A Thesis

entitled

Predicting Lower Extremity Injury in High School Football Players Using the Star Excursion Balance Test

by

Michael W. Stout, ATC

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

Dr. Phillip Gribble, Committee Chair

Dr. Kate Pfile, Committee Member

Dr. Brian Pietrosimone, Committee Member

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

The University of Toledo
May 2012
An Abstract of
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Objective: The objective of this study was to determine the ability of the Star Excursion Balance Test (SEBT) to reliably and accurately predict lower extremity injuries in high school football players.  Design: This study used a prospective cohort design. Subjects: Two hundred and thirty nine male junior varsity and varsity football players from five different high schools around the greater Toledo, Ohio area were recruited for this study. Measurements: Each subject was tested by a group of certified athletic trainers on three reach distances of the SEBT: anterior, posteromedial, and posterolateral. Composite scores were also derived from those measures. The testing took place prior to the 2009 and 2011 high school football seasons. During those seasons acute lower extremity injuries (LEI) were documented and then compared at the end of the season to determine if there were significant differences between the groups. Results: Forty-one of the 239 athletes experienced a LEI over the course of the 2009 and 2011 seasons. When comparing injured vs. non-injured athletes there was no statistical difference in the anterior reach direction (p = 0.06), posteromedial direction (p = 0.91), posterolateral direction (p = 0.052), or composite score (p = 0.26). However preliminary data showed statistical significance when comparing contact vs. non-contact injuries (p = 0.02).
Conclusion: We found that there were no statistically significant differences between athletes who did and did not experience a LEI, therefore the SEBT currently can not be used to predict LEI in high school football players. However our preliminary data shows that the SEBT may be able to predict contact vs. non-contact injuries in high school football players (p = 0.02).
Acknowledgements

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Next I would like to thank all of athletic trainer who helped with the testing the subjects prior to the 2009 and 2011 football seasons. With all of your help this project went more smoothly than I could have ever imagined. I would also like to send a special thanks to Brian Nelson, ATC and Ayami Sato, ATC for there assistance with tracking injuries during the 2011 football season.

Lastly I would like to thank the staff, coaches, and players at all the schools used for the testing. Without you this would thesis would never have been written.

From the bottom of my heart, I thank you.
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Chapter 1

Introduction

1.1 Introduction:

In two 1965 studies led by Freeman\textsuperscript{1,2} the first comparisons to ankle instability, proprioceptive and functional deficits were made. Freeman et al concluded that ligamentous injuries to the foot and ankle frequently lead to balance deficits.\textsuperscript{2} Injuries to the ankle complex are one of the most common injuries in sports today.\textsuperscript{3-7} Previous studies have reported an incidence of acute ankle sprain in athletes that range from 11\% to 20\%.\textsuperscript{7-9} A lower extremity injury for the purpose of this study is defined as: acute trauma to the ankle complex during a team sponsored event which results in a participant to miss the rest of that event or the next team sponsored event.\textsuperscript{4,10} Athletes who suffer from ankle sprains are more likely to re-injure the same ankle which can result in disability and can lead to chronic pain or instability in 20-50\% of these cases.\textsuperscript{7} It is estimated that sports injuries account for 50\% of all injuries in adolescents, which leads to an 8\% drop out rate from sports due to these injuries.\textsuperscript{11} In the 2009 seasons it is estimated that 1,174,157 athletes participated in college and high school football,\textsuperscript{12,13} it is also estimated that 15\% (176,123) sprained their ankle.\textsuperscript{14} Taping and bracing have
historically been used to try and prevent the occurrence of ankle sprains but a recent push towards the implementation of proprioceptive and balance training has arose.

1.2 Chronic Ankle Instability (CAI)

Ankle re-injury rates have been shown to be as high as 80%. The resulting instability from these repeated injuries to the ankle have given way to the classification of chronic ankle instability (CAI). Patients with CAI exhibit lingering lateral ankle instability which can result in continual ankle sprains due to functional and or mechanical instability. Many factors have been linked the cause of this phenomenon, some of which include strength deficits, inadequate postural control, and improper kinematics.

CAI is leading to more and more injuries and loss of playing time every year. Predictive measures have been developed, and have shown success, to help identify those with CAI. Those who have been determined to have CAI can make efforts to prevent the injuries from happening in the first place. Strides in recent years have been made to develop preventative programs to try and help prevent ankle sprains, these programs range from ankle proprioceptive and balance training to muscle strengthening. Promising evidence has come from these studies resulting in reducing the rates of ankle injuries. The long-term goal is to find and develop the best preventative programs to help those with CAI.

1.3 Identifying Ankle Instability Risk Factors

Efforts have been made in recent years to help identify those with chronic ankle instability. The Star Excursion Balance Test (SEBT) is quick and inexpensive way to assessing someone’s balance. This test has been shown as an adequate and reliable
procedure to help identify those with CAI.\textsuperscript{3,21,22,26,27} Due to the success and inexpensiveness of this test makes it a premier option for sport medicine professionals to use in the field to identify those with CAI. Other procedures such as postural sway have also showed promise in identifying CAI.\textsuperscript{4,28} Those with the access to tools such as force plate can also use those to help identify those with CAI.\textsuperscript{5,20,28-30}

1.4 The Star Excursion Balance Test (SEBT):

As previously mentioned the SEBT is a proven way to identify those with CAI.\textsuperscript{3,21,22,26,27} Because of it’s effectiveness and low cost, this will be the test of choice to identify those with CAI for this study. Hertel al\textsuperscript{31} describe the SEBT as a commonly used rehabilitation and assessment tool for dynamic postural control that has been proven reliable. The SEBT consists of 8 reaching directions: anterior, posterior, medial, lateral, anterior medial/lateral, and posterior medial/lateral. The test is performed with a single leg stance and the axis of the 8 directions. Patient is instructed to reach as far as possible in the 8 directions with the opposite foot and tap the toes when the maximum distance is achieved without loosing balance or using the tap foot to maintain balance.\textsuperscript{38} Recent research and pilot work has been shown movement in the anterior, medial, and posterior directions require the greatest amount of motion in the sagittal plane.\textsuperscript{22,32}

In numerous studies the SEBT has been shown to be an effective assessor of balance and postural control\textsuperscript{1,26,27} and in some cases a predictor of injury.\textsuperscript{22}

1.5 The Role of Balance as a Predictor

Using balance to assess ankle stability is not a new idea. Studies in recent years have been fine-tuning this idea to make it an effective way to assess ankle instability. Balance can be assessed in a number of ways. In a 2010 study Pollock et al\textsuperscript{22} used the
SEBT and found that athletes who suffered ankle sprains had lower scores on pre-season balance scores. Other measures have also been shown to be successful. Postural sway, as used by McGuine et al,\(^4\) was used to measure balance and those with lower scores showed to have seven times the ankle sprains as those with higher scores. In this study the NeuroCom New Balance Master v6.0 was used to compare and assess the pre-season scores of the athletes. Other studies using similar methods have also found similar findings. However this process is time consuming and very expensive. In 2008 McKeon et al\(^5\) produced a systematic review with the goal of researching the effectiveness of detecting deficits in postural control with the use of instrumented testing. Studies involved in this review looked at testing measures including: force plates, NeuroCom, portable stabilometers, Chattanooga Balance Machines, and Biodex Stability Systems. From the review McKeon et al\(^5\) concluded that deficits in postural control are most likely the cause of chronic ankle sprains.

1.6 Statement of the Problem

Currently the literature is unable to provide us with a quick, reliable, and inexpensive pre-season screening tool to predict lower extremity injuries in football players.

1.7 Purpose Statement

The purpose of this study is to determine the ability of the Star Excursion Balance Test to predict lower extremity injuries in high school football players.
1.8 Hypothesis

Primary Hypothesis:

(H1) Football athletes who perform the SEBT with shorter reach distances will have higher injury rates than those with longer reach distances.

Secondary Hypotheses:

(H2) A cut-off score that will be associated with sensitivity and specificity greater than 0.70 will be found with the SEBT measures.

(H3) Along with predicting injuries we feel that athletes who experience and ankle injury will have significantly shorter reach distances than those who experience knee injuries; but both groups of injured players will have lower SEBT scores compared to the non-injured group.

(H4) Those with non-contact injuries will have lower scores than those that suffer a contact injury or the non-injured group.
Chapter 2

Literary Review

2.1 Lower Extremity Injury

2.1.1 Anatomy of the Lower Extremity

For our purposes when describing lower extremity injury (LEI) we were strictly focusing on ankle and knee injuries. The ankle joint is comprised of four bones: the tibia, fibula, talus, and calcaneus. These bones come together to form a multi-axial joint known as the talocrural joint also called the mortise. Stability is added to this joint by a number of ligaments. On the lateral side there are three main ligaments of support. These ligaments are the anterior talofibular, posterior talofibular, and calcaneofibular. The ligaments of the medial side consist of deltoid ligament consisting of anterior and posterior tibiotalar, tibiocalcaneal, and tibionaviccular portions. Other ligaments include the anterior and posterior tibiofibular. The ankle is a multi-axial joint that can produce plantar flexion, dorsiflexion, pronation, and supination.33

The knee, like the ankle, is also made up of 4 bones: tibia, fibula, femur, and patella. These bones articulate as a hinge joint allowing for flexion and extension movements. Stability is added to the knee from 5 in-lying and surrounding ligaments. Inside the knee joint there are the anterior and posterior cruciate ligaments (ACL/PCL).
The ACL is attached to the posterior portion of femur and anterior portion of the tibial plateau. This ligament prevents anterior translation of the tibia on the femur. The PCL is the exact opposite, attaching on the anterior portion of the femur and posterior portion of the tibia preventing posterior translation. The knee also has both medial and lateral collateral ligaments preventing valgus and varus forces. The knee also consists of two menisci, which reduce friction during movement and weight bearing activity. The menisci are horned shaped and rest of the medial and later portions of the tibial plateau underneath the femoral condyles.33

2.1.2 Injuries

In a 2007 study that summarized a 16 year period of injury surveillance in the NCAA, documented 182,000 injuries, and over 50% of the them were to the lower extremity (knee and ankle). Ankle sprains accounted for 15% of all injuries making it the most common of all.34 In 2003 an estimate of direct and indirect medical costs for treating high school soccer and basketball ankle sprains was performed by the US Consumer Products Safety Commission, their findings were staggering totaling $1.17 billion dollars.24 In 2005 Willems et al35 produced a pair of studies looking at the intrinsic risk factors for inversion ankle sprains in both male and female subjects. Since this study focuses on male football players the risk factors for females will not be discussed. In the study 241 male physical education students were evaluated for possible intrinsic factors for inversion ankle sprains. The subjects were then followed prospectively for 1 to 3 years. During this time 44 subjects suffered an inversion sprain, and Willems et al concluded that running speed, cardiovascular endurance, balance, dorsiflexion strength,
coordination, muscle reaction, and dorsiflexion range of motion were all associated with ankle inversion sprains.

### 2.2 The Star Excursion Balance Test

The Star Excursion Balance Test (SEBT) is a quick, inexpensive, and cheap way to assess lower extremity deficiencies and dynamic balance. The SEBT consists of 8 reaching directions: anterior, posterior, medial, lateral, anterior medial/lateral, and posterior medial/lateral. The test is performed with a single leg stance at the axis of the 8 directions. The 8 directions form a star grid with each direction separated 45° apart. The patient is then instructed to reach as far as possible in the 8 directions with the opposite foot and tap the toes when the maximum distance is achieved without losing balance or using the tap foot to maintain balance.

In 1998 Kinzey et al. performed a study looking at the reliability of the SEBT. Twenty healthy subjects were assessed twice during two separate sessions using the SEBT. Following the assessments intraclass correlations coefficients were producing ranging for 0.67 to 0.87 implying that the SEBT was in fact a reliable measure.  

Four years later, in 2002, Olmstead et al. looked to determine the efficacy of the SEBT and its ability to detect deficits in subjects with CAI. For this study 20 subjects with unilateral CAI and 20 subjects without CAI were assessed using the SEBT. Each subject preformed 3 reaches in all 8 directions and the data was compared. They found that subjects with CAI had significantly decreased reach directions when standing on the injured ankle and significantly decreased reach directions when compared to uninjured individuals (78.6cm vs. 82.8cm, 78.6cm vs. 81.2cm).
In the next year the evolution of the SEBT continued. Gribble et al explored the considerations of normalization of the test. In this study foot type, height, leg length, and range of motion were all considered during the use of the SEBT. During the examinations they found a strong correlation for leg length. They concluded that a leg length normalization should be used when performing the SEBT. This is done by taking the patients leg length dividing it by the reach distance, and then multiplying it by 100 to get a percentage.

In 2006 Plisky et al developed one of the first LEI injury prediction models using the SEBT. In this study 235 high school basketball players were followed over the course of a single season and there injuries were documented. Prior to the season each athlete was assessed in all 8 directions of the SEBT, which was normalized to leg length. After the season 54 LEIs were documented. To increase sensitivity and specificity a Receiver Operating Characteristic (ROC) curve was determined and a cutoff score of 4cm was established. This ROC indicated that subjects with or at least a 4cm deficiency in reach distance were more likely to experience an injury. Plisky et al found that athlete who fell under the cutoff score were 2.5 times more likely to experience an injury. This was the first study that suggested that the SEBT could be used to predict LEI injury.

Also in 2006 Hertle et al preformed a study looking at simplifying the SEBT. The goal of this study was to determine which reach directions of the SEBT are most affected by CAI. Forty-eight subjects were tested in all 8 directions of the SEBT. Each subject preformed each reach 3 times and reach distances were analyzed. They found that subjects with CAI had significantly decreased reach scores in the anterior medial, medial,
and posterior medial directions. Hertle et al.\textsuperscript{39} concluded that preformed all 8 reaches was redundant, and that clinicians could just used the suggested 3 directions.

In 2008 Robinson et al. looked to determine the appropriate number of practice trials that should be preformed before data is collected when using the SEBT.\textsuperscript{40} In this study all 8 directions were measured. Prior to this study most SEBT protocols included 6 practice trials before actual measures were taken. This study found that for most directions maximum reach distances were achieved after only 4 practice trials. Robinson et al. concluded that previously used 6 practice trials should be reduced to 4.\textsuperscript{40}

Most of the studies to this point had more of a focus on ankle deficiencies. In 2009 Herringtons et al.\textsuperscript{41} compared SEBT reach distances in those with ACL deficiencies. Twenty-five ACL deficient, and 25 control subjects were assessed in this study. After SEBT measures significant differences were found when comparing ACL deficient subjects to the matched control subjects. Perhaps the most interesting finding of this study was that the uninjured leg of the ACL deficient subjects also showed deficiencies when compared to the healthy subjects.\textsuperscript{41}

2.3 SEBT and Fatigue

In 2004 thirty subjects were assessed to look at the effects of fatigue on CAI and dynamic postural control.\textsuperscript{26} These subjects were separated into two groups: healthy (16), and CAI (14). In this study Gribble et al.\textsuperscript{26} put the subjects through 5 testing sessions of the SEBT before and after a fatigue protocol or no fatigue. The fatigue protocol for this study consisted of an iokenetic plan preformed on a Biodex III. For this study 3 separate sagittal plane movements were fatigued: ankle plantar flexion and dorsiflexion, knee flexion and extension, and hip flexion and extension. Sessions 1-3 consisted of the
isokenetic fatigue measures, session 4 consisted of the isokenetic fatigue measures and a lunge protocol, and session 5 had no fatigue. The results showed that subjects with CAI showed significantly shorter reach distances after a fatiguing protocol. Gribble et al concluded that fatigue had notable changes on dynamic postural control.26

In 2007 the effects of fatigue on balance was taken a step further. Gribble et al3 explored the effects of fatigue on creating proximal joint alterations in those with CAI. Again thirty subjects were split into two groups (CAI = 14, Control = 16). Each subject preformed anterior, medial, and posterior reaches of the SEBT before and after a fatigue protocol. Like the previous study a lunge and isokenetic fatiguing instrumentation was used. They concluded that functional fatigue may expose deficits in proximal joint neuromuscular control.3

2.4 Gaps In Literature

Currently there is no model in the literature that explores the use of the SEBT to predict LEI in high school football players. The closest to this would have to be the 2006 study by Plisky et al38 which used the SEBT to predict LEI in high school basketball players. However, the biggest limitation of this study is in fact the lack of total athlete exposures. Following athletes for only a single season does not produce the necessary amount of data that would be needed to confidently say the SEBT it effective in predicting LEI.

Our study will continue to supply data to the currently on going study at the University of Toledo. As presented by Pollock et al22 in 2010, this model has demonstrated that those athletes who suffer a traumatic ankle injury have in lower scores on the SEBT. However these findings have yet to be deemed significant, hopefully with
the addition of our data we will be able to confidently state the SEBT is an effective measure in predicting LEI that produces significant findings.
Chapter 3

Methods

3.1 Methods

For this study 239 male varsity and junior varsity football athletes were recruited. These subjects came from 5 separate high schools in the greater Toledo area. Each athlete was assessed using the Star Excursion Balance Test (SEBT) for their maximum reach distance in three directions: anterior, posterolateral, and posteromedial. These evaluations were administered by groups of Certified Athletic Trainers trained in SEBT procedures during the summers of 2009 and 2011. Subjects were included if they had passed a pre-participation physical. All subjects used for this study were cleared by a physician and had active pre-participation exam forms on file. Each subject submitted a University Institutional Review Board approval form signed by the athlete themselves, if over the age of 18, or signed by their parent or guardian. Over the course of the 2009 and 2011 seasons the total number of exposures were documented along with all lower extremity injuries. As previously mentioned a LEI was defined as acute trauma that caused the athlete to miss one or more team sponsored game or practice. These injuries include: ankle sprains, Achilles tendon strains, MCL/LCL sprains, ACL/PCL sprains, and hamstring strains.
3.2 Protocol and SEBT Instrumentation

Each subject was assessed bilaterally to determine his maximum reach distance using the SEBT. This score was documented during the summers of 2009 and 2011 prior to the beginning of the high school football season. Certified Athletic Trainers remained in contact with those athletes they assessed, and at the end of the season were contacted by the examiner to report the documented injuries. Prior to the SEBT measures, leg length was measured. This was achieved by laying the athlete supine and measuring the distance from anterior superior iliac spine down to the medial malleolus. Then the subject was instructed on how to perform the SEBT for anterior, posteromedial, and posterolateral directions. With the athletes toe of the stance leg touching the axis they were told to reach as far as possible in the anterior direction, and tap their toe of the non-weight bearing foot without using it to maintain balance. Then the athlete was instructed to place their heel of the stance leg on the axis, and reach as far as possible in the posteromedial and posterolateral directions, again tapping their toe of the non-weight bearing foot without using it to maintain balance. And in all cases the subject must return, under control, to an upright double-legged stance. In all trials the subject foot of the stance leg was parallel with anterior line of the star. After giving instructions the subject then performed four practice trials in each direction. Once the practice trials were completed the subjects completed 3 test trials in each direction. These maximal reach distances for each of the three trials in each direction were then averaged and then normalized by dividing the average by the leg length multiplying it by 100. Composite scores were also averaged. This process was repeated for each leg. Trials were repeated if the:
1. Subject lost balance
2. Subject lifted the heel or shifts the foot of the stance leg
3. Used the non-weight bearing foot to maintain or regain balance during the toe touch.
4. Subject was unable to return the non-weight bearing to a double-legged standing position.

3.3 Statistical Analysis

SPSS version 14 Software was used to run the statistical analysis, with an $\alpha$ level of 0.05. In this study there were three independent variables: 1) group: injured and non-injured. 2) Location of injury: knee, ankle, and non-injured. 3) Mechanism of injury: contact, non-contact, and non-injured. There were also four dependent variables: maximum reach distance in the three aforementioned directions (anterior, posterolateral, and posteromedial), and the average of the three directions. Each score was normalized by dividing the subjects score by their leg length. Leg length was measured with the subject lying supine and the distance from anterior superior iliac spine to medial malleolus was documented. Independent t-tests were used to determine the significance of each dependant variable for hypothesis #1. We also compared knee injuries, ankle injuries, and non-injuries; as well as contact injuries, non-contact injuries, and non-injuries using two separate one-way ANOVAs. If statistical differences are found a Tukey Post Hoc analysis will be used. In addition, effect sizes were calculated using the Cohen’s $d$ effect size calculator ([Non-injured mean − Injured mean]/Injured Standard Deviation).
To test one of our secondary hypotheses of maximizing the SEBTs specificity and sensitivity in the four directions, a cut off score was determined. To plot sensitivity (true positives, True +) versus 1 -specificity (false positives, False +) we used a Receiver-Operator Characteristic (ROC) curve.

For this study we also used the SEBT to calculate post-test odds and post-test probability (using provided formula) to estimate the athlete’s probability of suffering an ankle injury. We used a 3-step calculation to determine if there was an increase in pre-test to post-test probability of injury for those who’s scores fell below the cut off score.

1. Convert the pre-test probability to odds:
   a. Pre-test odds = pre-test probability / (1 – pre-test probability)

2. Multiply the odds by the appropriate +LR value:
   a. Pre-test odds X +LR = post-test odds

3. Convert the post-test odds back to probability:
   a. Post-test odds / (post-test odds + 1) = Post-test Probability
Chapter 4

Results

4.1 Results

The demographics of the 239 male high school football athletes included in this study can be found in Table 1. Table 2 illustrates the normalized reach distances of all 239 subjects, and the associated t and p values. The groups were broken down into injured and non-injured for statistical comparison. The summary of Receiver Operator Characteristic (ROC) curve analysis calculated cut-off scores, along with associated sensitivity, specificity, and odds ratios can be found in Table 3. A 2 by 2 contingency table is found provided in Table 4 comparing true positives (Athlete injured below the cut-off score), true negatives (non-injured athletes above the cut-off score), false positives (non-injured athletes below the cut-off score), and false negatives (injured athletes above the cut-off score).

4.2 Anterior Reach (AR)

While athletes who did not experience a lower extremity injury had a higher mean reach distance of (70.54 ± 7.78%) compared to athletes who did experience a lower extremity injury (67.93 ± 9.92%) (Table 2), this difference was not statistically
significant \( (t = -1.86, p = 0.06) \). A low to moderate effect size was associated
0.37(0.03,0.70) (Table 2).

From the ROC curve analysis, a cut-off score of 67.3\% of leg length maximized
sensitivity (0.56) and specificity (0.65), with an Odds Ratio = 2.35 (Table 3).

**4.3 Posteromedial Reach (PMR)**

Posteromedial reach means (84.48 ± 10.23\%) for the non-injured group while
higher than those in the injured group (81.41 ± 11.26\%) however there was no statistical
difference \( (t = -1.71, p = 0.91) \). A small associated effect size was observed
0.29(-0.05,0.63) (Table 2).

The PMR ROC curve analysis, a cut-off score of 82\% maximized sensitivity
(0.54) and specificity (0.60) with an Odds Ratio = 1.75 (Table 3).

**4.4 Posterolateral Reach (PLR)**

While the means for the non-injured group in the PLR direction were larger
(73.16 ± 10.78\%) than the injured means (72.11 ±12.96\%) there was no statistical
difference between groups \( (t = -0.55, p = 0.052) \) (Table 2).

From the ROC curve analysis, a cut-off score for the PLR direction of 68.8\% of
leg length maximized sensitivity (0.43) and specificity (0.72), with an Odd Ratio = 1.85
(Table 3).

**4.5 Composite Score (CS)**

Composite Score reach means for the non-injured group (76.17 ± 8.20\%) were
higher than those in the means of those in the injured group (73.83 ± 9.60\%) however no
statistical difference was found between the two groups \( (t = -1.61, p = 0.26) \) (Table 2). A
low to moderate associated effect size was observed: 0.35(0.02, 0.69).
The ROC curve analysis yielded a cut-off score for the CS of 73.4% of leg length maximizing sensitivity (0.46) and specificity (0.66) with an Odds Ratio = 1.65 (Table 3).

4.6 Ankle vs. Knee Injuries

Of the 239 subjects, 41 experienced injuries during their respective seasons, 28 of them were ankle injuries and 13 were knee injuries (Table 5). There was no statistical difference when comparing the two groups. However there was nearly statistical difference in the posteromedial direction (p = .056), with those with ankle injuries scoring lower when compared to those with no injuries (Table 5).

4.7 Contact vs. Non-Contact Injuries

When looking at contact vs. non-contact injuries there was a statistical difference between non-contact injuries and athletes who did not suffer any injuries (p = 0.02) on performance of the posteromedial direction (Table 6).

Table 4.1: Demographics

<table>
<thead>
<tr>
<th>Age (2011)</th>
<th>Height(cm)</th>
<th>Weight (kg)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>172.72 ± 0</td>
<td>79.45 ± 0</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>174.5 ± 9.78</td>
<td>74.2 ± 14.51</td>
<td>23</td>
</tr>
<tr>
<td>15</td>
<td>174.14 ± 7.92</td>
<td>73.5 ± 18.09</td>
<td>27</td>
</tr>
<tr>
<td>16</td>
<td>178.36 ± 7.95</td>
<td>82.01 ± 14.51</td>
<td>41</td>
</tr>
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<td>17</td>
<td>181.74 ± 7.04</td>
<td>89.41 ± 19.69</td>
<td>31</td>
</tr>
<tr>
<td>18</td>
<td>179.5 ± 6.93</td>
<td>76.42 ± 3.98</td>
<td>6</td>
</tr>
<tr>
<td>Age (2009) Median</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>177.87 ± 7.98</td>
<td>79.19 ± 14.40</td>
<td>110</td>
</tr>
</tbody>
</table>

Table 4.2: Normalized Reach Score [(reach distance/leg length) * 100]

<table>
<thead>
<tr>
<th>Direction</th>
<th>Non-Injured(n=196)</th>
<th>Injured(n=41)</th>
<th>t</th>
<th>p</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>70.54 ± 7.78</td>
<td>67.93 ± 9.92</td>
<td>-1.86</td>
<td>0.06</td>
<td>0.37(0.03,0.70)</td>
</tr>
<tr>
<td>Posteromedial</td>
<td>84.48 ± 10.23</td>
<td>81.41 ± 11.26</td>
<td>-1.71</td>
<td>0.91</td>
<td>0.29(-0.05,0.63)</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>73.16 ± 10.78</td>
<td>72.11 ± 12.96</td>
<td>-0.55</td>
<td>0.52</td>
<td>0.09(-0.25,0.43)</td>
</tr>
<tr>
<td>Composite</td>
<td>76.17 ± 8.20</td>
<td>73.83 ± 9.60</td>
<td>-1.61</td>
<td>0.26</td>
<td>0.35(0.02,0.69)</td>
</tr>
</tbody>
</table>
Table 4.3: Summary of Prediction Model from Receiver Operator Characteristic Curve Analyses

<table>
<thead>
<tr>
<th>Reach Direction</th>
<th>Cut-Off Score</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>67.3%</td>
<td>0.56</td>
<td>0.65</td>
<td>2.35</td>
</tr>
<tr>
<td>Posteromedial</td>
<td>82%</td>
<td>0.54</td>
<td>0.6</td>
<td>1.75</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>68.8%</td>
<td>0.42</td>
<td>0.72</td>
<td>1.85</td>
</tr>
<tr>
<td>Composite</td>
<td>73.4%</td>
<td>0.46</td>
<td>0.66</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Table 4: 2 by 2 Contingency Table to Assess True Positives and True Negatives

<table>
<thead>
<tr>
<th>Reach Direction</th>
<th>Injured (+)</th>
<th>Non-Injured (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>Positive Test 23</td>
<td>Negative Test 69</td>
</tr>
<tr>
<td></td>
<td>Negative Test 18</td>
<td>170</td>
</tr>
<tr>
<td>Posteromedial</td>
<td>Positive Test 22</td>
<td>Negative Test 79</td>
</tr>
<tr>
<td></td>
<td>Negative Test 19</td>
<td>160</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>Positive Test 19</td>
<td>Negative Test 57</td>
</tr>
<tr>
<td></td>
<td>Negative Test 22</td>
<td>182</td>
</tr>
<tr>
<td>Composite</td>
<td>Positive Test 19</td>
<td>Negative Test 68</td>
</tr>
</tbody>
</table>

Table 4.5: SEBT performance (% leg length ±SD) between Ankle Injuries, Knee Injuries, and Non-Injured players

<table>
<thead>
<tr>
<th></th>
<th>Anterior</th>
<th>Posteromedial</th>
<th>Posterolateral</th>
<th>Composite</th>
<th>Total Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td>67.24 ± 1.62</td>
<td>79.54 ± 11.25</td>
<td>70.57 ± 10.23</td>
<td>72.47 ± 7.90</td>
<td>28</td>
</tr>
<tr>
<td>Knee</td>
<td>69.43 ±12.56</td>
<td>85.46 ±10.57</td>
<td>75.42 ±17.52</td>
<td>76.78 ±12.36</td>
<td>13</td>
</tr>
<tr>
<td>Non-Injured</td>
<td>70.55 ± 7.78</td>
<td>84.48 ± 10.23</td>
<td>73.16 ± 10.78</td>
<td>76.17 ± 8.20</td>
<td>196</td>
</tr>
<tr>
<td>F2.2316</td>
<td>2.04</td>
<td>2.92</td>
<td>0.989</td>
<td>2.46</td>
<td></td>
</tr>
<tr>
<td>P-Value</td>
<td>0.13</td>
<td>0.056</td>
<td>0.37</td>
<td>0.09</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.6: SEBT performance (% leg length ±SD) between Contact and Non-Contact Injuries and Non-Injured Players

<table>
<thead>
<tr>
<th></th>
<th>Anterior</th>
<th>Posteromedial</th>
<th>Posterolateral</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td>73.89 ± 15.86</td>
<td>91.41 ± 15.30</td>
<td>80.98 ± 18.32</td>
<td>82.06 ± 15.91</td>
</tr>
<tr>
<td>Non-Contact</td>
<td>68.81 ± 8.48</td>
<td>77.90 ± 11.72</td>
<td>75.17 ± 10.78</td>
<td>73.97 ± 8.82</td>
</tr>
<tr>
<td>Non-Injured</td>
<td>70.64 ± 7.49</td>
<td>84.28 ± 10.18</td>
<td>75.17 ± 10.24</td>
<td>76.86 ± 7.66</td>
</tr>
<tr>
<td>F2.128</td>
<td>0.77</td>
<td>3.95</td>
<td>0.59</td>
<td>1.91</td>
</tr>
<tr>
<td>P-Value</td>
<td>0.46</td>
<td>0.02</td>
<td>0.56</td>
<td>0.15</td>
</tr>
</tbody>
</table>
Chapter 5

Discussion

5.1 Discussion

The purpose of this study was to determine the ability of the SEBT to predict LEI in high school football players. Currently the literature is unable to definitively support the use of a quick, reliable, and inexpensive pre-season screening tool to predict LEI in football players. The SEBT has had limited application to screen high school basketball players, but the outcome measures did not employ normalized reach distances and the most interesting findings were in relation to female athletes.\(^{38}\)

In our first hypothesis, we stated that high school football athletes that suffered a LEI would demonstrate shorter reach distances when performing the SEBT in the pre-season compared to those athletes that did not suffer a LEI. While injured athletes scored lower, there were no statistically significant differences, suggesting that there is no relationship between the SEBT scores and risk for lower extremity injury. However the differences in the anterior reach (\(p = 0.06\)) and posterolateral reach (\(p = 0.052\)) were nearly significant. It should also be pointed out that moderate effect sizes (ES) for the anterior reach [0.37(95%CI: 0.03,0.07)] and composite scores [0.35(95%CI: 0.02,0.69)]
with confidence intervals that did not cross zero were found. Further testing to increase the sample size may help to realize significant relationships.

Our second hypothesis stated that a model could be developed to maximize sensitivity, specificity, which could be used to calculate an odds ratio that would demonstrate strong prediction of injury from SEBT performance. The posterolateral reach direction had a cut-off score associated with strong specificity (0.72), but had a small odds ratio of 1.85. This would suggest that performance on this reach direction had good ability to rule in injured athletes, but the cut off score is only able to show a 1.85 times more likely risk to experience an injury compared to those who were above the cut off score. Our highest odds ratio was found with the anterior reach direction (2.35), with moderate specificity (0.65). This would indicate that athletes below the cut off score of 0.67 were 2.35 times more likely to experience an injury then those who were above the cut off score. Therefore, the anterior reach seems to be the reach direction with the strongest predictive capability. However, it is debatable if a 2.4 times increased risk of injury is clinically important. A clinician will need to determine if the moderate injury prediction is worth the time investment to implement this screening tool for this athlete group.

Our third hypothesis addressed if differences in SEBT performance would exist between athletes who experienced ankle injuries versus those that suffered knee injuries. Although we did not find statistical differences between the two, we did however find a nearly significant difference (p = .056) in the posteromedial direction, with the athletes suffering an ankle injury performing worse than the non-injured athletes. Further
research should be done with larger samples to see if there are truly difference in reach distances between those who go on to experience ankle or knee injuries.

For our final hypothesis we wanted to explore the differences between SEBT performances of athletes that suffered contact and non-contact injuries. The preliminary analysis showed that there was a statistical difference between non-contact injured and non-injured groups in the posteromedial direction \((p = .02)\) (Table 6). It is also interesting to note that in all reach directions, non-injured reach distance means were actually smaller than contact injury reach distance means. Unfortunately, this data was not collected on the football athletes from 2009, so this preliminary data only consists of the 129 subjects tested at the beginning of the 2011 season. Ultimately more research is needed with larger samples to fully assess the ability of the SEBT to predict non-contact lower extremity injuries.

5.2 Study Comparisons

The 2006 Plisky et al\textsuperscript{38} would suggest there is relationship between SEBT scores and risk for lower extremity injury. In their study they looked at SEBT score of 235 high school basketball players, and had 54 documented injuries. This study found significant differences between athletes who did and did not experience lower extremity injury \((p < 0.05)\). When comparing our two studies together the sample sizes are extremely close in size \((235 \text{ vs. } 239)\), however our studies conflict in the effectiveness of the SEBBT to predict injury. Plisky et al\textsuperscript{38} methods also differed from ours in the fact that they adjusted more for the baseline data then we did in this study. They took into account the athlete’s age, history of injury, and use prophylactic bracing and taping. This may have played a huge difference in the difference of our findings. It should also be noted that their
strongest significant finding, that female athletes who did not have a composite score of 94% of their leg length were 6.5 times more likely to experience and LEI, is not comparable with our study because we only tested males. Additionally, the normalized scores reported in that study are much higher than have been reported in the literature that has used SEBT performance. This raises concerns about the methodology utilized in the Plisky et al study.

Willems et al in 2005 looked at ankle injury risk in 241 male physical education students over a period of 1-3 years. They found that running speed, cardiovascular endurance, balance, dorsiflexion strength, coordination, muscle reaction, and dorsiflexion range of motion were all associated with ankle inversion sprains. This supports our findings that athletes with anterior reach deficits, even though not statistically significant, are at higher risk for lower extremity injuries. It is interesting however to see the incorporations of overall fitness that Willems et al took into account. In the future, it may be useful to include additional measures of physical performance to provide a comprehensive assessment of injury risk.

Gribble et al, found that subjects with chronic ankle instability had significantly shorter reach distances on the SEBT after a fatigue protocol compared with healthy control subjects. It has also been well documented that people with CAI have lingering functional and mechanical instability that may result in continual sprains. When combining this with the SEBT’s ability to identify those with CAI, it brings up some interesting points. Our pre-season testing may have correctly identified athletes with CAI, but some of same subjects may have not had the same potential risk of injury as other subjects in the study as all athletes may not have experienced the same intensity of
activity during a practice, and especially games. For instance on a 23 player high school football varsity roster, we can conservatively estimate that 16 athlete see more than 5-10 plays a game and approximately 12-14 of them see more than 20 plays. Similarly in practice, not all athletes get the same amount of repetitions as others. It’s even more evident in basketball. If you were to take into account the increased risk of people with CAI to experience numerous ankle sprains,7,17 the SEBT's ability to identify CAI,3,21 and the role of fatigue resulting in lower SEBT scores26 it is possible that we may have identified subjects with CAI who produced scores below the cut-off score but did not go on to have an injury because they did not experience the same amounts of exposure to fatigue or injurious plays as the other subjects. If each athlete was to receive the same amount of repetitions and the same amount of fatigue we may have seen more LEI over the course of the season. In the future, it may be interesting to examine injury risk with our similar methods, but broken down into starters and non-starters on the player roster.

Another interesting addition would coincide with outcome measures looked at by Willems et al35. We think it would be interesting to see if there would be a way to incorporate some of their outcome measure into the SEBT comparisons. We feel that overall fitness and strength play a huge factor in risk for injury. For example, one possibility would be to examine the 10th – 12th grade results on the Presidential Fitness tests that all must complete during freshman year physical education classes.

5.3 Limitations

Our study did have a number of limitations. Over the course of the 2 competitive seasons separate teams of certified athletic trainers tested subjects. However, it should be noted that each certified athletic trainer was educated and determined to be well prepared
in administering the SEBT. Also Hertel et al\textsuperscript{31} reported that inter and intra rated reliability of the SEBT were high (ICC = 0.93). Unlike Plisky et al\textsuperscript{38}, we did not control for athletes who wore any type of lower extremity brace or those who were taped before practices and games. While the subjects were not able to wear braces of be taped during the testing procedure, some did however choose to use these prophylactic measures during the season which may have prevented a LEI. Another limitation is that some athletes participated on different playing surfaces. In the two seasons in question all teams practiced on grass but some played games on field turf, while other played solely on grass. Finally, while our sample is similar to the limited investigations that exist in the literature, there is still a need to increase the sample size to verify the use of the SEBT in predicting LEI in this athlete population.

5.4 Conclusion

In conclusion, our study to determine if the SEBT could be used as a strong predictor of lower extremity injury showed no statistically differences in those that did or did not suffer a LEI. However, if our methods would have incorporated a larger sample over a longer period time, account for taping/bracing, and previous injury history we may have found stronger results.

As mentioned previously, it may be useful in the future to consider the level of exposure by individual players by considering the starters vs. the non-starters. This may have influenced the overall injury incidents.

In closing, we cannot confidently conclude that the SEBT can be used as pre-season screening tool to predict LEIs in high school football players. However, the anterior reach may provide value as an individual, condensed assessment tool. Further
testing should be administered with larger samples and fewer limitations to see the SEBTs true ability to predict LEIs. In the future if the SEBT can be confidently used to identify at risk athletes the next step would be to administer preventative rehabilitation protocols and or implement the use of prophylactic taping and bracing.
References:


