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Pre-participation functional screenings does not identify high school basketball athletes at risk of sustaining an ankle injury

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Pre-Participation Functional Screenings Does Not Identify High School Basketball Athletes at Risk of Sustaining an Ankle Injury

by

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

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An Abstract of

Pre-Participation Functional Screenings Does Not Identify High School Basketball Athletes at Risk of Sustaining an Ankle Injury

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Background: Participation in high school athletics continues to grow over the years. Adolescents competing in organized competition has grown from 3.9 million in 1971 to 7.7 million in 2012.[1] With the increasing number of adolescents taking part in athletics, the number of injuries sustained raises as well. One of the most common injuries sustained in high school athletics is an ankle injury.[2] Of these ankle injuries, the most common injury is a lateral ankle sprain.[2] Pre-participation screenings often lack functional tests that may identify an individual's risk of injury. Incorporating functional tests during a pre-participation screen could not only identify athletes at risk of injury, but can help lead to the appropriate action to prevent injury. Few functional tests, the modified functional movement screen (MFMS), the anterior reach of the star excursion balance test (SEBT-A), and weight bearing lunge test (WBLT), show early potential of identifying individuals at increased risk of injury. **Purpose:** The purpose of this study was to determine if there are differences on the MFMS, SEBT-A, and WBLT in individuals who sustain an ankle injury and those who do not. A secondary purpose was to determine differences between males and females on these functional assessments.

Methods: 34 (24 male, 10 female) junior varsity and varsity high school basketball players were screened using the MFMS, SEBT-A, and WBLT before the start of the basketball season. Injuries were recorded by the certified athletic trainer at the high school during the season. An injury had to meet all three of the following criteria; 1) occurred during an organized practice or competition, 2) required medical attention, and 3) restricted participation for 1 or more days beyond injury. **Results:** When comparing injured vs. non-injured scores, there was no significant difference in the WBLT (p=0.26), SEBT-A (p=0.06), and MFMS (p=1.00). Looking at the reach difference there was no significant difference between injured and non-injured athletes (p=0.82). When comparing the scores on the tests between males and females, there was a significant difference on the MFMS (p=0.04) but no significant difference between the WBLT (p=0.66) and the SEBT-A (p=0.06). **Discussion:** Our findings do not support previous research as our 3 functional assessments showed no significant difference between injured and non-injured groups. The SEBT-A shows promise within the small sample size given and more research should be done to examine this more closely. **Conclusion:** Neither of the WBLT, SEBT-A, or the MFMS could statistically identify athletes at risk of suffering an ankle injury. However, more research should be done with these functional tests within a variety of settings to identify their usefulness in a pre-participation screen.

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List of Abbreviations

AEs............................Athlete Exposures
ASLR ....Active Straight Leg Raise
ATC...........................Certified Athletic Trainer
ATFL.........................Anterior Talofibular Ligament

BMI ....Body Mass Index

CAI............................Chronic Ankle Instability
CFL ....Calcaneofibular Ligament

FAAM ....Foot and Ankle Ability Measurement
FAI ....Functional Ankle Instability
FMS...........................Functional Movement Screen

IAC............................International Ankle Consortium

MFMS ....Modified Functional Movement Screen
MI..............................Mechanical Instability

OR ....Odds Ratio

PI...............................Perceived Instability
PTFL ....Posterior Talofibular Ligament

RS..............................Recurrent Sprain

SEBT.........................Star Excursion Balance Test
SEBT-A......................Anterior reach of the Star Excursion Balance Test

WBLT ....Weight Bearing Lunge Test

Chapter One

Introduction

1.1 Background

Participation in high school athletics has grown from 3.9 million in 1971 to 7.7 million in 2012.[1] Being involved in athletics puts an individual at risk for injury. From 2005 to 2010, over 25,000 injuries occurred to high school athletes.[3] Of these injuries, 3,864 involved the knee and 5,373 were ankle sprains, with injury rates of 2.98 and 3.13 per 10000 athlete exposures (AEs) respectively.[2,3] High school basketball players had the highest ankle injury rate for both males and females at 5.16 and 5.03 per 10000 AEs respectively.[2] Injuries sustained to the ankle often results in emergency room visits and physical therapy appointments, with estimated total health care costs for treating ankle sprains of approximately $2 billion annually in the United States.[4] Due to the high costs of this common injury, clinicians would benefit from a pre-participation screen that could identify individuals who may be at risk of an ankle injury. A pre-participation functional assessment can identify weaknesses and asymmetries that can guide a clinician to implementing a rehabilitation designed to correct the deficiencies in order to help prevent an injury. There are efficient functional assessments at detecting movement pattern deficiencies, dynamic postural control, and functional ankle range of motion.

The Functional Movement Screen (FMS) was developed to test individuals dynamic and functional capacity.[5] The FMS is made of seven movement patterns that requires the individual to have a balance between mobility and stability.[5] The FMS has been used previously to predict injury in professional football players, collegiate female athletes, and military personnel.[6-9] Although these studies showed the FMS to identify injury risk, there are also studies that contradict these findings.[10] There is limited research on the full FMS to be able to identify individuals at risk of a lower extremity injury specifically. Recent work utilized a modified version of the FMS (MFMS) to predict lower extremity injuries in collegiate football players found using four tests (deep squat, hurdle step, active straight leg raise, and inline lunge), out of the original seven, had a higher diagnostic odds ratios compared to three tests and the full FMS.[7] Currently there is no information published on the predictive capabilities in the high school population or with basketball athletes.

Dynamic balance deficits have been linked with increased risk of suffering an ankle sprain.[11] A functional assessment that can identify these dynamic balance deficits may be able to identify an athlete who is at risk of suffering an ankle injury. One such test is the Star Excursion Balance Test (SEBT). The SEBT is an assessment of dynamic postural control and movements in the lower extremity that can be applied in clinical settings. However, there are some limitations to acquiring objective measures in clinical settings as the original SEBT was designed to test 8 different reach directions. A recent review of the SEBT literature suggests the most effective directions at finding individuals with deficits that could lead to injury were the anterior, posteromedial, and posterolateral reach, with the anterior reach (SEBT-A) having the highest odds ratios compared to the other directions for ankle injuries.[12]

The SEBT has been utilized in both male and female populations. Gribble and Hertel discovered males to have a significantly higher raw reach distance compared to females in the posterior, posteriomedial, and medial reach directions.[13] Although these differences were noted, once the data was normalized to leg length, there was no significant difference in any direction between males and females.[13,14] Baseline scores between males and females in the anteromedial, medial, and posteromedial reach directions had no significant difference once normalized to leg length.[14] Another study using collegiate male and female basketball players also found no significant difference in the anterior reach direction.[15] One study contradicts these findings.[16] They discovered females scored better than males in the anterior, medial, and posterior directions both before and after fatigue protocols.[16] However, when looking at injury risk in high school basketball players, differences do exist.

Plisky et al. utilized the anterior, posterolateral, and posteromedial directions of the SEBT and examined injury risk in high school basketball athletes.[17] Using these three directions, Plisky et al. found normalized composite right reach distance of less than or equal to 94% to be associated with lower extremity injury.[17] They also determined an anterior right/left reach distance difference of 4 cm or greater was associated with an increase in lower extremity injury.[17] Suggesting this function assessment which has traditionally be evaluated based on normalized reach distances should also be evaluated on asymmetries between limbs.

Ankle dorsiflexion may be another indicator of pattern limitations that can lead to functional deficits and thereby increased risk of injury. The weight-bearing lunge test (WBLT) has been established as a clinical assessment tool for functional, closed-chain ankle dorsiflexion restriction[18], with good inter-rater reliability.[19,20] Ankle range of motion is a key part to lower body kinematics. Specifically, limited ankle dorsiflexion has been shown to increase ground reaction forces when performing landing tasks.[21]

Increased vertical ground reaction forces are linked to increased ankle injury rate by increasing the stress applied to the ankle joint thus increasing risk of injury or consequent damage to the bony structures.[22] Furthermore, following an ankle sprain the talus is unable to achieve full dorsiflexion, which allows for more inversion and internal rotation,[23] and may predispose individuals for future ankle sprains. The WBLT provides a functional, objective test to quantify ankle dorsiflexion, but it has not yet been used formally to assess risk for ankle sprain.

Current pre-participation exams often do not include functional screenings to identify improper kinematics. The MFMS, SEBT, and WBLT are three tests that can be performed in a time efficient way that identifies improper movements and balance control in the lower extremity.[7,9,12,17] The literature is limited and more research needs to be done to create a more effective pre-participation exam that identifies individuals at risk of an ankle sprain.

1.2 Statement of Problem

Currently, there is little to no published work using pre-participation functional movement tests to accurately identify high school basketball athletes that may be at risk for an ankle sprain. While tests such as the MFMS, SEBT-A and WBLT are cost and time effective and may provide insight in to functional pattern deficits, the application of these outcomes to identification of ankle sprain risk, specifically in adolescent basketball athletes, is limited.

1.3 Statement of Purpose

The purpose of this study was to determine if there are differences on the MFMS, SEBT-A, and WBLT in individuals who sustain an ankle injury and those who do not. A secondary purpose was to determine differences between males and females on these functional assessments.

1.4 Specific Aims & Hypothesis

SA1: To determine if there is a difference in score on the MFMS, SEBT-A, and WBLT in high school basketball players who suffer an ankle injury and those who do not sustain an injury.

H1: The scores on the MFMS, SEBT-A, and WBLT will be lower in adolescent basketball players that suffer an ankle injury during the competition season compared to non-injured players.

SA2: To determine if there is any difference in scores between the males and females on the MFMS, SEBT-A, and WBLT.

H2: Males will score significantly higher than females in the MFMS, SEBT-A, and WBLT.

SA3: To determine if there is any difference in the symmetry of the right and left reach distance in high school basketball players who suffer an ankle injury compared to those who did not.

H3: High school basketball athletes will have a larger right/left reach difference compared to non-injured athletes.

Chapter Two

Literature Review

2.1 Epidemiology

The total number of high school athletes has been increasing annually.[1] During the 2012-13 school year the total number of athletes in high school sports totaled 7.7 million.[1] There were 971,796 high school athletes who participated in basketball, 538,676 boys and 433,120 girls.[1] From the 2005-06 school years to the 2010-11 school year, 25,700 injuries occurred with 11,268,426 athlete exposures (AE).[3] Swenson et al.[2] examined the rate of ligamentous ankle injuries in high school athletes from 2005-06 basketball season to the end of the 2010-11 basketball season reporting a rate of 3.65 ankle sprains per 10,000 AEs. Out of the 1,491 ankle sprains, 831 occurred in boys and 660 in girls, with injury rates of 5.16 and 5.03 respectively.[2] Contact with another person was the main mechanism of injury, accounting for 53.8% of the injuries in boys and 44.6% in girls.[2] Non-contact ankle sprains were the second most common mechanism of injury, with boys reporting a non-contact injury 21.4% of the time and girls 27.1% of the time.[2] Doherty et al. found the prevalence of lateral ankle sprains to be 15.31% of all ankle injuries at a rate of 0.93 per 1,000 AEs.[24] Another study found lateral ankle sprains to make up 85% of all ankle sprains.[25] Within a period of 3 years after an initial ankle sprain, roughly 34% of the patients will report at least one re-injury while others report continually having symptoms.[26] A very common consequence of lateral ankle sprains is the development of chronic ankle instability (CAI), with associated repeated injury bouts and lingering subjective instability and giving way in the ankle.[26,27]

2.2 Anatomy

The ankle is composed of the distal tibia, distal fibula, talus, and calcaneus. These bones make up three joints; the talocrural, the subtalar, and distal tibiofibular. These joints are supported statically by the ligaments of the ankle which are divided into three groups; lateral, medial, and ligaments of the syndesmosis.[28] The lateral group consists of the anterior talofibular ligament (ATFL), calcaneaofibular ligament (CFL), and posterior talofibular ligament (PTFL).[28] All three lateral ligaments attach at the distal end of the lateral malleolus and go to the body of the talus (ATFL), lateral aspect of the calcaneus (CFL), and lateral and posterior aspect of the talus (PTFL).[28] The ATFL, which is the weakest of the three ligaments[29], plays a major role in restricting anterior displacement of the talus and plantar flexion of the ankle.[28]

The ankle is also stabilized through many muscles and tendons. On the lateral side of the ankle the peroneus longus and brevis eccentrically contract to help control supination of the rearfoot.[30] The anterior muscles of the lower leg; the tibialis anterior, extensor digitorum longus and brevis, and peroneus tertius all contribute to dynamic stability of the ankle as well.[30]

2.3 Mechanism of Injury

One the most common mechanism of a lateral ankle sprain, which can lead to other pathologies, is inversion of the plantar-flexed foot.[31] In an article by Konradsen[32], he states that a deficit in kinesthesia puts a person in an increased risk of stumbling during locomotion, thus experiencing a later ankle sprain. Some risk factors of a lateral ankle sprain include body mass index (BMI), balance deficits, and a history of ankle sprain, which would result in a deficit of kinesthesia.[11,33,34] Along with general decreased kinesthesia, damage to the ATFL has been shown to increase the internal rotation of the rearfoot, placing the other static stabilizers at risk of injury.[30] One model suggests the cause of lateral ankle sprains to be an increased supination moment at initial contact.[35] With rigid supination, a person would have a more inverted rearfoot which would put them at risk for a lateral ankle sprain.[30] When the supination moment exceeds the pronation moment from the lateral ligaments and the peroneal muscles, excessive inversion occurs, which causes the lateral ankle sprain to occur. [35]

2.4 Chronic Ankle Instability

2.4.1 Identifying CAI

Chronic ankle instability is commonly defined as a history of recurrent sprains along with a sensation of "giving way".[36] CAI affects many athletes while they are participating in sports and years after their athletic careers have ended. The International Ankle Consortium (IAC) criteria for CAI includes: a history of at least 1 significant ankle sprain, a history of the previously injured ankle joint "giving way" and/or recurrent sprain and/or "feelings of instability", and a Foot and Ankle Ability Measure (FAAM) score of <90% for activities of daily living (ADLs) and <80% for sport.[27]

Although the IAC model of recurrent sprains and a "giving way" sensation identifies people with CAI, there are other insufficiencies people with CAI may experience, but is not consistently documented. Hertel initially suggested a CAI model that included mechanical and functional insufficiencies.[30] Mechanical insufficiencies include laxity, arthokinematic restrictions, degenerative changes, and synovial changes.[30] Functional insufficiencies include impaired proprioception and neuromuscular control, strength deficits, and impaired postural control.[30] Hiller further redefined the CAI model to include three subgroups; mechanical instability (MI), perceived instability (PI), and recurrent sprain (RS).[37]

2.4.2 Postural Control

Many studies have looked at the deficits following a lateral ankle sprain and subsequent CAI.[23,26,30,36,38-48] Postural control has been shown to decrease following an acute lateral ankle sprain and for months following injury.[26,36,49-54] Goldie et al. assessed postural control in subjects who suffered an inversion injury at the ankle.[52] Their study contained two groups; one group that had rehabilitation and one that didn't.[52] They discovered the trained group no significant difference between the injured limb and uninjured limb using a single leg stance test ($p > .05$).[52] They found postural control to be significantly worse in the untrained individuals between the injured leg and uninjured leg ($p < .05$).[52] In a meta-analysis done by Munn et al.[54] they found the pooled data of postural sway displacement to be greater in the ankle instability group compared to healthy control subjects ($p=0.002$). Measuring mediolateral force on a force plate during a one legged stance, Goldie et al.[52] discovered subjects had worse postural control in the injured limb 8 weeks after injury compared to the uninvolved limb ($p<0.05$). Another study found differences in balance between healthy subjects and functional ankle instability (FAI) subjects while performing a double-leg stance test ($p=0.03$) and a multiple hop test ($p<0.001$).[26] The double leg stance and multiple hop test show people affected with FAI are impaired in both static and dynamic balance tasks.[26] There is a large amount of literature available regarding balance deficits in people with an acute ankle sprain and people with CAI.[23,26,44,50,52,55]

Dynamic postural control studies also show altered postural instability after a jump landing in patients who have suffered an ankle injury.[40,46,56,57] Multi-planar transverse and frontal plane movement create rear-foot supination, which puts the ankle in an injurious position.[46] In a single leg jump stabilization task individuals with an unstable ankle required more time to stabilize than people with a stable ankle.[58] They also found there was more time to stabilization in the medial/lateral aspect compared to anterior/posterior time to stabilization.[58]

2.4.3 SEBT in Subjects with CAI

The SEBT is a test of dynamic postural control that requires neuromuscular characteristics such as lower extremity coordination, flexibility, and strength.[17] There have been many studies that show people with ankle instability to have a reduced reach distance compared to both their healthy limb as well as a control group.[12,17,43,44,55,59,60] Gribble et al.[44] found a significant reach distance after fatigue among subjects with CAI in the anterior, medial, and posterior reach directions compared to the control group ($p=0.026$, $p=0.022$, $p<0.001$ respectively). Hertel et al.[59] found a significant difference comparing CAI affected limb to the healthy limb while performing the anteriomedial, medial, and posteriomedial reach ($p=0.005$, $p=<0.0005$, $p=0.03$ respectively). Similarly, Plisky et al. found high school athletes who had anterior reach right/left differences greater than or equal to 4 cm, decreased normalized right anterior reach distance, and decreased normalized posteromedial, posterolateral, and composite reach distances bilaterally were more likely to have a lower body injury ($p<0.05$).[17] After adjusting for other variables such as gender and age, the final regression model showed normalized composite right reach distance less than or equal to 94% and anterior right/left reach distance difference of 4 cm or more was associated with lower extremity injury for all subjects ($p<0.05$).[17]

2.4.4 CAI Gait Kinematics

Recent literature has shown that people identified as having CAI have differences in their gait patterns compared to healthy subjects.[41,61-65] Two studies found subjects with an unstable ankle to be more inverted before heel strike.[64,65] Both studies concluded the increased inversion at heel strike to be associated to the high recurrence rate of ankle injury.[64,65] Chinn et al.[41] showed that a CAI group had almost 3 degrees less dorsiflexion compared to the control group during mid to late stance phase during gait assessment. Other studies have also shown limited dorsiflexion after ankle injury. Limited ankle dorsiflexion has been shown to increase ground reaction forces when performing landing tasks.[21] This is important due to the increased stress the ankle joint undergoes during a landing task.[22] Full dorsiflexion puts the talocrural joint in its closed packed position.[23] Following an ankle sprain the talus is unable to achieve this position, which allows for more inversion and internal rotation.[23] The excess motion allowed following an ankle sprain may predispose individuals for future ankle sprains.[23]

2.4.5 Proximal Joint Kinematics

The ankle is not the only thing affected by CAI; many problems exist proximally at the knee and hip.[30,38,39,42-44,47,48,55] Two studies found lowered gluteus maximus activation in subjects with CAI.[39,47] Beckman and Buchanan[38] found decreased gluteus medius activation with ankle perturbation on subjects with previous ankle injury. In contrast, Webster and Gribble did not find a decrease in gluteus medius activation, but did fine diminished gluteus maximus activation in CAI subjects during closed chain movements.[47] Also, Friel et al.[42] found hip abductor muscle strength was significantly less on the CAI involved limb compared to a healthy limb. Improper postural control at the hip can lead down the kinetic chain and lead to improper placement of the femur at the tibia as well as the ankle joint at foot contact during gait.[47] Improper foot placement during gait, such as increased inversion or lack of dorsiflexion, may predispose individuals for subsequent ankle injuries.[64,65]

2.5 Injury Prediction

Prospective injury prediction studies have been done in a variety of settings.[4,6-8,12,17] The FMS has been shown to identify collegiate female athletes at risk of a lower extremity injury (Odds Ratio (OR)=3.85, Sensitivity=0.58, Specificity=0.74).[6] Two studies have shown the SEBT to be able to predict lower extremity injuries.[12,17] The anterior reach had the highest odds ratio and speeds up the testing process. A quick, time effective testing session that can identify at risk individuals before the season starts can help clinicians provide the proper intervention, thus lowering injury rates in athletes.

2.5.1 Modified Functional Movement Screen for Injury Prediction

The Functional Movement Screen assesses the proprioceptive and kinesthetic awareness of body segments that require proper function to perform each test and has been previously used in professional football players, collegiate female athletes, and military personnel.[5,6,8,9] The FMS has been shown to have a good interrater reliability (0.76 and 0.98) allowing multiple clinicians to test many subjects in a short time.[66,67] Originally the FMS requires the individual to perform seven different movement patterns that assess the quality of movement in both the lower and upper extremity. Recent literature has tried to identify a threshold to use as a point at which individuals below a certain point would be labeled as having an increased risk of injury. A score of 14 or below has recently been identified as the cut-of score with an odds ratios of 3.85 for collegiate females and 11.67 for professional football players.[6,8] These studies though have been recognized as having methodological flaws and no threshold has been set for high school athletes. Chorba et al.[6] evaluated the specificity, sensitivity, and positive likelihood ratio of the FMS in assessing lower body injury risk of collegiate female athletes. They found a sensitivity of 0.579 (CI_{95}= 0.335 to 0.798); specificity of 0.737 (CI_{95}=0.488 to 0.909); positive likelihood ratio of 2.200 (CI_{95}=0.945 to 5.119).[6] Chorba et al.[6] looked at the correlation between scores and lower body injuries after removing the shoulder mobility test. They discovered a strong correlation (r=0.952, P=0.0028) between composite FMS score and lower body injury with the shoulder mobility test removed from the composite score.[6] Further research has been done to determine if a modified FMS can provide a higher odds ratio when determining risk of lower extremity injury. Gribble et al.[7] looked at a four test FMS using only the deep squat, inline lunge, hurdle step, and active straight let raise. They found a sensitivity of 0.71, specificity of 0.59, and odds ratio of 3.57.[7] These four tests, which make up the Modified FMS (MFMS) showed the higher odds ratio (3.57 compared to 1.8) for predicting lower extremity injury compared to the composite score of the entire FMS.[7]

2.5.2 SEBT for Injury Prediction

The SEBT requires neuromuscular characteristics such as lower extremity coordination, flexibility, and strength.[17] The further a subject is able to reach, the more functional capabilities they are thought to have.[59] Due to the neuromuscular control the SEBT requires, it may be a more effective test to identify athletes at risk of a lower extremity injury.[17] The SEBT has a strong interrater and intrarater reliability (0.93 and 0.96).[68] The SEBT was originally done in 8 directions. Hertel et al. concluded performing all 8 directions was redundant in identifying subjects with CAI.[59] Hertel et al.[68] determined a significant learning effect after 6 practice trials. The test has been further simplified to 3 directions; anterior, posterior medial, and posteriorlateral.[12] The number of practice trials has also been reduced to 4 without affecting the validity of the test.[60]

2.5.3 WBLT for Injury Prediction

Although the weight bearing lunge test (WBLT) has never been studied as a pre-participation test, it has been used by clinicians as a functional dorsiflexion measuring tool.[18] The farther a subject's foot is from the wall equates to more dorsiflexion at the ankle. Limited dorsiflexion is thought to predispose the ankle to injury due to the inability of the ankle to reach the closed-pack position thus keeping the ankle in a hyper-supinated position.[30,69] The WBLT has also been shown to have good interrater reliability.[19,20] The WBLT provides a functional, subjective test to compare ankle dorsiflexion within subjects.

2.6 Summary

After reviewing the current literature, it is necessary to find a functional assessment tool that can help identify athletes at increased risk of a lower body injury. The MFMS and SEBT-A show promise at identifying risk factors of ankle injuries but more research needs to be conducted especially for the WBLT since there is not a lot of literature looking at prospective injury prediction. A prospective study looking at scores of all three tests may give us more information as to which test is sensitive enough to distinguish between individuals who will go on to sustain an ankle injury and those who do not.

Chapter Three

Methodology

3.1 Study Design

Prospective cohort study

3.2 Subjects

A total of 34 high School junior varsity and varsity male and female basketball players (24 male, 10 female) cleared for full participation prior to the competitive season volunteered to participate in this study. Each was given a consent form to be signed by a parent or legal guardian. Each subject signed an assent form and filled out a health history questionnaire. Subjects were excluded if they were not cleared by a physician at the start of the season.

3.3 Instrumentation

An FMS kit that includes a two by six inch board, hurdle and measuring stick. A standard metric tape measure will be used for the SEBT-A and WBLT.

3.4 Procedures

The testing took place before the start of the basketball season. Each subject was given a demonstration of each test before performing them. The order of the tests and limbs were randomized. Prior to testing, each subject completed a consent form signed by a parent or legal guardian, an assent form, and a health history questionnaire. The subjects were then tested using the MFMS, SEBT-A, and WBLT. (Figure 1)

Figure 1-**Flow Chart of Testing Procedures**

3.4.1 MFMS

The MFMS tests were performed bilaterally based on the guidelines set by Cook.[5,70] Each subject was given a demonstration of the test before testing trials and given three attempts at each test and were given a score between zero and three for each trial. The lowest score of the three trials was recorded as the final score on that test.[5,70] A score of zero was given if there was pain with the test. A score of one meant they were unable to do the test. A score of two meant they were able to do the test but used compensatory movements to accomplish the test. A score of three was given if the movement was performed correctly without any compensatory movements.[5,70] The four tests utilized were the deep squat, hurdle step, in-line lunge, and active straight leg raise.

The test procedure for the deep squat the subject was placed in the starting position.[5] (Figure 2) To achieve the starting position, the subject placed his/her feet shoulder width apart and the feet aligned in the sagittal plane.[5] The hands were positioned on the dowel so the elbows were at a 90-degree angle with the dowel overhead.[5] The dowel was then pressed overhead with the shoulders flexed and abducted with the elbows extended.[5] The individual then slowly squatted down while keeping their heels on the ground and dowel pressed overhead.[5] (Figure 3) If the subject was unable to achieve this position a 2x6 board was placed under their heels.[5] A three was given if the upper torso was parallel with the tibia or toward vertical, the femur was below parallel with the ground, the knees stayed aligned over the feet, and the dowel remained aligned over the feet.[5] A two was given if the subject achieved the same criteria as a three with a 2x6 board under the heels.[5] A one was given if the tibia and torso did not remain parallel, the femur was not below parallel to the ground, the knees were not aligned over the feet, or lumbar flexion was noted while performing the test with a 2x6 board under the heels.[5]

***Figure 2*-Deep Squat Starting Position**

***Figure 3*-Deep Squat Testing Position**

The hurdle step testing procedure was started by placing the subject with feet together and aligning the toes touching the base of the hurdle.[5] (Figure 4) The height of the hurdle was then adjusted to the height of the subject's tibial tuberosity.[5] The subject held the dowel across the shoulder below the neck.[5] The individual then proceeded to step over the hurdle and touch their heel to the floor while maintaining the stance leg in an extended position.[5] (Figure 5) The subject then returned the leg to the starting position. A three was given if the hips, knees, and ankles remained aligned in the sagittal plane, minimal to no movement was noted in the lumbar spine, and the dowel and string remained parallel.[5] A two was given if alignment was lost between hips, knees, and ankles, movement was noted in the lumbar spine, or the dowel and string did not remain parallel.[5] A one was given if the foot and string made contact or loss of balance occurred during the test.[5]

***Figure 4*-Hurdle Step Starting Position**

***Figure 5*-Hurdle Step Testing Position**

The in-line lunge testing procedure started with the tester measuring the subject's tibia length.[5] The length of the tibia was achieved by measuring from the floor to the tibial tuberosity.[5] The subject was then placed on a marked board with foot placed with the big toe at 0 and the other heel placed at the tibial height distance.[5] (Figure 6) The dowel was placed behind the back touching the head, thoracic spine, and sacrum.[5] The hand opposite of the front foot was placed at the cervical spine while the other hand was placed at the lumbar spine.[5] The subject was then asked to lunge down and touch the back knee to the board and return to the starting position.[5] (Figure 7) A three was scored if the dowel remained in contact with the lumbar spine, no torso movement was noted, dowel and feet remained in the sagittal plane, and the knee touched the board.[5] A two was given if contact between the dowel and lumbar spine was lost, movement was noted in the torso, dowel and feet did not remain in sagittal plane, or the knee did not touch the board.[5] A one was given if the subject lost balance during the test.[5]

***Figure 6*- In-Line Lunge Starting Position**

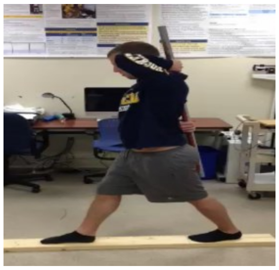

***Figure 7*- In-Line Lunge Testing Position**

The active straight leg raise (ASLR) was performed by placing the subject laying supine with arms in an anatomical position, head flat on the floor, and a 2x6 board underneath the knees.[70] (Figure 8) The tester then measured the mid-point between the anterior superior iliac spine (ASIS) and the mid-point of the patella and placed the dowel perpendicular to the ground at this mark.[70] The subject was asked to raise the test leg with a dorsiflexed ankle and extended knee until the end range was found.[70] (Figure 9) During this motion, the opposite knee had to remain in contact with the ground; toes pointed upward, and head flat on the floor. Once the end range was found, the location of the medial malleolus was noted.[70] To achieve a score of three, the medial malleolus must have been located past the dowel.[70] If the medial malleolus did not pass the dowel, the dowel was placed at the test leg medial malleolus and scored accordingly.[70] A two was given if the ankle/dowel was placed between the mid-thigh and mid-patella and a one was given if the ankle/dowel was below the mid-patella.[70]

Figure 8-**ASLR Starting Position**

Figure 9- **ASLR Testing Position**

3.4.2 SEBT-A

The SEBT-A will follow the protocol previously described.[55] A standard metric tape measure was placed on the floor. The subject stood with the big toe of the stance leg at 0. (Figure 10) The subject was then asked to reach out and lightly tap as far as possible. (Figure 11) If the subject shifted weight onto the reach limb, loses balance, or lifts or shifts any part of the stance foot, the trial was unsuccessful.[55] For each leg, four practice trials were given[60] followed by three test trials recorded in centimeters. The mean of the three trials was then normalized as a percentage of their stance leg length.[13] Leg length was measured using a standard tape measure from the anterior superior iliac spine to the center of medial malleolus.[13]

***Figure 10*-SEBT-A Starting Position**

***Figure 11*-SEBT-A Testing Position**

3.4.3 WBLT

The WBLT was tested bilaterally using the same protocol as Bennell et al.[19] The subject was aligned with their big toe on the tape measure approximately 3 or 4cm from the wall. (Figure 12) While maintaining ground contact with the heel of the test limb, the subject then lunged forward until the anterior knee touched the wall. (Figure 13) The subjects were allowed to hold on to the wall for balance and have their other foot set comfortably behind their test foot. The subject then increased their distance until they could no longer maintain heel contact with the floor. The subject was then progressed forward 1cm at a time until the maximum distance was found.

***Figure 12*-WBLT Starting Position**

***Figure 13*-WBLT Testing Position**

3.4.4 Injury Monitoring

Injury monitoring will be performed by the same Certified Athletic Trainer (ATC) at the high school. Injury data will be recorded to indicate extremity, type of injury, and mechanism of injury. A reportable injury has to meet all of the following conditions: (1) occurred as a result of participation in an organized high school competition or practice, (2) required medical attention, and (3) resulted in restriction of the high school athlete's participation for 1 or more days beyond the day of injury.[71] For this study, we did not differentiate between contact and non-contact mechanisms of injury in our injured population.

3.5 Statistical Analysis

For specific aim one, we compared injured and non-injured group scores of each test using independent t-tests. For specific aim two, we compared male and female group scores of each test using independent t-tests. For specific aim three, we compared the difference score between the right and left limbs between injured and non-injured groups using independent t-tests. All analyses (means ± standard deviations) were performed using SPSS 21.0 (IBM Corp., Armonk, NY). Cohen's d effect sizes were also analyzed. Significance was set *a priori* at $P<0.05$.

Chapter Four

Results

Thirty-four athletes were screened during the pre-season (24 male, 10 female) (Table 1). Of these 34 athletes, 4 suffered an ankle injury (3 males, 1 female). Due to only having 4 injured subjects, we compared the right limb between the injured and non-injured groups.

Table 1-Demographics

	N	Age	Height (cm)	Mass (kg)
Male	24	15.92 ± 1.02	178.44 ± 7.54	69.65 ± 10.20
Female	10	16.30 ± 0.82	169.42 ± 9.51	80.97 ± 20.61

The first aim of the study was to identify differences between injured and non-injured groups on the WBLT, SEBT-A, and MFMS. Our statistical analysis revealed no significant difference between injured and non-injured groups on the WBLT, SEBT-A, and MFMS. (Table 2)

Table 2-Means and Standard Deviations for Injured vs. Non-Injured Groups

Group	N	Mean ± SD	t-value	p-value	Effect Size (CI_{95})
WBLT					
Injured	4	7.00 ± 2.99	-1.16	0.26	0.53 (-0.09-1.36)
Non-injured	30	8.37 ± 2.13			
SEBT-A					
Injured	4	55.96 ± 6.12	-1.94	0.06	1.05 (-3.15- 1.03)
Non-injured	30	62.57 ± 6.44			
Total MFMS					
Injured	4	7.50 ± 1.29	0.00	1.00	0.00 (-0.49-0.49
Non-injured	30	7.50 ± 1.53			

Our next aim was to see if there was any significant difference between males and females on the WBLT, SEBT-A, and MFMS. There was a significant difference on the MFMS. However, there were no significant difference in the WBLT and the SEBT-A (Table 3).

Table 3-Means and Standard Deviations for Male vs. Female Groups

Group	N	Mean ± SD	t-value	p-value	Effect Size (CI_{95})
WBLT					
Male	24	8.33 ± 1.94	0.45	0.66	0.16 (-0.56- 0.92)
Female	10	7.94 ± 2.94			
SEBT-A					
Male	24	60.44 ± 6.31	-1.91	0.06	0.71 (-2.83- 1.35)
Female	10	65.05 ± 6.70			
Total MFMS					
Male	24	7.17 ± 1.49	-2.14	0.04	0.85 (-1.29 – -0.37)
Female	10	8.30 ± 1.16			

Our third aim looked at the asymmetry between right and left reach differences between injured and non-injured groups, there was no significant difference found (Table 4).

Table 4-Means and Standard Deviations for Reach Differences in Injured vs. Non-Injured Groups

Group	N	Mean ± SD	t-value	p-value	Effect Size (CI_{95})
Injured	4	2.91 ± 0.85	-0.23	0.82	0.15 (-0.1 – 0.75
Non-Injured	30	3.23 ± 2.80			

Chapter Five

Discussion

5.1 Introduction

The main purpose of this study was to identify differences on the WBLT, SEBT-A, and MFMS between high school basketball athletes who suffered an ankle injury and those who did not. The secondary aim was to identify if there was any difference between male and female athletes on all three tests. Our results showed no significant difference between the injured and non-injured groups on all three tests; however, the male basketball athletes scored significantly lower than the female athletes on the MFMS. We found the reach difference between the male and female groups to be close to significance with females reaching further than males. We found no significant difference in the reach differences between the male and female groups.

5.2 Comparison to past FMS research

The FMS has been used in military groups, professional athletes, and collegiate female athletes, and typically includes all 7 tests of the FMS.[6,8,9] The main design of the FMS is to identify functional deficiencies, which may lead to identifying subjects at risk of sustaining an injury.[5,70] Previous research has been able to use the FMS test as a pre-season screen, with individuals who score lower being at a significantly increased risk of injury.[6,8] However this test has not been able to consistently identify athletes at increased risk of injury.[10] Of the research that shows poor performance on the FMS to be associated with injury, the cut-off scores are different between studies.[6-8] Two previous studies put the cut-off score of 14 and below as at an increased risk of injury.[6,8] One study put the cut-off score as 18.5.[7]

In a study focusing on female collegiate athletes (soccer, volleyball, and basketball) they completed the full, 7 test FMS in the preseason.[6] Chorba et al. found a score of 14 and below (out of 21) statistically significant to sustaining an injury. [6] Besides using the full FMS, they tracked all lower body injuries and even included the lumbar spine rather than just tracking one specific injury. [6] Kiesel et al. used the full FMS and looked at injury risk in professional football players.[8] They found the FMS to have a high diagnostic odds ratio (OR) to identify athletes at risk of injury.[8] However, they defined injury as anyone placed on the injured reserve and had a time loss of 3 weeks.[8]

In the current investigation, we were unable to identify significant differences in FMS scores between injured and non-injured athletes. This could possibly be due to our focus on only ankle injuries where the FMS test was designed to evaluate upper and lower body movement patterns. Although we narrowed the test through using the MFMS to screen only for tests assessing the lower extremity, our investigation only tracked injuries to one joint of the lower extremity possibly decreasing the sensitivity of the MFMS to identify differences. Another plausible reason for our lack of significance may be our definition of an injury.

In the current investigation, we defined injury as anyone that was pulled from participation for 1 or more days beyond the day of injury. Another study using the MFMS looked at the injury rates of collegiate football players. [7] The authors defined an injury very similarly to our definition.[7] Their definition included injury to the ankle or knee during participation in an organized practice or competition, required medical attention by a team certified athletic trainer or physician, and resulted in restriction of participation for one or more days beyond injury.[7] Chorba et al. defined an injury as occurring during an organized practice or competition, required medical attention, or the athlete sought advice from a certified athletic trainer, athletic training student, or physician.[6] This differs from our definition due to the fact there is no report on time loss. In our study, including athletes that asked for advice from the certified athletic trainer, which did not restrict participation, would possibly add to the number of recorded injuries. Kiesel et al. defined as anything that put the athlete on injured reserve and time loss of 3 weeks or more.[8]

Previous research focuses on comparing between teams and does not include male and female comparisons. One study compared the scores of the FMS between healthy male and female athletes.[72] They found females scored significantly lower on the total composite score compared to males.[72] Their results were based on females scoring significantly lower on two individual tests; the inline lunge and trunk stability push-up.[72] We did not look at the scores of individual test; as we compared the total MFMS composite score and identified males to score significantly lower than females. Our results may have differed due to females possibly having increased lower body flexibility compared to males which would change the score of the active straight leg raise as well as the hurdle step. An explanation for this could be the way males and females develop strength and coordination. One study found males to have a bigger increase in lower limb muscle strength at a later age compared to females.[73] Although males may typically be more developed muscularly, this did not translate into better performance on the MFMS in our study. Coordination during activity and sports may stem from the experience each athlete has of being physically active. For example, a high school junior who has played basketball for 8 or 9 years may be more coordinated during a functional assessment compared to an athlete the same age who has only participated in sports for 2 to 3 years. The difference we found between males and females could arise from the level the skill level of each athlete.

5.3 Comparison to past SEBT research

Previous studies involving the SEBT have been able to identify athletes at risk of lower extremity injury; however, these studies utilized 3 reach directions compared to only using the anterior reach direction as in the current investigation. [17,74] Furthermore, in our current investigation, we only tracked ankle injuries while a previous study who investigated high school athletes was able to identify individuals at increased risk for all lower extremity injuries.[17] Another difference is the actual SEBT scores used. We only utilized the anterior reach difference, while the previous authors utilized the anterior, posteromedial, and posterolateral.[17]

There have been studies that examined the difference between male and female reach difference in the SEBT. One study found a significant difference between raw scores between male and female.[13]; however, they discovered there was no significant difference once the reach difference was normalized to leg length.[13] Our results support their work with no identified reach difference between males and females once normalized to leg length. The normalizing of the leg length eliminates the height differences in our male and female groups.

5.4 Comparison to past WBLT research

Past research using the WBLT is very limited. The main use of the WBLT in literature is the reliability of the test to functionally assess ankle dorsiflexion.[18] Hoch et al. found a significant correlation between the WBLT and the SEBT-A.[75] This suggests that any loss of range of motion at the ankle would have adverse effects on dynamic postural control.[75] Any loss of dynamic postural control may lead to an increased risk of injury.[17] Future studies may want to look at asymmetries between the right and left limb or dominant limb vs. non-dominant limb. Hoch et al. looked at the symmetry of ankle dorsiflexion in healthy adults and found asymmetries up to 1.5 cm.[18] Future research using the WBLT and risk of injury might want to look at asymmetries greater than this or possibly determine a cut-off difference that may predispose an athlete to an ankle injury. Examining total dorsiflexion range of motion rather than looking at asymmetries, could be the reason why no significance was found in the current investigation.

5.5 Clinical Significance

Although we did not find any significant difference in any of the tests between the injured and non-injured subjects, the MFMS and the SEBT has been thought to be an accurate predictive diagnostic test, more research needs to be done to further develop a better pre-participation screening. Previous research has shown good results in using the SEBT and FMS in identifying athletes at risk of injury. Narrowing the criteria down to just include ankle sprains may have hindered our results and these functional screening tests may be better tests for identifying all lower extremity injury risk. The WBLT is a good clinical assessment at measuring functional ankle dorsiflexion. Future studies should focus on discovering a dorsiflexion deficit that equates to ankle injury risk. The MFMS, SEBT-A, and WBLT are good clinical assessment tools at identifying functional deficits as well as postural control. All three tests could easily be implemented as either a pre-participation assessment or post-injury assessment to identify any major deficits or asymmetries that should be addressed.

5.6 Limitations

A large limitation to this study is the overall sample size of the data. To truly see the effectiveness of these functional exams and the ability to predict ankle injuries, the sample size would need to be a lot larger. Due to only collecting data at one high school site for a single year, our injured group was very small limiting the ability to identify any significance or trends in the data. The study would have more power if injury tracking occurred over multiple seasons. Another limitation could be our definition of injury. We focused on ankle injuries while past research has considered lower body injuries, including lower back. In order to determine the ability of each test at identifying ankle injuries, future studies should aim to include a larger number of teams over the course of one season or gather information from multiple seasons.

5.7 Conclusions

Even though the MFMS, SEBT-A, and WBLT could not statistically identify athletes at risk for an ankle injury, the large effect sizes of the SEBT-A warrants further research using larger sample sizes. More research should be done in the future in order to determine if there is a cut-off score to each test that may show an increased risk of injury.

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