTURAL CONTROL AND FUNCTIONAL TEST SCREENING TO PREDICT ANKLE INJURY IN ATHLETES

Principal Investigator: Phillip Gribble, Ph.D., ATC

Other Staff (identified by role): Kristen Pollock, ATC (research assistant)

Naoko Aminaka, ATC, MS (research assistant)

Junji Shinohara, ATC, MS (research assistant)

Kathryn Webster, ATC, MA (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.
- Your son/daughter/legal charge has the right to refuse to take part in this research, or agree to take part now and change his or her mind later.

- If you decide to allow your son/daughter/legal charge to take part in this research or not, or if you decide to allow your son/daughter/legal charge to take part now but change your mind later, your decision will not affect his or her routine care.
- Please review this form carefully. Ask any questions before you make a decision about whether or not you want your son/daughter/legal charge to take part in this research. If you decide to allow your son/daughter/legal charge to take part in this research, you may ask any additional questions at any time.
- Your son/daughter/legal charge participation in this research is voluntary.

PURPOSE (WHY THIS RESEARCH IS BEING DONE)

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

You are being asked to allow your son/daughter/legal charge to take part in a research study that will examine the relationship between dynamic balance and functional performance and ankle and knee injury among high school football and basketball athletes. The purpose of the study is determine if performance on a simple balance test and a series of functional tests can help predict the risk of ankle injuries that are suffered by high school football and basketball athletes. If we are able to determine that this testing can predict these injuries effectively, in the future researchers and clinicians may be able to screen and identify high school football and basketball players 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 and basketball.

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

Volunteer participant

Inclusion criteria:

- Physically active individuals medically cleared by a physician for participation in either football or basketball
- Between the ages of 14 and 18 years

Exclusion criteria:

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

Your son/daughter/legal charge is enrolling in the study as one of approximately 400 participants from 4 high schools in the Toledo area. 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 function tests will be performed at the high schools that are participating.

DESCRIPTION OF THE RESEARCH PROCEDURES AND DURATION OF YOUR INVOLVEMENT

If you give consent for your son/daughter/legal charge to participate, he or she will be asked to come to his or her school on the designated testing day, arranged and approved by the school's coach, Athletic Director and Athletic Trainer, with this form and the Assent form that has been provided signed by you and the participating child. If your son/daughter/legal charge cannot make this designated testing date or do not have the required consent and assent forms with them, another date will be arranged to conduct this testing prior to the first day of schedule team practice.

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

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

At the next station, a member of the research team will demonstrate the dynamic balance test, called the Star Excursion Balance Test (SEBT). The SEBT requires the participant to stand on one leg in the middle of a grid on the floor and then try to reach with the other leg to touch a spot on the floor as far as they can along a line on the grid. If the participant loses their balance,

puts too much weight on the reaching foot or moves the foot of the leg they are standing on, the reaching trial is repeated. After the demonstration, the participants will practice the SEBT standing on their right leg four times and then on their left leg four times so that they can become familiar with how to do perform the test. Then they are given five minutes to rest.

Following the practice trials and the five minute rest, the participant will move to the last 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.

After the SEBT performance, your son or daughter will go to another station where an Athletic Trainer will observe him or her perform 7 functional tests. The tests are 1) a squat, 2) stepping over a short hurdle, 3) a lunge, 4) a shoulder mobility reach test, 5) a straight leg raise, 6) a push-up, and 7) a trunk rotary stability test. Each test will be explained and demonstrated to the child. After he or she has a chance to ask questions and feel comfortable with each test, they will perform each test as instructed 3 times. The Athletic Trainer will grade the performance on a 3 point scale and record the number. It will take approximately 30 minutes to complete this series of tests.

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

The number of injury incidents will be analyzed by the research team along with the pre - season balance and functional performances to determine a score that can predict the ankle injury “incidents”.

This study is examining the ability of dynamic balance and functional performance to predict ankle and knee injury in high school football and basketball athletes. Your son/daughter/legal charge will come for the single testing session described above and participate for approximately 30 minutes.

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

RISKS AND DISCOMFORTS YOU MAY EXPERIENCE IF YOU TAKE PART IN THIS RESEARCH

When participating in any research study, you may encounter some risks. Although the risk for taking part in this study is very low, your son/daughter/legal charge may experience one or more of the following:

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

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

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

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

COST TO YOU FOR TAKING PART IN THIS STUDY

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

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.

IN THE EVENT OF A RESEARCH-RELATED INJURY

In the event of injury resulting from your son/daughter/legal charge taking part in this study, treatment can be obtained at a health care facility of your choice. You should understand that the costs of such treatment will be your responsibility. Financial compensation is not available through The University of Toledo or The University of Toledo Medical Center. 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 by your son/daughter/legal charge at any time without penalty or a loss of benefits to which he or she are otherwise entitled. If you decide not to allow your son/daughter/legal charge to participate or to discontinue participation, your decision will not affect your future relations with the University of Toledo or The University of Toledo Medical Center.

NEW FINDINGS

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

OTHER IMPORTANT INFORMATION

There is no additional information

ADDITIONAL ELEMENTS

There are no additional elements to the study.

Name of Subject (please print)

Signature of Subject or

Person Authorized to Consent

Relationship to the Subject (Healthcare Power of Attorney authority or Legal Guardian)

Name of Person Obtaining Consent
(please print)

Signature of Person Obtaining Consent

Name of Witness to Consent Process
(when required by ICH Guidelines)

(please print)

Signature of Witness to Consent Process
(when required by ICH Guidelines)

Appendix E

RESEARCH SUBJECT ASSENT FORM

USING DYNAMIC POSTURAL CONTROL TO PREDICT ANKLE INJURY IN ADOLESCENT ATHLETES

Principal Investigator: Phillip Gribble, Ph.D., ATC

Other Staff (identified by role): Kristen Pollock, ATC (research assistant)

Naoko Aminaka, ATC, MS (research assistant)

Junji Shinohara, ATC, MS (research assistant)

Kathryn Webster, ATC, MA (research assistant)

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

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

We are doing a research study about ankle injuries during sports and how we can prevent them. A research study is a way to learn more about people. If you decide that you want to be part of this study, you will be asked to come to your school before football or basketball practice starts for the year and do a balance test. The researchers will measure how far you can reach with one

leg while standing on the other leg. How far you can reach will tell them how good your balance is. During the football and basketball seasons at your school, we will be working with the Athletic Trainer to find out how many ankle injuries happen. Then we will try to use the balance scores to help understand the ankle injuries happened.

There are a few small risks if you participate. There is a small chance you could fall over during the balance test. But, we will give you practice to make sure you feel good about doing the balance test before you do it. Also, we will make sure there is someone standing close by in case you feel unstable. Finally, even though the test doesn't take very long, we will make sure you have a chance to rest in case you get tired.

Not everyone who takes part in this study will benefit. A benefit means that something good happens to you. We think these benefits might be that it will help doctors, athletic trainers, and coaches prevent ankle injuries in the future. We want to use balance tests that athletes can do at their schools to help find out who may need extra help in preventing an ankle injury before they start playing football or basketball.

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

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

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

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

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

I, _____, want to be in this research study.

(Print your name here)

Sign your Name: _____ Date:

Appendix F

Star Excursion Balance Test Data Collection Form

Subject # _____

Sex: M F

Age _____

Height _____

Weight _____

Right leg length _____

Left Leg Length _____

Anterior Reach		
Right Stance Leg		
	Raw	Normalized
Trial 1		
Trial 2		
Trial 3		
AVG		

Left Stance Leg		
	Raw	Normalized
Trial 1		
Trial 2		
Trial 3		
AVG		

Posteriomedial Reach		
Right Stance Leg		
	Raw	Normalized

Left Stance Leg		
	Raw	Normalized

Trial 1		
Trial 2		
Trial 3		
AVG		

Trial 1		
Trial 2		
Trial 3		
AVG		

Posteriorlateral Reach		
Right Stance Leg		
	Raw	Normalized
Trial 1		
Trial 2		
Trial 3		
AVG		

Left Stance Leg		
	Raw	Normalized
Trial 1		
Trial 2		
Trial 3		
AVG		

Right Composite Score		
	Raw	Normalized

Left Composite Score		
	Raw	Normalized