A Thesis

entitled

Lower Extremity Injury Predictability of the Functional Movement Screen and the Star Excursion Balance Test

by

Matthew D. Morrell, ATC

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

________________________________________
Dr. Phillip Gribble, Committee Chair

________________________________________
Dr. Brian Pietrosimone, Committee Member

________________________________________
Dr. Kate Pfile, Committee Member

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

The University of Toledo

May 2012
An Abstract of
Lower Extremity Injury Predictability of the Functional Movement Screen and the Star Excursion Balance Test

by
Matthew D. Morrell

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

The University of Toledo

May 2012

Background: Since lower extremity injuries are the most prevalent of football injuries, it is important to examine the ability of current pre-participation examination systems in identifying athletes who are at potential risk for injury. Two current assessment tools being utilized to identify athletes at risk for lower extremity injury are: the Functional Movement Screen (FMS) and the Star Excursion Balance Test (SEBT). Purpose: The purpose of this research was to compare the ability of the FMS and SEBT to differentiate between college football players that do and do not suffer an acute lower extremity injury, as well as determine cut-off scores that allowing the creation of prediction models for lower extremity injury. Methods: One-hundred and eighty Division I college football players were screened using both the FMS and SEBT as part of their pre-participation examination. Throughout the season injuries were recorded and players were placed into 2 groups: injured and non-injured. Students t-tests were ran comparing the means of the injured and non injured groups for the FMS and each component of the SEBT. A 1-way ANOVA was ran between 3 groups: contact injured, non-contact injured and non-injured. Receiver operator characteristic curves were formulated and cut-off scores that
maximized sensitivity and specificity were obtained. **Results:** The SEBT anterior reach score was the only test that revealed a significant difference ($P = 0.035$) between injured and non-injured groups. The SEBT anterior reach score also revealed a significant difference ($P = 0.015$) between groups that were non-contact injured and those who were non-injured. **Conclusion:** The SEBT anterior reach test was better than all others that we examined at predicting those who would get injured.
I would like to dedicate this work to my mother and step-father. If not for the constant support from them I would not be where I am today.
Acknowledgements

I would like to thank my entire committee for their help, but especially my committee chair, Dr. Phillip Gribble, for all his many hours of help leading to the completion of this project. I would also like to thank the University of Toledo football team for their help in volunteering for this study, as well as the University of Toledo football athletic training staff who were crucial in the data collecting process. Lastly, I’d like to thank my fellow internal GA’s who helped keep a smile on my face throughout this daunting process.
# Table of Contents

Abstract .............................................................................................................................. iii

Acknowledgements ........................................................................................................ vi

Table of Contents ............................................................................................................. vii

List of Tables ..................................................................................................................... viii

List of Abbreviations ........................................................................................................ ix

1 Introduction .................................................................................................................. 1
  1.1 Background ................................................................................................................ 1
  1.2 Problem Statement .................................................................................................... 3
  1.3 Purpose Statement ..................................................................................................... 3
  1.4 Significance of Study ............................................................................................... 4
  1.5 Hypothesis ................................................................................................................ 4
  1.6 Limitations ................................................................................................................ 5

2 Literature Review .......................................................................................................... 7
  2.1 Epidemiology ............................................................................................................ 7
  2.2 Functional Movement Screen .................................................................................. 10
  2.3 Star Excursion Balance Test .................................................................................... 20

3 Methodology .................................................................................................................. 23
  3.1 Experimental Design ............................................................................................. 23
  3.2 Subjects ................................................................................................................... 23
3.3 Instrumentation ........................................................................................................24
3.4 Independent Variables ............................................................................................24
3.5 Dependent Variables ...............................................................................................24
3.6 Procedure ................................................................................................................25
3.7 Statistical Analysis ..................................................................................................26

4 Results ........................................................................................................................28

5 Conclusion ..................................................................................................................32
  5.1 Introduction ............................................................................................................32
  5.2 Comparison to previous FMS research .................................................................33
  5.3 Comparison to previous SEBT research ...............................................................34
  5.4 Clinical Significance .............................................................................................35
  5.5 Limitations .............................................................................................................36
  5.6 Conclusions ..........................................................................................................36

References ......................................................................................................................37
## List of Tables

4.1 Demographics ........................................................................................................................................................................28
4.2 Injured vs Non-injured Comparisons...........................................................................................................................................29
4.3 Cut-off Scores and Odds Ratios......................................................................................................................................................29
4.4 FMS 2x2 Contingency Table .............................................................................................................................................................30
4.5 SEBT Composite 2x2 Contingency Table .....................................................................................................................................30
4.6 SEBT Anterior 2x2 Contingency Table ........................................................................................................................................30
4.7 SEBT Posteriormedial 2x2 Contingency Table .................................................................................................................................30
4.8 SEBT Posteriorlateral 2x2 Contingency Table ....................................................................................................................................30
4.9 Mechanism of Injury Comparison ...................................................................................................................................................31
List of Abbreviations

FMS............................Functional Movement Screening
SEBT..........................Star Excursion Balance Test
CAI............................Chronic Ankle Instability
Chapter 1

Introduction

1.1 Background

Football is an extremely popular sport with the number of collegiate football athletic programs increasing by nearly 100 between the years of 1988 and 2004.\textsuperscript{1} This caused the number of athletes participating in college football to increase by over 12,000 athletes.\textsuperscript{1} With the increased prevalence of football in college athletics, there is also an increase in potential injury risk during practice and competition. Injuries in football have been found to occur mostly in the lower extremity,\textsuperscript{1} encompassing both contact and non-contact injuries.\textsuperscript{1} With such high injury rates in the lower extremity, it is important to examine the epidemiology of these injuries and to assess the ability of current pre-participation examination systems in identifying athletes who are at potential risk for injury. Two current assessment tools being utilized to identify athletes at risk for lower extremity injury are: the Functional Movement Screen (FMS) and the Star Excursion Balance Test (SEBT).\textsuperscript{2-8}

The FMS is an evaluation tool used to assess the ability to complete seven functional movements that are said to be the fundamental basis for all other movements.\textsuperscript{9,10} Persons being evaluated are given a score of zero to three depending on
how well they perform each of the movements, making a total of twenty-one possible points. The FMS has been proven as a reliable tool when used by individuals trained in its procedures. Previous studies have utilized the FMS as a predictive tool for female collegiate athletes and National Football League players. Both studies found that having a score below fourteen out of twenty-one significantly increased the risk of injury. However, both studies used a very broad definition of injury, and therefore their data may be misleading and not effectively represent a true injury cut-off score. Currently there is no published research describing the FMS as a predictor of acute lower extremity injury in college football players. However, in an unpublished thesis by Ford this relationship was studied and found that athletes that scored less than 15.5 were 3.2 times more likely to suffer a lower extremity injury. Since only one competitive year was studied by Ford more research must be done to validate the score that was found.

The SEBT is another evaluation tool that has been used to predict injuries in different groups of subjects. This test evaluates dynamic postural control by having subjects maintain balance on one limb while reaching in three different directions (anterior, posterolateral, and posteriormedial) with their other limb. Most research utilizing the SEBT has been to evaluate persons with a current condition such as chronic ankle instability or anterior cruciate ligament deficiency. However, some research has assessed the SEBT’s ability as a predictor of injury in high school football and basketball players. Pilsky et al found that the SEBT was able to predict a 2.5 times greater chance at having a lower extremity injury in high school basketball players if their anterior reach score was different by 4 cm bilaterally. However, this data was not normalized as current research now recommends therefore this finding needs further
investigation. Recent work by Pollock et al.\textsuperscript{8} examining high school football players found significantly shorter normalized anterior and composite reach scores of players that went on to suffer a lower extremity injuries. Additionally recent unpublished pilot research on collegiate football players found that those scoring less than 72.75\% on the normalized anterior reach score were 4.94 times more likely to suffer a lower extremity injury.

1.2 Problem Statement

With the majority of football related injuries occurring to the lower extremity it is important to find a tool which can be utilized clinically to identify factors which my predispose athletes to injury. Previous research using either the FMS or SEBT has been conducted to determine the ability to predict injury in different populations;\textsuperscript{4,7,8} however, no formally published work exists that has included the use of both tools in examining injury prediction among Division I college football players.

1.3 Purpose Statement

The primary purpose of this research was to compare the ability of the FMS and SEBT to differentiate Division I college football players that do and do not suffer acute lower extremity injuries, as well as determine cut-off scores that will yield a high sensitivity to specificity ratio for both the FMS and SEBT, allowing the creation of robust prediction models for lower extremity injury. The secondary purposes were to: 1. determine whether the FMS and SEBT better predict knee or ankle injuries; 2. determine whether the FMS and SEBT better predict contact or non-contact injuries; 3. determine whether the FMS or SEBT is better at predicting lower extremity injuries.
1.4 Significance of Study

The ability to predict injuries with the FMS and SEBT could provide valuable information if implemented into a pre-participation examination. By identifying neuromuscular deficiencies, a rehabilitation program could then be created to assist in the prevention of future injuries. Preventing injuries will allow for increased participation in athletics and could ultimately aid in the reduction in overall healthcare costs by reducing the need for diagnostic tools, such as x-rays and MRIs, as well as possible surgeries.

1.5 Hypothesis

SEBT

**H$_1$:** Collegiate football athletes who experience an acute lower extremity injury to the ankle or knee during the competition season will demonstrate shorter normalized reach distances on the SEBT during pre-season assessments compared with the athletes who do not experience a lower extremity injury.

**H$_2$:** There will be a predictive normalized score on the SEBT that will produce sensitivity and specificity scores above 0.70 for the prediction of athletes with or without lower extremity injuries in collegiate football players.

**H$_3$:** The normalized SEBT scores during the pre-season of those that suffer ankle injuries during regular season participation will be lower than those that suffer knee injuries and the non-injured group.

**H$_4$:** The normalized SEBT scores during the pre-season of those that suffer non-contact lower extremity injuries throughout the regular season participation will be lower than athletes that suffer contact injuries and the non-injured group.
**FMS**

**H₅:** Collegiate football athletes who experience an acute lower extremity injury to the ankle or knee during the competition season will demonstrate a lower score on the FMS during pre-season assessments compared with the athletes who do not experience a lower extremity injury.

**H₆:** There will be a predictive normalized score on the FMS that will produce sensitivity and specificity scores above 0.70 for the prediction of athletes with or without lower extremity injuries in collegiate football players.

**H₇:** The FMS scores during the pre-season of those that suffer ankle injuries during regular season participation will be lower than those that suffer knee injuries and the non-injured group.

**H₈:** The FMS scores during the pre-season of those that suffer non-contact lower extremity injuries throughout the regular season participation will be lower than athletes that suffer contact injuries and the non-injured group.

**Overall**

**H₉:** The SEBT will have greater sensitivity and specificity in injury prediction overall compared to the FMS.

**1.6 Limitations**

A number of the participants in this study have been tested using the FMS and SEBT in previous years; therefore, a learning effect may be present for some athletes. With the possibility of multiple examiners administering both the FMS and SEBT there was a chance for a poor inter-rater reliability, however all of the examiners who were administering the test had previous experience doing so. Since the injury tracking was
not performed by the primary investigator, there was a risk that not all injuries were consistently identified. However, the primary investigator checked with the injury reporter weekly to minimize this chance of error. Another possible limitation was that some athletes were required to wear prophylactic taping or bracing during practice and competition depending on their position or injury history, required by the coaching staff or athletic trainer. The use of these taping or bracing methods had the possibility to reduce injuries which may have otherwise occurred and contributed to the outcome and interpretation of the FMS and SEBT as predictive tools.
Chapter 2

Literature Review

The ability to reduce injury rates through effective injury prediction is an important step for clinical practice. The existing literature is limited, but promising; however no previously published work has considered collegiate football players. It is important to examine current literature involving the injury rates experienced in football before preparing a recommendation for a new component to the pre-participation examination, the current standard should be evaluated. Possible components to be added to a pre-participation examination include the Star Excursion Balance Test and the Functional Movement Screening.

2.1 Epidemiology

Between the years of 1988 and 2004 the number of colleges supporting a football program increased substantially from 524 to 621, with the number of total athletes increasing by over 12,000.\textsuperscript{1} Previous studies have examined injury epidemiology in high school\textsuperscript{17}, collegiate\textsuperscript{1} and profession football\textsuperscript{18}. Injuries to be recorded were defined as events that occurred during an organized team practice or competition which required evaluation by either a certified athletic trainer or a physician and resulted in the loss of at least one day of participation.\textsuperscript{1,17,18}
**Injury Rates**

Injury rates were calculated by comparing the number of injuries to the number of athlete exposures (AE), where one exposure is defined as a time when one athlete participates in one practice or competition.\(^1,17,18\) Injuries were recorded in one of three ways: (1) using the NCAA injury surveillance system\(^1\), (2) using an internet based injury surveillance program through the Research Institute of the National Children’s Hospital in Columbus, OH\(^17\), or (3) using injury data collected from one NFL team.\(^18\)

Dick et al\(^1\) formulated injury rates for pre-season practice, in-season games, and spring practice for collegiate football. During pre-season practices the injury rate was 3.80 injuries per 1000 AEs, during in-season games this number rose to 35.90 injuries per 1000 AEs, while in spring practice the injury rate was 9.62 injuries per 1000 AEs.\(^1\)

Rechel, who examined high school football players, found an injury rate at 4.36 injuries per 1,000 AEs, a number higher than any of the other high school sports investigated.\(^17\)

Finally, when looking at NFL football players, Feeley observed a total of 728 injuries among 42,030 AEs which amounted to an injury rate of 17.3 per 1,000 AEs.\(^18\)

**Body Part Injured**

In the study by Dick et al\(^1\) injuries sustained during this study were divided into five distinct regions of the body: head/neck, upper extremity, trunk/back, lower extremity and other/system. Of all the body regions, the lower extremity was injured the most, accounting for 53.7\% of all recorded injuries.\(^1\) Rechel\(^17\) also found that the most commonly injured area of the body was the lower extremity, with 57.2\% of all injuries,\(^17\) with football injuries accounted for 48.6\% of all injuries during practice and 46.2\% of all
injuries during competitions to the lower extremity. This shows, by an overwhelming majority, that most football injuries occur in the lower extremity.

**Injury Severity**

Another important classification of injury pertains to the severity. Dick et al. classified lower extremity injuries which caused the athlete to be removed from competition for more than a total of ten days as severe. During both the preseason (practice) and in-season (practice and games) the most severe injuries occurred in the lower extremity. The most abundant severe injury was knee injuries, with 26.0% of all severe injuries during preseason and 32.8% of all in-season severe injuries. The second most abundant severe injury was ankle ligament sprains which occurred at a rate of 8.7% in preseason and 11.8% in-season. Feeley et al, who studied NFL football injuries, defined severe injuries slightly differently, as causing the athlete to miss six or more consecutive days of competition. Of all the injuries 6.4% were said to be severe and 35 total injuries sustained during the ten year study required a surgical intervention that caused the athlete to be placed on the injured reserved list and miss the entire season. It is important to have a consistent definition of injury severity as researchers attempt to create injury prediction models.

**Mechanism of Injury**

Understanding the method by which these injuries occur is also a crucial component in the prediction of sport related injuries. The NCAA surveillance study also examined the mechanism by which football injuries occurred, stating that the majority of the reported injuries happened in one of three different mechanisms: player contact, other
contact (with a ball or dummy) and noncontact. The majority of injuries happened as a result of player contact during all three seasons (preseason, regular season, spring season), with noncontact occurring the second most. Although noncontact injuries did not account for the highest total number of overall injuries, it was the most prevalent mechanism for injuries to the anterior cruciate ligament (ACL) in the knee. Of the noncontact ACL injuries, 28.6% occurred during games and 34.8% occurred during practice with a mechanism of knee rotation about a planted foot.

This research shows by an overwhelming majority how great the risk of injury is for athletes participating in football. The common trend throughout all the studies also indicates that the majority of the injuries suffered by the athlete were to soft tissue areas of the musculoskeletal system in the lower extremity. Looking for common trends among injured participants is crucial when attempting to predict these injuries. With such high injury rates occurring from a non-contact mechanism it can be inferred that certain biomechanical deficiencies are present in individuals who are suffering these injuries. Being able to identify these deficiencies could be an invaluable tool in reducing future injuries. With an injury rate nearly double that of any other sport, football serves as a good model to examine how well a musculoskeletal screening can predict injuries. It is of particular interest to determine if an injury prediction tool can identify risk of non-contact injury in a sport that is highly susceptible to contact mechanisms.

2.2 Functional Movement Screen

With such high injury rates found in college, high school and professional football being able to pre-screen athletes in an effort to predict injuries could be beneficial in trying to reduce future injury. A quick, easy, and cost effective prediction
test would be very beneficial for a football team because of a large number of athletes; therefore a test requiring a large amount of time to complete would not be efficient. Currently, pre-participation physical examinations cover general health conditions but what is missing from these examinations is a test of the athletes’ ability to complete fundamental movements which are the base for many athletic movements.

The Functional Movement Screen (FMS) attempts to assess these basic movements through seven fundamental movement patterns. These movement patterns require the subject to be put in positions where they are vulnerable to weakness and loss of balance if adequate stability and mobility are not utilized. The movements are said to be the basis for all other functional movements seen throughout sport. These movement patterns are based on fundamental proprioceptive and kinesthetic awareness principles which look at the body as a complete chain. The movements include: Deep Squat, Hurdle Step, Lunge Step, Shoulder Mobility, Straight Leg Raise, Trunk Stability Push-up, and Rotary Stability Test.

The FMS is scored on a nominal scale from zero to three, with zero being the worst score and three being the best score. A score of zero is only given when the subject is unable to complete the movement due to pain. A score of one is given to subjects who are not able to complete the movement. A score of two is given when subjects can complete the movement however some compensation is noted and a score of three is given when the subject can complete the movement perfectly. Some movements require the subject to be tested bilaterally and in this case scores are taken for each side and the lowest score is recorded. With seven total movements and three points being
possible for each movement the highest possible score which can be achieved is twenty-one points.  

An FMS test kit includes all the supplies that are needed to administer the test. This includes a dowel, a two inch by six inch board, a bungee cord, and two poles. The dowel, which has a tape measure printed on it, is used in the Deep Squat, In-Line Lunge, Shoulder Mobility, Hurdle Step, and Straight Leg Raise tests. The two inch by six inch board, which also includes a tape measure on it, is used in the Deep Squat, In-Line Lunge and Hurdle Step tests. The board, bungee cord and poles are all used to create a hurdle for the Hurdle Step test.

**Deep Squat**

The first movement described is the deep squat, it requires the subject to start with their feet shoulder width apart and pointed straight forward. The subject is then instructed to hold a dowel overhead with their arms extended maximally while they perform the deep squat motion slowly. If the subject is unable to complete this motion a two inch by six inch board is placed under their heels and they are asked to retry the test.

A score of three out of three on this test is earned when the following conditions are met: (1) the upper torso is parallel with the tibia or toward vertical, (2) the femur is below horizontal, (3) the knees are aligned over the feet, and (4) the dowel is aligned over the feet. A score of two out of three is given if the subject requires the use of two inch by six inch board under their heels in order to complete the movement correctly. A score one out of three is earned when one of the following conditions are not met with use of the two inch by six inch board inserted below the heels: (1) the tibia and upper torso are not parallel, (2) the femur does not go below horizontal, (3) the knees are not over the
feet, and (4) there is flexion in their lumbar spine. This movement was included in the evaluation because it assesses the bilateral symmetry of the hips, knees, ankles, shoulders and thoracic spine, as well as the functional mobility of the hips, knees, and ankles.

**Hurdle Step**

The hurdle step is a functional movement which asks the subject to step over a cord which connects two poles (the hurdle). The height of the hurdle is measured as the same height as the subject's tibial tuberosity. After setting up the hurdle, the subject holds a dowel just inferior to the neck resting on the shoulders. Once the correct starting position has been established the subject then steps over the hurdle, touches their heel to the ground and then returns to the starting position. This is repeated bilaterally and each side is scored individually.

A score of three out of three is earned on this test when all the following are met: (1) the athlete’s hips, knees and ankles remain aligned in the sagittal plane, (2) little movement is noted in the lumbar region of the spine, and (3) the dowel remains parallel to the string. Scores are reduced to two out of three on this movement when any of the following alterations are made: (1) alignment is lost between the hips, knees, and ankles, (2) movement is noted in the lumbar spine, and (3) the dowel does not remain parallel to the string. A score of one out of three is received when the athlete makes foot contact with the string during the movement and/or an obvious loss of balance is noticed. This movement is included in the assessment because it tests dynamic stability of the joints of the lower extremity.
**In-Line Lunge**

The in-line lunge is a functional movement requiring many different steps. Before beginning this test the subject’s tibia length is recorded using the height of the hurdle from the hurdle step. The two inch by four inch board is used for this test and the subject is asked to stand on the board with one foot in front of the other. The distance between the subject’s feet is adjusted to be equal to the height of the subject’s tibia. The dowel is then held parallel to the spine, against the subject’s back. The hand that corresponds to the subject’s front leg is placed superior on the dowel and the opposite hand is placed inferior on the dowel. After the correct starting position has been established, the subject is asked to lower the knee of the back leg in a lunge motion until it touches just behind the heel of the front foot and then return to the starting position. This test is then repeated bilaterally with the lowest score being recorded.

A score of three out of three is earned by (1) keeping the dowel in contact with the back, (2) noticing no movement through the torso, (3) maintaining the dowel and feet in the sagittal plane, and (4) touching the knee behind the heel of the front foot. A score of two out of three is earned when (1) the dowel does not remain in contact with the extended lumbar spine, (2) movement is detected in the torso, (3) the dowel and feel do not remain in the sagittal plane, and (4) the knee does not touch behind the front foot. A score of one out of three is given when a loss of balance is detected. This movement tests mobility, stability and flexibility of the lower extremity.

**Shoulder Mobility Test**

The shoulder mobility test is an upper extremity functional test which requires the subject to make a fist and reach as far back behind their neck with one hand while
reaching up their spine with the other hand. The distance between the two hands is then measured, either by the tape measure on the dowel or by the number of hand lengths between the two fists.

A score of three out of three is given on this test when the fists are within one hand length or about eight inches of each other. A score of two out to three is given when the fists are within one and a half hand lengths or about 12 inches of each other. A score of one out of three is given when the fists are greater than one and a half hand lengths or 12 inches apart. This test assess the subject’s shoulder range of motion as well as scapular mobility and thoracic extension.

**Straight Leg Raise**

To begin the straight leg test the subject is instructed to lay supine on the floor while the tester locates the midway point between the subject’s anterior superior iliac spine and patella. At the midway point the dowel is placed perpendicular to the ground and the subject is then asked to actively raise their leg as far as possible while keeping their foot in full dorsiflexion and knee in full extension.

A score of three out of three is given when the athlete is able to raise the test leg past the dowel that has been measured at the midway point between the anterior superior iliac spine and the patella. A score of two out of three is given when the subject is unable to raise their leg to the dowel but is above the patella, and a score of one out of three is given when the leg can not be raised to the patella. This test examines hamstring and calf flexibility along with trunk stability.
Trunk Stability Push-up

The trunk stability test is a functional test which is used to assess overall core stability. The starting position for this movement is a prone position with the knees extended and ankles in full dorsiflexion. The subject’s hands are then placed in a position depending on their sex; males are asked to start with their thumbs even with their chin while females start with their thumbs even with their clavicle. Once the starting position has been established the subject is asked to perform one push up, with their body moving evenly and lumbar spine staying in line with their body.\(^{10}\)

For males, a score of three out of three is given when one push-up is performed with the thumbs at the top of the forehead. For females, a score of three out of three is given when one push-up is performed with the thumbs aligned with the chin.\(^{10}\) A score of two out of three is given to males who must move the thumbs down in line with the chin in order to complete the movement. Females receive a two out of three when they complete the push-up with the thumbs aligned with the clavicle.\(^{10}\) Males and females receive a score of one out of three when they are unable to complete the movement that is required to receive a score of two out of three.\(^{10}\) This movement tests the ability of the subject to maintain spinal stability while performing a closed chain upper extremity movement.\(^{10}\)

Rotary Stability Test

For the rotary stability test the subject assumes a quadruped position and is instructed to lift one unilateral knee and elbow, touching them together and returning them to the starting position. If that cannot be performed the subject is then asked to lift the opposite knee and elbow, touch them and then return to the starting position.
A score of three out to three for this movement is given when the athlete is able to perform one correct unilateral repetition, which includes keeping the spine stable and touching the knee and the elbow. A score of two out of three is received if the athlete is able to touch the opposite knee to the elbow while keeping the spine parallel. A score of one out of three is received if the subject is unable to complete the movement of touching the opposite knee to the elbow. This movement is used to assess the subject’s trunk stability during both upper and lower extremity movement.

**Implementation of the FMS**

Currently, there is no research purposing guidelines on the number of times a subject should perform practice on these test before scoring takes place. The inter-rater reliability of the FMS between expert and novice raters has been studied by Minick et al. For bilateral movements each side was recorded as well as an overall score for the movement, which made for a total of seventeen scores for comparison. A significant agreement was found between the raters as they only disagreed on three of the seventeen parts being measured. With a high agreement between raters, it is possible for multiple trained individuals to conduct the FMS and thereby making it easier to gain comparable data when testing large cohorts of subjects.

Multiple studies have examined the ability of the FMS to predict injuries with the purpose of establishing a cut-off score between injured and non-injured players.

At the completion of a single high school basketball season, Wieczorkowski reported 20 players out of 82 screened suffered an injury to the lower extremity. Significance was not found directly between the scores of injured and non-injured players; however, an ROC curve found that a cut-off score of 14.5 out of 21 maximized
sensitivity and specificity of the FMS in injury prediction. These results indicate that an athlete scoring less than 14.5 on the FMS was twice as likely to suffer an injury as someone scoring above 14.5.

Kiesel et al. investigated the ability of the FMS to predict injury among 62 NFL players. An injury was defined as being placed on the injured reserve and missing a minimum of three weeks of competition. This provides a significant limitation as it was not clearly defined as to why the athlete was placed on the injured reserve. There currently is no research validating the FMS’s ability at predicting injuries which resulted from player to player contact, therefore including this in a cut-off score may be invalid. Since it is possible that these injuries were included in this study a huge limitation may be present. Keeping the limitation in mind, it must be noted that the study found a significant (p<.05) difference between the scores of injured and non-injured athletes.

With the use of an ROC curve analysis a value of 14 was said to be the ideal cut-off score for injuries. An odds ratio of 11.67 was calculated; which the author suggests represents an 11 times higher chance of getting injured if an athlete’s score falls below cut-off score of 14. The post-test probability calculated was 0.51, which leads to an athlete being 51% more likely to get injured if they get below a score of 14. This figure was much higher than the pre-test probability of 15% that was previously set.

Using a similar design and methods, Chorba et al recorded 18 injuries in 38 female collegiate athletes, 17 of which to the lower extremity. Like Kiesel et al, a significant limitation exists in this study. Injuries were defined as only consulting with a member of the medical staff, not mentioning time missed or the location of the injury. Also, the cut-off score was arbitrarily taken from Kiesel et al, which may be invalid, and
not formulated from the data collected even though they were dealing with a different population. Their results showed that athletes who scored less than 14 were four times more likely to be injured.\textsuperscript{6}

Division one collegiate football players were examined using the FMS with the hopes of predicting lower extremity injuries in a recently unpublished work by Ford.\textsuperscript{12} Injuries were defined, in a similar fashion to Dick et al,\textsuperscript{1} as causing the athlete to miss at least one competition or practice. It was found that a score of 15.5 maximized sensitivity and specificity in this study.\textsuperscript{12} Falling below this score increased the athletes risk of injury by roughly three times.\textsuperscript{12} While this study did find significant results, it is limited by the fact that it only includes one year of data. In order to be certain that these results did not occur by chance, more research must be continued that uses more clearly defined classification of injury.

The Functional Movement Screen is a comprehensive exam that evaluates a subject’s skill at completing seven fundamental movements. The research in this section has identified that the FMS can accurately predict injury among different sports;\textsuperscript{6,2} however, flaws in methodology make it imperative for a better designed study to be performed. While limited research\textsuperscript{12} has been completed on the FMS’s ability to predict injuries in division one collegiate football players, in order to form more substantial results more research on this subject must be performed. It is important to develop further research on this topic because with the ability to predict injuries, rehabilitation programs may be developed to potentially reduce injury risk.
2.3 Star Excursion Balance Test

The Star Excursion Balance Test (SEBT) is used to provide quantifiable measures of dynamic postural control. Through the identification of deficits in dynamic postural control it may be possible predict future injuries. The current protocol for the SEBT includes balancing on one leg with hand on the hips while reaching as far as possible in eight different pre-set directions, anterior, anteromedial, anterolateral, posterior, posteromedial, posterolateral, medial and lateral. The task is completed correctly if balance is maintained while keeping hands on hips and softly touching the toe of the reaching leg onto the mat. The eight different reach directions for this test have been found to be redundant and time consuming. Robinson and Gribble suggests the task can be simplified to include only four practice trial followed by three test trails to be recorded. Research has shown that the most consistent way of recording SEBT scores for comparison is by normalizing to the subject’s leg length. The SEBT has been shown to have a strong intratestere and an intertestere reliability, with ICCs ranging from .81 to .93 and from .78 to .94 respectively. Current research on the SEBT has focused mainly on deficiencies in subjects with a lower extremity dysfunction such as chronic ankle instability. However, research is limited on the effects of the SEBT predicting the potential for injury in healthy individuals.

Studies by Olmsted and Herrington both found differences between a healthy population and an unhealthy population. Performance on the SEBT in subjects with chronic ankle instability (CAI) was studied by Olmsted. Their results found reach scores to be lower in the CAI group compared to the control group while standing on the injured limb, demonstrating that the SEBT may be useful at differentiating CAI subjects.
from a healthy population or healthy limb. Dynamic postural control has also been studied on the SEBT in subjects who have an anterior cruciate ligament (ACL) deficient knee. Differences were found between the ACL deficient limb and the control group in the following reach directions: anterior \((p=.0032)\), lateral \((p=.005)\), posteromedial \((p=.0024)\), and medial \((p=.001)\); however, no differences were seen between the ACL deficient limb to uninjured limb in the test group. With the ability to determine differences in injured subjects after the injury has occurred, perhaps a more important question is whether or not the SEBT has the ability to predict injuries before they occur.

Plisky et al used the SEBT in an attempt to predict injuries in high school basketball players. The study included 235 athletes during the 2004-2005 high school basketball season in Indiana. The SEBT was performed in the anterior, posterolateral and posteromedial directions. After the season injury data was collected on all participants and 50 players were reported to have suffered an acute lower extremity injury. For all subjects, a deficit of 4 cm or more between the right and left anterior reach scores, coupled with decreases in posteromedial, posterolateral, and overall composite score was found to put them at an increased risk of injury \((p<.05)\). It was also found that a composite reach score of less than 94% when compared bilaterally, predisposed athletes for injury.

Unpublished work by Sato et al demonstrates a similar study examining high school basketball players with the SEBT. While significance was not found between the scores of injured and non-injured subjects in any of the reach distances, for the anterior reach direction, a score of less than 64.8% was associated with a 3.67 greater likelihood of a lower extremity injury, while a composite score of less than 69.93% was associated
with a 5.33 greater likelihood of lower extremity injury. Odds ratios for selected scores on the posteromedial direction and posterolateral direction were 2 and 2.94, respectively.³

The SEBT has been used to predict lower extremity injuries in high school football athletes by Pollock et al.⁸ Significant differences were found between injured and non-injured athletes in the normalized scores of the anterior (p=.013) and composite (p=.044) reach scores. Although cut-off scores were not reported, the significance found in this study provides a basis for future research on football players.

With its ability to detect differences in subjects with injuries such as CAI and ACL deficient knees, questions rise about the SEBTs ability to predict injuries in healthy subjects. Limited research³⁴⁸ has shown the SEBT as a beneficial tool in predicting injuries of high school basketball players, however, no research has been done examining the potential of the SEBT in predicting injuries in college football players. Therefore, it is not known if the SEBT can be used effectively in this particular athletic population. If it is found effective, then clinicians may be able to use this tool to identify and hopefully create intervention for athletes at risk for a lower extremity injury.

Looking at previously reported injury rates,¹¹¹⁷¹⁸ it is obvious that there is need a for a lower extremity injury prediction device. Both the FMS⁵⁷ and the SEBT⁴⁸ have shown the potential for identifying injury risk to the lower extremity, however this has not been applied in division one collegiate football players. Although both tools have been used in previous studies, no study has examined and compared to determine which may provide better predictive qualities for clinical practice.
Chapter 3

Methodology

3.1 Experimental Design

Using a prospective cohort study, pre-season performance using the FMS and the SEBT were used to predict lower extremity injury among Division I NCAA football athletes. Scores from the FMS and SEBT were recorded before the season. Throughout the season daily exposure rates for practice and games were recorded by certified athletic trainers. All injuries that cause part of all of one or more practices to be missed were recorded. Specific type of injury, mechanism of injury, whether or not the athlete was using a prophylactic taping or bracing and history of previous injury was also recorded. At the conclusion of the season FMS and SEBT scores for each player, injured and non injured athletes, knee injuries and ankle injuries, and contact injuries and non-contact injuries were compared.

3.2 Subjects

One hundred and eighty Division I Collegiate Football Athletes at The University of Toledo volunteered for this study. The subjects understood and signed consent forms approved by The University of Toledo Institutional Review Board. Athletes that did not clear the pre-participation examination due to previous athletic injury were excluded from the study.
3.3 Instrumentation

A Functional Movement Screen test kit including a two inch by six inch board, hurdle and measuring dowel was used. A Star Excursion Balance Test grid with pre-labeled start positions and movement directions measurements was used to administer the SEBT.

3.4 Independent Variables

1. Group
   a. Injured
   b. Non-Injured

2. Location of Injury
   a. Ankle
   b. Knee
   c. Non-Injured

3. Mechanism of Injury
   a. Contact
   b. Non-contact
   c. Non-Injured

3.5 Dependent Variables

1. Functional Movement Screen score (total out of 21)

2. Star Excursion Balance Test composite score (% reach distance normalized to leg length)

3. Star Excursion Balance Test mean anterior reach score (% reach distance normalized to leg length)
4. Star Excursion Balance Test mean posteromedial reach score (% reach distance normalized to leg length)

5. Star Excursion Balance Test mean posterolateral reach score (% reach distance normalized to leg length)

3.6 Procedure

Subjects were evaluated on their performance of the following parts of the Functional Movement Screen: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability test. Each movement was given a grade of zero to three. A score of three was given when the movement is performed perfectly, a score of two was given when the movement is completed but with compensation, a score of one was given when the subject cannot complete the movement, and a score of zero was given if the movement cannot be completed due to pain. Subjects were asked to perform the movements three times with their lowest score being recorded. A scoring rubric was used by examiners administering the test (Figure 1)

The SEBT was performed in the anterior, posteriormedial, and posteriolar lateral directions. Prior to testing participant’s leg length was measured from the inferior portion of the anterior inferior iliac spine to the distal end of the medial malleolus. For the anterior reach, the participants were asked to stand with their hands on their hips and 1st distal phalanx of the test leg positioned at the starting position in the center of the pre-made grid. Participants were then asked to reach with their non-weight bearing leg as far as possible along the anterior line, softly touching their foot to the mat and then returning to the starting position. For the other two movements, the participants started with the
posterior aspect of their heel on the location marked as the middle of the grid and then reached as far as they could in each direction, softly touch their foot to the mat and return to the starting position. They were asked to repeat the trial if any of the following happened: balance was lost, the heel of the test leg was lifted, the foot shifted, the touch was performed with too much pressure, or they were not able to return to the starting position. Subjects received verbal instructions and demonstration on how to perform the test. As recommended by Robinson and Gribble\textsuperscript{21} each subject was given the opportunity to complete four practice trials, then three test trials were recorded. The scores of each trial were averaged and normalized by the subject’s leg length and then reported as a percentage of leg length.\textsuperscript{16}

The athletes participated in their season while athlete exposures and injury documentation of the lower extremity was conducted by a certified athletic trainer. The athletic trainer documented each lower extremity injury that occurred and reported them to the primary investigator on a weekly basis throughout the season.

3.7 Statistical Analysis

For each dependent variable separate independent t-tests were performed to detect a potentially statistically significant difference in FMS and SEBT scores between the injured and non-injured groups (Hypotheses # 1 and 5).

A receiver-operator characteristic (ROC) curve which graphs the sensitivity vs. the specificity was utilized for both the FMS and SEBT to determine an injury cut-off score (Hypotheses #2 and 6). Once the cut-off score had been determined a 2x2 contingency table was produced to show where athletes who suffered an injury and athletes who did not suffer an injury lie with respect to the established cut-off score.
Likelihood ratios were also calculated, with a positive likelihood ratio linked to athletes with a score which falls below the cut-off determined by the ROC and a negative likelihood ratio linked to athletes with a score which is above the determined cut-off. To estimate an athlete’s probability of being injured, the following three step calculation was utilized.

1) Convert pre-test probability to odds

   Pre-test odds = pre-test probability / (1 – pre-test probability)

2) Multiply the odds by the appropriate (+) Likelihood Ratio Value

   Pre-test odds (x) Positive Likelihood Ratio = Post-test odds

3) Convert the post-test odds back to probability

   Post-test odds / (post-test odds + 1) = Post-test probability

Five separate one-way analysis of variance (ANOVAs) were performed for each dependent variable to detect a potential statistically significant difference between knee injuries and ankle injuries, compared to the non-injured group (Hypotheses #3 and 7). Five separate one-way ANOVAs were also performed for each dependent variable to detect a potential statistically significant difference between contact and non-contact injuries, compared to the non-injured group (Hypotheses #4 and 8).

Finally, the data that support Hypotheses #2 and 6 was compared observationally to address hypothesis #9.

The mean level of significance were set at a priori alpha level of <0.05. All statistical analysis was performed using SPSS 17.0 (SPSS, Inc. Chicago, IL.)
Chapter 4

Results

Over a two year period a total of 180 Division I collegiate football athletes who were tested in the pre-season using the FMS and SEBT met the inclusion criteria for our study. Of the athletes that were screened, 33 athletes suffered an acute injury to the lower extremity (knee or ankle) that caused them to miss at least one day of competition during the season while 147 did not suffer an injury. Demographic information on the two groups is depicted in Table 1.

Table 1- Demographics

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Age</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injured</td>
<td>33</td>
<td>19.76</td>
<td>189.65</td>
<td>109.10</td>
</tr>
<tr>
<td>Non-Injured</td>
<td>147</td>
<td>19.79</td>
<td>186.11</td>
<td>100.75</td>
</tr>
</tbody>
</table>

In all of the comparisons, the group of injured athletes scored lower in the pre-season compared to the non-injured athletes (Table 2). However the only statistically significant difference was on the SEBT anterior reach score.
Table 2: Means and Standard Deviations for Injured vs. Non-Injured Group Comparisons

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th>Mean ± SD</th>
<th>t1,178</th>
<th>P_value</th>
<th>d(95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS Injured</td>
<td>16.27 ± 1.57</td>
<td>-1.28</td>
<td>0.202</td>
<td>0.25 (-0.13 – 0.62)</td>
<td></td>
</tr>
<tr>
<td>FMS Non-Injured</td>
<td>16.67 ± 1.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEBT Ant. Injured</td>
<td>67.97 ± 7.25%</td>
<td>-2.13</td>
<td>0.035*</td>
<td>0.43 ( 0.05 – 0.81)</td>
<td></td>
</tr>
<tr>
<td>SEBT Ant. Non-Injured</td>
<td>70.86 ± 7.01%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEBT PM Injured</td>
<td>84.30 ± 9.55%</td>
<td>-1.42</td>
<td>0.157</td>
<td>0.28 (-0.10 – 0.65)</td>
<td></td>
</tr>
<tr>
<td>SEBT PM Non-Injured</td>
<td>87.22 ± 10.93%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEBT PL Injured</td>
<td>76.08 ± 9.97%</td>
<td>-0.624</td>
<td>0.533</td>
<td>0.09 (-0.29 – 0.47)</td>
<td></td>
</tr>
<tr>
<td>SEBT PL Non-Injured</td>
<td>77.32 ± 10.34%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEBT Comp Injured</td>
<td>76.11 ± 7.25%</td>
<td>-1.66</td>
<td>0.099</td>
<td>0.29 (-0.09 – 0.66)</td>
<td></td>
</tr>
<tr>
<td>SEBT Comp Non-Injured</td>
<td>78.47 ± 7.41%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant

Table 3 depicts the Cut-off scores derived from the ROC curve analysis along with the associated sensitivity and specificity. Also shown are the odds ratios which show the likelihood that a score below the associated cut-off will lead to a future injury. The anterior reach had the highest associated Odds Ratio for prediction of lower extremity injury. Tables 4-8 depict the 2x2 contingency tables that reflect the distribution of true positive and true negatives based on the cut-off scores from the ROC analyses.

Table 3: Receiver Operator Characteristic Curve Analyses and Risk Prediction Results

<table>
<thead>
<tr>
<th></th>
<th>Cut-off</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS</td>
<td>15.5</td>
<td>0.42</td>
<td>0.74</td>
<td>2.08</td>
</tr>
<tr>
<td>SEBT ANT</td>
<td>70.84%</td>
<td>0.79</td>
<td>0.55</td>
<td>4.63</td>
</tr>
<tr>
<td>SEBT PM</td>
<td>87.66%</td>
<td>0.64</td>
<td>0.51</td>
<td>1.83</td>
</tr>
<tr>
<td>SEBT PL</td>
<td>74.23%</td>
<td>0.49</td>
<td>0.64</td>
<td>1.70</td>
</tr>
<tr>
<td>SEBT COMP</td>
<td>77.90%</td>
<td>0.64</td>
<td>0.55</td>
<td>2.18</td>
</tr>
</tbody>
</table>
Table 4: FMS 2x2 Contingency Table to reflect true positives and true negatives

<table>
<thead>
<tr>
<th></th>
<th>Injury (+)</th>
<th>Injury (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS &gt;15.5</td>
<td>14</td>
<td>33</td>
</tr>
<tr>
<td>FMS &lt;15.5</td>
<td>19</td>
<td>114</td>
</tr>
</tbody>
</table>

Table 5: SEBT Composite 2x2 score Contingency Table to reflect true positives and true negatives

<table>
<thead>
<tr>
<th></th>
<th>Injury (+)</th>
<th>Injury (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEBT &lt; 77.90%</td>
<td>21</td>
<td>66</td>
</tr>
<tr>
<td>SEBT &gt; 77.90%</td>
<td>12</td>
<td>81</td>
</tr>
</tbody>
</table>

Table 6: SEBT Anterior score 2x2 Contingency Table to reflect true positives and true negatives

<table>
<thead>
<tr>
<th></th>
<th>Injury (+)</th>
<th>Injury (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEBT &lt; 70.84%</td>
<td>26</td>
<td>68</td>
</tr>
<tr>
<td>SEBT &gt; 70.84%</td>
<td>7</td>
<td>79</td>
</tr>
</tbody>
</table>

Table 7: SEBT Posteriomedial score 2x2 Contingency Table to reflect true positives and true negatives

<table>
<thead>
<tr>
<th></th>
<th>Injury (+)</th>
<th>Injury (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEBT &lt; 87.66%</td>
<td>21</td>
<td>72</td>
</tr>
<tr>
<td>SEBT &gt; 87.66%</td>
<td>12</td>
<td>74</td>
</tr>
</tbody>
</table>

Table 8: SEBT Posteriolateral 2x2 Contingency Table to reflect true positives and true negatives

<table>
<thead>
<tr>
<th></th>
<th>Injury (+)</th>
<th>Injury (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEBT &lt; 74.23%</td>
<td>16</td>
<td>53</td>
</tr>
<tr>
<td>SEBT &gt; 74.23%</td>
<td>17</td>
<td>94</td>
</tr>
</tbody>
</table>

Finally, Table 9 reflects the 1-Way ANOVA’s to compare athletes that suffered a contact injury mechanism versus a non-contact mechanism and the non-injured athletes. Overall the non-contact injured group scored lower than the non-injured groups for each
of the screening tests. This difference was statistically significant for the SEBT anterior reach test.

**Table 9: Comparison of the Prediction of Injury Based on the Mechanism of Injury**

<table>
<thead>
<tr>
<th></th>
<th>FMS</th>
<th>SEBT comp</th>
<th>SEBT Ant</th>
<th>SEBT PM</th>
<th>SEBT PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td>16.16 ± 1.69</td>
<td>77.09 ± 6.96%</td>
<td>70.94 ± 9.98%</td>
<td>85.04 ± 8.48%</td>
<td>75.30 ± 8.42%</td>
</tr>
<tr>
<td>Non-Contact</td>
<td>16.33 ± 1.52</td>
<td>75.55 ± 7.52%</td>
<td>66.26 ± 4.81%*</td>
<td>83.87 ± 10.28%</td>
<td>76.53% ± 10.94%</td>
</tr>
<tr>
<td>Non-Injured</td>
<td>16.67 ± 1.63</td>
<td>78.47 ± 7.41%</td>
<td>70.86 ± 7.01%</td>
<td>87.22 ± 10.93%</td>
<td>77.32 ± 10.35%</td>
</tr>
<tr>
<td>F_{2,179}</td>
<td>.857</td>
<td>1.53</td>
<td>3.98</td>
<td>1.05</td>
<td>.248</td>
</tr>
<tr>
<td>P-value</td>
<td>.426</td>
<td>.219</td>
<td>.020</td>
<td>.352</td>
<td>.780</td>
</tr>
</tbody>
</table>

*There was a significance difference (P = 0.015) between the scores of those who had non-contact injuries and those who weren’t injured.
Chapter 5

Conclusion

5.1 Introduction

The purpose of this study was to determine the injury predictive capabilities of both the Star Excursion Balance Test and the Functional Movement Screen in Division I college football players. This study involved preseason SEBT and FMS testing of a Division I college football team over two years followed by observation of injuries over the two seasons. We were able to show that overall athletes who suffered an injury scored lower than those who did not suffer an injury. However, the only test that showed statistical significance was the SEBT anterior reach score. Therefore, we can say that the SEBT anterior reach score has the best predictive capabilities for injuries to the lower extremity, partially supporting our first hypothesis.

This study was the first study to provide a direct comparison between the injury predictive capabilities of the Star Excursion Balance Test and the Functional Movement Screen. When looking at the odds ratios derived from the cut-off scores it is clear that the SEBT anterior reach (4.63) was stronger at predicting lower extremity injuries than the FMS (2.08). However, only the SEBT anterior reach odds ratio and SEBT composite odds ratio (2.18) were higher than the FMS. With this information we may be able to suggest that the SEBT anterior reach would be a useful tool for lower extremity injury
prediction; while utilization of the FMS and other parts of the SEBT may not be as useful.

Comparisons were also made in this study between contact and non-contact injuries (Hypothesis 3). While the injured group scored lower than the non-injured group in every test, only the differences in SEBT anterior reach test scores were statistically significant. This suggests that the SEBT anterior reach score is able to differentiate between football athletes that will suffer a non-contact injury and those that will not. This is important for clinical and research applications as non-contact injuries are potentially preventable, while realistically contact injuries pose more of a challenge to prevent. Therefore, the SEBT may serve as an effective screening tool to clinicians to identify at-risk athletes in this population for an injury that is potentially avoidable.

5.2 Comparison to previous FMS research

In previous research using the FMS to predict injuries in football players varying cut-off scores have been reported. Kiesel et al\(^2\) found that a FMS score of below 14 significantly increased a professional football player’s chances of getting an injury. The Kiesel et al\(^2\) study contrasts with our study as we found that a score below 15.5 increased the likelihood of injury; however, our data did not show statistically significant differences between our groups. The differences in the prediction models and associated cut-off scores between the studies may be attributed to different definition of injury in the two studies, particularly the fact that we included only lower extremity injuries and Kiessel\(^2\) included all injuries that resulted in the player missing at least 3 weeks of playing time. With perhaps a more appropriate specific definition of lower extremity
injury used in our study, we believe that the 15.5 cut-off score may be more representative and appropriate.

Research by Chorba et al\textsuperscript{6} which found that a score below 14 on the FMS predicted injury in female soccer athletes is also different than the score of 15.5 that we found. However, because Chorba et al\textsuperscript{6} used the Kiesel et al\textsuperscript{7} cut-off score for the study it is hard to determine if that is completely accurate for reasons discussed above. In a recent investigation from our group, Wieczorkowski et al\textsuperscript{5} performed a similar comparison of FMS scores in high school basketball players and found that a cut-off score of 14.5 maximized the injury prediction model. However, similar to our study, significance was not found between groups that did or did not suffer a lower extremity injury by Wieczorkowski.\textsuperscript{5} Therefore, our group consistently demonstrates that the FMS is not able to differentiate groups of injured and non-injured athletes using the FMS in football and basketball players.

5.3 \textbf{Comparison to previous SEBT research}

While the SEBT has been shown to consistently differentiate groups of patients with and without a variety of lower extremity injuries,\textsuperscript{25} there is limited application of the SEBT to predict lower extremity injury risk, especially in football athletes. Previous research by our group examined the ability of the SEBT to predict lower extremity injury in high school football players. Using similar methods to our study, Pollock et al\textsuperscript{8} found that both the anterior reach scores and composite reach scores were statistically significant at differentiating injured and non-injured groups, and had associated odds ratios greater than 5 associated with cut-off scores. The consistency in the two studies
lends support to the anterior reach of the SEBT as a useful tool to predict lower injury risk in football players.

Plisky et al\textsuperscript{4} used the SEBT to predict injuries in high school basketball players. Similar to this study Plisky et al\textsuperscript{4} found that a decreased anterior reach score increased a players likelihood of an injury. However, Plisky et al\textsuperscript{4} did not normalize their data as we did in our study, and the reported performance scores are much higher than reported in our study and in the literature, therefore making a true comparison difficult.

\textbf{5.4 Clinical Significance}

Of all the outcomes that we examined, statistical significance in differentiating injured and non-injured groups was only found with the anterior reach score. When compared to the FMS the SEBT was better at predicting injuries in collegiate football players, therefore the SEBT could be considered as a useful tool for screening football players for lower extremity injury risk. Specifically, the anterior reach score of the SEBT may be the only direction worth utilizing. This would simplify the test and make it much easier to test a large team in a timely manner. Additionally, our results do not support the time and effort needed to incorporate the FMS into injury screening. However, it may be useful to examine components of the FMS for prediction purposes, similar to what we show here that a component of the SEBT may be more worthwhile than including all aspects of the FMS or SEBT as the tests were initially designed.

Clinically, the use of the SEBT in preseason testing may lead to early recognition of potential injuries. With this information clinicians may be able to develop a rehabilitation protocol in order to address the musculoskeletal imbalances thought to be associated with a poorer performance before a season starts and thereby reducing the
athlete’s likelihood of injury. Future research should focus on using the SEBT anterior reach score alone as a predictor of injury.

5.6 Limitations

Although we sought out to control as many limitations as possible there are still some that should be noted. The definition of injury for this study involved any lower extremity injury that caused a player to miss at least one practice or game. With that definition there were some injuries included in this study that involved player to player contact, something that we assume could not be predicted by the FMS or SEBT. Another limitation was that this study was performed on an elite Division I football team where the competition is high and the pressures to win are strong. With that being said, it is possible that some athletes played through injuries that most would consider serious enough to remove from competition.

5.7 Conclusion

Our study shows that the SEBT anterior reach score is better at predicting lower extremity injuries than the other components of the SEBT as well as the FMS. We have shown that the SEBT anterior reach is better at distinguishing between individuals who may suffer a non-contact injury and individuals not likely to experience an injury.
References


5. Wieczorkowski MP. Functional Movement Screening as a Predictor of Injury in High School Basketball Athletes, University of Toledo; 2010.


12. Ford A. Functional Movement Screening as a Predictor of Injury in Division One Collegiate Football Players, University of Toledo; 2011.


