

University of Montana

ScholarWorks at University of Montana

Graduate Student Theses, Dissertations, &
Professional Papers

Graduate School

2017

Reviewing the Use of Injury Screening Assessments and Identifying Risk of Injury

Riley A. Kenney

University of Montana, Missoula

Follow this and additional works at: <https://scholarworks.umt.edu/etd>



Part of the [Sports Sciences Commons](#)

Let us know how access to this document benefits you.

Recommended Citation

Kenney, Riley A., "Reviewing the Use of Injury Screening Assessments and Identifying Risk of Injury" (2017). *Graduate Student Theses, Dissertations, & Professional Papers*. 10924.
<https://scholarworks.umt.edu/etd/10924>

This Professional Paper is brought to you for free and open access by the Graduate School at ScholarWorks at University of Montana. It has been accepted for inclusion in Graduate Student Theses, Dissertations, & Professional Papers by an authorized administrator of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.

REVIEWING THE USE OF INJURY SCREENING ASSESSMENTS AND IDENTIFYING RISK OF INJURY

By

RILEY ALYSE KENNEY

Bachelor of Science, University of Montana, Missoula, Montana, 2017

Professional Paper

presented in partial fulfillment of the requirements for the degree of

Masters of Athletic Training,

The University of Montana Missoula, MT

May 2017

Approved by:

Scott Whittenburg, Dean of The Graduate School

Valerie Moody, Chair

UM Athletic Training

Melanie McGrath, Committee Member

UM Athletic Training

Ryan Mizner, Committee Member

UM School of Physical Therapy and Rehabilitation Science

ABSTRACT

Kenney, Riley, MAT, May 2017

Athletic Training

REVIEWING THE USE OF INJURY SCREENING ASSESSMENTS AND IDENTIFYING RISK OF INJURY

Lower extremity injuries account for over half of reported sports related injuries with the ankle and knee being the most commonly injured joints. The majority of non-contact injuries related to these two joints can potentially be prevented through individualized prevention programs. Biomechanical injury screening has the potential to identify the risk factors associated with injury and allows the implementation of targeted rehabilitation strategies to combat the identified deficits. There is substantial need for screening assessments that are practical and accurate for the clinical athletic trainer. This literature reviewed examined the dorsiflexion lunge test, Functional Movement Screen (FMS), Y-Balance, Star Excursion Balance Test and the lower extremity strength assessment as preseason screening tools and their ability to predict future injury of primarily the knee and ankle. Practicing athletic trainers need an assessment tool that is inexpensive, easy to implement and has the ability to screen large numbers of athletes efficiently. The Y Balance test is recommended to implement as part of the preseason pre-participation exam so the athletic trainer can identify athletes who are at higher risk for injury and develop an individualized rehabilitation program to improve this deficits and ultimately reduce injury rates. This assessment screen has the highest sensitivity and best likelihood ratios. These values are specific for non-contact injuries and produce a minimal amount off false positives.

Chairperson: Valerie Moody

Table of Contents

Introduction.....	4
Impact of Injury.....	6
Predicting Injury.....	7
Lower Extremity Injuries.....	9
Knee Injuries	
Screening Tools.....	9
Risk Factors.....	11
Ankle Injuries	
Screening Tools.....	13
Risk Factors.....	14
Screening Assessment Procedures	
Lower Limb Length.....	15
Y Balance/SEBT.....	15
Functional Movement Screen.....	16
Muscle Strength.....	19
Dorsiflexion Lunge.....	22
Discussion.....	22
Clinical Recommendation.....	26
Conclusion.....	30
Figures 1-6.....	32
Tables 1-4.....	34
Graphs 1-3.....	44
References.....	46

Introduction

Since 1988, the National Collegiate Athletic Association (NCAA) Injury Surveillance System has collected injury and exposure data from 15 sports through reporting by athletic trainers.¹ Participation in athletics has increased 80% and 20% in females and male sports respectively. The number of certified athletic trainers working in the collegiate setting has also increased 86% since 1995. The NCAA Injury Surveillance System estimates over one million injuries have occurred across the 15 studied sports in the last five years.¹ Sixty-four percent of these injuries occurred at practice and 22% required a period greater than seven days to return to full competition. Annually, over 8,000 injuries require surgery with nearly 2,000 needing emergency transport.¹

Over half of the total injuries were reported as sprains, including anterior cruciate ligament (ACL) tears, or strains. The same percentage, over 50%, of injuries were to the lower extremity, mainly the ankle and knee.¹ An average of 11,000 ankle sprains occur each year over the 15 studied sports with men's basketball yielding the highest prevalence. An annual increase of 1.3% in the incidence of ACL injuries was also reported with an estimated 2,000 per year.¹ There was more overall injuries in practice over games because there was 4.5 times as many practice athlete-exposures than competition.¹

The injury risk across all sports in intercollegiate athletics is one injury every two games and one injury every five practices.¹ This rate indicates a need to identify and modify the risk factors that predispose athletes to injury to reduce this growing epidemic of NCAA injuries. Injury prevention strategies could significantly reduce the 37% and 42% of non-contact injuries

that occur at practice and in games respectively.¹ The first step before implementing individualized rehabilitative exercises to correct deficits is to identify injury risk factors.

Biomechanical preseason injury screening assessments have the ability to identify athletes who are at a higher risk for injuries. Research has shown the effectiveness of several testing methods, such as the Functional Movement Screen, Star Excursion Balance Test, musculature strength, joint range of motion, and motion analysis, in determining factors associated with injury. However, there is little evidence about the accuracy of these tests used in combination rather than each individually. Therefore, the purpose of this professional paper is to review common injury screening assessments to determine which, if any, are able to better predict risk of injury that are readily available and easy to implement for the practicing clinician. At the conclusion of this paper is a recommendation to practicing athletic training clinicians regarding appropriate selection of injury screening assessments based on the best evidence available.

Review of Literature

The ability to predict injury through the use of screening assessments has been researched significantly. This area of research was examined to identify relationships between scores of different testing methods and injury occurrence. This examination focused on knee and ankle athletic related injuries due to their high prevalence. Most research has centered on the risk factors surrounding ACL injuries in athletes, although risk factors have been identified concerning ankle injuries as well. The literature strongly indicates a need for accurate and efficient screening assessments to reduce the frequency of lower extremity athletic injuries.

Psychological Impact of Injury

Considering personal grief, disability consequences and high costs associated with athletic injuries, the importance for the prevention of these injuries is significant. Normal response to athletic injury includes sadness, isolation, irritation, lack of motivation, anger, frustration, changes in appetite, sleep disturbances and disengagement.² If these responses are not addressed properly then they may manifest and become problematic. Caloric restriction leading to disordered eating is a common issue following major injury because the athlete is unable to exercise daily due to injury limitation. Substance use and abuse may be used to modulate the emotions experienced because of injury. Twenty-one percent of collegiate athletes reported high alcohol use and a correlation was found between depressive symptoms and alcohol abuse.²

Athletes also undergo the five stages of grief in varying capacity after an injury.³ First, they experience denial in which they assume the health care professionals with the diagnosis must be mistaken, refuse to believe the extent of the injury and often seek a second opinion. Anger then sets in and the athlete resents the injury and usually the health care professional, such as an athletic trainer, that is working with them. Daily tasks are suddenly more difficult and the athlete becomes frustrated with the limitations caused by the injury. Athletes then try to push their limits early to speed up the recovery process in the third stage, bargaining, because missing playing time is more painful than the actual injury. Depression is the worst stage and generally the most difficult to overcome.³ Thirty-three percent of injured Division I football athletes self-reported high levels of depressive symptoms compared to 27% of the uninjured population.² Factors such as considerable success before injury, an injury that

requires surgery, long rehabilitation with restricted playing time, inability to return to the prior level of competition and being replaced in their position by a teammate have been found as predictors of athlete suicide risk.²

Loss of identity, isolation from the team and inability to cope with the stressors associated with injury both affect rehabilitation and predispose an athlete to injury.³ Although athletes are at a higher risk for developing disordered eating, depression and substance abuse following injury, this population is also less likely to seek help for mental health issues than non-athletes.² Therefore, there is a significant importance in the prevention of these injuries. However, prevention programs would be more effective if they were individualized to each athlete. In order for this to happen, preseason screening tools are needed that have the ability to identify athletes who are at a higher risk for injury.

Predicting Injury

There is a significant need to establish injury screening tools and subsequent prevention programs to minimize the financial, emotional and medical burden of sport injuries. Research addressing the possibility and effectiveness of injury prediction methods is conflicting. Historically, the Functional Movement Screen (FMS) has been utilized in pre-participation assessments to identify athletes with a higher risk of injury. The FMS consists of seven bodyweight movement tasks that are intended to quickly and easily identify restrictions or alterations in normal movement.⁴ It has been found that neuromuscular control, core stability and contralateral muscular imbalances are the main factors that predispose athletes to injury and the FMS has the ability to detect these factors.⁴

Multiple studies have investigated the correlation between FMS score and injury prevalence. One study found that 69% of the female collegiate subjects in lower extremity dominant sports who scored less than fourteen sustained an injury.⁴ They concluded through linear regression that there is a predictive relationship between FMS score (less than 14) and injury risk in athletes without a history of major musculoskeletal injury.⁴ Athletes scoring less than fourteen were also four times more likely to sustain an injury in their competitive season. Another study established a 0.91 specificity of the FMS for serious injury which was defined as the athlete on injured reserve for a minimum of three weeks.⁵ The authors, however, could not establish a cause and effect relationship between injury risk and low FMS score. In a similar study involving professional football players, at least one asymmetry on the FMS regardless of the total score increased the injury risk.⁵

The consequences associated with injury and the need for accurate screening tools are not limited to athletes. The injury rate among firefighters is nearly the highest across all occupations at 88,500 each year.⁶ Forty-four percent have suffered a sprain or strain while on duty. Linear regression found a correlation between firefighters' FMS score and past musculoskeletal injury.⁶ Previous injury lowered FMS by 3.44. Logistic regression, on the other hand, found no significant correlation between FMS score and injury occurrence.⁶ In the military, about one million non-deployed active service members have experienced an injury. Musculoskeletal injuries accounted for 24% of all medical evacs and nearly 40% of recruits in boot camp suffered an injury.⁷ Service members with a FMS score under 14 and three mile run time greater than 20.5 minutes were four times more likely to sustain an injury. Run time and FMS score combined were better predictors of traumatic rather than overuse injuries.⁷

Most of the studies available only established a correlational relationship between a specific screening tool and injury risk. To produce a causal relationship, a cutoff value of the screening assessment needs to be determined to separate athletes into high and low risk groups. A randomized control trial with an intervention program for high risk athletes then must determine if injury risk is truly caused by the predetermined variable.⁸ Currently there is no screening test that can predict injury with adequate test properties and no intervention study with evidence in support of screening result.⁸ Although some may say that injury prediction through screening test is unrealistic⁸, there is a high demand for such a test by athletes, coaches, health care professionals and team owners.

Lower Extremity Injuries

Lower extremity injuries account for 53% of all injuries sustained across nine sports which is equivalent to over 800,000 lower extremity injuries nationally across high school athletics.⁹ In basketball, the lower extremity is the most frequently injured body area, accounting for 62% of all injuries. The ankle is by far the most commonly injured joint at 18% of all injuries.⁹ However, injury to the knee and patella resulted in more games missed than the two most commonly injured areas, ankle and lumbar spine.⁹

Knee Injuries

Screening Tools

Along with the ankle, the ACL of the knee is one of the most common lower extremity injury in the NCAA sports.¹⁰ Between 150,000 and 200,000 ACL injuries are reported across the United States each year. 30,000 of those injuries occur in female athletes resulting in nearly

\$650 million of medical costs each year.¹¹ The average expense of an ACL injury, including surgery and rehabilitation services, total around \$17,000. The common mechanism of injury includes a noncontact, deceleration motion involving lateral pivoting or twisting and landing.¹²

ACL injuries result in osteoarthritic change and overall cartilage damage in fifty to ninety percent of patients seven to twenty years after injury.¹³ There is also an increased risk for a re-injury after ACL reconstruction as high as one in every four people. The risk of a second tear is higher in athletes under eighteen years old.¹⁴ Due to the expenses and long term consequences associated with ACL ruptures, recent research has been focused on identifying risk factors that may predict the likelihood of injury.

It has been shown that females, especially athletes, are more susceptible to ACL tears than males. The NCAA Injury Surveillance System reported that of the female athletes who suffered an ACL injury, 60% had a noncontact mechanism whereas 59% of the ACL injured males were described as a contact injury.¹⁰ This study spanning fifteen NCAA sports showed a continued disparity of the overall injury rate between male and female athletes. Anatomical, hormonal and neuromuscular differences between males and females have been determined to influence this injury rate disparity. Factors such as thigh length, femoral notch width, Q angles, and navicular drop cannot be altered to improve biomechanical aspects of the lower extremity.¹²

Most of the research pertaining to lower extremity injury screening, ACL ruptures in particular, identify one specific risk factor that was found using one diagnostic test which was designed to look for that specific deficit. Currently, the gold standard is 3D video measurement

joint kinematics to screen at risk people.¹⁵ However, 2D video analysis, EMG information, Landing Error Scoring System (LESS), postural sway and the Star Excursion Balance Test (SEBT) have all been used to recognize common deficits and dysfunctional movements associated with lower extremity injury. However, it is currently unknown if these diagnostic assessments have the ability to predict lower extremity injury. They are successful in identifying alterations in movement that may predispose athletes to injury and therefore indicate a need for prevention programs.

Risk Factors

Previous injury history is the most consistent predictor of future injury, but cannot be modified.⁵ Instead, biomechanical variations that can be improved have been the target of much of the research involving lower extremity injury prediction risk factors. The majority of the studies mention lower extremity valgus, mainly during drop-jump, as a critical predictor in ACL injury risk.^{6,11,16,17} Deficits in neuromuscular control, postural stability and quadriceps dominance are also commonly cited topics of interest.^{6,11-14,16,18} The overall goal of identifying risk factors is to design an assessment tool in order to determine athletes at a higher risk of injury. There is a great need for a screening assessment that inspects all potential risk factors to understand the injury rate disparity between sexes, reduce healthcare expenses and eliminate the long-term consequences associated with ACL tears.

The National Basketball Association (NBA) determined that the style of play of the athlete and the individual workload increases risk of injury. This is broken down into the average speed players run during the game, total number of games played, average distance

covered by the player throughout the game, average number of minutes played and the average number of field goals attempted.¹⁹ According to the authors' algorithm, they concluded that by resting the top 20% of the high-risk scores at any given day, there is a potential to prevent 60% of all injuries. They believe that injury risk evolves daily and the assessment of the risk needs to be adapted daily as well.¹⁹

The LESS can successfully distinguish ACL risk factors with good inter- and intra-rater reliability. But the ability to predict ACL injury based on these risk factors was not included in the study.²⁰ When used to assess military cadets, authors found that LESS can quickly and reliably assess movement patterns in a large population. They identified several differences between males and female abnormal landing patterns. Males tended to most commonly utilize an uneven heel strike landing with tibial external rotation. Females landed with a wider stance which leads to valgus collapse of the knee.²⁰ Despite these differences, all of these factors are considered high risk movements in ACL injury.

Postural stability has also been identified as a risk factor for ACL injury. A deviation of the center of mass increases the valgus load on the ACL and makes this structure vulnerable. Including balance components in training and especially rehabilitation programs after injury, both single and double leg, is crucial in improving postural stability.¹⁴ Similarly, neuromuscular control is important in maintaining balance and has been determined to be the primary contributor of ACL injury. Neuromuscular training has the potential to significantly decrease ACL injury rates, but the efficacy and efficiency of training protocols could be improved if they could be designed specifically for predetermined high risk athletes.¹² Feed forward mechanisms to load and stabilize the joint are required ACL injury occurs at 17-50 milliseconds after initial

ground contact. There is no time for mechanosensory feedback so the knee must rely on the neural reactivation of knee flexors just before ground contact and proprioception.¹³

Regardless of the importance of identifying risk factors closely associated with knee injury, accurate prescreening tools are in high demand to classify high risk athletes. Without injury prediction methods, health care professionals are unable to provide individualized interventions to these athletes in an attempt to decrease the injury risk and associated consequences of injury.

Ankle Injuries

Screening Tools

The SEBT is an inexpensive, quick and reliable test that can be used to screen for lower extremity injuries.²¹ Poor balance during this test was associated with an increased risk of ankle injury. The strongest predictor, however, is a history of ankle injury which increases the likelihood of risk fivefold.¹⁷ As with the knee, this factor cannot be modified. Instead, balance and the associated postural sway are considered the most closely related to ankle injury.^{22,18} A simple single leg balance test can be used as a screening tool by health care professionals to identify high risk athletes.²² This can be done objectively with the athlete on a force plate that measure deviations in center of mass. Or, it can be performed with the health care professional scoring athletes' sway. Again, similar to knee screening tools, only correlational relationships have been found between ankle injuries and the associated risk factors. Researchers do seem more confident in the ability to predict susceptibility to injury with single leg balance tests nevertheless.

Risk Factors

Ankle injuries are a common occurrence in basketball, often with residual symptoms affecting performance and chondral lesions.¹⁷ Preventative strategies need to be implemented, but first risk factors associated with ankle injuries must be identified. Postural sway, muscle weakness and imbalance, poor flexibility, hypermobile ankle joint, poor proprioception and previous injury are intrinsic factors that have been recognized as increasing injury risk.¹⁸ Correlations have been found between a high variation of postural sway and a greater likelihood of injury. However, this correlation in one study could only explain 20% of the increase in injury prevalence.¹⁸ Similarly, another study discovered an association between ankle sprains and a positive single leg balance test.²² The authors stated that this correlation predicts susceptibility to ankle injury, but the exact mechanism responsible for the increased risk of injury is unknown. They also found that the failure to tape the ankles was detrimental in athletes with a positive single leg balance test.²²

Summary

The desire for injury prediction methods has been at the forefront of clinicians involved in sports medicine for decades. Coaches continue to push athletes to improve their performance, but with that, comes injuries and the psychological responses to injury. Lower extremity injuries account for more than half of all sports injuries and are arguably the most preventative. The profession of athletic training is moving more towards a preventative mindset rather than rehabilitative. However, clinicians are in need of more information that will help identify athletes who are susceptible to ankle and knee injuries. Injury screening

assessments provide clinicians with the opportunity to identify at risk athletes and therefore install an individualized preventative rehabilitation program to reduce this risk.

Screening Assessments Procedures

Lower Limb Length

Limb length is used to normalize data collected in all the screening tests. Athletes are placed in a supine position on a treatment table. A standard tape measure is placed on the anterior superior iliac spine (ASIS) to the distal portion of the medial malleolus bilaterally. Possible pelvis malposition is not taken into account during these measurements.

Y Balance

The Y balance test is an adaptation to the Star Excursion Balance Test (Fig. 1). The intra- and interrater reliability of the Y balance test is 0.85-0.91 respectively.²³ It has been found that a difference greater than four centimeters between limbs in the posteromedial direction significantly ($p=0.001$) increases the risk of a non-contact injury by 3.86. Similarly, a deficit of the same difference in the anterior direction increases likelihood of a non-contact and/or contact injury by 2.5.²³ Three tape measures can be fixed to the floor in a Y shape (Fig. 2), or standard athletic tape may also be used in the same pattern. The athlete then places the distal end of the longest toe at the center point where the three lines intersect.

The athlete is then instructed to maximally reach in each direction, posteromedial, posterolateral and anterior, tap the tape measure with the foot and return to the starting position while keeping the stance foot flat on the ground. The trial is repeated if the athlete

loses his/her balance during the exercise or when returning to the starting position or if the athlete places the reaching foot on the ground to maintain posture. Each athlete is allowed four to six practice runs in each direction before completing three trials where the maximal distance is recorded. Devices may also be used that have a sliding mechanism where subjects stand facing forward on one block and slide other blocks as far as possible with the tip of the toe in all three directions without moving the body (Fig. 3).²³

The Star Excursion Balance Test has a similar procedure to the Y Balance test, but also includes reaches in the posterior, anteromedial, anterolateral, lateral and medial directions in addition to the anterior, posteromedial and posterolateral direction for a total of eight reaches.²⁴ Typically tape is placed on the floor in an asterisk like formation and the patient stands facing forward, reaches in all eight directions and then the clinician measures the distances with a standard tape measure.

Functional Movement Screen

Athletes with scores of fourteen or less on the Functional Movement Screen (FMS) are significantly associated with injuries. Sensitivity and specificity of the FMS as a whole are 0.55 and 0.49 respectively for overall risk of injury.²⁵ A significant correlation has been found between FMS (Fig. 4) scores under fourteen and injury prediction in athletes without previous ACL reconstruction.⁴

Deep squat

The athlete stands with feet shoulder width apart, grasps a dowel in both hands and presses the dowel directly above the head. The athlete then descends in a squat as deep as

possible while maintaining an upright torso and keeping heels and dowel in position.²⁶ A score of three is awarded if the upper torso is parallel with the tibia, the femur is below horizontal and the knees and dowel are aligned over the feet. A two is recorded if these criteria are met only when the heels are elevated on a block. As with all of the test positions, a zero is given if there is any pain associated with the movement.²⁷

Hurdle Step

While standing tall, the athlete places a dowel behind the neck, across the shoulders. They then raise the light leg and step over the hurdle while maintaining foot alignment with the ankle, knee and hip. The athlete touches the floor with the heel and returns to the starting position.²⁶ A score of three is earned if the hips, knees and ankles remain aligned in a sagittal plane with minimal movement in the lumbar spine. If the athlete fails to achieve these criteria, a two is given.²⁷

Inline Lunge

First, the athlete places a dowel along the spine with it touching the head, upper back and middle of the buttocks. The right hand should be against the back of the neck and the left on the lower back. The athlete then steps onto a 2x6 with a flat right foot and the left heel placed ahead at a distance equal to the length of his/her tibial tuberosity. While keeping the dowel in contact with the body, the athlete descends into a lunge so the right knee touches the 2x6 behind the left heel and returns to the starting position.²⁶ A score of three is described as a lunge with no torso movement, dowel remains in contact with the body and vertical and dowel and feet stay in a sagittal plane.²⁷

Shoulder Mobility

After making a fist with the fingers around the thumb, the athlete places the right fist overhead and down the back as far as he/she can while simultaneously placing the left fist up the back as far as possible without creeping the hands closer together. The examiner then measures the distance between the two closest points of each fist.²⁶ If the fists are within one hand length and one-and-a-half hand lengths, then a score of three and two are given respectively.²⁷ A shoulder clearing test can also be given by having the athlete place his/her right palm on his/her left shoulder while raising the elbow as high as possible. If this is painful, the shoulder mobility test should not be performed.²⁶

Active Straight Leg Raise

The athlete lays supine with the back of the knees against a 2x6, toes pointing up and arms next to his/her side with palms facing up. The athlete then pulls the toes of the right foot toward the shin and raises the right leg straight off the ground as high as possible while keeping the back of the left leg on the 2x6.²⁶ A three is recorded if the vertical line of the malleolus resides between the mid-thigh and ASIS. If the vertical line is between the mid-thigh and joint line, then a score of two is given.²⁷

Trunk Stability Pushup

The athlete assumes a prone position with feet together and hands shoulder width apart. The athlete begins with his/her thumbs at the top of the forehead with the knees fully

extended and ankles dorsiflexed. The athlete is then instructed to perform one pushup in this position. A score of three indicates the athlete is able to lift the body as a unit with no lag in the lumbar spine. If the athlete cannot perform a pushup in this position, the thumbs move to chin level and the procedure is repeated.²⁶ A score of two is given if the pushup is completed in this second position with no lumbar spine lag. A score of one is given if the subject cannot perform a repetition with the body lifting as a unit.²⁷

Rotary Stability

The athlete gets on his/her hands and knees over the 2x6 with hands under the shoulders and knees under the hips. The thumbs, knees and toes must contact the sides of the board with toes pulled toward the shins. The athlete then reaches the right hand forward and right leg back at the same time. Without touching down, the right elbow is pulled in and touched to the right knee, and then returned to the extended position again before resuming to the start position. If the athlete is unable to perform this movement, it may be modified to a diagonal pattern. The right arm and left leg are extended and then the same procedure is followed.²⁶ A score of three indicates that the athlete could perform the correct unilateral repetition; a two is for a correct diagonal repetition while maintaining proper positioning.²⁷

Muscle Strength

Hip muscle strength, particularly external rotators and abductors, is important in resisting the external forces placed on the knee and ankle during functional movements. The knee's most vulnerable position is in hip adduction and internal rotation resulting in knee valgus and tibial internal rotation.¹¹ Proper hip musculature strength, especially in the gluteus

medius, is required to counteract this position and protect the knee. Isometric strength of the hip abductors and extensors can be assessed using a hand-held dynamometer. For the hip extensors, the athlete is supine on the table with the knee flexed at ninety degrees. The dynamometer is placed on the middle of the posterior thigh and is secured using a mobilization strap. The athlete is then instructed to maximally extend the hip while keeping the pelvis on the table. Trials continue until two measurements are obtained that are similar and repeat bilaterally.²⁸ The athlete then moves to a side lying position with the test leg on top and hips rolled slightly forward to look at abduction strength. The dynamometer is placed proximal to the knee on the lateral aspect of the thigh. The athlete then maximally abducts the hip against the mobilization strap securing the dynamometer. Adduction strength is taken in the same side lying position, but now the test leg is on bottom. The dynamometer is placed just proximal to the medial femoral condyle as the researcher held the top leg.²⁸ Internal and external hip rotators are tested with the athlete sitting with the lower legs off the table. The dynamometer is placed just proximal to the medial malleolus for external rotation and above the lateral malleolus for internal rotation. Hip flexion is also collected with the athlete in a seated position with the dynamometer about 2cm proximal to the femoral condyles.²⁸

Co-activation of the hamstrings and quadriceps protect the knee joint against anterior tibial translation. Although this majority of this co-activation is controlled by the quads, 80% to 40% hamstring, deficits in hamstring strength directly limit the potential for muscular co-contraction to protect the ligaments.¹² This may lead to quad dominance that is defined as the imbalance between the recruitment pattern of the knee flexors and extensors. There may also

be a leg dominance which is an imbalance in strength between limbs. This may result in one side having a greater dynamic control and an over reliance on one limb.¹²

Isokinetic quadriceps strength can be measured using an isokinetic device, which is a computer controlled electromechanical dynamometer. The device provides resistance during isokinetic movement and during isometric muscle contractions. Signals from the force, angle, and velocity are processed and displayed on the computer monitor. The test limb is attached to the dynamometer via a padded cuff which is attached to housing containing strain gauges. Different limb lengths can be accommodated by moving the housing along a metal lever arm. The axis of the dynamometer motor is adjusted to match the axis of rotation of the tibiofemoral joint, while the distal edge of the shin attachment is placed about five centimeters proximal to the lateral malleolus of the test leg. Athletes are positioned on the machine by a trained operator with hip flexed to ninety degrees and knee flexed to seventy-five degrees.²⁹ Both waist and trunk straps were used for stabilization. Athletes perform two submaximal contractions lasting two to three seconds and one maximal isometric contraction. Athletes are given a total of three trials, with the last one being maximal contraction. Hamstring and quadriceps strength are assessed both eccentrically and concentrically at varying angular velocities depending on the study. Quadriceps strength can also be assessed with a hand-held dynamometer (Fig. 5). The athlete sits with knee flexed between 85 and 90 degrees and maximally extends the leg against the resistance of the dynamometer which is placed on the distal anterior tibia.²⁹ Although isometric electromechanical dynamometry is considered the gold standard in assessing quadriceps strength, the hand-held dynamometer has a specificity of

0.72 and sensitivity of 0.83 compared to gold standard when determining return to play after knee injury.²⁹

Weight Bearing Dorsiflexion Lunge Test

The weight bearing dorsiflexion lunge test (WBDFL) is used to assess active ankle flexibility (Fig. 6). The athlete places his/her foot perpendicular to the wall and flexes the knee forward towards the wall. The foot is progressively moved away from the wall until maximum range of ankle dorsiflexion is reached without the heel lifting from the floor.³⁰ A tape measure records the distance from the great toe to the wall while minimizing errors that are common when using a goniometer. ICCs of 0.97-0.98 for intra-observer reliability and 0.99 for inter-observer reliability in the injured population have been reported.³¹

Another method for determining maximum dorsiflexion range of motion involves the use of an inclinometer. The athlete stands on a box 30-45 cm high with the knee flexed or on the ground in a similar position to the traditional WBDFL test. The athlete then performs forward displacement of the trunk as far forward as possible while keeping the heel on the box. The short arm of the inclinometer is placed on the posterior portion of the Achilles tendon about one centimeter superior to the posterior calcaneal tuberosity.³¹ This device has a high reliability of 0.85-0.96. Phone apps such as TiltMeter have been shown to have comparable reliability in measuring dorsiflexion range of motion and is free to install.³¹

Discussion

Most research pertaining to screening assessments and their ability to predict future injury focuses on the Functional Movement Screen. This test is the most common assessment

used in settings outside traditional athletics, such as the military, police academies and firefighters. The majority of studies agree that the cutoff score for a higher injury risk is a score less than or equal to fourteen (Table 1). However, one study found a 4.7 time increase in injury risk with scores under 17.³² Another study established different threshold scores for men and women under 12 and 15 respectively.²⁵ Sensitivity for the FMS is between 0.55-0.60 and specificity 0.49-0.61 depending on the study. However, the last study looked at determined that at least one asymmetry, regardless of total score increased injury risk.⁵ Overall, the FMS identifies athletes with dysfunctional movement patterns, specifically a low score and asymmetry, and indicates these athletes are more likely to suffer a time loss injury. Implementing the FMS into a pre-participation exam (PPE) for athletes is a reasonable suggestion. This tool requires minimal equipment and is inexpensive as long as the athletic trainer has an understanding of the testing movements and scoring. There is a certification available for FMS that would make the scoring more reliable; however, it is not necessary before administering the FMS. With a total of seven different movement tests, it may prove to be difficult to carry out in large volumes of athletes with a limited amount of testing time.

The weight bearing dorsiflexion lunge test has great inter- and intra-rater reliability while collecting easy to interpret objective data. Studies have shown differences in maximal dorsiflexion between the dominant and non-dominant leg. Most studies have found an association between lower than average dorsiflexion and chronic injuries, mainly patellar tendinopathy (Table 2). One study found that range of motion under 36.5 degrees predisposes young athletes to patellar issues.³³ Another reported the same but with a slightly higher cutoff value of 45 degrees.³⁴ However, these studies didn't necessarily look at the ability of this value

to predict future injury, just listed that lack of dorsiflexion is a risk factor for developing patellar tendinopathy. Most studies don't look solely at dorsiflexion ranges when determining injury risk. They tend to include a wide variety of factors, many which are non-modifiable, such as femoral notch width and Q-angle. Due to this, there is a lack of evidence in the significance of dorsiflexion deficits in acute injury risk. Instead authors include things like age and past injury history, which affects dorsiflexion range of motion, and participation in regular weight training as more predictive factors of injury risk. This screening assessment is easy to implement as a clinical athletic trainer. The testing procedure is quick, and requires minimal training and equipment. However, research indicates the need to include the dorsiflexion lunge test with at least one other screening assessment tool to improve the predictive ability of injury risk.

Objective lower extremity strength assessments are difficult to determine without the proper equipment. A hand held dynamometer or an isometric/isokinetic dynamometer is required to assess an athlete's maximal isometric or isokinetic strength. For the most part, it makes this testing procedure unrealistic for the practicing athletic trainer on a budget. But, research indicates that there is a relationship between hip musculature and injuries. One study measured the muscles of the six actions of the hip joint using a hand held dynamometer (Table 3). They found a relationship between hip muscular imbalances and the prevalence of chronic overuse injuries in runners.²⁸ The abductors and flexors on the injured side were significantly weaker than the non-injured side while the adductors of the injured side were significantly stronger. A second study used an isokinetic kin-com machine to measure concentric and eccentric hamstring and quadriceps strength. They reported that a mixed ratio of hamstring eccentric strength to concentric quadriceps strength is highly specific for detecting a risk of

hamstring injuries.³⁵ A similar study found that a lower hamstring to quadriceps strength ratio increased the risk of traumatic leg injuries. Quad dominance in particular increases the strain on the ACL and is a potential risk factor for tears.³⁶ All of the studies looked at showed that an imbalance in muscular strength whether it's between the agonist and antagonist muscles or a side to side balance increases the risk of lower extremity injury.

The Star Excursion Balance Test (SEBT) has largely been used in the past to detect balance issues that predispose an athlete to ankle injury and also in return to play protocols after ankle and knee injuries. Several studies have indicated that asymmetry in reaching distance has the potential to determine athletes at a higher risk of future injury. Plisky et al.²⁴ found a 2.5 time increase in lower extremity injury risk with side to side differences in anterior reach (Table 4). He also reported that females with a composite reach distance less than 94% of limb length are six times more likely to sustain a lower extremity injury. A similar study focused just on the incidence of non-contact knee and ankle injuries in collegiate athletes. They also found a significant association between non-contact injury and a side to side asymmetry in both absolute and normalized anterior reach distance.³⁷

The SEBT is composed of eight different reaching directions. However, it has been shown that reach performance in all eight directions is unnecessary and repetitive. The posteromedial (PM) direction is most strongly associated with performance when looking at the ankle.³⁸ PM, anteromedial (AM) and the medial directions also identify significant differences in the limbs without repeating too many similar movements. Going off these findings, the Y Balance test (YBT) was adapted from the SEBT to minimize the testing time and effort. Patients' reaches are assessed in the anterior, PM and posterolateral (PL) directions. Comparable to the

findings of the studies involving the SEBT, asymmetry between limbs was found to increase injury risk. Gonell et al.²³ determined that a side to side difference of greater than 4cm in the PM direction increased the likelihood of sustaining a non-contact injury 3.86 times. He also found that a low composite score almost double the injury risk. Smith et al.³⁹ reported a 2.2 time increase in injury in athletes with an anterior reach asymmetry of over 4cm. A low sensitivity and no association between injury risk and composite score was also stated in this study.

The YBT is a reliable screening assessment that yields easy to use data with a specificity of 0.67 and sensitivity of 0.87.³⁷ Multiple authors suggested implementing this test into the PPE to identify and then improve deficits throughout the season. All studies looked at specified that side to side asymmetry in reach distance, independent of the direction, increases injury risk. Four centimeters has commonly been used as the threshold for differences in reach values. However, it has been suggested to only use this cutoff number in the populations it was designed for.³⁹ The use of the YBT and SEBT and their accuracy in predicting injury varies between levels of competition and type of sport. The data is potentially more useful when used without a cutoff score and just looks at general asymmetries, especially in the posteromedial and anterior directions. Future studies should focus on the ability of just the anterior reach direction in isolation and its ability to predict injury as a more streamlined assessment of injury risk.

Clinical Recommendation

Practicing athletic trainers are often short on time and resources, especially in the secondary school setting. Therefore, the ideal injury prediction assessment should be inexpensive, applicable to multiple sports and genders, specific for injuries that are common in each sport, require minimal equipment and training, and allow for a large number of athletes to be tested efficiently. Also, a test with a higher sensitivity value over specificity is preferred because the athletic trainer's goal is to avoid false negatives when screening athletes. These athletes are at a higher risk for injury, but will receive no additional targeted rehab to lower this risk. False positives, on the other hand, aren't as detrimental because adding extra preventative rehab exercises for athletes without deficits isn't proven to be harmful. Ideally, the test should have a negative likelihood ratio less than 0.1 to effectively rule out the risk of injury with a negative test result. A positive likelihood ratio of over ten significantly increases the probability of injury with a positive test score. Although no assessment tool is perfect in all of these categories, each does have their strengths and weaknesses.

The FMS has the largest amount of research specifically looking at its ability to predict future injury in athletes of a variety of settings. However, because the FMS is made up of seven movements which are each scored on a scale of zero to three, it may be difficult to implement this testing method with a larger group of athletes. Although minimal equipment is required because the athletic trainer doesn't necessarily need the FMS specific testing kit, they do need some training to properly score the movements. It would be more efficient to train seven different people, one per testing movement, to set up a station based assessment screen, but this would be difficult in smaller school setting with limited personnel.

The cutoff score of fourteen has been used as the threshold for higher injury risk for athletes that score below fourteen. This value is highly specific, but has a very low sensitivity at 0.26. Therefore, there will be many false negatives even though the FMS is good at determining true negatives. This leads to a positive likelihood ratio of 2.00 and a negative ratio of 0.85 (graph 1). It has also been determined that athletes are at a higher risk of injury if at least one side to side asymmetry is present. The sensitivity increases to 0.58 when focusing on this outcome of the FMS. Nevertheless, there are only minimal changes in the post-test probabilities at 20% and 10% for a positive and negative test score respectively (graph 2). The number of false positives identified increases and the amount of false negatives decrease, but it still represents close to half of the total injured population.

The Y Balance Test had the highest reported sensitivity of all the assessment tools at 0.87.³⁷ This test produces very few false negatives, but will have a relatively high number of false positives. The YBT also had the best likelihood ratios which produced the greatest effect on post-test probabilities (graph 3). The negative likelihood ratio of 0.19 is equivalent to a moderate change in post-test probability at 3% which is the lowest of the screening assessments.

The YBT requires only a tape measure and athletic tape, materials that every athletic trainer has on hand, while minimal training is required because of the simple testing procedure. There is also minimal time commitment for the YBT making it easier to implement on a large number of athletes than the FMS. The studies have identified that side to side asymmetry in reaching distance as well as the composite score to be effective predictor of future injury. Most of the studies separate contact and non-contact injuries which is arguable the most useful

aspect in recommending this screening assessment. Athletic trainers can work only to prevent the non-contact injuries because generally these occur due to deficits in the kinetic chain or neuromuscular issues which can be improved through rehab. Although there is limited research, there is a possibility of using the YBT in addition to other testing methods to more accurately identify those at risk because the YBT is so easy to implement.

The Weight Bearing Dorsiflexion Lunge test is also inexpensive, quick and easy to implement for practicing athletic trainers. The equipment is similar to the YBT and minimal training is necessary due to the simple testing procedure. However, most studies used the WBDFL test to identify athletes at higher risk for chronic patellar tendinopathies.^{34,40} There is limited research on the ability of the WBDFL to predict acute injuries and most studies combine the WBDFL with a variety of other screening assessments. Due to this, no sensitivity or specificity values have been determined solely for the WBDFL test's ability to predict acute injury. Therefore, the WBDFL test is not recommended for athletic trainers to use independently. It is a possibility to combine this test with other screening assessments because it is very applicable to implement for the practicing athletic trainer, especially when the goal is to identify those at risk for chronic injury.

The gold standard for measuring lower extremity strength is an isometric electromechanical dynamometer.²⁹ This machine is extremely expensive and is most likely not available to athletic trainers. The hand-held dynamometer has proven to be similar to the gold standard when determining strength to return to play with a specificity of 0.72 and sensitivity of 0.83.²⁹ The hand-held dynamometer also allows the athletic trainer to assess strength in other muscles than just the quadriceps and hamstrings such as the hip musculature. Studies

have shown the side to side strength imbalances of the hip musculature to be a risk factor in chronic injuries.²⁸ Hamstring to quadriceps strength ratio is the main predicting factor in ACL ruptures.³⁶ This indicates that strength assessment is an important factor in screening for injury risk. Unfortunately, the equipment needed for objective measurements is expensive and largely inapplicable for athletic trainers in a small setting. Similar to the DFL test, lower extremity strength measurements are often used in conjunction with other screening assessments and no sensitivity/specificity values have been reported for injury prediction.

Conclusion

Lower extremity injury accounts for nearly 50% of all collegiate athletic injuries with 11,000 ankle sprains and 2,000 ACL tears annually. The NCAA injury rate is 13.8 injuries for each 1,000 athlete exposures.¹ This increasing injury rate indicates a need to identify the risk factors associated with lower extremity injury, especially non-contact injuries. After determining which athletes are at a higher risk of injury, athletic trainers will have the ability to implement targeted, individualized, rehabilitation programs to improve identified deficits and ultimately reduce the injury rate.

Athletic trainers are often responsible for a large number of athletes therefore having a limited amount of time and resources. These health care professionals are at the forefront of dealing with athletic injuries and are in need of an injury risk assessment tool that allows them to identify individual deficits to more effectively rehab these athletes who are at a higher risk of injury. This assessment tool must be inexpensive, quick and easy to implement and have the ability to screen large numbers of athletes. The Y Balance test meets all these criteria while

providing a more significant change in post-test probabilities than the other screening assessments.

The Y Balance test is recommended for practicing athletic trainers because it is specific to non-contact injuries, it produces very few of the possibly detrimental false negatives and the post-test probability of an athlete with and without an asymmetry in the anterior reach distance is 30% and 3% respectively, the best of the screening assessments. Although research is lacking, there is a possibility of combining the YBT and other screening assessments such as the DFL test, lower extremity strength assessment and the Landing Error Scoring System for a more accurate understanding of individual deficits. The YBT is recommended for athletic trainers of all levels and settings to implement during the preseason, pre-participation exam to identify athletes at a higher risk for injury throughout the season and modify these deficits to decrease the likelihood of injury.



Fig. 1: Star Excursion Balance Test

<https://www.youtube.com/watch?v=YG5Hf7jwDrQ>



Fig. 2: Y Balance Test with athletic tape

<http://www.institutocohen.com.br/biolabcohen.php>



Fig. 3: Y Balance Test with slide boards

https://www.functionalmovement.com/store/23/y_balance_test_kit

The Functional Movement Screen



Fig. 4: Functional Movement Screen

<http://thestrengthathlet e.com/scienceresearch/2014/4/10/functional-movement-screen-for-strength-sports>



Fig. 5: Lower extremity strength assessment of the quads with hand-held dynamometer

(Sinacore JA, 2017) ²⁹



Fig. 6: Dorsiflexion Lunge test

<https://www.weckmethod.com/articles/ankle-strengthening-exercises-stretches-to-reduce-injury>

Table 1 Functional Movement Screen

	Kiesel et al ⁵	Knapik et al ²⁵	Shojaedin et al ³²
Study Design	Prospective Cohort	Prospective Cohort	Prospective cross sectional
Participants	238 professional football players on a total of two teams	770 male and 275 female incoming freshman cadets age 18-22 in the Summer Warfare Basic Training	100 healthy college aged recreational and competitive athletes (50 male and 50 female) in football, handball and basketball Excluded if using a prophylactic device or suffered a recent injury
Intervention Investigated	FMS included in PPE and conducted by strength and conditioning staff with extensive FMS experience Injuries were tracked throughout the preseason and coded as joint or musculoskeletal injury At the end of preseason, players were separated as sustaining an injury or remaining uninjured Injury was defined as a time loss injury	FMS conducted before training by research staff. Each tester was trained only in the one test they were administering, but all monitored by PT certified in FMS PT diagnosed SWAB training related injuries and recorder throughout the year Injury defined as physical damage to body resulting in a clinic visit	FMS was conducted by two PTs prior to the competitive season Athletes were separated into the groups injured, non-injured, below or above the cutoff score of 17
Main Findings	25% of the football players were injured with the knee being the most commonly injured. The mean FMS score 16.9 for all subjects, injured: 16.1, non-injured: 17.4	18.6% of males and 24.7% of females sustained an injury Males were at a higher injury risk with FMS scores under 12 with sensitivity of 0.55 and specificity 0.49	The average FMS score was 16.7 A score of less than 16.5 resulted in a 4.7 times greater chance of injury There was a statistical difference between preseason FMS scores of the injured and non-injured groups

	<p>Significant difference in the number of players with at least one asymmetry on the FMS between the injured and non-injured groups</p> <p>A score of less than 14 yielded an injury risk of 1.87 with sensitivity of 0.26 and specificity of 0.87</p> <p>One asymmetry increased the risk of injury to 1.8 with sensitivity of 0.58 and specificity of 0.62</p> <p>A combination of asymmetry and score below 14 was highly specific for injury at 0.87</p>	<p>Females were at higher injury risk with FMS scores under 15 with sensitivity 0.60 and specificity 0.61</p>	<p>Athletes competing in basketball had lower scores on all seven FMS tests</p> <p>27% of participants scored under 14</p> <p>Of participants scoring under 17, 22 were injured and 9 remained healthy. 24 were injured and 34 remained healthy in the group of people who scored over 17</p>
Level of Evidence	2b	2b	2a
Conclusion	<p>Athletes with dysfunctional movement patterns (low FMS score and asymmetry) are more likely to suffer a time loss injury</p> <p>The cutoff score was validated in this study at less than 14</p> <p>One asymmetry increased the injury risk regardless of overall FMS score</p>	<p>The FMS predicted injury risk with moderate accuracy in female cadets and low accuracy in males</p>	<p>There was a 4.7 time greater chance of injury with a FMS score less than 17</p> <p>Including the FMS as part of the PPE is low cost and simple to implement</p>

Abbreviations: PPE, Pre Participation Exam
PT, physical therapist

Table 2 Weigh Bearing Dorsiflexion Lunge

	Backman et al ⁴⁰	Malliaras et al ³⁴	Gabbe et al ³³
Study Design	Prospective Cohort	Cross-Sectional	Prospective Cohort
Participants	75 Swedish junior basketball players at the national elite level age 14-20 (38 males and 37 females)	113 male and female volleyball players over 18 years old	126 adult Australian community level football clubs
Intervention Investigated	<p>Excluded if history of Osgood-Schlatters, ACL reconstruction or anterior knee pain presently</p> <p>DF range tested and development of patellar tendinopathy over one year</p> <p>DF lunge test angle recorded with inclinometer</p> <p>Clinical exam by PT one year later for anterior knee pain, decrease in knee function, palpable tenderness, activity related pain or pain with decline single leg squat or if these symptoms occurred anytime throughout the year</p>	<p>Pain scale with decline single leg squat and ultrasound image were taken one week before the season with DF lunge scores split athletes into 3 groups: normal tendon, abnormal and no pain, and patellar tendinopathy</p>	<p>Baseline assessments conducted 3 weeks prior to competitive season by PTs including weight bearing DF lunge test</p> <p>4 month injury surveillance by club PT. Injury defined as damage resulting in missed participation and or treatment from a health care professional</p>
Main Findings	<p>Average DF was 38.7 degrees on the dominant leg and 40.0 degrees on the non-dominant</p> <p>12 athletes with unilateral tendinopathy. There was no difference in tendinopathy between the dominant and non-dominant leg</p> <p>36.5 degrees of DF was the cutoff for tendinopathy. 18-29% risk in high</p>	<p>Significant difference in DF range between tendon health groups mainly on the right side</p> <p>45 degrees was the most accurate cutoff score with an increased risk of tendinopathy 1.8-2.8x</p> <p>No indication of predicting development of injury, just</p>	<p>53% of the participants sustained LE injuries</p> <p>DF lunge was the only factor found to be associated with LE injury</p> <p>Players with a history of 2 or more injuries in the previous season were at an increased risk of injury</p> <p>Athletes were more than 13 cm of</p>

risk group (less than 36.5 degrees of DF) compared to 1.8-2.1% in the low risk group

predisposing factors

DF were less likely to get injured than those with less than 9cm of DF

Higher incidence of tendinopathy in athletes with history of 2 or more ankle sprains with predispose them for lower DF range

Cutoff scores not applicable to other ages/sports

Level of Evidence

2b

1

2b

Conclusion

DF lunge range of motion under 36.5 degrees predispose young basketball players to patellar tendinopathy

Players with less than 45 degrees of DF are at a greater risk of having patellar tendinopathy

DF lunge range of motion was the single univariate association for LE injuries. Other factors included age, past injury history and participation in regular weight training

Abbreviations: DF, dorsiflexion
PT, physical therapist
LE, lower extremity

Table 3 Lower Extremity Strength Assessments

	Niemuth et al ²⁸	Croiser et al ³⁵	Soderman et al ³⁶
Study Design	Descriptive Analysis	Prospective Cohort	Prospective Cohort
Participants	<p>30 recreational runners, 17 females and 13 males (10 miles per week) with a single leg overuse injury referred by a PT clinic</p> <p>30 non-injured randomly selected recreational runners, 16 females and 14 males</p> <p>Patellofemoral pain, plantar fasciitis, IT band friction syndrome, stress fracture, Achilles tendinopathy and medial tibial stress syndrome included</p> <p>Excluded if they participated in competitive running, had bilateral pain</p>	<p>462 soccer players on the Belgian, Brazilian and French professional teams with an average age of 26 years old</p>	<p>146 athletes from Swedish soccer teams</p>
Intervention Investigated	<p>2 trials of max isometric contraction of the 6 muscle groups of the hip joint (flexors, extensors, adductors, abductors, internal and external rotators) were recorded by a PT with a hand-held dynamometer</p>	<p>Preseason isokinetic testing of the hamstring and quadriceps with a kin-com dynamometer</p> <p>3 submax warmup repetitions before 3 reps at 60 degrees/sec and 5 reps and 240 degrees/ sec with 1 minute rest in between sets</p> <p>Athletes separated by imbalances of 15% bilateral differences, concentric H/Q ratio and mixed ratio</p>	<p>Muscle torques with kin-com dynamometer were conducted preseason</p> <p>5 trials recorded at 90 degrees/sec to determine maximal isokinetic contraction</p>

		deficiencies	
		Hamstring injuries were recorded over 9 months and defined as pain with palpation, active contraction or stretch, diagnosis with MRI or ultrasound and 4 weeks of playing time missed	
Main Findings	<p>The abductors and flexors of the injured side were significantly weaker than the non-injured side. The adductors were significantly stronger on the injured side</p> <p>The external rotators trended toward weakness, but were not significant</p> <p>The only difference in hip flexion strength was between participants who were injured for the first time versus those who reinjured</p> <p>There was similar strength in the non-injured limbs in both the experimental and control groups</p>	<p>47% of all athletes had an isokinetic strength disorder. 35 athletes sustained a hamstring injury</p> <p>Players with untreated strength imbalances were at a 4-5x higher risk for hamstring injury</p> <p>H eccentric/Q concentric ratio was highly specific for injury</p> <p>Simple eccentric exercise program could decrease the hamstring injury occurrence</p> <p>Restoring balance after isokinetic testing decreased the injury rate</p>	<p>50 traumatically injured athletes with 5 ACL tears and 17 overuse injuries recorded</p> <p>Low H/Q concentric ratio was related to higher risk of injury</p> <p>All 5 ACL tears had a lower H/Q ratio on the injured side and were all lower than 55%</p> <p>Higher H/Q concentric ratio was found in athletes with overuse injuries</p> <p>Hyperextension of the knee, low concentric H/Q ratio, low postural sway, and a high exposure to soccer were the most important risk factors</p> <p>Females take longer to generate max hamstring torque during isokinetic testing which could be a potential risk factor in ACL tears</p>
Level of Evidence	2b	1	2b
Conclusion	There is a relationship between hip muscle imbalances and injury	Strength imbalance side to side with a low H/Q ratio increases the risk of	A lower H/Q ratio increases the risk of traumatic leg injuries and a higher

patterns in runners with overuse
injuries, the hip abductors in
particular

hamstring injury

ratio increases the risk of an overuse
injury

Quad dominance increases the
strain on the ACL

Abbreviations: H/Q, Hamstring
To Quadriceps strength ratio

Table 4 Star Excursion Balance Test/Y Balance Test

	Plisky et al ²⁴	Gonell et al ²³	Smith et al ³⁹	Stiffler et al ³⁷
Study Design	Prospective Cohort	Prospective Cohort	Prospective Cohort	Retrospective Cohort
Participants	<p>235 high school basketball players (130 males, 105 girls)</p> <p>Excluded if there was vestibular dysfunction or lower extremity injury within one month</p>	<p>74 male professional soccer club athletes</p>	<p>184 Division I collegiate athletes competing in basketball, cross-country, football, golf, volleyball, track and field, swimming, tennis and soccer</p> <p>Participants were excluded if they had a current injury</p>	<p>147 Division I athletes from one university</p> <p>Excluded if there was a history of lower extremity injury</p>
Intervention Investigated	<p>Subjects were prospectively followed throughout the competitive season</p> <p>Previous injury history, current lower extremity symptoms and use of brace/tape were recorded</p> <p>6 practice trials and 3 recorded trials for max reach distance in PM, PL and Ant direction with the SEBT</p> <p>Leg length was also measured to normalize reach distances</p> <p>Injuries were tracked throughout the year. Injury was defined as</p>	<p>Athletes were prospectively followed throughout the competitive season</p> <p>Previous injury history, MOI and previous time loss due to injury were recorded</p> <p>6 practice trials and 3 recorded trials to determine max reach distance in ANT, PM and PL directions</p> <p>Injuries were recorded by a PT and defined as an event that caused the athlete to miss at least one training day</p> <p>Athletes then separated</p>	<p>Athletes were followed for one sport season</p> <p>Everyone was blinded from the YBT score as it was conducted with the PPE by certified raters</p> <p>4-6 practice attempts and 3 recorded trials for max distance in the PM, PL and ANT directions</p> <p>Injuries were tracked and defined as the first musculoskeletal problem with a non-contact MOI that caused patients to go the athletic training room and required intervention</p> <p>Contact injuries were excluded, but overuse</p>	<p>Preseason PPE testing with the SEBT conducted by raters trained by the certified athletic trainer</p> <p>Injury history, injury status, surgical history and starting status were recorded</p> <p>4 practice trials with 3 test trials for maximum reach distance</p> <p>Athletes were separated into healthy or injured group if they sustained a non-contact knee or ankle injury in the competitive season</p> <p>Injury was defined as an acute non-contact</p>

	injury to the limb during practice or game which caused restricted participation or removal from play in current or next practice/game	into equal reach, difference of greater than 4cm or less than 4cm groups. Injuries were classified as contact or non-contact	injuries were included	musculoskeletal condition which required the athlete to be removed from play for at least one day
Main Findings	<p>23% of subjects suffered an injury with 92.5% of those being traumatic</p> <p>Females with a composite reach distance less than 94% of limb length were 6x more likely to be injured. This was not true in males</p> <p>ANT right vs left difference of 4cm or greater, a decreased normalized right ANT reach and decrease PM, PL and composite distances bilaterally were all significantly associated with LE injury</p>	<p>A side to side difference of greater than 4cm in the PM direction yielded a 3.86x increase in the risk of a non-contact injury</p> <p>Low scores in the ANT direction had a 2x increase in risk of a contact injury</p> <p>All injury risk was increased 2x with a composite reach less than average and a 2.25x increase for non-contact</p>	<p>There were 81 non-contact injuries</p> <p>ANT reach asymmetry of 4cm or greater resulted in a 2.2x increase in injury with low sensitivity</p> <p>Composite score was not associated with an increase in injury risk</p> <p>No significant difference between the injured and non-injured reaches</p>	<p>There were 29 non-contact injuries recorded</p> <p>Side to side asymmetry in the ANT reach distance, absolute and normalized to limb length, was significantly associated with non-contact injury with a sensitivity of 0.87 and specificity of 0.67</p> <p>Using the typical 4cm asymmetry cutoff produces only 48% of the injured group and 73% of the healthy group being screened correctly</p> <p>There was an 82% accuracy in classifying injury with ANT reach asymmetry, sport, sex and athlete exposure</p>
Level of Evidence Conclusion	2b SEBT is a quick a reliable screening assessment for large groups of people	2b Inequalities between right and left reaches over 4cm have a 4x increase risk of missed days due to non-	2b Clinical use of the YBT and association to injury in multiple sports is	2b Side to side asymmetry in the ANT direction of the SEBT is associated with an increase in predictive

A greater side to side difference in ANT reach distance resulted in a 2.5x increase for injury

SEBT can be put in the PPE and can improve deficits with neuromuscular preseason training

contact injury

Lower composite scores result in a greater possibility of missed days

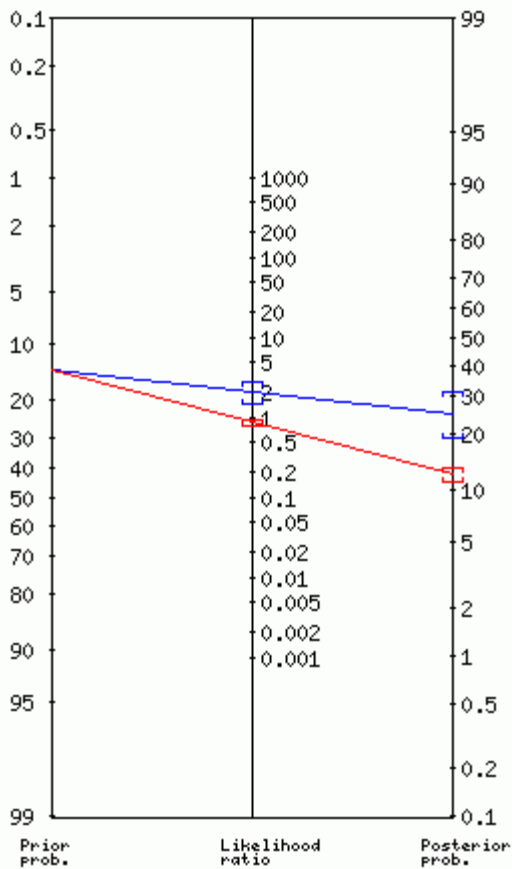
The YBT could be a useful preseason test and to determine return to play following injury

questionable

Asymmetry between limbs was a greater predictor of injury than overall reach differences between injured and non-injured athletes

probability of a non-contact knee or ankle injury

Abbreviations: PPE, pre participation Exam PM, posteromedial PL, postero-Lateral ANT, anterior MOI, mechanism Of injury

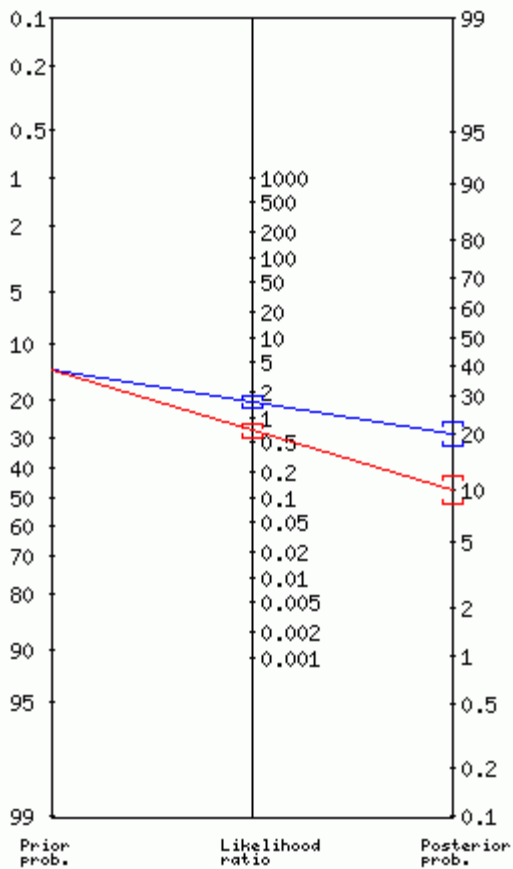


Graph 1: Nomogram FMS score under 14

Sensitivity: 0.26 Specificity: 0.87

+LR: 2.00 Post-test: 25%

-LR: 0.85 Post-test: 12%

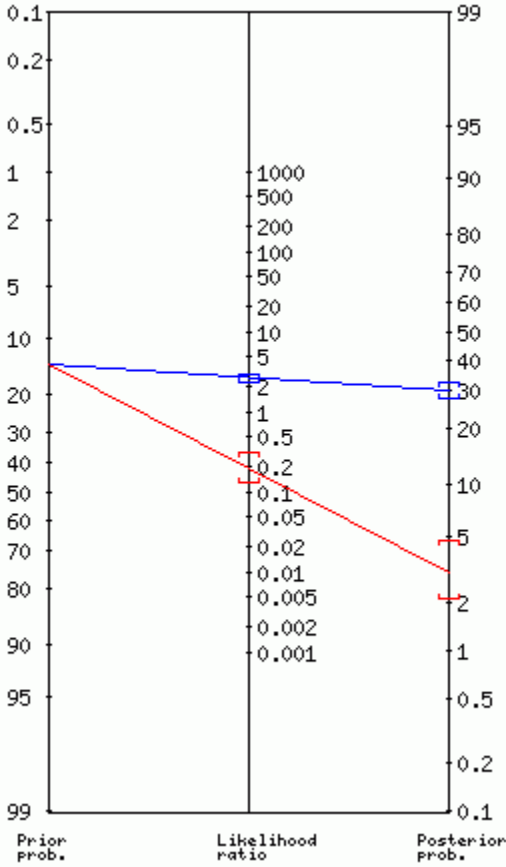


Graph 2: Nomogram FMS asymmetry

Sensitivity: 0.58 Specificity: 0.62

+LR: 1.53 Post-test: 20%

-LR: 0.68 Post-test: 10%



Graph 3: YBT non-contact injuries and anterior reach asymmetry
Sensitivity: 0.87 Specificity: 0.67
+LR: 2.64 Post-test: 30%
-LR: 0.19 Post-test: 3%

References

1. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *J Athl Train*. 2007;42(2):311-319.
2. Putukian M. The psychological response to injury in student athletes: a narrative review with a focus on mental health. *Br J Sports Med*. 2015;bjsports-2015-095586.
3. Klenk C a. Psychological Response to Injury , Recovery , and Social Support : A Survey of Athletes at an NCAA Division I University. *Response*. 2006:1-41.
4. Chorba RS, Chorba DJ, Bouillon LE, Overmyer C a, Landis J a. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *N Am J Sports Phys Ther*. 2010;5(2):47-54.
5. Kiesel KB, Butler RJ, Plisky PJ. Prediction of injury by limited and asymmetrical fundamental movement patterns in american football players. *J Sport Rehabil*. 2014;23(2):88-94.
6. Peate WF, Bates G, Lunda K, Francis S, Bellamy K. Core strength: a new model for injury prediction and prevention. *J Occup Med Toxicol*. 2007;2:3.
7. Lisman P, O'Connor FG, Deuster P a., Knapik JJ. Functional movement screen and aerobic fitness predict injuries in military training. *Med Sci Sports Exerc*. 2013;45(4):636-643.
8. Bahr R. .Why screening tests to predict injury do not work and probably never will...:a critical review. *Br J Sports Med*. 2016;50(13):776-780.
9. Drakos MC, Domb B, Starkey C, Callahan L, Allen A a. Injury in the national basketball association: a 17-year overview. *Sports Health*. 2010;2(4):284-290.
10. Agel J, Rockwood T, Klossner D. Collegiate ACL Injury Rates Across 15 Sports: National Collegiate Athletic Association Injury Surveillance System Data Update (2004-2005 Through 2012-2013). *Clin J Sport Med*. 2016;0(0):1-6.
11. Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. The Effects of Core Proprioception on Knee Injury. *Am J Sports Med*. 2007;35(3):368-373.
12. Ford KR, Mclean SG. Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes A Prospective Study Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Ant. *Am Orthop Soc Sport Med*. 2005;33(4):1-10.
13. Zebis MK, Andersen LL, Bencke J, Kjaer M, Aagaard P. Identification of athletes at future risk of anterior cruciate ligament ruptures by neuromuscular screening. *Am J Sports Med*. 2009;37(10):1967-1973.
14. Paterno M V, Schmitt LC, Ford KR, et al. Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport. *Am J Sports Med*. 2010;38(10):1968-1978.

15. Mclean SG, Walker K, Ford KR, Meyer EG, Hewett TE, Bogert AJ Van Den. Evaluation of a two dimensional analysis method as a screening and evaluation tool for anterior cruciate ligament injury. *Br J Sports Med*. 2005;39:355-363.
16. Redler LH, Watling JP, Dennis ER, Swart E, Ahmad CS. Reliability of a field-based drop vertical jump screening test for ACL injury risk assessment. *Phys Sportsmed*. 2016;44(1):46-52.
17. McKay GD, Goldie P a, Payne WR, Oakes BW. Ankle injuries in basketball : injury rate and risk factors Ankle injuries in basketball : injury rate and risk factors. 2001;(November 2006):103-108.
18. Wang HK, Chen CH, Shiang TY, Jan MH, Lin KH. Risk-Factor Analysis of High School Basketball-Player Ankle Injuries: A Prospective Controlled Cohort Study Evaluating Postural Sway, Ankle Strength, and Flexibility. *Arch Phys Med Rehabil*. 2006;87(6):821-825.
19. Talukder H, Vincent T, Foster G, et al. Preventing in-game injuries for NBA players Paper ID : 1590. *MIT Sloan Sport Anal Conf*. 2016;2015:1-13.
20. Beutler AI, de la Motte SJ, Marshall SW, Padua D a, Boden BP. Jump-landing, ACL injury risk, motor patterns, qualitative movement screen 16. *J Sport Sci Med*. 2009;298(704):663-671.
21. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star excursion balance test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sport Phys Ther*. 2006;36(12):911-919.
22. Trojian TH, McKeag DB. Single leg balance test to identify risk of ankle sprains. *Br J Sports Med*. 2006;40(7):610-3; discussion 613.
23. Gonell AC, Romero JAP, Soler LM. Relationship Between the Y Balance Test Scores and Soft Tissue Injury Incidence in a Soccer Team. *Int J Sports Phys Ther*. 2015;10(7):955-966.
24. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a Predictor of Lower Extremity Injury in High School Basketball Players. *J Orthop Sport Phys Ther*. 2006;36(12):911-919.
25. Knapik JJ, Cosio-Lima LM, Reynolds KL, Shumway RS. Efficacy of Functional Movement Screen for Predicting Injuries in Coast Guard Cadets. *J Strength Cond Res*. 2015;29(5):1157-1162.
26. Strategies C. Excerpted from the book, Movement: Functional Movement Systems— Screening, Assessment, Corrective Strategies Verbal instructions for the Functional Movement Screen. 2010.
27. Cook G. Fms Scoring Criteria. *Mov Funct Mov Syst -- Screening, Assessment, Correct Strateg*. 2010.
28. Niemuth PE, Johnson RJ, Myers MJ, Thieman TJ. Hip muscle weakness and overuse

- injuries in recreational runners. *Clin J Sport Med*. 2005;15(1):14-21.
29. Sinacore JA, Evans AM, Lynch BN, Joreitz RE, Irrgang JJ, Lynch AD. Diagnostic Accuracy of Handheld Dynamometry and 1-Repetition-Maximum Tests for Identifying Meaningful Quadriceps Strength Asymmetries. *J Orthop Sport Phys Ther*. 2017;47(2):97-107.
 30. Cejudo A, Sainz de Baranda P, Ayala F, Santonja F. A simplified version of the weight-bearing ankle lunge test: Description and test-retest reliability. *Man Ther*. 2014;19(4):355-359.
 31. Shea SO, Grafton K. The intra and inter-rater reliability of a modified weight-bearing lunge measure of ankle dorsiflexion. *Man Ther*. 2013;18(3):264-268.
 32. Shojaedin SS, Letafatkar A, Hadadnezhad M, Dehkoda MR. Relationship between functional movement screening score and history of injury and identifying the predictive value of the FMS for injury. *Int J Inj Contr Saf Promot*. 2014;21(4):355-360.
 33. Gabbe BJ, Finch CF, Wajswelner H, Bennell KL. Predictors of lower extremity injuries at the community level of Australian football. *Clin J Sport Med*. 2004;14(2):56-63.
 34. Malliaras P, Cook JL, Kent P. Reduced ankle dorsiflexion range may increase the risk of patellar tendon injury among volleyball players. *J Sci Med Sport*. 2006;9(4):304-309.
 35. Croisier J-L, Ganteaume S, Binet J, Genty M, Ferret J-M. Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med*. 2008;36(8):1469-1475.
 36. Söderman K, Alfredson H, Pietilä T, Werner S. Risk factors for leg injuries in female soccer players: A prospective investigation during one out-door season. *Knee Surgery, Sport Traumatol Arthrosc*. 2001;9(5):313-321.
 37. Stiffler AMR, Bell DR, Sanfilippo JL, Hetzel SJ, Pickett KA, Heiderscheid BC. Star Excursion Balance Test Anterior Asymmetry is Associated with Injury Status in Division I Collegiate Athletes. *J Orthop Sport Phys Ther*. 2017;0(0):1-27.
 38. Hertel J, Braham RA, Hale SA, Olmsted-Kramer LC. Simplifying the Star Excursion Balance Test: Analyses of Subjects With and Without Chronic Ankle Instability. *J Orthop Sport Phys Ther*. 2006;36:131-137.
 39. Smith CA, Chimera NJ, Warren M. Association of Y balance test reach asymmetry and injury in Division I Athletes. *Med Sci Sports Exerc*. 2015;47(1):136-141.
 40. Backman LJ, Danielson P. Low Range of Ankle Dorsiflexion Predisposes for Patellar Tendinopathy in Junior Elite Basketball Players: A 1-Year Prospective Study. *Am J Sports Med*. 2011;39(12):2626-2633.