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May, 2015

To the Dean of the Graduate School:

We are submitting a thesis written by Jamie Perry entitled Correlations between the Functional Movement Screen (FMS), the Balance Error Scoring System (BESS), and Injury.

We recommend acceptance in partial fulfillment of the requirements for the degree of Masters of Science in Sport and Fitness Administration.

Thesis Advisor

Committee Member

Committee Member

Dean, College of Education

Dean, Graduate School

CORRELATIONS BETWEEN THE FUNCTIONAL MOVEMENT SCREEN (FMS),
THE BALANCE ERROR SCORING SYSTEM (BESS), AND INJURY

A Research Proposal

Presented to the Faculty

Of the

Richard W. Riley College of Education

In Partial Fulfillment

Of the

Requirements for the Degree

Of

Master of Science

In Sport and Fitness Administration

Winthrop University

May 2015

By

Jamie Perry

Abstract

Men's ice hockey is a fast and exciting sport that draws elite athletes into its rink. The demands of the sport place athletes at an exceptionally high risk for musculoskeletal injury if they are not properly conditioned. Determining at risk athletes during pre-season screenings is of particular importance to the medical staff, and any opportunity to provide prophylactic treatment is sought after. The purpose of this study was to investigate a potential correlation between a) total FMS scores and total BESS scores, b) total FMS scores and the incidence of injury, c) total BESS scores and the incidence of injury, d) scores on the rotary stability screen and total BESS scores, and e) scores on the inline-lunge screen and total BESS scores.

Data were collected using participants from one selected East Coast Hockey League (ECHL) team. Athletes completed the FMS and the BESS shortly after reporting for training camp and injuries were reported from the head athletic trainer from October through February of the 2014-2105 hockey season. Results indicated that no significant correlations were found between the FMS and the BESS; one screen could not predict scores or ability on the other. Neither the FMS nor the BESS were successful at identifying at risk athletes for potential injury and although the rotary stability and the in-line lunge screen require a great amount of balance and core stability, neither were significantly correlated, or able to predict ability on the BESS.

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Chapter 1

Introduction

Thought to be one of the most aggressive and fastest team sports, men's ice hockey has a great potential for injury. Players move about on a solid ice surface confined by rigid boards along the rink's periphery. They move on skates at speeds nearing 30 mph around goalposts made of steel, using sticks composed of wood, carbon graphite, or aluminum to rocket a small rubber puck at speeds sometimes around 100 mph (Flik, Lyman, & Marx, 2005). Blunt trauma is said to be the most common cause of injury, followed by fatigue and overuse (Ferrara & Schurr, 1999; Stuart & Smith, 1995). A collision with either an opponent or the boards is the cause of more than half of all injuries. Concussions are the single most common injury, followed by medial collateral ligament sprains although syndesmotoc sprains resulted in the longest average time lost for players (Flik et al., 2005).

The excessive force generated during acceleration and deceleration phases of skating (Tyler, Nicholas Campbell & McHugh, 2001) combined with the loss of stability from the ice surface place athletes at a high risk for non-contact musculolkeletal injuries (Sim, Simonet, Melton, & Lehn, 1987). While skating, hip extensor and abductor muscles are the prime leg movers. The hip flexor and adductor muscles work to stabilize the hip and decelerate the limb. A strength imbalance between propulsive and stabilizing muscles is thought to be a basic mechanism for adductor strains (Tyler et al., 2001), a recognized problem in professional ice hockey players (Lorentzon, Wedren, & Pietila, 1988; Molsa, Airaksinen, Nasman, & Torstila, 1997). Effective strategies for injury prevention must

include, identifying the incidence of specific injuries and the risk factors associated with those injuries. Interventions should be developed to address the risk factors and the effectiveness of the interventions at actually reducing the incidence of injury (Flik et al., 2005).

Pre-season testing in professional sports has become increasingly common (Whatman, Hing, & Hume, 2011). The ability to identify altered kinematics during sport specific movement as a means to predict and prevent future injury is considered, by many, to be a vital component of the pre-participation screen. Studies have shown that a decrease in range of motion, anatomical symmetry, and insufficient core stability as well as reduced neuromuscular control can increase the risk of acute and overuse injury (Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2010). Poor neuromuscular control and core instability have been shown to impact static and dynamic balance. Research has been done continuously to contribute to the reliability and validity of sport specific screening and testing, but results have been inconclusive. Repeating these studies, as well as performing new ones, can only positively impact the world of injury prevention.

To date, no studies have compared the Functional Movement Screen, (FMS) which measures motor control within movement patterns and competence of basic movements uncomplicated by specific skills, to the Balance Error Scoring System (BESS) which measures static postural stability. Each test has been reviewed extensively, but no correlation between the two has been investigated. It takes multiple studies and years of research to get definitive results, but if the tests prove to be

synergistic, an advancement in sport specific research would be developed and in time, potentially a new gold standard for injury prediction and prevention.

Statement of the Problem

The purpose of this study was to investigate the relationship between the FMS and the BESS, whether the rotary stability screen from the FMS correlated with total BESS scores, if the in-line lunge screen from the FMS correlated with the BESS and to determine if either the FMS or the BESS individually could predict injuries sustained throughout the season in East Coast Hockey League (ECHL) professional hockey athletes.

Research Hypotheses

- There will be a positive correlation between high FMS scores and low BESS scores.
- There will be a positive correlation between high FMS scores. and fewer injuries sustained.
- There will be a positive correlation between low BESS scores and fewer injuries sustained.
- There will be a positive correlation between a high score on the rotary stability screen and a low score on the BESS.
- There will be a positive correlation between a high score on the in-line lunge screen and a low score on the BESS.

Delimitations

- Participants must be active male ECHL professional hockey athletes.
- All screenings must be completed at the start of the 2014-2015 season.
- Participants must not have suffered a concussion within the last three months.
- Participants must not have suffered a musculoskeletal injury that resulted in restricted activity in the last 3 months.
- Injuries reported to the researcher must come directly from the head athletic trainer.

Limitations

- The researcher had no control over athletes cut or waived from the team or trades made throughout training camp through the end of the 2014-2015 ECHL season.
- A small sample size due to location, accessibility and trades made throughout the season may impact results.
- Lack of practice in scoring and interpreting results of the FMS by the researcher may result in lack of reliability of the study and scores.
- Lack of experience in performing the FMS or variation of skill level in performing the assessment may lead to altered results unrelated to a subject's functional movement.
- Athletes variation in training and conditioning received or performed in the off season may lead to a variation in the athlete's ability to perform the FMS and cause differences in scores seen throughout participants.

Definition of Terms

Balance Error Scoring System, (BESS) a portable and cost effective, objective assessment of an individual's static postural stability (UNC, 2009)

Dynamic Balance postural stability and equilibrium of forces acting on the body throughout movement

Functional Movement the ability to produce and maintain a steadiness between mobility and stability along the kinetic chain while performing fundamental patterns with accuracy and efficiency (Mills, Taunton, & Mills, 2005).

Functional Movement Screen (FMS) evaluation of fundamental movements, motor control within movement patterns, and competence of basic movements uncomplicated by sport specific skills; determines the greatest areas of movement deficiency; demonstrates limitations or asymmetries in movement

Injury any musculoskeletal event that kept an athlete out of practice, game or required attention of the team physician

Kinematics a branch of dynamics that deals with aspects of motion apart from considerations of mass and force (Whatman, Hing, and Hume, 2010).

Neuromuscular Control the ability to control movements through coordinated muscle activation (Frohm et al, 2010).

Static Balance the ability to sustain the body in static equilibrium or within its base of support (Goldie et al., 1989; Olmsted et al., 2002)

Chapter 2

Review of Related Literature

Introduction

The risk for injury in athletics is high for any participant. Non-contact injuries are continually a concern but when collisions with teammates, other opponents and impact from objects propelled by various implements are added, that risk increases. Men's ice hockey is thought to be one of the toughest and fastest sports. Players move about on a solid ice surface confined by rigid boards along the rink's periphery on skates at high speeds. Their sticks are composed of wood, carbon graphite, or aluminum and are used to rocket a small rubber puck at speeds sometimes around 100 mph (Flik et al., 2005). These factors alone make ice hockey athletes at a high risk for injury.

The environmental conditions, in addition to the physical demands and requirements of hockey, place athletes at a high risk for non-contact musculoskeletal injuries (Sim et al., 1987). A strength imbalance between propulsive (hip extensors and abductor) muscles, stabilizing, and decelerator muscles (hip flexors and adductors) are thought to be a basic mechanism for adductor strains (Tyler et al., 2001), a recognized problem in professional ice hockey players (Lorentzon et al., 1988; Molsa et al., 1997). Blunt trauma is said to be the most common cause of injury, followed by fatigue and overuse (Ferrara et al., 1999; Stuart et al., 1995). Collisions with an opponent or the boards are the cause of more than half of all injuries sustained. Concussions lead as the single most common injury, followed by medial collateral ligament sprains, although

syndesmotic sprains resulted in the longest average time lost for players according to Flik, Lyman, and Marx (2005).

Effective strategies for injury prevention include, first and foremost, identifying the incidence of a specific injury as well as the risk factors associated with it. Muscle-strength deficiencies have been proposed as a major predictor of muscle strains. Neuromuscular control and flexibility also cannot be ignored and are key components to preventing injury. Neuromuscular control emphasizes control of the body and the coordination of movement to maintain stability. Training is often used with focus to the lower extremity in preventing ACL tears (Chang, Levy, Seay, & Goble, 2014). A lack of flexibility whether it be within a joint or an isolated muscle, an absence of range of motion, and a decrease in muscle extensibility and elasticity are risk factors for sprains and muscle strains. To prevent other limb injuries, balance and proprioception are vital. Peripheral and central nervous system receptors and mechanoreceptors within the muscles, ligaments and tendons need to activate together and at appropriate speeds (Gioftsidou et al., 2012) to ensure the ability to sustain the body within its base of support (Goldie et al., 1989; Olmsted et al., 2002).

After identification, interventions to address these risk factors need to be developed. Interventions may involve, but are not limited to, strengthening exercise programs to restore muscle imbalances, stretching programs to decrease muscle stiffness, and balance programs to improve proprioception (Gioftsidou et al., 2012). Focus is on correcting the identified risk factors, but effectiveness should not be relied upon without

testing the success of the intervention at reducing the incidence of that specific injury beforehand (Flik et al., 2005).

Balance

Injury prevention strategies that focus on preseason conditioning, functional training, proprioceptive balance training and sport specific skills, that continue into the competition season are most effective (Abernethy & Bleakley, 2007). Balance training has been used for the promotion of balance and sports-related skills as well as for prevention and rehabilitation of sport injuries (Lesinski, Hortobagyi, Muehlbauer, Gollhofer, & Granacher, 2014). Sport specific balance is an area of research that has grown dramatically in recent years. The goal is to control balance in sport specific positions which vary from less to more difficult depending on the specialization. Particularly, center of mass (COM) control is important in ice hockey because the biomechanical stability for maintenance of balance is limited by a narrow area of support combined with rotational movement. Base of support is generally greater than the area of contact and greater still than the area of support. This means that maintaining balance on a narrow area of support is often considered more difficult when compared to foot stance. However, the base of support is almost identical when standing two legged on skates and on the ground. Zemkova (2014) chose to test this theory and look at postural sway and sway velocity in ice hockey players while standing in a two-legged foot stance and again standing in a bipedal stance on ice skates. Postural sway has been a well-accepted indicator of balance instability (Chang et al., 2014). Subjects were measured on a force platform while standing on a variety of surfaces (firm, foam), one and two-legged, semi-

tandem and tandem stances, eyes open and closed and with varying knee and hip angles. The best two out of five thirty second trials were used in the evaluation as this method is considered reliable when measuring postural sway. As predicted center of pressure velocity was only slightly higher when athletes were standing on their skates opposed to the foot stance. This means that postural stability is not compromised during bipedal standing because the base of support is very similar. These findings are important because it demonstrates to clinicians that highly skilled athletes are able to perform successfully in spite of increased postural sway (Zemkova, 2014).

The gold standard regarding balance assessment has been the use of a scientific grade force plate. Understandably, however, this method of evaluation isn't feasible for many athletic programs and organizations. The BESS is used much more frequently because it's cost effective and easily administered on the sidelines. Inter and intra-rater reliability has shown questionable results for the BESS. A way to combine the accuracy of the force plate with the cost effective nature of the BESS would be ideal. Several recent studies have shown evidence that the low cost Nintendo Wii Balance Board (WBB) can be used a valid and reliable force plate alternative. The objective of Chang et al. (2014) research was to test this theory for himself. Evaluations were done on the WBB affixed to the force plate, as participants followed through a BESS protocol. Results showed that the WBB had a near perfect correlation with the force plate in each of the BESS specified positions. In contrast the BESS scores varied substantially across balance conditions and raters. Test-retest reliability was poor in the third stance of the BESS (tandem stance on a firm surface). However, the WBB and force plate had moderate to

good test-retest reliability in all other conditions. The WBB and force plate themselves had excellent test-retest reliability with greater values than those seen for composite BESS scores of any individual rater. Overall, compared to the force plate, the WBB proved to be superior to the BESS (Chang et al., 2014).

Nashner (1993) stated that the ability to maintain postural control and balance depends on information provided by visual cues, vestibular function, and somatosensory feed-back from structures in the lower limb. McGuine, Greene, Best, and Levenson (2000) chose to study whether balance as a predictor of ankle injuries in basketball players was accurate. Potential intrinsic risk factors for ankle injuries include proprioception, postural sway, range of motion, strength and foot type. A pilot study required subjects to perform a standard balance assessment test battery and repeated it 4 days later. A compilation (COMP) score of postural sway was obtained through three single leg trials for 10 seconds with eyes open and three with eyes closed. The other leg was then tested. For this study, subjects went through a modified Romberg test, barefoot, while on a force platform. Subjects performed three trials with their eyes closed and three with their eyes open as the participants did in the pilot study. Ankle injuries included eversion, inversion and syndesmotoc ankle sprains reported by the head athletic trainer. The pre-season COMP scores were significantly higher in those athletes who sustained an ankle injury than in those who remained injury free throughout the season. McGuine et al. (2000) concluded that an increased COMP score corresponded to an increase in ankle sprain injury rates.

In order to prevent limb injuries, peripheral and central nervous system receptors, mechanoreceptors within the muscles, tendons, and ligaments have to be activated. Balance improvements will protect athletes from possible forthcoming injuries. A study involving professional soccer players was done to compare two balance programs with different frequencies of application. Exercises involved heading and passing drills while standing on hemi-cylindrical or hemi-spherical boards. Group A performed the selected exercises six times a week for three weeks and Group B performed the exercises three times for six weeks. It was determined that both programs were beneficial to increasing balance and proprioceptive abilities. The frequency could be adjusted to particular point in the training season. During preparation with more practice time, athletes could use the six times weekly for three-week protocol, whereas during the competition phase of training, athletes may only have time for three sessions throughout the week (Gioftsidou et al., 2012).

An additional proposed remedy for decreased balance and proprioceptive abilities is yoga. A study using college students was performed. Two groups were developed, a control group and a yoga class group. The yoga group attended 22-25 classes over an eight-week period. Testing was done before and after the training period. Strength increases were modest, but steadiness among the least stable participants showed the greatest improvements over the eight weeks. There was no access to force plates so a timed, one-legged balance test was used. Two trials with eyes open and two with eyes closed were performed for each foot. It was determined that yoga training improved timed balance substantially.

Neuromuscular control

In addition to balance, studies have shown that reduced neuromuscular control increases the risk of acute injury (Tyler et al., 2001). Neuromuscular control emphasizes the conscious control of the body and the coordination of various special movements to maintain stability. It involves a combination of flexibility training, plyometrics, weight training, agility work, stretching and sport specific skills and can improve joint position sense, stability and protective reflexes. Chang and Ping-Tung (2014) wanted to examine neuromuscular training on the prevention of ACL injuries in females. They selected five studies and created a systematic review of their results. All studies used a variety of the combination components to neuromuscular training in varying frequencies between three times a week for six weeks, three times a week for eight weeks, and a twelve-week regimen. It was determined that all studies were successful in reducing the incidence of ACL injuries and a special emphasis should be placed on the hamstrings. By improving the strength of the hamstrings, decreasing the difference in strength between the quadriceps and hamstring muscle groups and increasing explosive power of the muscle, more support was provided to the ACL. Chang stated that three factors may influence the effectiveness of a neuromuscular training program in preventing ACL injury. First, strengthening the hamstring muscle group facilitating knee stability. Second, improve the antagonistic contraction abilities of the quadriceps and hamstrings as athletes frequently show imbalances. Lastly, reduce knee valgus and varus upon landing and increase joint stability through dynamic response actions (Chang & Ping-Tung, 2014).

Resistance training alone is beneficial for improving strength, power, and speed but these exercises usually only target one muscle in a single plane even through most sport activities require multiplanar movements and multiple muscle activations to stabilize, accelerate, and decelerate the body. Integrated (neuromuscular) training provides a more functional, sport specific approach to team training sessions. The purpose of DiStefano, DiStefano, Frank, Clark, & Padua, (2013) study was to compare effects of an isolated resistance training program (ISO) to an integrated training program (INT). Similar to Chang et al. (2014) study the INT involved progressive resistive exercise, core stability, power and agility exercises followed by evaluation on a jump landing test, sit and reach, t-test, vertical jump, sit-ups and push-ups. Testing of these measures was also completed prior to the first training sessions and exercises protocols were completed twice a week for eight weeks. After analyzing pre-test and post-test data revealed that INT groups performed better on the LESS (landing test), had faster t-test times and completed more sit-ups and push-ups. The INT program improved all aspects of functional performance that were assessed. Both groups performed more push-ups, jumped higher, and reached further compared to their pre-test scores (DiStefanon et al., 2013).

Core Stability

Current research suggests that decreased core strength may contribute to injuries of the back and extremities, that appropriate training may decrease musculoskeletal damage, and that core stability can be tested using functional movements (Peate, Bates, Lunda, Francis, and Bellamy, 2007). Core stability is achieved through stabilization of

the abdominals and torso allowing ideal production, transfer and control of force when moving through a complete kinetic chain activity (Okada, Huxel, & Nesser, 2011).

Research presented a conceptualization of core stability that Leimohn, Baumgaratner, and Gagnon (2005) referred to as spinal stability; that the spine is a series of spinal segments and spinal stability is the ability of each of those segments to resist translation or rotation throughout movement in all of the anatomical planes (Mills, Taunton, & Mills, 2005).

Liemohn et al. (2005) chose to follow Bergmark's (1989) classification scheme for grouping core muscles into either the Global Stabilization System (GSS) or the Local Stabilization System (LSS). Larger and smaller muscles of the trunk are the chief contributors of the GSS and LSS respectively. The small cross sectional area of the intertransversarii mediales, interspinales and rotators and their close proximity to the center of rotation of the spinal segments, suggests that these LSS muscles are particularly important to the coordination required for core stability. The purpose of this study was to develop a measurement schedule that would quantify core stability and maximize internal consistency reliability and stability reliability. Participants were measured on a stability platform for a four item battery of core stability consisting of a kneeling arm-raise, quadruped arm raise parallel to the tilt axis, a quadruped arm-raise perpendicular to the tilt axis and bridging. Researchers collected data multiple times during each testing day to successfully identify a measurement schedule that would yield reliable test scores because subjects tended to improve with practice. Subjects were tested on four different days testing for five trials each day. A one way analysis of variance was calculated and interclass reliability coefficients were demonstrated. The reliability coefficients were

typically high reaching 0.90. Also, reliability of the score within a day must be high in order to establish high reliability over multiple days. Days three and four presented the highest reliability coefficients. Overall finding showed that administering five trials on three days of the Stability Platform tests are sufficient to obtain scores with good internal and stability reliability (Liemohn et al., 2005).

Hodges and Richardson (1997) examined the sequence of muscle activation during whole body movements and found that some core stabilizers were continuously activated prior to any limb movements. These core stabilizers were the transverse abdominis, multifidus, rectus abdominis and oblique abdominals. These findings support the theory that movement control and stability are developed in a core to extremity pattern; that without core stability, many functional movements may prove difficult. The purpose of this study was to further examine these theories exactly. Okada et al. (2011) wanted to determine if core stability and functional movement screens could predict performance. Participants were run through the FMS's seven basic screens representing basic human movement and McGill's trunk muscle endurance tests to assess core stability. Performance assessments consisted of the Backward Overhead Medicine Ball Throw (BOMB), the T-test, and the single leg squat. Pearson's product moment correlations were used to evaluate relationships between test variables. Results demonstrated a significant correlation between core stability and performance tests as well as between FMS and performance tests. However, no significant correlations were found between core stability and FMS variables. One would believe a strong core would be necessary to perform well, but components of the FMS such as mobility and

coordination may have influenced results. Researchers concluded that core stability is needed to withstand shear forces on the spine that occur during multidirectional movements. Significant positive and negative correlations were found between FMS and performance. Reasons being, BOMB recruits similar body patterns to the hurdle step, rotary stability and push up screens of the FMS. The hurdle step assesses stability of hips, knees and ankles bilaterally whereas the rotary stability screen examines trunk stability combined with total body motion in multiple planes. Both tests require total body coordination and integration. No significant correlations between core stability and FMS variables may suggest that despite a strong core, success on the FMS may not be obtained if poor mobility and coordination are present. It is also possible that only minimal core strength is necessary to perform well.

Richardson and Jull (1995) developed a training regimen focusing on lumbo-pelvic stability (LPS), specifically the transverse abdominis and the lumbar multifidus. They stated that isometric contractions of these muscles at low levels of voluntary contractions while lying prone or during quadruped kneeling will decrease compensatory muscle activation. Purportedly, LPS may contribute to athletic performance by aiding in the efficient transmission of force generated by the lower body, through the trunk and into the upper body. Mills set out to determine if there is an effect on LPS and athletic performance after a ten-week training program. Participants were randomly assigned to one of three groups; the treatment group (T), the pseudo-treatment group (PT), and the control (C). Training was divided into three stages with the first two were four weeks in duration and consisted of exercises promoting awareness for the transverse abdominis,

lumbar multifidus, and the pelvic floor. These three muscles were initially contracted individually with total contraction time increasing week to week until each participant progressed to co-contracting movements. Once co-contraction was learned, torques on the pelvis with upper and lower limb movements were added. During the final two weeks, an unstable surface was introduced in which similar exercises were performed in positions that are more functional, while the transverse abdominis, lumbar multifidus and pelvic floor remained co-contracted. The PT group recruited the rectus abdominus and external obliques through trunk flexion, rotation and lateral bending. The PT group trained equally as often as the T-group. Evaluations were done using a Pressure Biofeedback Unit. Agility, leg power and static balance were measures of athletic performance. A non-parametric Friedman analysis showed a significant increase in LPS following the ten-week training period of the T and PT groups. Significant agility improvements were only found in the T-group as well as for the leg power analysis. Post-hoc comparisons found significant improvements for all groups for static balance. Ultimately however, a Spearman's regression revealed no significant correlations between LPS and athletic performance (Mills et al., 2005).

Functional Testing

The functional testing and screening of individuals for risk of future injury and as a means of optimizing performance has become common, particularly in professional sports, and is used to identify altered kinematics during weight bearing activities. (Whatman, Hing, & Hume, 2011) Movement screening not only identifies mobility and stability issues but guides the transition to increased levels of training by establishing a

movement baseline. (Cook, 2010) The movements of concern to clinicians primarily occur in the frontal and transverse planes (Whatman et al., 2010). Abnormal motion of the trunk, pelvis, hip and knee in these planes is a key risk factor for the development of injuries such as patellofemoral dysfunction (Powers, 2003). Anterior cruciate ligament (ACL) injury, patellofemoral pain syndrome (PFPS) and cartilage degeneration can occur due to poor movement patterns and excessive knee valgus (Bell et al., 2012). Another prevailing theory is that abnormal hip muscle function manifests as altered hip and knee biomechanics during functional tasks (Crossley et al., 2011). These conditions highlight the importance of proper lower extremity alignment (Bell et al., 2012). Five lower extremity functional tests were selected by Whatman et al. (2010), to investigate their reliability on assessing dynamic trunk and lower extremity alignment. The functional tests chosen were the small knee bend (SKB), single leg SKB, lunge (dominant leg), hop lunge (dominant), and the step down. Tests demonstrating peak kinematics in the transverse and frontal plane during loading were selected for their link to risk of injury. Reliability proved good to excellent for all functional tests (Whatman et al., 2010).

According to another study performed by Crossley et al. (2011), there is a growing body of evidence that hip muscle function is considered a factor in the development and persistence of anterior knee pain (AKP). Two studies observed delayed onset of gluteus medius electromyography (EMG) activity in people with AKP (Brindle, Mattacola, & McCrory, 2003; Cowan, Crossley, & Bennell, 2009). Hip movement dysfunctions and strength imbalances observed during squatting can contribute to medial knee displacement (MKD) through lack of neuromuscular control in hip external rotators

and abductors. The lower leg may also manifest this problem via tibial adduction and external rotation, tightness of the gastrocnemius or soleus restricting dorsiflexion of the ankle. The requirement for ankle dorsiflexion range of motion can increase up to 25% in sport specific activities, stair climbing and sit to stand (Bell et al., 2012). A clinical assessment tool often used to determine hip muscle function is the single leg squat (SLS) (Crossley et al., 2011). The double leg squat was also considered effective by Bell et al. 2012. Crossley's study (2011) set out to determine reliability of this functional task and the relationship between AKP and gluteus medius activity. During the screening, leg dominance was determined by using the leg the participant would use to kick a ball. Criteria determining the rating on each squat included, posture of the trunk over the pelvis, posture of the pelvis, hip joint posture and movement, and knee joint posture and movement. Results showed activation of the anterior gluteus medius was delayed in people with poor single leg squat task performance. It was also indicated that the SLS has clinical utility in determining hip muscle function (Crossley et al., 2011). It's also of importance that the lack of ankle motion seen in the MKD group of Bell's 2012 study could explain the inability for athletes to perform these basic tasks (i.e. squatting, stair climbing, sport specific drills, etc.), in proper alignment.

The Functional Movement Screen

The functional movement screen (FMS) was designed to capture fundamental movements, motor control within movement patterns and competence of basic movements uncomplicated by specific skills. FMS has been purported to determine the greatest areas of movement deficiency, demonstrate limitations or asymmetries, and

eventually correlate these with an outcome (Cook, 2010). FMS was not designed to evaluate patients displaying pain in basic movement patterns. An athlete presenting pain at any point ceases the FMS and is evaluated through the SFMA (Selective Functional Movement Assessment); an alternative scale also discussed in Cook (2010).

The FMS requires strength, flexibility, range of motion, coordination, balance, and proprioception in order to successfully complete seven functional movement patterns (Kiesel, Plisky, & Voight, 2007). The first three tests, the squat, hurdle step and lunge are of primary importance and are considered fundamental tests because they represent the three essential foot positions humans utilize every day. The remaining tests include the active straight leg raise, the trunk stability push up, rotary stability and shoulder mobility, and will help refine the information gathered by the first three tests. These seven tests are put together sequentially and the interaction with one another identifies the weakest link in the pattern (Cook, 2010). The majority of screening tests are 'split pattern' except for the squat and the trunk stability push up because they are observed once from the left side of the body, and once from the right, yet evaluated together. The lesser of the scores between the left and right sides of the body are taken as the final score (O'Connor, Deuster, Davis, Pappas, & Knapik, 2011). Straight pattern tests are observed once as they require the whole body to complete the task. The functional movement screen utilizes a scoring system of zero to three. Flawless performance of a movement pattern is given a score of three. A subject will receive a score of two if they have ability to perform a functional movement but some compensation is noted. Inability to perform or complete a movement is given a one. Pain at any point in the movement is reevaluated with a score

of zero and referred to the Selective Functional Movement Assessment (SFMA).

Maximum score for the FMS is 21.

Current research suggests that a decrease in core strength may contribute to injuries of the back and extremities, and that core stability can be tested using functional movement methods (Peate et al., 2007). Fundamental movement, as defined by Mills, Taunton and Mills (2005), is the ability to produce and maintain balance between mobility and stability along the kinetic chain while performing fundamental patterns with accuracy and efficiency (Okada et al., 2011). Athletes often use compensatory movement to achieve high performance. These inadequate strategies may reinforce poor biomechanical movement patterns during their sport specific activity resulting in injury (Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010). A study by Okada, Huxel, and Nesser, (2011), was designed to determine the relationship between core stability, functional movement, and performance. Core stability and strength not only helps to prevent injuries, but is vital for human movement in producing efficient trunk and limb actions (Okada et al., 2011). The results showed no correlation between FMS and core stability, but found significant correlations between FMS and performance and core stability and performance respectively. Hodges and Richardson (1997) examined the sequence of muscle activation during whole body movements and found that some of the core stabilizers were consistently activated before any limb movements. Participants were put through a series of core stability tests coupled with the FMS consisting of all seven basic human movements. The movement screens work together to assess trunk and core strength and stability, neuromuscular coordination, symmetry of movement, flexibility,

acceleration, deceleration, and dynamic stability (Peate et al., 2007). To perform the FMS well, core stability is necessary to withstand shear forces on the spine occurring in multidirectional tasks though no significant correlations were found. This suggests that poor mobility and coordination despite strong core musculature may not be enough to perform well through the FMS. It is also possible that only minimal core strength is necessary to complete these tasks (Okada et al., 2011). Previous small studies demonstrate low FMS scores are associated with injury predictability in American football players (O'Connor et al., 2011) and female collegiate athletes (Chorba et al., 2010). Results from Kiesel et al (2007), reported that athletes with dysfunctional movement patterns are more likely to suffer a time-loss injury, but this cannot be used to establish a cause and effect relationship. It was again demonstrated that despite poor abilities in one area of the FMS, athletes were still able to perform well during other functional tasks. Grading guidelines state that if an athlete scores asymmetrically or a one or less on the in-line lunge, speed and agility training should not ensue until the movement pattern is corrected (Cook, Burton, Kiesel, Rose, & Bryant, 2010). In the study performed by Hartigan, Lawrence, Bisson, Torgerson and Knight, (2010) however, performance during the in-line lunge assessment showed no relation to balance, power, and speed.

The Balance Error Scoring System

Balance or postural control is a necessary component of activities of daily living and sport. (Bell, Guskiewicz, Clark, & Padua, 2011) The Balance Error Scoring System (BESS) was initially developed as an easy, objective, and cost effective tool for the

evaluation of postural stability in athletes after suffering a concussion. (Hunt, Ferrara, Bornstein, & Baumgartner, 2009) It has been used to investigate balance in athletes not only with concussions, but ankle injuries and varied training backgrounds. It consists of three stances: double leg stance, single leg stance, and a tandem stance, all performed with hands on hips, and eyes closed. The athlete will go through each series of stances twice; once on a firm surface, usually the ground, and once on a foam surface. Each trial is given 20 seconds and the number of errors the athlete makes during each of these stances is recorded. An error is defined as opening the eyes, lifting hands off hips, stepping, stumbling or falling out of position, lifting forefoot or the heel, abducting the hip more than 30 degrees or failing to return to the test position in more than five seconds. (Bell, Guskiewicz, Clark, & Padua, 2011) The maximum error score for any single condition is ten, the worst score for the full test is 60. Modification of the original BESS is required to ensure reliability, according to Hunt et al., (2009). Two studies were completed, one using the unchanged BESS, and one utilized a modified BESS. Any participant who had sustained a lower extremity musculoskeletal injury and/or head injury within the three months prior testing was excluded from the study. Study one found BESS to have insufficient reliability with low variances associated with double leg stance, as found in other related research (Hunt et al., 2009). Double leg stance accounted for limited variance with virtually no errors on both firm and foam surfaces. Even with double leg stance removed from the data during study one, the reliability coefficient only increased to .71 which is still below accepted levels. Poor sensitivity during baseline and post injury evaluation led Hunt and her team to perform a follow up study with a

modified BESS protocol. Hunt also believed that increasing the number of trials each participant completed would increase reliability rates. The revised protocol used four total conditions from the original testing battery: the single leg and tandem stance on firm and foam surfaces. Each athlete completed three trials of all four conditions. The new reliability coefficient was calculated to be .88 for study two (Hunt et al., 2009). Another study chose to determine reliability amongst the stances individually as well as BESS as a whole. Finnoff and his research team decided the correlation coefficient should be at least .75 for the system to be considered a reliable test. After testing, all but two stances were above .75; the single leg and tandem stances on the foam surface. However, the total intrarater reliability coefficient was .74. Results show that certain subcategories from the scoring system may be valid clinical assessments for postural stability measures but BESS as a whole, may not (Finnoff et al., 2009). This is not to say the BESS cannot be used based on two studies alone. A review of studies found reliability to be moderate to good with moderate to high validity. The articles chosen, 44 in total, analyzed a number of populations and their average errors. Scores increase with concussion, functional ankle instability, external ankle bracing, fatigue, and age. It's important to consider all aspects before testing participants (Bell, Guskiewicz, Clark, & Padua, 2011).

Conclusion

Men's ice hockey is one of the most aggressive and fastest team sports and places athletes at an extremely high risk for injury. Injuries not only occur due to direct contact with the boards or other athletes on the ice, but can occur from muscle imbalances, anatomical problems, and lack of neuromuscular control. Athletic healthcare providers

continually seek ways to prevent injuries. By identifying those athletes at risk of injury early, the appropriate protocols can be put into effect to correct abnormalities and reduce costly injuries. The only way to ensure those results become more consistent is continued study. By coupling the FMS with another commonly used screening tool, the BESS, a possible correlation is tested. This is not ignoring however, the scrutiny that the BESS receives, often times until it is modified to increase reliability. An athlete who performs poorly on one assessment would be expected to perform poorly on the other considering both require some of the same abilities. The common attributes between the two screening tools are neuromuscular control, anatomical symmetry, balance, and core stability. Sports medicine professionals seek to ensure their athletes have the best chance to perform and succeed on the playing field. Research based practice allows for up to date protocols, accurate assessment and optimal performance.

Chapter 3

Methods and Procedures

Introduction

Functional movement screening in professional sports has become increasingly more common. (Whatman, Hing, & Hume, 2011) The ability to identify altered kinematics during sport specific movement as a means to predict and prevent future injury is considered, by many, to be a vital component of the pre-participation screen. Studies have shown that a decrease in range of motion, lack of anatomical symmetry, insufficient core stability as well as reduced neuromuscular control can increase the risk of acute and overuse injury. (Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2010) Poor neuromuscular control and core instability have also been proven to impact static and dynamic balance. Research has been done continuously to contribute to the reliability and validity of sport specific screening and testing, but results repeatedly come back inconclusive.

To date, no studies have been done that compare the FMS to the BESS. Each tool has been examined for validity, but no studies analyzing any possible correlation between the two. Some of the individual screens in the FMS suggest that the main ability needed for successful completion is balance, specifically the in-line lunge and rotary stability. A goal of this study was to determine if there was a positive correlation between the BESS and each specified test respectively.

Participants

Fifteen athletes were recruited to take part in the FMS, BESS and injury correlational study. Players were chosen based on location and accessibility to the researcher. All athletes were male, ages 18-33 and currently playing for a premier 'AA' hockey team recognized by the ECHL.

Research Design

The study was a prospective correlation design. Each subject performed a battery of tests that included the seven tests of the FMS and the six conditions of the BESS. The research was approved by the Institutional Review Board at Winthrop University of Rock Hill, South Carolina. For the first hypothesis, independent variables were the FMS and BESS and the dependent variable was the scores on those screens. When analyzing a possible correlation between total FMS scores and injuries, the FMS scores were the independent variable and the injuries sustained were the dependent variable. This same model was followed when investigating a correlation between total BESS scores and injury. For hypothesis four and five, the independent variable was the score on the specific FMS screen we had selected and the total BESS scores were the dependent variables. Data were analyzed and evaluated using Pearson's Bivariate Correlations in SPSS software.

Procedures

The team and each participant agreed to voluntarily participate in this study and each participant completed an informed consent document. Medical history for all subjects was reviewed to exclude any athlete who had sustained a musculoskeletal injury

or a concussion within the last three months. Such conditions have been shown to impact performance on the FMS and BESS negatively. All professional ice hockey athletes were tested at their organization's home facilities. Athletes were briefed on FMS and given a demonstration on the movements as well as information on the BESS protocol. All participants were identified by a code to maintain anonymity. Identifying which athletes belong to which number, was kept on a locked personal computer of the researchers. All data collected throughout the study were kept in this same location.

The specific FMS protocol used was selected based upon its popularity in higher levels of professional hockey and in other professional sports. Subjects completed each of the included seven tests in the FMS; the squat, hurdle step, lunge, shoulder mobility, active straight leg-raise, push-up and rotary stability test (Kiesel et al., 2007). Each component of the FMS was scored with the following scale; three indicating the movement was completed pain free through the full range of motion with no compensations and a two demonstrates pain free range of motion but some compensation. A score of one meant the subject could not complete the movement and a zero was given when the patient experienced pain through any part of the movement. Additionally, the hurdle step, lunge, shoulder mobility, active straight leg raise, and rotary stability were scored separately for the left and right sides of the body with the lesser of the two scores recorded for the final. The maximum score possible on the FMS is 21 (O'Connor et al., 2011).

The BESS protocol utilized was identical to that developed by researchers and clinicians at the University of North Carolina's Sports Medicine Research Laboratory

(UNC Sports Medicine Laboratory, 2009). A script was provided and read to all athletes before each stance to ensure all participants received the same instruction. Participants were tested on two surfaces, a firm surface and a foam surface, while performing three stances, double leg, single leg, and a tandem stance for 20 seconds each. The foam pad measured ten inches in length, ten inches in width and two and a half inches tall. During the double leg stance, athletes stood with feet together, hands on the hips, and eyes closed. In the single leg stance the athlete lifted their dominant foot off the ground by flexing their hip to thirty degrees and their knee to forty-five. The non-dominant leg was determined by asking the patient which foot they would kick a ball with and asking them to stand on the opposite leg. Tandem stance was performed by standing heel to toe with the dominant foot as the back foot. Hands still remain on the hips with eyes closed. Errors were determined by watching for participants to open their eyes, move their hands from their hips, stumbling or falling, abduction or flexion of the hip beyond the instructed degrees, failing to return to testing position for longer than five seconds and lifting the forefoot or heel off the testing surface. The maximum total of errors during any stance is ten. Each error is assigned one point with the exception of remaining out of position for greater than five seconds. Failure to return to the instructed position receives the maximum ten points. The total score is calculated by adding up all error points from all six stances.

After all FMS and BESS scores were recorded, the head athletic trainer for the team kept a record of all injuries that occurred throughout the season and reported the injuries to the primary researcher. An injury was operationally defined as any event that

kept an athlete out of practice or game or required attention of the team physician (Molsa et al., 1997; Tyler et al., 2001; Noyes, Lindenfeld, & Marshall, 1988). Information about when the injury transpired, during a practice or a game along with what period or about how far into practice the athlete was, was given to the researcher. Also included, were details about the injury and follow-ups on how long the athlete was under restricted activity. The head athletic trainer was asked to send an updated injury report every Monday. The injury report explained any new injuries that may have occurred throughout the week as well as updates for those athletes with previous injuries.

Chapter 4

Results

Of the 15 players who participated in testing, eight were cut, released, traded, or moved up to the AHL by the conclusion of the 2014-2015 season. Data were still recorded for their FMS and BESS scores and any injuries sustained while with the tested team. No athletes were contacted following their absence to inquire about injuries sustained. All analysis conducted were two-tailed Pearson bivariate correlations with mean and standard deviation data completed. Comparative means paired sample T-tests were run when analyzing total FMS scores and total BESS scores, high total FMS scores and injury rates, and low total BESS scores and injury rates.

Hypothesis #1: There will be a positive correlation between total FMS scores and total BESS scores.

There was no significant correlation between total FMS scores ($M = 16.00$, $SD = 1.48$, $N = 12$), and total BESS scores ($M = 17.27$, $SD = 6.34$, $N = 15$), $r = 0.14$ and $p = 0.67$. Athletes who performed well on the FMS were not equally able to perform well on the BESS.

Hypothesis #2: The BESS will serve as a helpful predictor for injury.

The BESS, ($M = 17.27$, $SD = 6.34$, $N = 15$), showed a trend toward injury prediction but was not statistically significant. Of 13 possible subjects, ($M = 0.38$, $SD = .506$, $N=13$), only five athletes sustained a lower body injury, ($r = 0.52$, $p = 0.071$) and no subjects sustained an upper body injury.

Hypothesis #3: The FMS test will serve as a helpful predictor for injury.

The FMS, (M = 16.00, SD = 1.48, N = 12), proved similar in that it was not a significant predictor of injury, ($r = -0.24$, $p = 0.45$). According to our findings, FMS and BESS should not be used individually or combined to predict injury in at risk athletes.

Hypothesis #4: Scores on the rotary stability screen will have a positive correlation with total BESS scores.

The FMS analyzes rotary stability by requiring an athlete to balance on only one arm and one leg after beginning in a quadruped position and to use their core strength to score well. However, there was no significant correlation found between the FMS rotary stability scores (M = 2.15, SD = 0.38, N = 13), and total BESS scores (M = 17.27, SD = 6.34, N = 15) $r = .37$, $p = 0.22$. This demonstrates that balance alone is not an indicator of an athlete's ability to complete the rotary stability screen.

Hypothesis #5: There will be a positive correlation between the in-line lunge screen and total BESS scores.

Lastly, considering the in-line lunge test of the FMS requires balance to score well, scores on this screen (M = 2.25, SD = .45, N = 12) and total BESS scores (M = 17.27, SD = 6.34, N = 15) were analyzed for correlations. No significant correlations were found between the two variables, ($r = .49$, $p = .10$). Again, this indicates that balance is not the only necessary component to completing the inline-lunge and scoring well.

Chapter 5

Discussion

The purpose of this study was to determine whether the FMS was correlated to performance on the BESS, whether the FMS or the BESS could be used to predict injuries, if total BESS scores correlated to the rotary stability screen in the FMS, and if total BESS scores correlated with the in-line lunge screen within the FMS.

None of the analyses yielded significant findings. It was hypothesized that if high scores were achieved on the FMS, correlation would leave the subject performing well, meaning receiving a low score on the BESS. The scores on the FMS were not correlated with the scores of the BESS. Athletes showed that to complete one screening tool well, they did not need to perform well on the other. It was also found that neither the FMS, nor the BESS, individually or combined, were significant predictors of injuries in the selected population. Injuries were recorded for athletes who performed well and those who performed poorly on both tests. The two individual screens taken from the FMS to test correlation with the BESS did not prove significant. It was hypothesized that because both the rotary stability screen and the in-line lunge require a great amount of balance and core stability, the BESS scores would correlate with the individual screens. These findings suggest that other components are necessary, or perhaps more significant, in the ability of the athlete to perform the tests well other than balance.

The results for the first hypothesis were similar to those of Okada et al. (2011). The study put participants through a number of functional movement screens, core stability tests, and performance tests and found no significant correlation between FMS and core stability. Our findings also support those of Zemkova, (2014), who found that

despite an increase in postural sway, athletes were able to perform sport specific tasks well. All of this data would suggest that despite a strong core, success on the FMS might not be obtained. It is also possible that only minimal core strength is necessary to perform well (Okada et al., 2011). A hockey player's balance is much more dynamic than static which could also explain why subjects performed well on the FMS and not the BESS. The FMS gave participants a screen more closely related to their sport specific movements.

The literary research that supports hypothesis number one also supports our finding for hypothesis four and five; that there was no significant correlation between total BESS score and score on the rotary stability screen and score on the in-line lunge respectively.

There was an overwhelming amount of previous research that suggested a score of less than 14 on the FMS was a predictor of injury (Chorba et al., 2010). One of the implications of our study was our small population size and having only one score under the 14 mark. However, athletes scoring higher than 14 sustained injuries throughout their season still leading to our conclusion that FMS is not a predictor of injury.

Contradictory in the literature, McGuine (2000) tested whether balance was a predictor of ankle sprains in basketball players. He used a modified Rhomberg's test which is similar in some ways to the BESS. After collecting data and recording incidence of injury, athletes who sustained an ankle injury had performed poorly on the pre-season balance test. Again, results in our study showed no significant correlations between the BESS and

injury meaning that an athlete's ability on the BESS alone does not mean they are at an increased risk for sustaining musculoskeletal injury.

As mentioned, the lack of correlation found in the present study may have been predicated on the small sample size. Having a more diverse and larger subject pool could have allowed some of the correlations that were close to showing significance that opportunity to do so. Although all FMS grading was done by one researcher, lack of experience with the test and procedure may have altered results. A more experienced FMS scorer would increase the validity and reliability of the FMS data. Providing athletes with practice trials and warm up trials would also prove beneficial. All trials in this study were recorded for analysis. Athletes and participants in any study would perform better with practice and this may positively affect results in a similar study. In regards to warm up, some data was recorded prior to a team practice and some was recorded after. Some athletes then had the opportunity to warm up possibly aiding their FMS results. It is to be said as well then that fatigue could have played an important role in poor scores. In the future, all recording should be done at the same time to provide parallel conditions for all participants.

Future research should include player demographics for more detailed analysis. It is possible that significant correlations would be found in particular age, weight, or height ranges as well as based on years of experience opposed to the entire population. Similar research studies should be conducted using a modified BESS as the literature has shown higher reliability and validity scores with these models. Strength differences should also be investigated considering strength imbalances between propulsive, stabilizing and

decelerator muscles has been shown to be a mechanism for adductor strains (Tyler et al., 2001). Research should also be done to examine whether a certain score on the BESS serves as a predictor of injury.

Appendices

Appendix A

IRB #

TO BE COMPLETED BY SPAR

Winthrop University

REQUEST FOR REVIEW OF RESEARCH INVOLVING HUMAN SUBJECTS Institutional Review Board

<p>RESEARCHER of RECORD: Jamie Perry COLLEGE/DEPARTMENT: College of Education PHONE NUMBER: HOME: WORK: 3232129 (6630) EMAIL: perryj13@winthrop.edu CELL PHONE: [REDACTED] ADDRESS: [REDACTED] [REDACTED]</p> <p>STATUS: <input type="checkbox"/> Faculty or Staff <u>(If a student, complete faculty advisor section)</u> <input checked="" type="checkbox"/> Graduate Student <input type="checkbox"/> Undergraduate Student</p>	<p>CO-RESEARCHERS:</p> <p>FACULTY ADVISOR: Dr. Alice McLaine ADVISOR PHONE: HOME: WORK: 3232177 (2177)</p> <p>EMAIL: mclainea@winthrop.edu CELL PHONE: ADDRESS:</p>
<p>TITLE OF RESEARCH:</p>	
<p>DATES OF THE RESEARCH PROJECT:</p> <p>Approval Requested for Start Date: 9/1/2014 (The requested start date should be at least 2 weeks after the next scheduled meeting of the IRB)</p> <p>End Date: 9/1/2015 (Maximum of one year; must be renewed annually)</p>	
<p>IS THIS RESEARCH BEING FUNDED BY RESEARCH GRANT?</p> <p><input type="checkbox"/> YES; Sponsor: <input type="checkbox"/> Funding Applied for; Sponsor:</p>	

<input checked="" type="checkbox"/> NO	
1.	<p><input checked="" type="checkbox"/> Yes <input type="checkbox"/> No Is this activity being carried out by student as a classroom assignment to be reviewed by the faculty member.</p> <p><input checked="" type="checkbox"/> Yes <input type="checkbox"/> No Will the information gathered or developed in this activity be used in a presentation or publication outside of the classroom?</p> <p>If you checked yes to both questions above, please explain how the information will be used outside of the classroom: This information will be used outside the classroom only if the research is published or as a presentation.</p>
2.	<p>INDICATE THE TYPES OF MEMBERS OF THE RESEARCH TEAM WHO WILL HAVE DIRECT CONTACT WITH HUMAN SUBJECTS:</p> <p><input type="checkbox"/> FACULTY MEMBER <input type="checkbox"/> STAFF MEMBER <input type="checkbox"/> UNDERGRADUATE STUDENT <input checked="" type="checkbox"/> GRADUATE STUDENT <input type="checkbox"/> OTHER; SPECIFY:</p>
3.	<p>A. BRIEFLY DESCRIBE THE PURPOSE OF THE RESEARCH IN NON-TECHNICAL LANGUAGE: The purpose of this study is to investigate correlations between a functional movement screen and a balance test as a means to predict injuries in at risk, professional, male, ice hockey, athletes. There has been no research discovered to date, looking into correlations between the two tests. With functional movement screening becoming increasingly popular in professional athletics, it is important, we as clinicians are using the most up to date, reliable, and valid tools with our athletes.</p> <p>B. DESCRIBE RESEARCH PROTOCOL OR METHODOLOGY TO BE USED: Before screening, athletes will be briefed on all movements tested during the FMS as well as procedures for the BESS and scoring for both. Medical histories will be reviewed for past or present injury. All participants who have suffered a concussion, musculoskeletal, or ligamentous injury within the last three months to the present will be excluded from participating. For this study, an injury was defined as any event that kept an athlete from any percentage of practice, a game, and/or required attention from a physician. Each movement for the FMS will be completed by all participants before BESS testing will begin. After both protocols are finished by all athletes, scores will</p>

	<p>be analyzed and at risk athletes will be identified by the researcher only. FMS scores will not be distributed or shown following testing to the administration, medical staff, or athletes of each organization. BESS scores may be shared with medical staff only because each organization may have chosen to have each athlete perform the BESS anyway, even if the study was not being conducted. These aspects of the protocol are to be ensure all participants proceed through their season doing everything they would normally do; no extra workouts, no additional specified strengthening exercises, etc. All injuries will be reported directly from the head athletic trainer to the researcher and updated on progress weekly. No reporting of data can be used against the athlete in either his own organization or from future employers. Data collected is not vital to their career standing nor does it show an accurate account of each participants athletic ability.</p>
4.	<p>EXPLAIN BRIEFLY BUT COMPLETELY WHAT TASKS OR ACTIVITIES THE SUBJECTS IN THIS RESEARCH WILL BE DOING [If a survey/questionnaire is to be used, state how many questions will be asked and the expected time to complete the survey]: The functional movement screen (FMS): includes seven patterns to which each athlete must perform; the squat, hurdle step, the lunge, an active straight leg raise, the trunk stability push up, rotary stability and shoulder mobility. Each is scored on a ranking system, and given a score of 3-0. Three means the movement pattern was completed with unquestioned ability and a two, the ability to perform a functional movement is there but some compensation is noted. Inability to perform or complete receives a score of one and lastly, pain at any degree is given a score of zero. The BESS consists of three stances: double leg stance, single leg stance, and a tandem stance, all performed with hands on hips, feet together and eyes closed. The athlete will go through each series of stances twice; once on a firm surface, usually the ground, and once on a foam surface. Each trial is given 20 seconds and the number of errors the athlete makes during each of these stances is recorded. An error is defined as opening the eyes, lifting hands off hips, stepping, stumbling or falling out of position, lifting forefoot or the heel, abducting the hip more than 30 degrees or failing to return to the test position in more than five seconds. The maximum score for any single condition is ten meaning the max score for the full test is 60.</p>
5.	<p>DESCRIBE SUBJECTS FOR THIS RESEARCH, INCLUDING A STATEMENT OF WHO WILL BE RECRUITED AND THE ANTICIPATED POPULATION SIZE: Subjects will include East Coast Hockey League (ECHL) ice hockey athletes from the surrounding area. The researcher is talking with the athletic trainers and front office staff from those teams and discussing the study. Upon approval, the researcher will visit each teams home arena for a 'testing</p>

	day' where all testing will be completed on those athletes who sign the consent agreement.																					
	<p>DO YOUR SUBJECTS INCLUDE ANY OF THE FOLLOWING:</p> <table border="0"> <tr> <td><input type="checkbox"/> Yes</td> <td><input checked="" type="checkbox"/> No</td> <td>Infants and children younger than 7 years?</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td><input checked="" type="checkbox"/> No</td> <td>Institutionalized mentally impaired people?</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td><input checked="" type="checkbox"/> No</td> <td>Students enrolled in your own classes?</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td><input checked="" type="checkbox"/> No</td> <td>Students enrolled at Winthrop University?</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td><input checked="" type="checkbox"/> No</td> <td>Prisoners?</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td><input checked="" type="checkbox"/> No</td> <td>Other special populations? Specify -</td> </tr> </table>	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	Infants and children younger than 7 years?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	Institutionalized mentally impaired people?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	Students enrolled in your own classes?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	Students enrolled at Winthrop University?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	Prisoners?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	Other special populations? Specify -			
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6.	DESCRIBE HOW SUBJECTS WILL BE RECRUITED FOR THIS RESEARCH: Subjects will be asked by the researcher to participate.																					
7.	HOW WILL YOU ASSURE THAT PARTICIPATION OF THE SUBJECTS IS VOLUNTARY? Subjects will receive a consent and debriefing form. By signing the consent form, they agree to participate with the understanding that they can withdraw from the study at any time without penalty.																					
8a.	<p>CAN THE HUMAN SUBJECT BE DIRECTLY IDENTIFIED BY: <i>(For any responses of "yes" indicate in the space provided how the subject's privacy will be protected.)</i></p> <table border="0"> <tr> <td><input type="checkbox"/> Yes</td> <td rowspan="2">Name on Response form;</td> </tr> <tr> <td><input checked="" type="checkbox"/> No</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td rowspan="2">Photograph:</td> </tr> <tr> <td><input checked="" type="checkbox"/> No</td> </tr> <tr> <td><input checked="" type="checkbox"/> Yes</td> <td rowspan="2">Television/VCR/DVD tapes: Participants will be video recorded performing the FMS. Tapes will be kept locked up at the researcher's home. Viewing of each tape for scoring purposes will occur only with members of the research team present. No tapes or health information will be released to anyone outside of the research team or to any persons outside of the medical staff for each participant's organization.</td> </tr> <tr> <td><input type="checkbox"/> No</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td rowspan="2">Audiotape:</td> </tr> <tr> <td><input checked="" type="checkbox"/> No</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td rowspan="2">Coded Research Forms:</td> </tr> <tr> <td><input checked="" type="checkbox"/> No</td> </tr> <tr> <td><input type="checkbox"/> Yes</td> <td rowspan="2">Detailed Biographical Data:</td> </tr> <tr> <td><input checked="" type="checkbox"/> No</td> </tr> <tr> <td><input checked="" type="checkbox"/> Yes</td> <td rowspan="2">Informed Consent, Assent or Parental Permission forms: Consent forms will be kept with the recordings of the FMS at</td> </tr> <tr> <td><input type="checkbox"/> No</td> </tr> </table>	<input type="checkbox"/> Yes	Name on Response form;	<input checked="" type="checkbox"/> No	<input type="checkbox"/> Yes	Photograph:	<input checked="" type="checkbox"/> No	<input checked="" type="checkbox"/> Yes	Television/VCR/DVD tapes: Participants will be video recorded performing the FMS. Tapes will be kept locked up at the researcher's home. Viewing of each tape for scoring purposes will occur only with members of the research team present. No tapes or health information will be released to anyone outside of the research team or to any persons outside of the medical staff for each participant's organization.	<input type="checkbox"/> No	<input type="checkbox"/> Yes	Audiotape:	<input checked="" type="checkbox"/> No	<input type="checkbox"/> Yes	Coded Research Forms:	<input checked="" type="checkbox"/> No	<input type="checkbox"/> Yes	Detailed Biographical Data:	<input checked="" type="checkbox"/> No	<input checked="" type="checkbox"/> Yes	Informed Consent, Assent or Parental Permission forms: Consent forms will be kept with the recordings of the FMS at	<input type="checkbox"/> No
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<input type="checkbox"/> Yes	Photograph:																					
<input checked="" type="checkbox"/> No																						
<input checked="" type="checkbox"/> Yes	Television/VCR/DVD tapes: Participants will be video recorded performing the FMS. Tapes will be kept locked up at the researcher's home. Viewing of each tape for scoring purposes will occur only with members of the research team present. No tapes or health information will be released to anyone outside of the research team or to any persons outside of the medical staff for each participant's organization.																					
<input type="checkbox"/> No																						
<input type="checkbox"/> Yes	Audiotape:																					
<input checked="" type="checkbox"/> No																						
<input type="checkbox"/> Yes	Coded Research Forms:																					
<input checked="" type="checkbox"/> No																						
<input type="checkbox"/> Yes	Detailed Biographical Data:																					
<input checked="" type="checkbox"/> No																						
<input checked="" type="checkbox"/> Yes	Informed Consent, Assent or Parental Permission forms: Consent forms will be kept with the recordings of the FMS at																					
<input type="checkbox"/> No																						

	<input type="checkbox"/> Yes <input type="checkbox"/> No	the researcher's private home and not accessed after they have been signed. Other:
8b.	If you checked yes to any item in 8a; then: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	Will personally identifiable data be shared with others outside of this research team? If you checked yes, please explain.
9.	<p>THE RESEARCHER SHALL MAKE EVERY POSSIBLE ATTEMPT TO MAINTAIN CONFIDENTIALITY OF THE RESEARCH AND THE HUMAN SUBJECTS. IF FOR SOME REASON, THE RESPONSES, INFORMATION, OR OBSERVATIONS OF THE SUBJECT BECAME KNOWN TO PERSONS OTHER THAN THE RESEARCHERS, COULD THIS INFORMATION POTENTIALLY PLACE THE SUBJECT AT RISK OF:</p> <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	DAMAGE TO HIS/HER FINANCIAL STANDING? DAMAGE TO HIS/HER PRESENT OR FUTURE EMPLOYABILITY? CRIMINAL OR CIVIL LIABILITY? PSYCHOLOGICAL/EMOTIONAL PROBLEMS? EXPLAIN ANY "YES" ANSWERS AND STEPS THAT HAVE BEEN TAKE TO MINIMIZE RISK:
10.	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	ARE ANY OF THE TECHNIQUES LISTED BELOW INVOLVED IN THE RESEARCH? INVASIVE MEDICAL PROCEDURES? NON-INVASIVE MEDICAL PROCEDURES? STRENUOUS EXERCISE? OTHER PHYSICAL TESTING EXPLAIN ANY "YES" ANSWERS AND STEPS THAT HAVE BEEN TAKE TO MINIMIZE RISK: The FMS and BESS require athletes to perform certain tests and movements but none have been deemed strenuous.

11a	<p>DESCRIBE HOW LEGALLY EFFECTIVE INFORMED CONSENT WILL BE OBTAINED AND ATTACH A COPY OF THE CONSENT FORM. IF MINORS ARE TO BE USED AS RESEARCH SUBJECTS, DESCRIBE PROCEDURES USED TO GAIN CONSENT OF THEIR PARENT(S), GUARDIAN(S), OR LEGAL REPRESENTATIVE(S). Consent forms will be obtained on the day testing will ensue. Forms will be distributed to all potential participants prior to test day and will be reviewed by researcher prior to testing so that any questions may be answered. Any athletes who wish to participate will turn in their signed forms to the researcher personally.</p>
11b	<p>WAIVER OF SIGNED INFORMED CONSENT REQUIREMENT</p> <p>TO REQUEST A WAIVER OF A SIGNED INFORMED CONSENT, COMPLETE THE FOLLOWING:</p> <p><input type="checkbox"/> The only record linking the subject and the research would be the consent document, and the principal risk will be potential harm resulting from a breach of confidentiality. Each subject will be asked whether the subject wants documentation linking the subject with the research, and the subject's wishes will govern. Section 46.117(c)1</p> <p><input type="checkbox"/> The research presents no more than minimal risk of harm to the subjects, and involves no procedures, for which written consent is normally required outside of the research context. Section 46.117(c)2</p> <p><input type="checkbox"/> The research or demonstration project is to be conducted by or subject to the approval of state or local government officials and is designed to study, evaluate, or otherwise examine (i)public benefit or service programs; (ii)procedures for obtaining benefits or services under these programs; (iii)possible changes in or alternatives to those programs or procedures; or (iv)possible changes in methods or levels of payment for benefits or services under those programs; and the research could not practicably be carried out without the waiver or alteration. Section 46.116(c)</p> <p><input checked="" type="checkbox"/> The research involves no more than minimal risk to the subjects, the waiver will not adversely affect the rights and welfare of the subjects, the research could not practicably be carried out without the waiver, and whenever appropriate, the subjects will be provided with additional pertinent information after participation. Section 46.116(d)</p>

	<p>In cases where the documentation requirement is waived, the IRB may require the investigator to provide subjects with a written statement regarding the research.</p>	
12.	<p>STORAGE AND DISPOSAL OF DATA AND OTHER RESEARCH MATERIALS:</p> <p>A. How and where will the data and other research material be stored until no longer needed? The researcher's home.</p> <p>B. When will the disposal of data and research materials take place? Five years after research is completed, all research records will be terminated.</p> <p><i>At a minimum, investigators must maintain research records for at least three (3) years after completion of the research. All records must be accessible for inspection and copying by authorized representatives of the IRB, any federal department or agency supporting the research, and sponsor, if any. (Source: 45CFR46.115) If the Principal Investigator is a student, then the faculty advisor will be responsible for the record retention. If you are a member of a professional association or society, you may be required by their practices to keep records longer than 3 years.</i></p> <p>C. How will data and research materials be disposed ? All data and research records will be shredded or set to fire to be sure no information can be re-obtained by unauthorized personnel.</p>	
13.	<p>INDICATE ON THE CHECK LIST BELOW, ANY DOCUMENTS THAT APPLY TO YOUR RESEARCH AND ATTACH TO THIS PROTOCOL A COPY OF THE APPLICABLE DOCUMENT.</p> <p><input type="checkbox"/> SURVEY INSTRUMENT AND/OR INTERVIEW QUESTIONNAIRE</p> <p><input checked="" type="checkbox"/> INFORMED CONSENT AGREEMENT</p> <p><input type="checkbox"/> PARENTAL OR GUARDIAN PERMISSION FOR A MINOR CHILD</p> <p><input type="checkbox"/> ASSENT TO PARTICIPATE IN A RESEARCH STUDY (AGES 7-14)</p> <p><input type="checkbox"/> ASSENT TO PARTICIPATE IN A RESEARCH STUDY (AGES 15 – 17)</p> <p><input type="checkbox"/> COPIES OF ANY OTHER MAIL TO BE DELIVERED TO</p> <p><input checked="" type="checkbox"/> SCRIPTS OF VERBAL INSTRUCTIONS, ETC.</p>	
14.	<p><input type="checkbox"/> Yes <input checked="" type="checkbox"/> No</p>	<p>DO YOU CONSIDER THIS RESEARCH EXEMPT FROM REVIEW BY THE HUMAN SUBJECTS COMMITTEE? IF YES, Please check the reason for exemption from the list below:</p>

a.	<input type="checkbox"/>	Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (a) research on regular and special education instructional strategies; or (b) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods [45CFR46(b)(1)]
b.	<input type="checkbox"/>	<p>Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement) survey procedures, interview procedures or observation of public behavior, unless (a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (b) any disclosure of the human subjects' responses outside the research could reasonably place the subject at risk of criminal or civil liability or be damaging to the subjects' financial standing , employability or reputation. [45CFR46(b)(2)]</p> <p>Research involving children (subjects that have not attained the age of 18 years) is not exempt under this category unless the research involves only the observation of public behavior and the researchers do not participate or impact the activities being observed. [45CFR46.401(b)]</p>
c.	<input type="checkbox"/>	Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior if (a) the human subjects are elected or appointed public officials or candidates for public office; or (b) federal statute(s) without exemption that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter. [45CFR46(b)(3)]
d.	<input type="checkbox"/>	Research involving the collection study of existing data, documents, records, pathological specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. [45CFR46(b)(4)]
e.	<input type="checkbox"/>	Research and demonstration projects which are conducted by or subject to the approval of a Federal department or agency heads, and which are designed to study, evaluate, or otherwise examine; (a) public benefit or service programs of Federal programs; (b) procedures for obtaining benefits or services under those Federal programs; (c) possible changes in methods or alternatives to those Federal programs or procedures; or (d) possible changes in methods or levels of payment for benefits or services under those Federal programs. [45CFR46(b)(5)]
f.	<input type="checkbox"/>	Taste and food quality evaluation and consumer acceptance studies, (a) if wholesome foods without additives are consumed; or (b) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or

	the Food Safety and Inspection Service of the U.S. Department of Agriculture. [45CFR46(b)(6)]
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Certifications

By my signature below, I certify that each of the named co-researchers has accepted his/her role in this study. I agree to not begin any research activity on this study until written approval by the IRB has been received. I agree to a continuing exchange of information with the Institutional Review Board (IRB). I agree to obtain IRB approval before making any changes or additions to the project. I will provide progress reports at least annually, or as requested. I agree to report promptly to the IRB all unanticipated problems or serious adverse events involving risk to human subjects. A copy of the informed consent will be given to each subject and the signed original will be retained in my files, unless a waiver of a signed informed consent has been granted.

I further certify that I have successfully completed the following Human Subjects Training Course:

- CITI – Biomedical Research Investigator
- CITI – Social and Behavioral Research Investigator
- CITI – Undergraduate Researcher
- CITI – IRB Member

Signature of Researcher

Date

By my signature below, I certify that I have reviewed this research study and agree to counsel the student researcher in all aspects of the research study.

I further certify that I have successfully completed the following Human Subjects Training Course:

- CITI – Biomedical Research Investigator
- CITI – Social and Behavioral Research Investigator
- CITI – IRB Member

If Student Researcher; Signature of Faculty Advisor

Date

Approval by Department Chair of Researcher of Record <i>(Dean, if Chair is the Researcher or if Chair is otherwise unable to review.)</i>	
I have reviewed this research study. I believe the research is sound, that the study design and methods are adequate to achieve the study goals, and that there are appropriate resources (financial and otherwise) available to the researcher. I support the study, and hereby submit it for further review by the IRB.	
_____ <i>Signature of Department Head or Dean</i>	_____ <i>Date</i>

Note: Do not use personal home addresses and phone numbers on Informed Consent, Assent, Parental Permission or Debriefing statements.

Appendix B
Debriefing Form

Thank you for participating in our Correlations between FMS, BESS, and Injury study!

The purpose of this study is to look and see if there are links between the scores on a functional movement screen (FMS) and the Balance Error Scoring System test (BESS). From there, compare scores found between the two tests to see if they can help us identify athletes that might be at risk for injury and what that injury could be. Studies have shown that not having full range of motion, differences between the left and right side of the body, and bad control over muscles, nerves and stabilizing the body can increase the risk of both short and long term injuries. Poor muscle control and core instability have been proven to impact balance. Research has been done over and over again to make sure sport specific screening and testing, tests what it is supposed to and that we get the same results every time. Conclusions from this research always give us mixed answers. There has been a lot of research investigating the FMS as a screening tool as well as for the BESS test by themselves but as of now, no studies have been done or found that look at the FMS and the BESS together.

If you are interested in learning the results of this study, please contact the researchers after May 2015.

Researchers:

Jamie Perry: perryj13@winthrop.edu

If you have any concerns regarding this study, please contact the faculty advisor or the Director of Sponsored Programs and Research.

Faculty Advisor:
Research:

Dr. Alice McLaine
803-323-2177 ext.2177
mclainea@winthrop.edu

Sponsored Programs &

Teresa Justice, Director
(803) 323-2460
justicet@winthrop.edu

Appendix C
Winthrop University
Informed Consent Agreement

Researcher: Jamie Perry Graduate Student Undergraduate Student

Faculty Advisor: Dr. Alice McLaine Faculty Advisor's Position: Assistant Professor
Sport and Human Performance

Title of Study: Correlations Between FMS, BESS, and Injury

You are invited to take part in a research study. Before you decide to be a part of this study, you need to understand the risks and benefits. This consent form provides information about the research study. I will be available to answer your questions and provide further explanations. If you take part in this research study, you will be asked to sign this consent form. Your decision to take part in this study is voluntary. You are free to choose whether or not you will take part in the study. If you should decide to participate, you may withdraw from the study at any time.

Purpose of the research study:

...to investigate correlations between the scores on a functional movement screen (FMS) and the Balance Error Scoring System test (BESS). From there, compare scores found between the two tests to see if they can aid in the identification of at risk athletes and the prediction of injury.

Procedures or methods to be used in the study:

Before screening, you will be briefed on all movements tested during the FMS and how you will be scored, as well as procedures for the BESS. Your medical history will be reviewed for past or present injury. All participants who have suffered a concussion, musculoskeletal, or ligamentous injury within the last three months to the present will be excluded from participating. For this study, an injury was defined as any event that kept an athlete from any percentage of practice, a game, and/or required attention from a physician. Each movement for the FMS will be completed by all participants before BESS testing will begin. After both protocols are finished by all athletes, scores will be analyzed and at risk athletes will be identified. You will not be informed of your scores. This is to ensure all participants proceed through their season doing everything they would normally do; no extra workouts, no additional specified strengthening exercises, etc. All injuries will be reported directly from the head athletic trainer to the researcher and updated on progress weekly.

Possible Risks/Benefits Associated with Participating in Study:

Risks:

-strained muscles
of ice hockey

Benefits:

- adding to research that can only help the sport

Possible Costs/Compensation Associated with Participating in Study:

Costs: Time

Compensation: 0

Number of questions in the survey/questionnaire and anticipated time to complete the survey/questionnaire: N/A**Right to withdraw from the study:**

All participants have the right to withdraw from the study at any time without penalty.

Privacy of records or other data collected in the study:

The only persons with access to recorded data and information will be the researcher, appropriate faculty and staff at Winthrop University, and the medical staff of your organization.

Questions – contact information:

If you have any questions about this study, you may contact me using my Winthrop email account: perryj13@winthrop.edu

Or through my faculty advisor:

Address: 1162 Eden Terrace, Rock Hill SC 29733

Work Phone: (803) 323-2177 ext.2177

Email: mclainea@winthrop.edu

You may also contact:

Teresa Justice, Director

803-323-2460 justicet@winthrop.edu

Sponsored Programs and Research

Winthrop University

Rock Hill, SC 29733

Signatures:

By signing this consent agreement, you agree that you have read this informed consent agreement, you understand what is involved, and you agree to take part in this study. You will receive a copy of this consent form.

Signature of Participant_____
Date_____
Signature of Researcher_____
Date

Appendix D
FMS Screening Tool



Appendix E

FMS Dialog and Instructions

1. Deep Squat (DS)-Instructions

- Hold the dowel on top of your head with your elbows at 90 degrees of flexion.
- Press the dowel overhead and keep the elbows in full extension.
- Place your feet shoulder width apart.
- Keep your toes pointed forward at all times.
- Keep an upright posture and keep the dowel over your head.
- Descend into a deep squat in order for your thighs to break parallel with the floor.
- Return to the starting position.
- For a 2 and 1, put the patient's heels on the board

2. HS Instructions

- Position the string so it is at the level of the tibial tuberosity.
- Record this length for the ILL test.
- Place the dowel across the shoulders.
- Stand with your feet together and your toes touching the hurdle.
- Keep an upright posture and step over the hurdle without touching the string.
- Touch the floor with your heel and return to the starting position.
- Left and Right foot each have 3 trials.
- Score the leg that is moving over the hurdle.

3. ILL—Instructions

- Place the back (right) foot toe on the zero.
- Place the heel of the other (left) front foot on the distance of the tibia.
- Use the measurement taken in the HS for the tibia length.
- If the left foot is forward, the right arm is up and left arm is down.
- Put the right hand on the dowel in the Cx lordosis and the left hand on the dowel in the Lx lordosis.

4. SM—Instructions

- Measure the distance between the distal wrist crease to the tip of the 3rd finger.
- Have the patient stand with feet shoulder width apart.
- Place the thumbs in the fists.
- Move one UE into IR and the other into ER.
- Make sure there is a smooth motion (no creeping the arms into place).
- The tester measures the distance between the two hands (the two closest bony prominences).

4. SM—Verbal Instructions to the patient

- Make a fist with the thumbs tucked in the fist.
- In a single motion, place your R fist over your head on to your back and your left fist behind your back, attempting to touch the fists.
- Do not move your hands closer after their initial placement.

- Test the opposite arm.
- The arm up is the testing arm on the recording sheet.

5. ASLR--Instructions

- Lie supine with the arms in an anatomical position (palms up) with the head flat on the floor.
- The board is placed under the knees.
- ID the mid-point between the ASIS and the mid-patella.
- Place the dowel at this point perpendicular to the ground.
- Instruct the athlete to lift the test leg with a DF ankle and an extended knee.
- The opposite knee must remain in contact with the board, the DF ankle must stay up toward the ceiling (no ER of the hip), and the head must stay flat on the ground.
- Once the end-range position is achieved, the lateral malleolus is located.
- If the malleolus passes the dowel, the score is a 3.
- If the malleolus cannot pass the dowel, then realign the dowel.
- Place the dowel between mid-thigh and mid-patella.
- If the malleolus passes the dowel now, the score is a 2.
- If the malleolus cannot pass the dowel placed at the mid-patella, a score of a 1 is given.

6. TSPU--Instructions

- Prone with feet together, toes on the ground
- Arms start overhead
- Bring thumbs down to the forehead
- Knees are fully extended, ankles DF.
- Perform one push-up.
- The body should be lifted as a unit.
- There should be no lag in the lumbar spine.

6. TSPU--Instructions

- If the athlete cannot perform this correctly, move the hands down to the chin
- Make sure original hand position is maintained and then hands do not slide down when the athlete prepares to lift.
- Make sure the chest and stomach come off the floor at the same instance.
- Give the verbal cue to maintain a rigid torso, raise yourself as one unit with no lag in the low back up into a push-up position.

7. RS--Instructions

- Start in a quadruped position with the shoulders and hips at 90 degrees relative to the torso.
- The knees are at 90 degrees of flexion and the ankles are DF.
- Put the board between the knees and hands so they contact the board.
- Shoulder flexion and hip extension on one side.
- Raise up 6 inches off the board.
- The elbow, hand, and knee should all remain in line with the board.
- The torso should also remain in the same plane as the board.

- The same shoulder is extended and the knee is flexed so the elbow and knee touch over the board.
- The shoulder is flexed and the hip is extended and then placed back to the starting position.
- If this cannot be completed, move to the diagonal position and retest.
- Score the UE side

Appendix F

FMS Score Sheet

FMS

THE FUNCTIONAL MOVEMENT SCREEN

SCORING SHEET

NAME	DATE	DOB
ADDRESS		
CITY, STATE, ZIP	PHONE	
SCHOOL/AFFILIATION		
SSN	HEIGHT	WEIGHT
PRIMARY SPORT		PRIMARY POSITION
HAND/LEG DOMINANCE		PREVIOUS TEST SCORE

TEST	RAW SCORE	FINAL SCORE	COMMENTS
DEEP SQUAT			
HURDLE STEP	L		
	R		
INLINE LUNGE	L		
	R		
SHOULDER MOBILITY	L		
	R		
IMPINGEMENT CLEARING TEST	L		
	R		
ACTIVE STRAIGHT-LEG RAISE	L		
	R		
TRUNK STABILITY PUSHUP			
PRESS-UP CLEARING TEST			
ROTARY STABILITY	L		
	R		
POSTERIOR ROCKING CLEARING TEST			
TOTAL			

Raw Score: This score is used to denote right and left side scoring. The right and left sides are scored in five of the seven tests and both are documented in this space.

Final Score: This score is used to denote the overall score for the test. The lowest score for the raw score (each side) is carried over to give a final score for the test. A person who scores a three on the right and a two on the left would receive a final score of two. The final score is then summarized and used as a total score.

Appendix G

Balance Error Scoring System Protocol

Balance Error Scoring System (BESS)

Developed by researchers and clinicians at the University of North Carolina's Sports Medicine Research Laboratory, Chapel Hill, NC 27599-8700

The Balance Error Scoring System provides a portable, cost-effective, and objective method of assessing static postural stability. In the absence of expensive, sophisticated postural stability assessment tools, the BESS can be used to assess the effects of mild head injury on static postural stability. Information obtained from this clinical balance tool can be used to assist clinicians in making return to play decisions following mild head injury.

The BESS can be performed in nearly any environment and takes approximately 10 minutes to conduct.

Materials:

1) Testing surfaces

-two testing surfaces are need to complete the BESS test: floor/ground and foam pad.

1a) Floor/Ground: Any level surface is appropriate.

1b) Airex Foam Pad (19.5 x 15 x 2.5 inches; 1.8 lbs.)

The purpose of the foam pad is to create an unstable surface and a more challenging balance task, which varies by body weight. It has been hypothesized that as body weight increases the foam will deform to a greater degree around the foot. The heavier the person the more the foam will deform. As the foam deforms around the foot, there is an increase in support on the lateral surfaces of the foot. The increased contact area between the foot and foam has also been theorized to increase the tactile sense of the foot, also helping to increase postural stability. The increase in tactile sense will cause additional sensory information to be sent to the CNS. As the brain processes this information it can make better decisions when responding to the unstable foam surface.

2) Stop watch

-necessary for timing the subjects during the 6, twenty second trials

3) BESS Testing Protocol

-these instructions should be read to the subject during administration of the BESS

4) BESS Score Card (the Testing Protocol and a sample Score Card are located at the end of this document BESS Test Administration)

1) Before administering the BESS, the following materials should be present:

-foam pad

-stop watch

-BESS Testing Protocol

-BESS Score Card

- 2) Before testing, instruct the individual to remove shoes and any ankle taping if necessary. Socks may be worn if desired.
- 3) Read the instructions to the subject as they are written in the BESS Testing Protocol.
- 4) Record errors on the BESS Score Card as they are described below.

Scoring the BESS:

Each of the twenty-second trials is scored by counting the errors, or deviations from the proper stance, accumulated by the subject. The examiner will begin counting errors only after the individual has assumed the proper testing position.

Errors: An error is credited to the subject when any of the following occur:

- ◆ moving the hands off of the iliac crests
- ◆ opening the eyes
- ◆ step stumble or fall
- ◆ abduction or flexion of the hip beyond 30°
- ◆ lifting the forefoot or heel off of the testing surface
- ◆ remaining out of the proper testing position for greater than 5 seconds

-The maximum total number of errors for any single condition is 10.

Normal Scores for Each Possible Testing Surface

	Firm Surface	Foam Surface	
Double Leg Stance	.009 ± .12	.33 ± .90	
Single Leg Stance	2.45 ± 2.33	5.06 ± 2.80	
Tandem Stance	.91 ± 1.36	3.26 ± 2.62	
Surface Total	3.37 ± 3.10	8.65 ± 5.13	
BESS Total Score			12.03 ± 7.34

Maximum Number of Errors Possible for Each Testing Surface

	Firm Surface	Foam Surface
Double Leg Stance	10	10
Single Leg Stance	10	10
Tandem Stance	10	10
Surface Total	30	30

-if a subject commits multiple errors simultaneously, only one error is recorded.

For example, if an individual steps or stumbles, opens their eyes, and removes their hands from their hips simultaneously, then they are credited with only one error.

-subjects that are unable to maintain the testing procedure for a minimum of five seconds are assigned the highest possible score, ten, for that testing condition.

FIRM / GROUND TESTING POSITIONS



Double leg stance: Standing

on a firm surface with feet side by side (touching), hands on the hips and eyes closed

Single leg stance: Standing on a firm surface on the non-dominant foot (defined below), the hip is flexed to approximately 30° and knee flexed to approximately 45°. Hands are on the hips and eyes closed.

Non-Dominant Leg: The non-dominant leg is defined as the opposite leg of the preferred kicking leg

Tandem Stance: Standing heel to toe on a firm surface with the non- dominate foot (defined above) in the back. Heel of the dominant foot should be touching the toe of the non-dominant foot. Hands are on the hips and their eyes are closed.



FOAM TESTING POSITIONS

Double leg stance: Standing on a foam surface with feet side by side (touching), with hands on the hips and eyes closed

Single leg stance: Standing on a foam surface on the non-dominant foot (defined below), with hip flexed to approximately 30° and knee flexed to approximately 45°. Hands are on the hips and eyes closed.

Non-Dominant Leg: The non-dominant leg is defined as the leg opposite of the preferred kicking leg

Tandem Stance: Standing heel to toe on a foam surface with the non-dominant foot (defined above) in the back. Heel of the dominant foot should be touching the toe of the non-dominant foot. Hands are on the hips and their eyes are closed.

WARNING: Trained personnel should always be present when administering the BESS protocol. Improper use of the foam could result in injury to the test subject. Script for the BESS Testing Protocol

Direction to the subject: I am now going to test your balance.

Please take your shoes off, roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable).

This test will consist of 6 - twenty second tests with three different stances on two different surfaces. I will describe the stances as we go along.

DOUBLE LEG STANCE:

Direction to the subject: The first stance is standing with your feet together like this [administrator demonstrates two-legged stance]

You will be standing with your hands on your hips with your eyes closed. You should try to maintain stability in that position for entire 20 seconds. I will be counting the number of times you move out of this position. For example: if you take your hands off your hips, open your eyes, take a step, lift your toes or your heels. If you do move out of the testing stance, simply open your eyes, regain your balance, get back into the testing position as quickly as possible, and close your eyes again.

There will be a person positioned by you to help you get into the testing stance and to help if you lose your balance.

Direction to the subject: Put your feet together, put your hands on your hips and when you close your eyes the testing time will begin [Start timer when subject closes their eyes]

SINGLE LEG STANCE:

Direction to subject: If you were to kick a ball, which foot would you use? [This will be the dominant foot] Now stand on your non-dominant foot. [Before continuing the test

assess the position of the dominant leg as such: the dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion]
 Again, you should try to maintain stability for 20 seconds with your eyes closed. I will be counting the number of times you move out of this position. Place your hands on your hips. When you close your eyes the testing time will begin. [Start timer when subject closes their eyes]

TANDEM STANCE:

Directions to the subject: Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your eyes closed. I will be counting the number of times you move out of this position. Place your hands on your hips. When you close your eyes the testing time will begin. [Start timer when subject closes their eyes]

Balance Error Scoring System (BESS) (Guskiewicz)

Balance Error Scoring System-Types of Errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position >5 sec

The BESS is calculated by adding one error point for each error during the 6, 20 second tests.

SCORE CARD: (# errors)	FIRM Surface	FOAM Surface
Double Leg Stance (feet together)		
Single Leg Stance (non-dominant foot)		
Tandem Stance (non-dom foot in back)		

Which foot was tested: Left Right (i.e. which is the non-dominant foot)

Appendix H

Raw Results

Correlations

Notes

Output Created		24-MAR-2015 17:06:02
Comments		
Input	Data	G:\SPSS\THEREALDEAL.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	75
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=BESS_TOTAL FMS_TOTAL /PRINT=TWOTAIL NOSIG /STATISTICS DESCRIPTIVES /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.02

[DataSet1] G:\SPSS\THEREALDEAL.sav

Descriptive Statistics

	Mean	Std. Deviation	N
BESS_TOTAL	17.27	6.341	15
FMS_TOTAL	16.00	1.477	12

Correlations

		BESS_TOTA	FMS_TOTA
		L	L
BESS_TOTA	Pearson Correlation	1	.139
L	Sig. (2-tailed)		.666
	N	15	12
FMS_TOTAL	Pearson Correlation	.139	1
	Sig. (2-tailed)	.666	
	N	12	12

T-TEST PAIRS=BESS_TOTAL WITH FMS_TOTAL (PAIRED)
 /CRITERIA=CI(.9500)
 /MISSING=ANALYSIS.

T-Test

Notes

Output Created	24-MAR-2015 17:09:05	
Comments		
Input	Data	G:\SPSS\THEREALDEAL.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	75
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax	T-TEST PAIRS=BESS_TOTAL WITH FMS_TOTAL (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.	
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.01

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 BESS_TOTAL	17.00	12	5.309	1.532
FMS_TOTAL	16.00	12	1.477	.426

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 BESS_TOTAL & FMS_TOTAL	12	.139	.666

Paired Samples Test

	Paired Differences			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference
				Lower
Pair 1 BESS_TOTAL - FMS_TOTAL	1.000	5.309	1.532	-2.373

Paired Samples Test

	Paired Differences	t	df	Sig. (2-tailed)	
					95% Confidence Interval of the Difference
					Upper
Pair 1 BESS_TOTAL - FMS_TOTAL	4.373	.653	11	.527	

Correlations

Notes

Output Created		24-MAR-2015 17:12:01
Comments		
Input	Data	G:\SPSS\THEREALDEAL.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	75
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=BESS_TOTAL FMS_TOTAL UEI LEI /PRINT=TWOTAIL NOSIG /STATISTICS DESCRIPTIVES /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.02

Descriptive Statistics

	Mean	Std. Deviation	N
BESS_TOTAL	17.27	6.341	15
FMS_TOTAL	16.00	1.477	12
Upper Extr. Injuries	.00	.000	13
Lower Extr. Injuries	.38	.506	13

Correlations

		BESS_TOTA L	FMS_TOTA L	Upper Extr. Injuries
BESS_TOTAL	Pearson Correlation	1	.139	. ^a
	Sig. (2-tailed)		.666	.
	N	15	12	13
FMS_TOTAL	Pearson Correlation	.139	1	. ^a
	Sig. (2-tailed)	.666		.
	N	12	12	12
Upper Extr. Injuries	Pearson Correlation	. ^a	. ^a	. ^a
	Sig. (2-tailed)	.	.	.
	N	13	12	13
Lower Extr. Injuries	Pearson Correlation	.516	-.239	. ^a
	Sig. (2-tailed)	.071	.454	.
	N	13	12	13

Correlations

		Lower Extr. Injuries
BESS_TOTAL	Pearson Correlation	.516
	Sig. (2-tailed)	.071
	N	13
FMS_TOTAL	Pearson Correlation	-.239
	Sig. (2-tailed)	.454
	N	12
Upper Extr. Injuries	Pearson Correlation	. ^a
	Sig. (2-tailed)	.
	N	13
Lower Extr. Injuries	Pearson Correlation	1
	Sig. (2-tailed)	
	N	13

a. Cannot be computed because at least one of the variables is constant.

T-TEST PAIRS=BESS_TOTAL WITH LEI (PAIRED)
 /CRITERIA=CI(.9500)
 /MISSING=ANALYSIS.

T-Test

Notes

Output Created		24-MAR-2015 17:13:47
Comments		
Input	Data	G:\SPSS\THEREALDEAL.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	75
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST PAIRS=BESS_TOTAL WITH LEI (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.01

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 BESS_TOTAL	16.77	13	5.150	1.428
Lower Extr. Injuries	.38	13	.506	.140

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 BESS_TOTAL & Lower Extr. Injuries	13	.516	.071

Paired Samples Test

	Paired Differences			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower
Pair 1 BESS_TOTAL - Lower Extr. Injuries	16.385	4.908	1.361	13.419

Paired Samples Test

	Paired Differences	t	df	Sig. (2-tailed)
	95% Confidence Interval of the Difference			
	Upper			
Pair 1 BESS_TOTAL - Lower Extr. Injuries	19.351	12.036	12	.000

CORRELATIONS

```

/VARIABLES=FMS_RotStab BESS_TOTAL
/PRINT=TWOTAIL NOSIG
/STATISTICS DESCRIPTIVES
/MISSING=PAIRWISE.

```

Correlations**Notes**

Output Created		24-MAR-2015 17:16:24
Comments		
Input	Data	G:\SPSS\THEREALDEAL.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	75
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=FMS_RotStab BESS_TOTAL /PRINT=TWOTAIL NOSIG /STATISTICS DESCRIPTIVES /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.03

Descriptive Statistics

	Mean	Std. Deviation	N
FMS_RotStab	2.15	.376	13
BESS_TOTAL	17.27	6.341	15

Correlations

		FMS_RotSta b	BESS_TOTA L
FMS_RotStab	Pearson Correlation	1	.365
	Sig. (2-tailed)		.221
	N	13	13
BESS_TOTAL	Pearson Correlation	.365	1
	Sig. (2-tailed)	.221	
	N	13	15

Correlations

Notes

Output Created		24-MAR-2015 17:17:09
Comments		
Input	Data	G:\SPSS\THEREALDEAL.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	75
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=BESS_TOTAL FMS_InclineLunge /PRINT=TWOTAIL NOSIG /STATISTICS DESCRIPTIVES /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.06

Descriptive Statistics

	Mean	Std. Deviation	N
BESS_TOTAL	17.27	6.341	15
FMS_InclineLunge	2.25	.452	12

Correlations

		BESS_TOTAL	FMS_Incline
		L	Lunge
BESS_TOTAL	Pearson Correlation	1	.492
	Sig. (2-tailed)		.104
	N	15	12
FMS_InclineLunge	Pearson Correlation	.492	1
	Sig. (2-tailed)	.104	
	N	12	12

References

- Abernethy, L., & Bleakley, C. (2007). Strategies to prevent injury in adolescent sport: a systematic review. *Belfast Journal of Sports Medicine*, 627-638.
- Bell, D., Guskiewicz, K., Clark, M., & Padua, D. (2011). Systematic review of the balance error scoring system . *Sports Health: A Multidisciplinary Approach*, 3, 287-295. doi: 10.1177/1941738111403122
- Bell, D., Vesci, B., DiStefano, L., Guskiewicz, K., Hirth, C., & Padua, D. (2012). Muscle activity and flexibility in individuals with medial knee displacement during the overhead squat. *Athletic Training and Sports Health Care*, 4(3), 117-125.
- CaniacNation. (2013, August 12). Open ice with Ryan Murphy [Video file]. Retrieved from <http://www.youtube.com/watch?v=0EHIP8aTYTs>
- Chang, J., Levy, S., Seay, S., & Goble, D. (2014). An alternative to the balance error scoring system: using a low-cost balance board to improve the validity/reliability of sports-related concussion balance testing. *Clinical Journal of Sports Medicine*, 24(3), 256-262.
- Chang, WD., & Lai, PT. (2014). Neuromuscular training for prevention of anterior cruciate ligament injury in female athletes. *International Journal of Athletic Therapy & Training*, 17-21. Doi:10.1123/ijatt.2014-0042
- Chorba, R., Chorba, D., Bouillon, L., Overmyer, C., & Landis, J. (2010). Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *North American Journal of Sports Physical Therapy*, 5(2), 47-54.
- Cook, G. (2010). *Movement*. Aptos, CA: On Target Publications.

- Cook, G., Burton, L., Kiesel, K., Rose, g., & Bryant, M. (2010). Movement-functional movement systems: screening, assessment and corrective strategies.
- Crossley , K., Zhang, W., Schache, A., Bryant, A., & Cowan, S. (2011). Performance on the single leg squat task indicates hip abductor muscle function . *The American Journal of Sports Medicine*, doi: 10.1177/0363546510395456
- DiStefano, L., DiStefano, M., Frank, B., Clark, M., & Padua, D. (2013). Comparison of integrated and isolated training on performance measures and neuromuscular control. *Journal of Strength and Conditioning Research*, 27(4), 1083-1090.
- Ferrara, M., & Schurr, K. (1999) Intercollegiate ice hockey injuries: a casual analysis. *Clinical Journal of Sports Medicine*, 9, 30-33.
- Finnoff, J., Peterson, V., Hollman, J., & Smith, J. (2009). Intrarater and interrater reliability of the balance error scoring system (bess). *American Academy of Physical Medicine and Rehabilitation*, 1, 50-54. Doi: 10.1016/j.pmrj.2008.06.002
- Flik, K., Lyman, S., & Marx, R. (2005). American collegiate men's ice hockey: analysis of injuries. *American Orthopaedic Society for Sports Medicine*, 33(2), 183-187. Doi: 10.1177/0363546504267349
- Frohm, A., Heijne, A., Kowalski, J., Svensson, P., & Myklebust, G. (2012). A nine-test screening battery for athletes: a reliability study. *Scandinavian Journal of Medicine and Science in Sports*, 22, 306-315. Doi: 10.1111/j.1600-0838.2010.01267
- Gioftsidou, A., Malliou, P., Pafis, G., Beneka, A., Tsapralis, K., Sofokleous, P., Kouli, O., Roka, S., & Godolias, G. (2012). Balance training programs for soccer injuries

prevention. *Journal of Human Sport & Exercise*, 7(3), 639-647. Doi:

10.4100/jhse.2012.73.04

Goldie, P., Bach, T., & Evans, O. (1989). Force platform measures for evaluating postural control: reliability and validity. *Arch Phys Med Rehabilitation*, 70, 510-517.

Hartigan, E., Lawrence, M., Bisson, B., Torgerson, E., & Knight, R. (2014). Relationship of the functional movement screen in-line lunge to power, speed, and balance measures. *American Orthopaedic Society for Sports Medicine*, 6(3), 197-202. Doi: 10.1177/1941738114522412

Hodges, P., & Richardson, C. (1997). Contraction of the abdominal muscles associated with movement of the lower limbs. *Physical Therapy*, 77, 132-144.

Hunt, T., Ferrara, M., Bornstein, R., & Baumgartner, T. (2009) The reliability of the modified balance error scoring system. *Clinical Journal of Sports Medicine*, 19(6), 471-475. Retrieved from www.cjsportmed.com

Kiesel, K., Plisky, P., & Voight, M. (2007). Can serious injury in professional football be predicted by preseason functional movement screen? *North American Journal of Sports Physical Therapy*, 2(3), 147-158.

Lesinski, M., Hortobagyi, T., Muehlbauer, T., Gollhofer, A., & Granacher, U. (2014). Dose-response relationships of balance training in healthy young adults: a systematic review and meta-analysis. Doi: 10.1007/s40279-014-0284-5

Liemohn, W., Baumgartner, T., & Gagnon, L. (2005). Measuring core stability. *Journal of Strength and Conditioning*, 19(3), 583-586.

- Lorentzon, R., Wedren, H., & Pietila, T. (1988). Incidences, nature and causes of ice hockey injuries: a three year prospective study of a Swedish elite ice hockey team. *American Journal of Sports Medicine*, *16*, 392-396.
- McGuine, T., Greene, J., Best, T., & Levenson, G. (2000). Balance as a predictor of ankle injuries in high school basketball players. *Clinical Journal of Sports Medicine*, *10*, 239-244.
- Mills, JD., Taunton, JE., & Mills, WA. (2005). The effect of a 10 week training regimen on lumbo-pelvic stability and athletic performance in female athletes: a randomized control trial. *Phy Ther Sport*, *6*, 60-66.
- Molsa, J., Airaksinen, O., Nasman, O., & Torstila, I. (1997) Ice hockey injuries in Finland. A prospective epidemiological study. *American Journal of Sports Medicine*, *25*, 495-499.
- Nasher, L. (1993). Practical biomechanics and physiology of balance. In Jacobson, G., Newman, C., & Kartush, J., eds. *Handbook of Balance Function Testing*, 261-279.
- Noyes, F., Lindenfeld, T., & Marshall, M. (1988). What determines an athletic injury (definition)? Who determines an injury (occurrence)? *American Journal of Sports Medicine*, *16*, S65-S68.
- O'Connor, F., Deuster, P., Davis, J., Pappas, C., & Knapik, J. (2011). Functional movement screening: predicting injuries in officer candidates. *Medicine & Science in Sport & Exercise*.
- Okada, T., Huxel, K., & Nesser, W. (2011). Relationship between core stability,

- functional movement, and performance. *Journal of Strength and Conditioning Research*, 25(1), 252-261.
- Olmsted, L., Carcia, C., Hertel, J., & Shultz, S. (2002). Efficacy of the start excursion balance tests in detecting reach deficits in subjects with chronic ankle instability. *Journal of Athletic Training*, 37, 501-506.
- Peate, W., Bates, G., Lunda, K., Francis, S., & Bellamy, K. (2007). Core strength: a new model for injury prediction and prevention. *Journal of Occupational Medicine and Toxicology*, 2(3). Doi: 10.1186/1745-6673-2-3
- Powers, C. (2003). The influence of altered lower-extremity kinematics on patellofemoral dysfunction: a theoretical perspective. *Journal of Orthopaedic and Sport Physical Therapy*, 33(11), 639-646.
- Prentice, W. (2006). *Arnheim's principles of athletic training; a competency-based approach*. (12 ed., p. 578). New York, NY: McGraw Hill.
- Richardson, C., & Jull, G. (1995) Muscle control-pain control. What exercises would you prescribe? *Manual Therapy*, 1, 2-10.
- Sim, F., Simonet, W., Melton, L., & Lehn, T. (1987). Ice hockey injuries. *American Journal of Sports Medicine*, 15(1), 30-40. Doi: 0363-5465/87/1501-0030
- Stuart, M., & Smith, A. (1995). Injuries in junior a ice hockey: a three year prospective study. *American Journal of Sports Medicine*, 23, 458-461
- Tyler, T., Nicholas, S., Campbell, R., Donellan, S., & McHugh, M. (2002). The effectiveness of a preseason exercise program to prevent adductor muscle strains in professional ice hockey players. *American Journal of Sports Medicine*, 30(5),

680-683. Doi: 0363-5465/102/3030-0608

Tyler, T., Nicholas, S., Campbell, R., & McHugh, M. (2001). The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *The American Journal of Sports Medicine*, 29(2), 124-128.

University of North Carolina Sports Medicine Research Laboratory. (2009). Balance error scoring system (BESS) [Protocol, scoring and instruction]. Chapel Hill, NC: National Athletic Trainers Association. Retrieved from <http://www.sportsconcussion.com/pdf/management/BESSProtocolNATA09.pdf>

Whatman, C., Hing, W., & Hume, P. (2011). Kinematics during lower extremity functional screening tests- are they reliable and related to jogging? *Physical Therapy in Sport*, 12, 22-29. Doi: 10.1016/j.ptsp.2010.10.006

Zemkova, K. (2013). Sport-specific balance. 44, 579-590. Doi: 10.1007/s40279-013-0130-1