A Thesis

Entitled

Using the Star Excursion Balance Test as a Predictor of Lower Extremity Injuries in High School Basketball Players

By

Sato. Ayami, ATC

Submitted as partial fulfillment of the requirements for

the Master of Science Degree in Exercise Science

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The University of Toledo

May 2010
An Abstract of

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Objective: 1) To determine if the Star Excursion Balance Test (SEBT) can be used as a lower extremity injury prediction test in high school basketball players. 2) To determine if there will be a significant difference in the reach distances in SEBT between in the athletes who experience a lower extremity injury and the athletes who do not experience a lower extremity injury in high school basketball players. 3) To determine the cut-off score on each direction of the SEBT that maximizes specificity and sensitivity. Design and Setting: A prospective cohort design was employed. Independent samples t-tests were used to determine the significant difference between the groups (injured, non-injured) in each dependent variable [anterior reach distance (ARD), posteromedial reach distance (PMRD), posterolateral reach distance (PLRD), composite score (CS)]. Significance was set at p<0.05. A receiver-operator characteristic (ROC) curve was used to determine the cut-off score on each of the four SEBT measures that maximizes specificity and sensitivity. Subjects: Seventy men’s and women’s freshman, junior
varsity, and varsity basketball players were recruited from three different division I and 
II, three high schools associated within the Toledo area.  Measurements: All subjects 
were evaluated for the reach distance of SEBT in three directions, ARD, PMRD, and 
PLRD, and CS by one of three certified athletic trainers during the pre-season. The 
injury occurrence was reported at the end of season to determine if there was a significant 
difference between subjects that did or did not suffer a lower extremity injury on SEBT 
score.  Results: Four subjects were excluded due to the history of surgery to the lower 
extremity.  Out of 66, 16 subjects (24.24 %) experienced lower extremity injuries. 
Fourteen injuries (87.5%) were grade 1 to 2 inversion ankle sprains, and two injuries 
(12.5%) were grade 1 to 2 muscle strains.  For ARD, there was no statistically significant 
difference between subjects that did or did not suffer a lower extremity injury (t = 1.15, p 
= 0.26).  The ROC Curve cut-off score was 64.8%.  This was associated with 0.56 
sensitivity and 0.74 specificity, + LR = 2.17, - LR = 0.59, and an Odds Ratio = 3.67.  For 
PMRD, there was no statistically significant difference between subjects that did or did 
not suffer a lower extremity injury (t = 0.94, p = 0.35).  The ROC Curve cut-off score 
was 72.95%, which was associated with 0.44 sensitivity and 0.72 specificity, + LR = 
1.56, - LR = 0.78, and Odds Ratio = 2.00.  For PLRD, there was no statistically 
significant difference between subjects that did or did not suffer a lower extremity injury 
(t = 1.52, p = 0.13).  The ROC Curve cut-off score was 67.45%.  This was associated 
with 0.56 sensitivity and 0.64 specificity, + LR = 1.74, - LR = 0.59, and Odds Ratio = 
2.97.  For CS, the difference between subjects that did or did not suffer a lower extremity 
injury was nearly statistically significant (t = 1.93, p = 0.06).  The ROC Curve cut-off 
score was 69.53%, which was associated with 0.75 sensitivity and 0.64 specificity, + LR
= 2.08, - LR = 0.39, and an Odds Ratio = 5.32. **Conclusion:** We found there was no significant difference between subjects that did or did not suffer a lower extremity injury on SEBT normalized reach distances. However, there was a nearly significant difference using the composite score of SEBT between the injured and non-injured groups (p=0.058), with good sensitivity of cut off score (0.75) and specificity that was close to be good (0.64). Therefore, the SEBT might be able to be used as predictor of lower extremity injuries for high school basketball players, especially inversion ankle sprains, if we use a composite score of the anterior, posteromedial, and posterolateral directions.
Acknowledgements

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I would like to give thanks for all the basketball players who participated in this study, spending time for performing SEBT. I also would like to thank to parents and guardians.

Lastly, I would like to say thank you to the staffs who gave tremendous amount of support for this study, include athletic trainers who spent time for the data collections, and coaches at each school who supported me contacting basketball players in their teams.

I greatly appreciate you.
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Chapter 1

Introduction

Ankle sprains are one of the most common athletic injuries in basketball. In both the Men’s and Women’s National Basketball Association; approximately 65% of athletic injuries occurred in the lower extremity, with lateral ankle sprains among the most common injuries. Approximately 60% of athletic injuries in the National Collegiate Athletic Association (NCAA) men’s and women’s basketball were in the lower extremity, and again ankle ligament sprains were the most common injury. This injury rate is also similar in high school basketball. According to Borowski et al, the injuries to the ankle or foot were the most common injuries (39%), and the ligamentous sprains were the most frequent diagnoses (44%) among high school basketball players.

The prevention of ankle sprains in basketball players is very crucial, because of the volume of injuries that take place annually. An ankle sprain costs approximately 179 dollars for each emergency visit, and athletes suffering from an ankle sprain are estimated to lose approximately one to six days of playing time. An acute ankle sprain may develop into recurrent ankle sprain. Athletes who have a previous history of ankle sprain were two times more likely to sprain their ankle than athletes without a history of ankle sprain. Additionally, athletes who had more than five ankle sprains complained of ankle instability four times more often than the athletes who sprained an ankle only
Those who have suffered from multiple ankle sprains tend to have ankle instability, and suffer from recurrent ankle sprains and the sensation of giving way. This condition is often called chronic ankle instability (CAI) and is referred to as the occurrence of repetitive bouts of lateral ankle instability, resulting in numerous ankle sprains. 

CAI can be classified into three types: functional ankle instability (FAI), mechanical ankle instability (MAI) and the last one being a combination of FAI and MAI. MAI refers to the altered mechanics of the ankle complex, including pathological laxity of ligaments, impaired arthrokinematics, degenerative or inflammatory condition as a result of a previous inversion ankle sprain. On the other hand, FAI is usually attributed to diminished proprioception, balance, postural control, neuromuscular control, and strength of the muscles as a result of the inversion ankle sprain. For example, Sekir et al. found deficits in proprioception, balance, evertor muscle strength, and functional ability as well as repeated “giving way” episodes within the previous six months in subjects with more than two inversion ankle sprain. Moreover, Gribble et al. found that there was diminished dynamic postural stability at initial contact from jump landing in CAI compared to healthy subjects.

Multiple ankle sprains could increase the risk of chronic instability and degenerative arthritis in the future. According to Verhagen et al. out of 128 patients who had a history of grade 2 ankle sprain, 61 subjects had a fear of instability (48%), 28 subjects had pain (22%), 42 subjects had swelling (33%), and 69 subjects experienced recurrent ankle sprains (54%) 6.5 years after the initial ankle sprain. Also according to Konradsen et al. out of 648 subjects who experienced an inversion sprain, 32% of
individuals were experiencing pain, swelling or recurrent sprains seven years after the previous evaluation. The data from these studies leads to the conclusion that an individual who suffers an acute inversion ankle sprain might develop reoccurring ankle sprains and CAI. Therefore, the prevention of acute inversion ankle sprains will be very crucial and important in basketball players, especially in young athletes.

Several studies have suggested a correlation between diminished proprioception, balance, and postural stability, and ankle sprain occurrences. However, most of the balance and proprioceptive tests require expensive and time consuming devices, and are not realistically easy to use in the clinical setting. There is no well-designed, inexpensive, and convenient functional test that can easily be applied in any clinical setting, for the prediction of ankle sprain. The Star Excursion Balance Test (SEBT) is a one of the dynamic balance tests, which is inexpensive, convenient, and commonly used to measure the functional balance ability in the research and clinical settings. The SEBT is a dynamic and functional balance test, which requires using adequate muscle strength, neuromuscular control, range of motion, balance, postural control, and proprioception of the ankle, knee and hip joints of the stance leg. The purpose of this study is to determine if there is a relationship between SEBT score and lower extremity injuries, especially inversion ankle sprains, and also to determine if SEBT can be used as an effective lower extremity injury prediction test in high school basketball players. The results of this study may provide information on the prevention of lower extremity injuries, and may help decrease lower extremity injuries especially inversion ankle sprains in high school basketball. Moreover, if this study is able to predict lower extremity injury occurrence in high basketball players, the rate of injury occurrence and
development of chronic issues, such as CAI in adult basketball players may be decreased in the future. The hypothesis of this study is that there will be a significant difference in the reach distance in SEBT in the athletes who experience a lower extremity injury compared to athletes that do not experience a lower extremity injury in high school basketball players.

**Statement of the Problem**

There is no well-designed, inexpensive, and convenient functional test, which can be easily applied in a clinical setting, in order to predict lower extremity injury.

**Statement of the Study**

The purpose of this study includes: (1) to determine if the SEBT can be used as a lower extremity injury prediction test in high school basketball players, (2) to determine if there will be a significant differences in the reach distance in SEBT in athletes who experience a lower extremity injury and the athletes who do not experience a lower extremity injury in high school basketball players, and (3) to determine the cut-off score on each direction of the SEBT that maximizes specificity and sensitivity.

**Significance of the Study**

The results of this study may provide information on the prevention of the lower extremity injury in high school basketball. Moreover, if this study is able to predict lower extremity injury occurrence in high basketball players, the rate of injury occurrence
and development of chronic issues, such as CAI in adult basketball players may be decreased in the future.

**Research Hypotheses**

H1: Athletes who experience a lower extremity injury will demonstrate shorter normalized reach distances on the SEBT compared with the athletes who do not experience a lower extremity injury in high school basketball players.

H2: There will be a predictive 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 high school basketball players.
Chapter 2

Literature review

Pathomechanics of Inversion Ankle Sprain

The ankle is formed by the tibia, fibula, talus and calcaneus, which create three joints including the talocrural joint, distal tibiofibular joint, and subtaloar joint. These three joints coordinate along oblique axes of motions, such as pronation and supination with the cardinal planes of sagittal, frontal, and transverse plane motions as the cardinal plane. The stability of the ankle is created by: (1) The articular surface congruency during weight bearing, (2) static ligamentous support, and (3) dynamic musculotendinous support. An inversion ankle sprain occurs when the ankle is excessively inverted and internally rotated, with external rotation of distal tibiofibular joint. The acute inversion ankle sprain can lead to some adverse effects, such as altered mechanics of ankle joints, pathological laxity of ligaments, impaired arthrokinematics, diminished proprioception, balance, postural control, neuromuscular control, and strength of the muscles, which can cause functional ankle instability (FAI), mechanical ankle instability (MAI) or a combination of both. Several studies have examined the relationship between diminished proprioception, balance, and postural stability, and ankle sprain occurrences, with
proprioceptive, static and dynamic balance tests, such as a stabilometry, Biodex, Neurocom Balance Master, and have found some relationship.\textsuperscript{20,1,35,36,37} Even though there are several studies, which have found the inverse relationship between diminished balance and proprioceptive ability and ankle sprains, and suggest to use those factors for the prediction of ankle sprains, most of the balance and proprioceptive tests require expensive and time consuming devices, and are not realistically easy to use in the clinical setting.

The Star Excursion Balance Test

The Star Excursion Balance Test (SEBT) is one of the dynamic balance tests, which offers very little cost and convenience, and is commonly used to measure the functional balance ability in a research and clinical settings. A subject stands on single leg on the grid with hands on the hips and the standing foot’s heel is on the ground. The grid has tape measures in 8 different directions with a 45° angle difference between each tape measure. Each direction is named as: (1) Anterior, (2) Anteromedial, (3) Anterolateral, (4) Posteromedial, (5) Posterolateral, (6) Posterior, (7) Medial, and (8) Lateral. The subject uses the free leg to touch down on the tape measure as far as he/she can with his/her toe in each direction. The maximum reach distance is normalized to leg length and evaluated as the subject’s dynamic balance. The SEBT requires the subject to use adequate muscle strength, neuromuscular control, range of motion, balance, postural control, and proprioception of ankle, knee and hip joints of standing leg and can be used to assess improvements from rehabilitation.\textsuperscript{38,39}
Literature review of SEBT

Hertel et al\(^0\) examined the intratester and intertester reliability of SEBT and its learning effect, and found high levels of reliability on both intratester and intertester. They also found there was significant learning effect on SEBT, leading to a recommendation to have at least 6 practice trials before actual testing.\(^40\) Kinzey et al also examined the reliability of the SEBT with healthy subjects, and found moderate reliability. In their conclusion, they indicated that SEBT might not be the proper test to examine the dynamic balance.\(^41\) Hale et al indicated that the SEBT is reliable and sensitive to detect the functional limitations between involved and non-involved side of CAI subjects.\(^38\)

Herrington et al\(^2\) used the SEBT to determine whether SEBT detects ACL deficiency. Twenty five male and female subjects with ACL deficient and same numbers of matched healthy subjects were compared by SEBT scores for all eight directions. In this study, the subjects with ACL deficiency showed less postural control compared to the healthy subjects.\(^42\) Plisky et al\(^2\) used SEBT with only anterior, posteromedial, and posterolateral directions, as a prediction test of lower extremity injury in High school basketball players. They found that there was a significant correlation between lower extremity injuries, which were mostly acute sprains of ankles and knees, and the reach distance differences between right and left limbs in anterior direction. The basketball players who had a greater difference in anterior reach distance on right and left limbs are in 2.5 times greater risk for lower extremity injury. Moreover, the women’s basketball players who had diminished normalized reach distance tended to have a lower extremity
injury 6.5 times more than others. Plisky et al concluded that SEBT could be used as the prediction test of lower extremity injury of basketball players in high school.  

Gribble et al examined the influence of fatigue of both ankle and proximal joints on the SEBT with CAI subjects. In the study, healthy and CAI subjects performed the following fatigue protocols: (1) concentric – concentric ankle planter/dorsiflexion isokinetic protocol, and (2) forward lunges protocol, which targeted the knees and hips fatigue. After each fatigue protocol, the SEBT was performed and compared between each groups. The results indicated that the ankle fatigue protocol did not show significant effect on the SEBT score compared to the healthy group. However, the lunge fatigue protocol significantly affected the SEBT score on the anterior and posterior directions, but not on medial direction. Gribble et al concluded that the subjects who had CAI also had neuromuscular alterations in their proximal joints with fatigue, and the SEBT is able to detect the alterations of proximal joint. Gribble et al had another study to investigate the influence of fatigue protocols of ankle, knee and hip sagittal-plane motion on SEBT reach distance and knee and hip kinematics among CAI subjects. The results showed CAI subjects had shorter reach distances on SEBT and less knee flexion angle during SEBT compared to the non-injured side and healthy subjects. They concluded that CAI and fatigue diminished dynamic postural control by altering proximal joint kinematics to the ankle. Sefton et al compared four types of sensorimotor constructs, which included SEBT, force plate, isokinetic dynamometer, and electromyography to investigate which measurement was the best tool to distinguish between CAI and healthy subjects. The results indicated that there was no significant difference between CAI and healthy subjects on SEBT score while electromyography and
force plate had significant difference. They concluded the motoneuron pool excitability and static balance tests might be more clinically important for treating and rehabilitating CAI.  

Gribble et al\textsuperscript{46} used healthy subjects and determine if the time of day on SEBT influences or no t. Each subject was tested on the anterior reach distance at 10:00, 15:00, and 20:00. The results indicated that the reach distance measured at 10:00 was the greatest. Therefore, performance is perhaps on the SEBT is optimized in the mornings, but the test should be performed at the same time of day for consistent results.  

Hertel et al\textsuperscript{47} questioned whether all eight directions of SEBT were necessary to detect CAI, and found only three directions, included anteromedial, medial and posteromedial directions might be enough to use for SEBT. They also found the posteromedial direction had the highest distinguishing score of the CAI.  

Robinson et al\textsuperscript{48} studied to determine how many times of trials are necessary to reach the maximum stability during the SEBT. The result indicated that the maximum stability was achieved within the first four trials. Therefore, four practice trials in each direction are recommended before the actual testing.  

In this study, the anterior, posteromedial, and posterolateral directions were chosen to use due to the following reasons: (1) Anterior directions challenged subjects to use dorsiflexion. Willems et al examined risk factors of inversion ankle sprain, and found decreased dorsiflexion range of motion of the ankle was one of the intrinsic risk factors.  

(2) Posteromedial and posterolateral directions requires strength, neuromuscular control, and flexibility of proximal joints, which might influence postural
instability and ankle instability.\textsuperscript{30,43,44,49} (3) The posteromedial direction of the SEBT is the most significantly correlated direction to ankle instability.\textsuperscript{47}
Chapter 3

Methods

Subjects:
Seventy men’s and women’s freshman, junior varsity, and varsity basketball players were recruited from three different division I and II high schools within the Toledo area. All subjects were evaluated to determine the maximum reach distance of the Star Excursion Balance Test (SEBT) in three directions, anterior, posteromedial and posterolateral, by one of three certified athletic trainers during the pre-season. Subjects were excluded if there was: (1) a history of lower extremity surgery, (2) a history of an ankle, foot, or knee injury that caused the athlete to lose at least one practice or game, which happened less than a month prior to the study, (3) a vestibular dysfunction (4) a history of concussion, which happened less than a month prior to the study. Only the subjects that were cleared by a physician for sport participation were included. None of the subjects were allowed to use ankle taping or a prophylactic ankle brace during the testing session. All subjects and their parents/guardians (if needed) submitted a University Institutional Review Board approved informed consent form prior to this study. During the competitive season, the total number of exposures from practice and games were recorded. Additionally, each acute lower extremity injury incident, such as inversion ankle sprains, Achilles strains, MCL sprains, was documented along with the
mechanism of injury, history of previous lower extremity injury, and use of an ankle or knee support (ankle tape or ankle brace) by a certified athletic trainer throughout the 2009 - 2010 basketball season.

**Instrumentation and Protocol:**

All subjects were evaluated bilaterally for his or her SEBT reach distance by the same certified athletic trainer prior to the beginning of the first day of practice for the season. The certified athletic trainer of each school was contacted at the end of the season by the examiner of this study and asked to report the injury occurrence.

**Dynamic Postural Control:**

Dynamic postural control was assessed by the reach distances performed on the Star Excursion Balance Test (SEBT). The anterior, posteromedial and posterolateral the SEBT reach distance was measured in each subject. Before the SEBT procedures, the subject’s limb length was recorded in a supine position by measuring the distance from the inferior point of anterior superior iliac supine to the distal part of the medial malleolus with a standard tape measure. After the limb length measurement, all subjects performed four practice trials for the SEBT in each of the three directions, on both legs, and performed testing trials three times in each direction. The subjects were asked to stand on a single leg in the center of the SEBT testing grid. The distal head of the \( 1^{\text{st}} \) phalanx of the foot was positioned at the starting line (the center point of the grid) for the anterior direction and the most posterior point of the heel was positioned at the starting line for the posteromedial and posterolateral directions. The subjects were asked to perform reaches in each of the three directions with the non-weight bearing limb as far as they can, make a light touch with the most distal part of the reaching foot on the line, and
return under control back to the starting position to resume a double-limb stance. The maximal distance where the most distal part of the foot touched the ground was measured. The trial was repeated if the subject: (1) lost balance in the single leg stance, (2) lifted the heel or shifts the foot of the standing leg, (3) used a heavy touch with the reaching foot, or (4) failed to bring the reach foot back to the starting point. The distance of the three trials were averaged and used for the analysis for each direction. The average distance of the three testing trials of each direction were normalized by dividing by the subject’s limb length, and multiplying by 100.\(^{34}\) The right and left limb’s score were averaged for each direction, and used for analysis. Also, the composite scores for each leg were calculated by adding the three directions’ scores, and dividing by three in each right and left side. The composite scores of right and left limbs were averaged and used for analysis.

**Statistical Analysis:**

The Statistical Package for Social Sciences (SPSS version 17.0; SPSS Inc, Chicago Il) was used for data analysis. The \(\alpha\) level was set at 0.05 for the indication of the statistical significance. There was one independent variable (Group: injured and non-injured) and four dependent variables (normalized reaching distance in three directions: anterior, posteromedial, posterolateral; and a composite score: average of the three reaching directions). To determine the significant difference between the groups in each dependent variable, independent samples t-tests were used.

The secondary purpose was to determine the cut-off score on each of the four SEBT measures that maximizes specificity and sensitivity. A receiver-operator characteristic (ROC) curve was used to plot sensitivity (True +’s) versus 1 -specificity
(False +’s) for the screening test. The ROC determines what value for which a test was considered positive by examining different points on the curve corresponding to different cut-off points. The ROC curve maximizes True +’s and controls for False +’s and identifies this point on the curve at the left uppermost point of the graph. After finding the cut-off score on the each direction of the SEBT, a 2x2 contingency table was produced to dichotomize what athletes suffered an injury and those who did not, and those who were above or below the cut-off score. From the table, odds ratios, likelihood ratios, sensitivity and specificity were calculated.

To estimate the amount of influence an athlete’s SEBT score has on the probability of suffering an injury, post-test odds and post-test probability were calculated according to the formula provided. A 3-step calculation process was used to determine how much the probability of injury increased from pre-test to post-test when an athlete’s score fell below the cut-off score. For the likelihood ratio, the +LR value is negative for an athlete when their score was above the cut-off score and positive when their score was equal to or below the cut-off score determined by the ROC curve. Calculation of the increase in probability was as follows:

1) Convert the pre-test probability to odds:

\[ Pre-test \text{ odds} = \frac{pre-test \text{ probability}}{(1 - pre-test \text{ probability})} \]

2) Multiply the odds by the appropriate +LR value:

\[ Pre-test \text{ odds} \times +LR = post-test \text{ odds} \]

3) Convert the post-test odds back to probability:

\[ Post-test \text{ odds} / (post-test \text{ odds} + 1) = Post-test \text{ probability} \]
Chapter 4

Results

The subject demographics, which include the number of lower extremity injuries (e.g., ligamentous sprains, menisci injuries, muscle strains, contusions) are shown in Table 1. The mean normalized reach distances for the 3 reach directions and composite score are presented in Table 2. The 2 x 2 contingency tables (Positive result vs. Group) as well as sensitivity and specificity for each direction and the composite scores are shown in Table 3.

Out of 70 subjects, four subjects were excluded due to the history of surgery in the lower extremities. Out of 66, 16 subjects (24.24%) experienced lower extremity injuries during the 2009 – 2010 basketball season. Fourteen injuries (87.5%) were grade 1 to 2 inversion ankle sprains, and two injuries (12.5%) were grade 1 to 2 muscle strains (e.g., quadriceps strain, hamstring strain).

Anterior Reach Distance (ARD)

For ARD, there was no statistically significant difference between subjects that did or did not suffer a lower extremity injury (t = 1.15, p = 0.26) (Table 2). The ROC Curve cut-off score for the ARD was 64.8%. This was associated with 0.56 sensitivity and 0.74 specificity, +LR = 2.17, -LR = 0.59, and an Odds Ratio = 3.67 (Table 3).

Posteromedial Reach Distance (PMRD)
For PMRD, there was no statistically significant difference between subjects that did or did not suffer a lower extremity injury (t = 0.94, p = 0.35) (Table 2). The ROC Curve cut-off score for the PMRD was 72.95%, which was associated with 0.44 sensitivity and 0.72 specificity, + LR = 1.56, - LR = 0.78, and Odds Ratio = 2.00 (Table 3).

**Posterolateral Reach Distance (PLRD)**

For PLRD, there was no statistically significant difference between subjects that did or did not suffer a lower extremity injury (t = 1.52, p = 0.13) (Table 2). The ROC Curve cut-off score for the PLRD was 67.45%. This was associated with 0.56 sensitivity and 0.64 specificity, + LR = 1.74, - LR = 0.59, and Odds Ratio = 2.97 (Table 3).

**Composite Score (CS)**

For CS, the difference between subjects that did or did not suffer a lower extremity injury was nearly statistically significant (t = 1.93, p = 0.06) (Table 2). The ROC Curve cut-off score for the CS was 69.53%, which was associated with 0.75 sensitivity and 0.64 specificity, + LR = 2.08, - LR = 0.39, and an Odds Ratio = 5.32 (Table 3).
Table 1: Subject Demographics

<table>
<thead>
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<th>Age</th>
<th>Male (n=37)</th>
<th>Female (n=29)</th>
<th>Total (n=66)</th>
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<td>8</td>
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<td>11</td>
<td>4</td>
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</tr>
<tr>
<td>18</td>
<td>4</td>
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<td>5</td>
</tr>
<tr>
<td>Ankle Support</td>
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<tr>
<td>Tape/Ankle Brace</td>
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<td>19</td>
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<tr>
<td>None</td>
<td>26</td>
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<tr>
<td>Number of previous injuries</td>
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</table>
Table 2: Normalized reach distances [(reach distance/leg length)*100]

<table>
<thead>
<tr>
<th>Normalized reach distance</th>
<th>Non-Injured (n=50)</th>
<th>Injured (n=16)</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>68.36±7.45</td>
<td>65.84±8.13</td>
<td>0.33(-0.24,0.89)</td>
</tr>
<tr>
<td>Posteromedial</td>
<td>78.14±11.28</td>
<td>75.12±11.21</td>
<td>0.27(-0.30,0.83)</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>70.34±10.30</td>
<td>65.74±11.16</td>
<td>0.43(-0.14,1.00)</td>
</tr>
<tr>
<td>Composite</td>
<td>72.32±8.41</td>
<td>67.52±9.42</td>
<td>0.55(-0.02,1.12)</td>
</tr>
</tbody>
</table>
Table 3: 2 x2 Contingency Tables (Positive Test result vs. Group)

<table>
<thead>
<tr>
<th>Reach Direction</th>
<th>Injured</th>
<th>Non-Injured</th>
</tr>
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<tr>
<td><strong>Anterior</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+Test</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>–Test</td>
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<td>37</td>
</tr>
<tr>
<td><strong>Posteromedial</strong></td>
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<tr>
<td>+Test</td>
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<td>14</td>
</tr>
<tr>
<td>–Test</td>
<td>9</td>
<td>36</td>
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<tr>
<td><strong>Posterolateral</strong></td>
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<td>18</td>
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<tr>
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Chapter 5

Discussion

There were three purposes in this study: (1) to determine if the SEBT could be used as a prediction test for lower extremity injuries in high school basketball players, (2) to determine if there were a significant difference in the reach distance in SEBT performance in athletes who experience lower extremity injuries and the athletes who did not experience any lower extremity injuries in high school basketball players, and (3) to determine the cut-off score on each direction of the SEBT that maximizes specificity and sensitivity. There were also two research hypotheses, (H1): athletes who experience lower extremity injuries will demonstrate shorter reach distance when performing the SEBT than the athlete who does not experience lower extremity injuries, (H2): there will be a predictive 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.

The t-tests indicated there were no statistically significant differences between subject that did or did not suffer a lower extremity injury on SEBT reach distances for the three utilized reaching directions including the anterior (p=0.26), posteromedial (p=0.35), and posterolateral (p=0.13). This suggested no relationship between SEBT reach distance in these three directions and lower extremity injuries. Therefore, these individual reaching directions of the SEBT might not provide the best prediction of lower extremity injuries.
extremity injuries. However, there was a nearly significant difference between subjects that did or did not suffer a lower extremity injury for the composite score of the SEBT (p=0.058). This could indicate that an athlete who experienced lower extremity injuries had a tendency to have lower composite score on SEBT compared to the athletes who did not experience lower extremity injuries.

Using the ROC Curve analysis, the resultant cut-off scores indicated that anterior (0.74) and posteromedial (0.72) directions had strong specificity with cut off score of 64.8(%) and an odds ratio of 3.67 in the anterior direction, and a cut-off score of 72.95(%) and an odds ratio of 2.0 in the posteromedial direction. These results indicated that the athlete who had longer reach distance than 64.8 cm in anterior direction was 3.67 times less likely to have a lower extremity injury. Also an athlete who had longer reach distance than 72.95 cm in the posteromedial direction was 2 times less likely to have lower extremity injuries. However, there were no significant differences in those two directions, indicating there was no significant relationship between SEBT reach distance and lower extremity injuries. Therefore, using those two directions of SEBT as the predictor of lower extremity injuries may not have statistical differences, but still may have useful clinical prediction qualities.

On the other hand, there was a good sensitivity (0.75) with a cut off score of 69.53% on the composite score with 0.058 p value, which indicated a nearly significantly difference. This resulted in an odds ratio of 5.32 indicating that the athlete, who had lesser than 69.53 of the SEBT composite score, was 5.32 times more likely to suffer from lower extremity injuries. The SEBT composite score might be able to detect the subject who is at risk of lower extremity injuries. With good sensitivity, the test is able to rule
out injuries, and the specificity being nearly 0.70 indicates potential to rule in injury. Therefore, our results indicated that SEBT might be used as predictor test of lower extremity injuries for high school basketball players, especially inversion ankle sprains (14 out of 16 injuries were lateral ankle sprains), if we use composite score of anterior, posteromedial, and posterolateral directions.

Our findings were similar to Plisky et al\textsuperscript{2} who reported that high school basketball players who had bilateral decreased composite score tended to have a higher risk of lower extremity injuries. In their study, they found significant difference between subjects that did or did not suffer a lower extremity injury on SEBT normalized reach distances (p< .05). In their study, they used 235 high school basketball players, which was 3.6 times more than the subjects we used in this study. Plisky et al\textsuperscript{2} also adjusted the subjects’ baseline, such as grade, history of injury, ankle and knee support (eg, tape, brace, sleeve), and participation of neuromuscular training, before they analyzed data.

Shaw et al,\textsuperscript{50} indicated that the subjects who wore the Swede-O Universal lace-up ankle brace had better stabilization compared to the subjects who did not wear ankle braces. Kofotolis et al\textsuperscript{51} found that female Greek professional basketball players who did not wear external ankle supports had a higher risk for ankle sprains compared to players who wore external ankle support. Leanderson et al\textsuperscript{1} found that basketball players who had previous ankle injury had greater mean postural sway compared to basketball players who did not have history of ankle injuries. There were other studies, which found ankle instability to be associated with chronic ankle instabilities, which is likely to occur from incidence of previous ankle sprains.\textsuperscript{18-22} In our study, we mixed those subjects who had different previous injury experiences, ankle and knee external support use, and age.
Therefore, the small number of subjects and the factors listed above could help to explain why we did not find statistical differences, while Plisky et al\(^2\) found there was a significant difference between the basketball players with and without lower extremity injuries on SEBT reach distances.

Willems et al\(^3\) indicated decreased dorsiflexion range of motion of the ankle as one of the intrinsic risk factors that predicted ankle injuries. There were several studies which indicated that the posteromedial and posterolateral directions requires strength, neuromuscular control, and flexibility of proximal joints, which might influence postural instability and ankle instability.\(^{30,43,44,49}\) Hertel et al\(^4\) indicated that the posteromedial direction of the SEBT is the most significantly correlated direction to ankle instability.\(^47\)

In our study, there was a similar result which might support those previous studies. Our results showed the cut-off scores resulting from the ROC curves produced strong specificity in the anterior (0.74) and posteromedial (0.72) directions. While there was no statistically significant difference (p>.05), these specificity scores above 0.70 support our second hypothesis.

We found there was no significant difference between subjects that did or did not suffer a lower extremity injury on SEBT normalized reach distances. However, there was a nearly significant difference using the composite score of SEBT between the injured and non-injured groups (p=0.058), with good sensitivity of cut off score (0.75), and a moderate effect size (d=0.55). Therefore, the SEBT might be able to be used as predictor of lower extremity injuries for high school basketball players, especially inversion ankle sprains, if we use composite score of anterior, posteromedial, and posterolateral directions. We recommend using SEBT composite score of three
directions (anterior, posteromedial, and posterolateral) to assess the dynamic balance skills of high school basketball players before the season. In the future, this may lead clinicians to use neuromuscular training program for the athletes who demonstrate a lower SEBT composite score in an effort to prevent lower extremity injuries, especially inversion ankle sprains.

There were several limitations in this study. During testing, all the subjects were not allowed to wear any ankle or knee external support, or shoes. However, when the lower extremity injury occurred, all the subjects were wearing shoes, and some of them were wearing ankle or knee braces, or had the joint taped prior to participation. As previously indicated, there were many factors that could have affected baseline differences among the subjects, such as history of injury, ankle or knee external support, and age. Additionally, this study included a small number of subjects and therefore, the analysis did not separate and compare between genders. The intensity of performance was varied among the level of teams either because of skill, age, or gender and as a result may have introduced a large amount of variability to the sample.

The subjects’ SEBT score were assessed when the subjects were not in a fatigued state however, all the injuries occurred when subjects were performing physical activity, and potentially could have been fatigued (eg, during practices or games). Gribble at al\textsuperscript{43, 44} indicated CAI and fatigue diminished dynamic postural control by altering proximal joint kinematics. Therefore, it was not known if fatigue or duration of activity could have been a factor in injury prediction or risk. Further study should include larger number of participants in order to account for the baseline differences, to account for the factors
mentioned above, and assess SEBT scores under a fatigued state to increase the accuracy and validity of the results.
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