FUNCTIONAL MOVEMENT SCREEN AS A PREDICTOR OF INJURY IN HIGH SCHOOL BASKETBALL ATHLETES

by

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A DISSERTATION

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Participation in athletics includes an inherent risk of becoming injured that is related to the nature of the games and activities of the players. Current literature reports that approximately seven million high school students participate in sports yearly in the United States and, during the 2005-2006 sport seasons, 1.4 million injuries were reported. Considering this high number of injuries, there is little doubt that definitive research into the determination of factors that might help predict the degree of injury risk associated with sport participation is warranted.

Despite common association of variables such as joint laxity, range of motion, strength and balance with injury, these traditional measures have not proven to be reliable predictors of vulnerability. Consequently, attempts have been made to identify practical methods that may better permit identification of individuals who show a high likelihood of injury during athletic competition.

This study examined one such system, the Functional Movement Screen (FMS), which utilizes measures of mobility and stability to permit its developers to assert that it can be used to practically and accurately identify vulnerable athletes. Critical data on inter-rater and intra-rater performance were first obtained on a team of athletic trainers to ensure that they could reliably execute the testing methods. Following confirmation of this fact, 112 high school basketball athletes were screened with the FMS and their injuries (non-contact neuromusculoskeletal tissue damage in school-sanctioned basketball) were tracked throughout an entire season. Data analysis to determine if a commonly-used FMS cutoff score of less than 14 out of 21 could identify vulnerable athletes revealed that this value was not significantly related to the likelihood of sustaining an injury. Furthermore, logistic regression revealed that none of the individual predictors (gender, FMS movements, and movement asymmetries) were significant predictors of injury susceptibility. The results indicate that, despite the fact that multiple evaluators and trials can be practically used to evaluate FMS scores in a large group of high school basketball athletes, the test does not appear to be a valid tool in assessing injury risk in this population during an entire season.

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DEDICATION

To my parents, for their endless support and inspiration to achieve great things.

To my brother Jeff, for his support and inspiration to live an adventurous life each day.

And to Nicole, my future wife and companion.

I love each of you.

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CHAPTER I

INTRODUCTION

Operational Definitions

Injury – any tissue damage to skeletal, muscular, connective or neural tissues

Sprain – stretch or tear of a ligament

Strain – stretch or tear of a muscle or tendon

Mobility – the ability to produce a desired and efficacious motion

Stability – the capacity to resist a motion

Participation in athletics includes an inherent risk of becoming injured based upon the nature of the games and activities of the players. Current literature reports that approximately seven million high school students are participating in sports in the United States (Rechel, Yard, & Comstock, 2008). Of these athletes, 1.4 million injuries were sustained during the 2005-2006 sport seasons (Rechel et al., 2008). A report of the 1995-1997 high school sport seasons indicates that more than two million injuries were sustained, requiring 500,000 doctor visits and 30,000 hospitalizations (Powell & Barber-Foss, 1999). The volume of injuries reported in this setting, along with the fact that many of the more significant sports-related injuries may lead to long-term physical impairment (Powell & Barber-Foss, 1999), warrants research into the possibility of utilizing pre-participation screening methods that are able to identify athletes that are at a high risk of becoming injured. If such determinations could be made, sports medicine professionals could intervene to correct biomechanical deficits in an effort to promote safe participation and reduce the incidence of injury.

The following describes several risk factors for injury and the typical methods for evaluating an individual for those factors. Furthermore, potential use of a Functional Movement Screen for assessing basic movement patterns that could possibly be useful in pre-participation screening methods is described.

Risk Factors of Injury

Previous Injury

One variable that has been identified as a significant risk factor for injury is a history of previous injury (Emery, Meeuwisse, & Hartmann, 2005). Research reports an increase of four to five fold in the likelihood of reinjury at the site of previous injury for high school cross country, football, soccer and cheer (Murphy, Connolly, & Beynnon, 2003; Emery et al., 2005; Caine, Maffulli, & Caine, 2008). This may be related to deficiencies resulting from the initial injury including increased ligamentous laxity, altered range of motion, or decreased muscle strength or balance (Knowles et al., 2006; Caine et al., 2008).

Ligamentous Laxity

The primary function of ligaments is to guide joint motion and, in the context of injury, they also serve to control excessive joint motion. Ligamentous laxity describes the stiffness qualities within a joint's connective tissues, which can be evaluated through specific ligamentous and capsular tests that are administered by health care practitioners relying on the end-feel (the quality of ligamentous resistance at the end range of joint motion) to grade the tests. Results quantifying end-feel are based on a four-point scale with zero indicating normal, one, a firm, two, a soft, and three, an empty end-feel. Grades one through three may also be accompanied by pain. The actual quality of this parameter is determined by testing bilaterally to compare the injured to the uninjured joint. A firm end-feel indicates slight stretching of the ligament with an end-feel close to that of the healthy side. A soft end-feel indicates partial tearing of the ligamentous fibers with an increased glide of the joint surfaces upon one another or the joint line gapping significantly when compared to the contralateral side. An empty end-feel is consistent with complete tearing of the ligament with excessive joint motion during the testing.

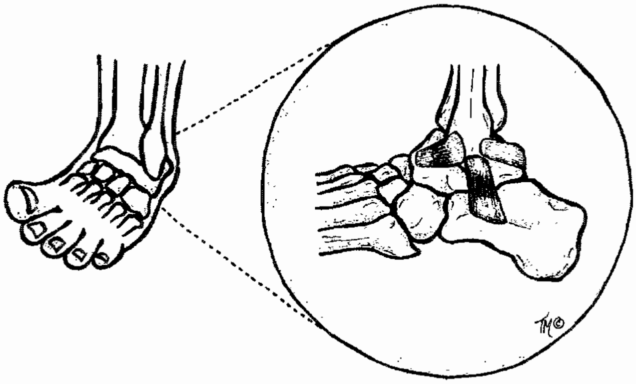

Figure 1.1: Grade I Sprain of Lateral Ankle Ligaments – Firm End-Feel

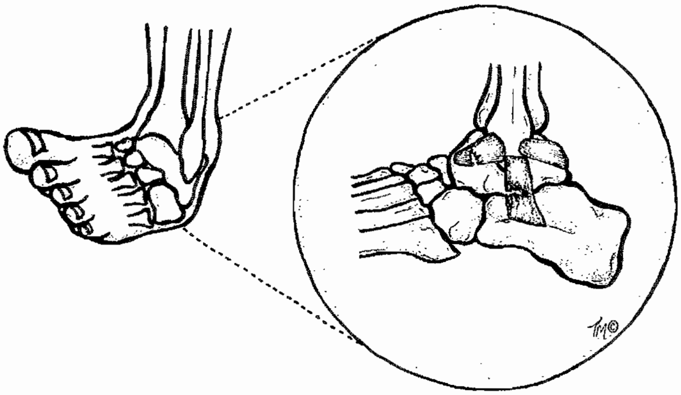

Figure 1.2: Grade II Sprain of Lateral Ankle Ligaments – Soft End-Feel

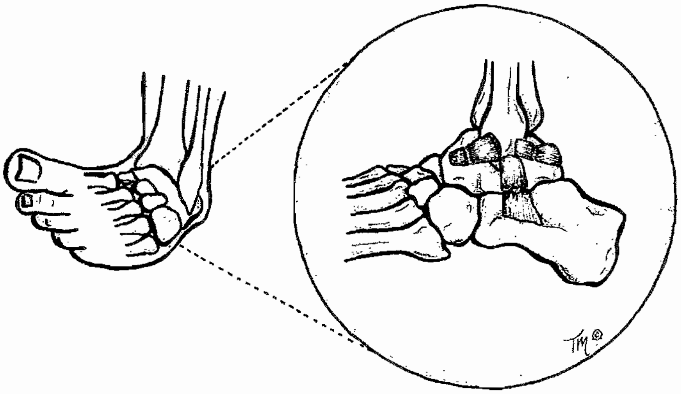

Figure 1.3: Grade III Sprain of Lateral Ankle Ligaments – Empty End-Feel

When evaluating the knee, more sophisticated instrumentation (KT 1000/2000) can be used to assess the anterior cruciate ligament. With these devices, anterior tibial displacement is assessed in millimeters as an indirect measure of anterior cruciate ligament laxity. Unfortunately, this type of measurement is not readily available for other joints of the body and, therefore, most joints require manual assessments of the parameter. Increased joint laxity following injury may also give a patient the feeling of instability, as the ligament no longer restrains excessive joint motion (McKay, Goldie, Payne, & Oakes, 2001). Furthermore, the lack of stabilization provided by the injured ligament may predispose an athlete to further injury (Ekstrand & Gillquist, 1983).

Range of Motion

Range of motion (ROM) testing is another common assessment during a patient evaluation. These measurements should be compared bilaterally and to normative data for the joint (Starkey & Ryan, 2002). ROM can be determined via gross observation by the practitioner or by using a goniometer. Goniometric ROM testing requires the identification of the approximate axis of joint rotation so the fulcrum of the goniometer can be placed at this location. Next, the stationary and movement arms are placed on the proximal and distal segments, parallel to the respective bones. Once the joint is moved through its full ROM, the amount of motion can be easily measured in degrees on the goniometer.

Figure 1.4: Goniometric Measurement of Joint ROM

Active ROM describes movement of a limb produced by the patient without assistance and tests the ability of the muscles to produce full-range movement while evaluating the health of the joint surfaces. Conversely, passive ROM is performed by the evaluator moving the limb for the patient and tests the length of the connective tissue and muscles resisting motion around the joint. ROM end-feels describe the quality of motion felt by the practitioner and represent normal and pathological conditions as described in Tables 1.1 and 1.2.

Table 1.1: Normal Range of Motion End-Feels (Starkey & Ryan, 2002)

End-Feel	Structure	Example
Soft	Soft tissue approximation	Knee flexion – contact between soft tissue of the posterior leg and thigh
Firm	Muscular stretch	Hip flexion with the knee extended – passive tension of the hamstring muscles
	Capsular/ligamentous stretch	Extension of the metacarpophalangeal joints of the fingers – tension in the palmar capsule
Hard	Bone contacting bone	Elbow extension – contact between the olecranon process of the ulna and the olecranon fossa of the humerus

Table 1.2: Abnormal Range of Motion End-Feels (Starkey & Ryan, 2002)

End-Feel	Description	Example
Soft	Occurs sooner or later in the ROM than is usual or occurs in a joint that normally has a firm or hard end-feel; feels boggy	Soft tissue edema
Firm	Occurs sooner or later in the ROM than is usual or occurs in a joint that normally has a soft or hard end-feel	Increased muscular tone Capsular, muscular or ligamentous shortening
Hard	Occurs sooner or later in the ROM than is usual or occurs in a joint that normally has a firm or firm end-feel; feels like bony block	Osteophyte Loose bodies in joint Fracture Joint dislocation
Empty	Pain limits ability to test end-feel; no resistance felt except for patient's protective muscle guarding	Joint inflammation Joint dislocation

While bilateral comparisons have always been a necessary part of an injury evaluation, asymmetries between two healthy limbs have more recently gained support in the literature as a risk factor for injury (Knapik, Bauman, Jones, Harris, & Vaughan, 1991; Baumhauer, Alosa, Renstrom, Trevino, & Beynnon, 1995; Nadler et al., 2001). Specifically, Knapik, et al. (1991) showed a positive relationship between ROM asymmetries and musculoskeletal injuries, where females with an asymmetry of greater than fourteen percent knee flexion or hip extension ROM are reported to be 2.6 times more likely to suffer an injury than those with more symmetrical strength.

Muscle Strength

Muscle strength, defined as the external force that a muscle or group of muscles can produce, is measured clinically using manually-resisted ROM testing through the joint's full range. These tests can be used to assess a specific joint ROM, multiplanar joint motion, or a muscle group. During manual resistance, the limb is stabilized proximal to the joint to prevent compensatory motions while resistance is provided against the distal joint segment. Strength is manually graded on a five-point scale as detailed in Table 1.3.

Figure 1.5: Manual Muscle Testing of Knee Extension

Table 1.3: Grading System for Manual Muscle Tests (Starkey & Ryan, 2002)

Description	Numerical Grade	Clinical Finding
Normal	5/5	The patients can move the body part through the full range of motion against maximal pressure.
Good	4/5	The patients can move the body part through the full range of motion against moderate pressure.
Fair	3/5	The patient can move the body part through the full range of motion against gravity, but not against resistance
Poor	2/5	The patient can move the body part through the full range of motion in a gravity-eliminated position.
Trace	1/5	The patient cannot produce motion, but a muscle contraction is palpable.
None	0/5	No contraction is palpable.

While manual tests are practical and convenient for a clinical setting, the resistance that can be generated during these tests is significantly less when compared to the forces that exist during sports participation and those generated during vigorous activity in healthy populations. Traditionally, the one-repetition maximum (or multiple-repetition maximum), defined as the greatest resistance that can be moved through the full ROM in a controlled manner, has been the standard for strength assessment (American College of Sports Medicine, 2010). Typical measures of upper body strength include the bench press and overhead press, whereas measures for the lower body include the leg press and squat (American College of Sports Medicine, 2010).

In a study measuring the isokinetic strength of 145 college-aged athletes, participants with asymmetrical ankle strength between antagonist muscle groups had higher rates of inversion ankle sprains (Baumhauer et al., 1995). More specifically, athletes with a greater amount of plantarflexion strength relative to dorsiflexion strength were more likely to be affected. Similarly, those with greater inversion strength compared to eversion strength were more likely to sustain inversion ankle sprain.

Following injury, a loss of strength would limit the dynamic stabilization of a body segment. For example, since the peroneal muscle group acts as a stabilizer of the lateral ankle during forced inversion, a lack of strength or delayed muscle contraction during ankle inversion would make the ankle will be more susceptible to damage of the passive support structures of the ankle, such as the ligaments and joint capsule (Baumhauer et al., 1995).

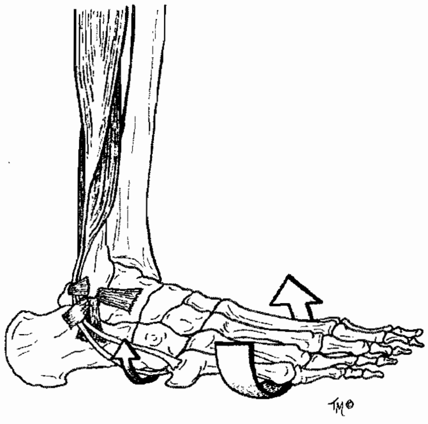

Figure 1.6: Action of the Peroneal Muscles in the Prevention of an Inversion Ankle Sprain

Balance

Balance is the ability to maintain the center of gravity of an object within the base of support with minimal postural sway. Success requires the concurrent sensory functions of the vestibular system (inner ear), vision, and perception of pressure and proprioception acting in concert with the motor system that controls muscle actions based upon this input (Guskiewicz & Perrin, 1996). Evaluation of balance is typically measured using timed, single leg stance with variations of sensory input disabled (Starkey & Ryan, 2002). For example, the clinician may progress balance testing from single leg stance with eyes open, to eyes closed (visual feedback disabled), to eyes closed with the head tilted back (visual and vestibular feedback altered) (Guskiewicz & Perrin, 1996). Each of these steps alters the sensory input for controlling balance and increases the demand on the other systems of feedback. A deficit in balance originating from any of these systems would quite naturally limit the ability to maintain stability during motion or static positioning. Following injury, neurological feedback about joint position from the mechanoreceptors in the region may become disrupted, resulting in reduced proprioception and balance, and increased injury susceptibility (Guskiewicz & Perrin, 1996).

Figure 1.7: Balance Testing

Summary

Although the clinical measurements and tests listed above are commonly used during a pre-participation physical examinations, the evidence is, at best, mixed as to whether joint laxity, ROM, strength or balance are indeed significant risk factors for injury occurrence. Joint laxity has been shown by several studies to be significant in both males and females (Krivickas & Feinberg, 1996; Ostenberg & Roos, 2000; Soderman, Alfredson, Pietila, & Werner, 2001), whereas other studies found no association (Godshall, 1975; Baumhauer et al., 1995; Hopper, Hopper, & Elliott, 1995; Beynnon, Renstrom, Alosa, Baumhauer, & Vacek, 2001). The same variability has been reported for a lack of joint ROM (Milgrom et al., 1991; Barrett & Bilisko, 1995; Arnason, Gudmundsson, Dahl, & Johannsson, 1996; Krivickas & Feinberg, 1996; Wiesler, Hunter, Martin, Curl, & Hoen, 1996; Twellaar, Verstappen, Huson, & van Mechelen, 1997;

Kaufman, Brodine, Shaffer, Johnson, & Cullison, 1999; McKay et al., 2001; Knapik et al., 2001; Beynnon et al., 2001; Soderman et al., 2001).

With regard to muscle strength, two studies (Baumhauer et al., 1995; Soderman et al., 2001) found an association between strength differences between antagonist muscles in the leg and thigh and injury, and one (Ekstrand & Gillquist, 1983) reported an association between decreased strength of the quadriceps muscles and injury, findings questioned by three other reports (Milgrom et al., 1991; Ostenberg & Roos, 2000; Beynnon et al., 2001).

Finally, research regarding the association between balance and injury has also displayed conflicting evidence with findings showing a positive relationship between balance and injury (Tropp, Ekstrand, & Gillquist, 1984; McGuine, Greene, Best, & Leverson, 2000), and others (Beynnon et al., 2001; Soderman et al., 2001) demonstrating no relationship. It must be noted that such comparisons are difficult between each of these areas of study as varying research designs associated with injury inclusion criteria, populations tested, planes of motion and confounding variables such as gender (Zelisko, Noble, & Porter, 1982; Gray et al., 1985; Hickey, Fricker, & McDonald, 1997; Myklebust, Maehlum, Holm, & Bahr, 1998; Gwinn, Wilckens, McDevitt, Ross, & Kao, 2000; Hewett, 2000; Powell & Barber-Foss, 2000; Ostenberg & Roos, 2000; Knapik et al., 2001), age (Chomiak, Junge, Peterson, & Dvorak, 2000) and skill level (Hopper et al., 1995; Chomiak et al., 2000; Stevenson, Hamer, Finch, Elliot, & Kresnow, 2000; Hosea, Carey, & Harrer, 2000) vary markedly across experiments. Collectively, all this work plus a fundamental understanding of human movement strongly suggest that the design of an effective pre-season screening tool will require much more research to carefully find and evaluate variables that may predispose an athlete to injury.

Functional Testing

Whereas gross instability or significant functional impairments can be identified with orthopedic testing, and these variables may be well associated with injury risk, such tests still fail to adequately replicate the complex, integrated demands of mobility and stability between multiple joints that are necessary to perform the basic movements associated with sports. Specifically, the mobility that is required in sporting events is defined as the ability to produce desired and efficacious motion and is impacted by the architecture of the joints, soft tissue length, and the strength and neural control of the surrounding muscle groups (Hickmans, 2007). Conversely, stability is the capacity to resist motion through the passive and active restraints around the joints. The complexity of this factor is further impacted as the passive elements include the joint capsule, ligaments and the joint surface's architecture, whereas muscle strength, neural control of the muscles, and balance are all determinants of the adequacy of the response of the active elements. Stability can also be static as a function of posture and balance, or dynamic through the production of controlled movement (Hickmans, 2007). For example, static stability can be described as maintaining an upright posture while sitting or balancing on one leg, whereas dynamic stability can be thought of as something like maintaining alignment of the hips, knees and feet while performing a squat.

In an attempt to create a pre-participation functional evaluation, Gray Cook and Lee Burton (http://functionalmovement.com) developed the Functional Movement Screen

(FMS). This battery of tests was designed to simultaneously evaluate joint mobility and stability through a series of seven movements. Although none are sport-specific maneuvers, they do challenge the upper and lower extremities and the trunk in functional tasks not unlike those that occur during athletic performance. As designed, the evaluation is practical, as the desired movements can be tested within five to ten minutes, allowing the clinician to quickly screen for deficiencies that may require more in-depth evaluation and possible rehabilitation to reduce the risk of injury. The movements of the FMS include the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability. (Figures 1.8-1.14)

Deep Squat

The purpose of the deep squat is to assess:

- Bilateral, dorsiflexion of the ankles, and flexion of the knees and hips while the feet are in contact with the ground (closed-chain)
- Extension of the thoracic spine
- Stability of the lumbar spine
- Flexion and abduction of the shoulders.

The deep squat mimics the "athletic" or "ready" position that is a part of many sporting activities. It is also designed to assess symmetrical movement of the lower extremities with concurrent stability of the trunk and upper extremities.

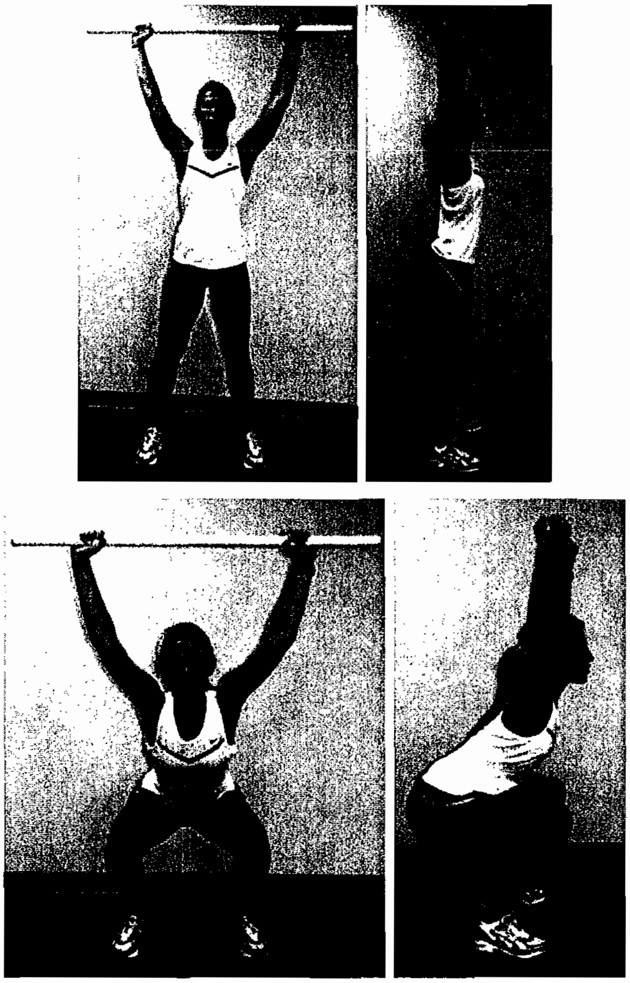

Figure 1.8: Deep Squat

Hurdle Step

The purpose of the hurdle step is to assess:

- Mobility of the hips, knees and ankles of the step-limb
- Stability of the hips, knees and ankles of the stance-limb
- Hip extension of the stance-limb
- Stability of the trunk

It evaluates stability in single leg stance along with mobility of the stepping limb, which is incorporated in jumping and running motions.

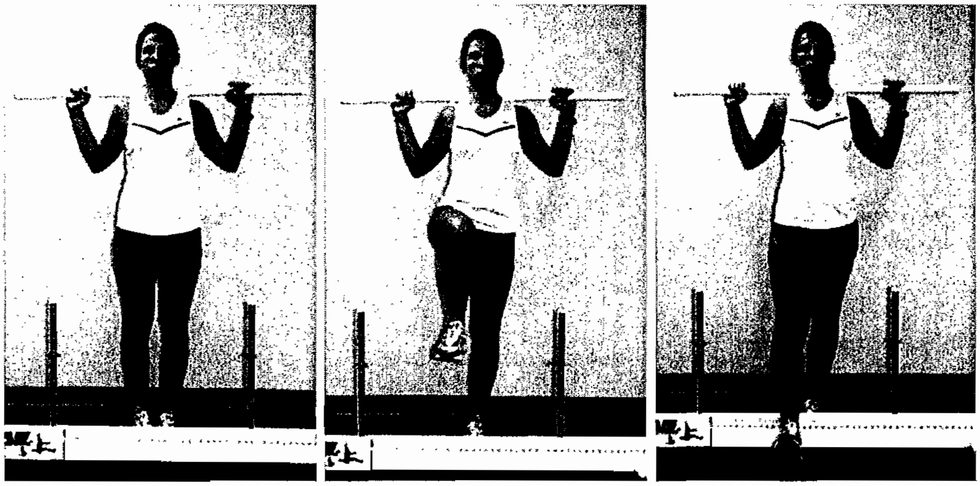

Figure 1.9: Hurdle Step

In-line Lunge

The purpose of the in-line lunge is to assess:

- Bilateral mobility and stability of the hips, knees and ankles
- Stability of the trunk

The in-line lunge mimics a split stance position that is utilized for running motions. It also challenges pelvic stability with concurrent hip flexion and extension of the contralateral limbs.

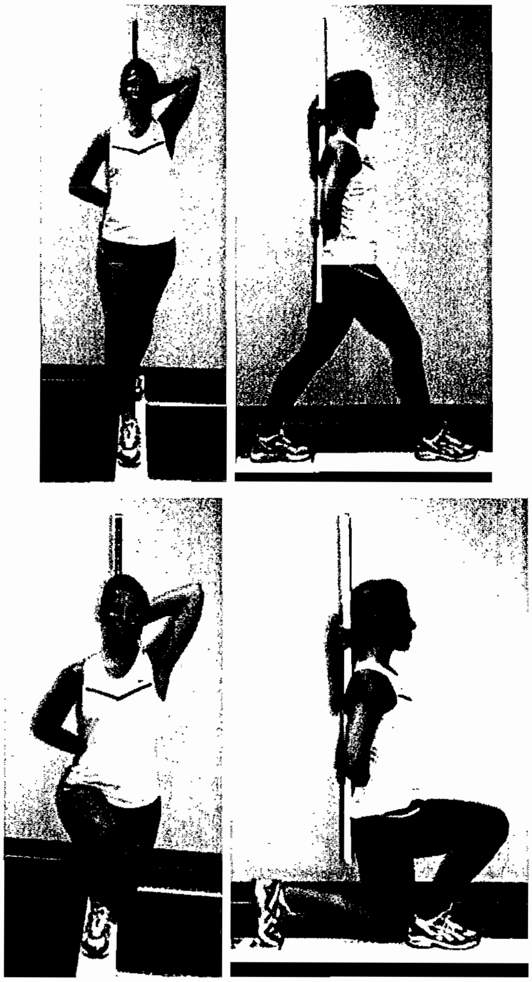

Figure 1.10: In-line Lunge

Shoulder Mobility

The purpose of the shoulder mobility test is to assess:

- Bilateral shoulder ROM, combining internal rotation, adduction and extension with one shoulder, and external rotation, abduction and flexion of the contralateral shoulder
- Scapular mobility
- Thoracic spine extension

These combined motions of the shoulder in the transverse, frontal and sagittal planes allow the clinician to quickly evaluate shoulder mobility. Pain during this test may indicate impingement syndrome of the rotator cuff.

Figure 1.11: Shoulder Mobility

Active Straight Leg Raise

The purpose of the active straight leg raise is to assess:

- Mobility of the hamstring, gastrocnemius and soleus muscles
- Active extension of the contralateral limb
- Stability of the pelvis

This movement tests mobility of the moving limb with concurrent stability and active extension of the stationary limb. It also challenges pelvic stability with concurrent hip flexion and extension of the contralateral limbs.

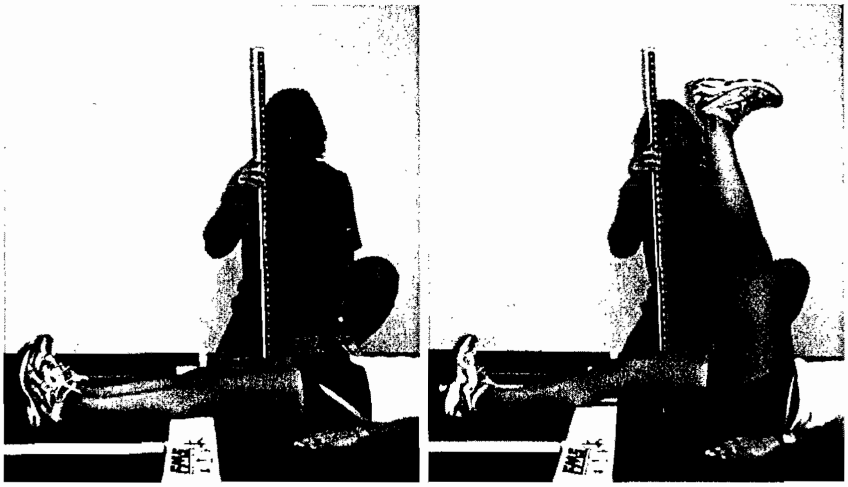

Figure 1.12: Active Straight Leg Raise

Trunk Stability Push-Up

The purpose of the trunk stability push-up is to assess:

- Trunk stability while a symmetrical, closed-chain upper extremity motion is performed
- Upper extremity strength

The trunk stability push-up challenges core strength, specifically at the lumbar spine and hips, and upper extremity strength during a one-repetition push-up.

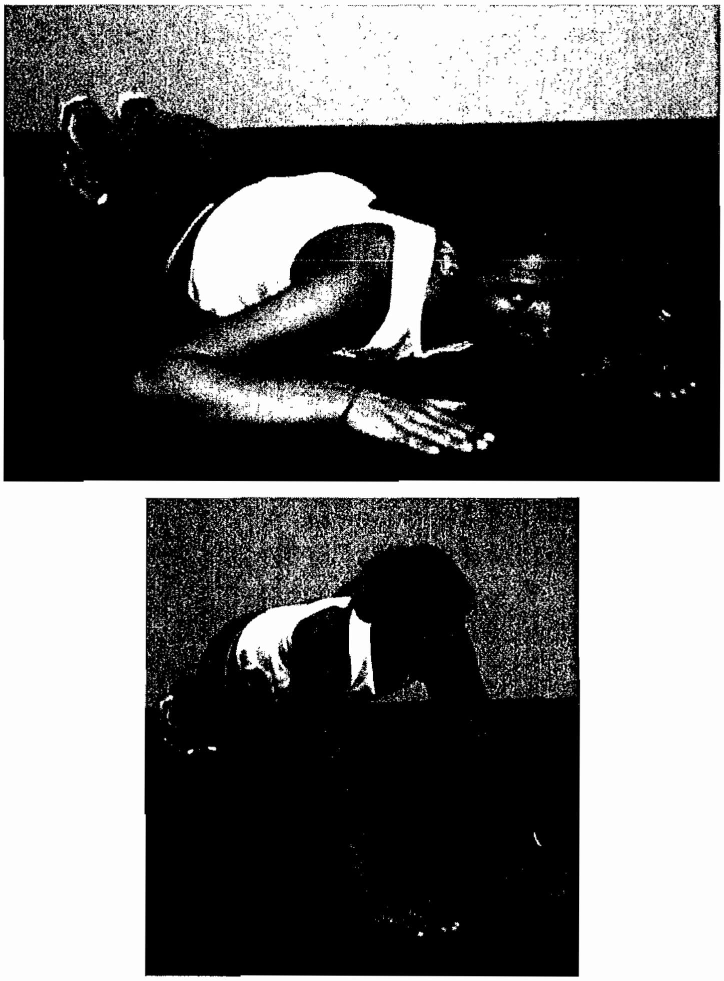

Figure 1.13: Trunk Stability Push-up

Rotary Stability

The purpose of the rotary stability test is to assess:

- Multiplanar trunk stability in a quadruped position with combined upper and lower extremity motion

The rotary stability test stresses the core musculature in maintaining alignment of the trunk while undergoing changes to support contacts with the ground and moving the upper and lower extremities. This test is designed to mimic complex motions associated with sports that demand stability during movement.

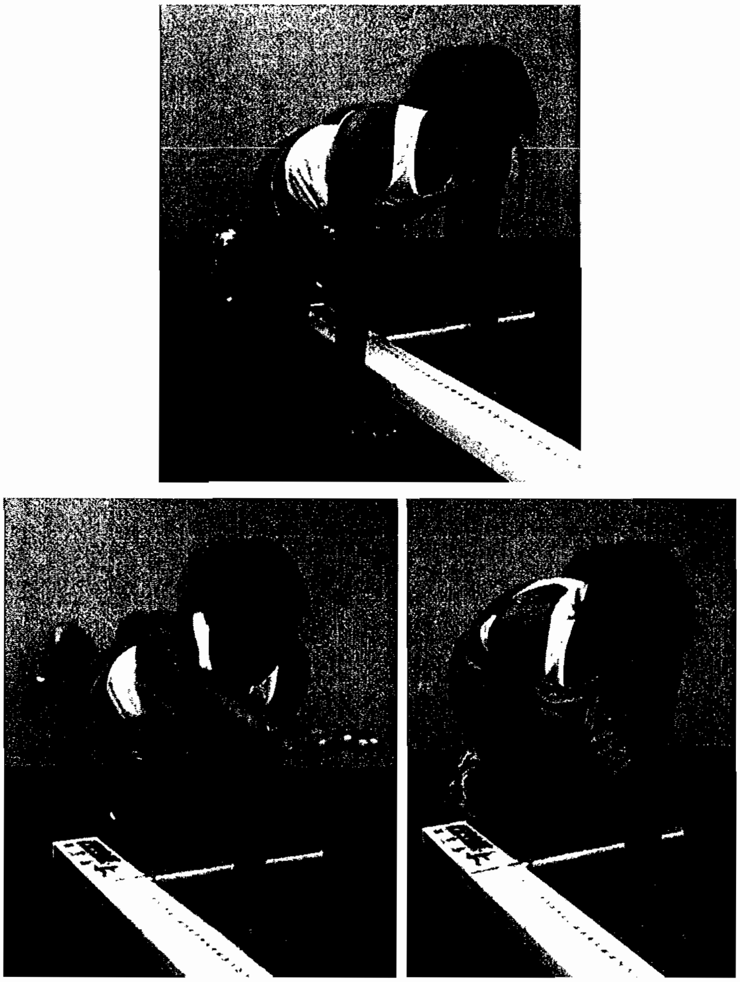

Figure 1.14: Rotary Stability

Study Description

There is little doubt that the amount of injuries that are sustained as the result of high school athletics, as well as the associated health care costs, and the effects on the lives of young athletes, warrants definitive research into the risk factors associated with participation. Despite the fact that biomechanical measures such as joint laxity, ROM, strength and balance have been identified as variables possibly associated with injury, these traditional measures alone may be inadequate to be valuable in mitigating these issues. Therefore, in this study, the potential for the FMS to use those variables in combination may permit evaluation of functional mobility and stability and ultimately yield an improved capacity to efficiently and correctly identify athletes that are at risk of becoming injured.

Specific Aim #1

Since the FMS requires subjective evaluation by trained observers, it was necessary to establish inter-rater reliability and intra-rater reliability for the team of evaluators. Inter-rater reliability is defined as the degree of agreement between raters while intra-rater reliability is the degree of agreement within a single rater across multiple trials. Strong agreement between raters and within raters is obligatory to confidently establish that the tests can be administered with reproducible results, an important factor if the screen is to be effectively used clinically. In this study, each rater was required to score athletes on the FMS individually, so it was essential to first verify that variability between raters was minimal. To-date, no such research has been published regarding the inter-rater and intra-rater reliability of scoring the FMS, but in the absence of these assumptions, the practicality of the FMS for general use is severely compromised.

Specific Aim #2

Once adequate inter-rater and intra-rater reliability are achieved, it becomes possible to evaluate the most critical question posed in the study which is, can a low score threshold be established on the FMS that could serve as a reliable predictor of injury for high school basketball athletes throughout a season? Because the FMS is intended to evaluate and address deficiencies in the mobility and stability of an athlete that might be linked to injury, the only injuries that were included in this study were non-contact injuries. They included any tissue damage that resulted from participation in a school-sanctioned practice or game. Chronic, overuse injuries that presumably resulted from the accumulation of repeated forces to a joint or body segment that led to the insidious onset of symptoms, and acute injuries that were the result of a single traumatic force to a body region were both included. Those disqualified occurred from contact with the ground (other than the foot contacting the ground), the ball, another player or any other object in the gymnasium as they would have introduced elements that were irrelevant to that which would have been expected to be associated with what could be evaluated by the FMS.

Kiesel, Plisky and Voight (2007) have shown in professional football athletes that a score less than fifteen out of twenty-one on the FMS predisposes an athlete to an eleven-fold increased chance of injury compared to those individuals that score fifteen or higher on the tests. This study included contact injuries and was successful at identifying athletes that were at risk of becoming injured. However, their inclusion of contact injuries may have skewed the results and potentially weakens the impact of their results on the question asked here. For example, an individual could score perfectly on the FMS but get blind-side tackled and sustain an impact injury. On the other hand, it could be argued that a high level of total-body stability and mobility could allow an individual to better avoid contact or tolerate a greater level of contact without sustaining an injury. However, for the purposes of this research, we chose to exclude contact injuries in attempt to minimize the potential role of unpreventable contact injuries on our results. Furthermore, Kiesel's study (2007) with professional football players only included those injuries that resulted in three or more weeks of missed participation due to injury. Thus, minor injuries that could indeed alter individual performance without any absence from games or practices are, by default, excluded. Lastly, although the large numbers and high incidence of injury that occur in football make it a reasonable sport to evaluate injuries, accurately differentiating contact versus non-contact injuries in this sport can be quite difficult due to the nature of the sport. Also, results from studying professional athletes may also limit the external validity for applying the outcomes to lower skilled or younger athletes, of which the numbers are much greater nationally.

Although the first published paper on the application of the FMS to injury prediction shows promise, there still remains little data to support the widely adopted, clinical-use of a cutoff score of 14 out of 21 to predict injury. This study was designed to further investigate the relationship between performance on the FMS and risk for non-contact injuries in high school basketball athletes.

Hypotheses

It was hypothesized that the inter-rater and intra-rater reliability would exceed 0.80, which would support the use of multiple raters and multiple sessions for screening a large group of athletes with the FMS. Secondly, it was hypothesized that high school basketball athletes that scored below a 14 out of 21 on the FMS would be more likely to sustain a non-contact injury during a basketball season. The potential that the players' gender, playing level, individual movement scores, net FMS score, and movement performance asymmetries was also evaluated as variables that might be useful in injury prediction.

CHAPTER II

METHODS

The Functional Movement Screen

The Functional Movement Screen (FMS) consists of seven tests. Each test is scored on a four-point scale, with three indicating perfect performance, two, minor deficits or perfect performance with modifications, and one, the inability to perform the movement. In all tests, the prevalence of pain during movement corresponds to a zero. Three attempts are performed for each test with the highest score recorded. If a score of three is achieved at any time, no further repetitions are required. For the tests that are divided for right and left, the composite score (lower of the two net scores) is used for the final score. The maximum score is 21.

Deep Squat

The deep squat begins by having the subject place his/her feet shoulder width apart, aligned in the sagittal plane while holding a dowel with both hands. Contact is then made between the dowel and the top of the head and the width of their hands on the dowel is adjusted so that the elbows are flexed to 90 degrees. The subject then presses the dowel overhead by extending the elbows, and a full squat is performed. A score of three is recorded if the individual is able to squat to a depth that achieves 90 degrees of knee flexion while maintaining:

- heel contact with the floor
- knees aligned over feet
- torso and arms parallel with tibia or toward vertical
- dowel aligned over feet and symmetrical in the frontal plane

If the subject is not able to perform the deep squat to satisfy these criteria within three attempts, a 2-inch base is placed under their heels and the task is repeated. If the fore-mentioned criteria are subsequently achieved with a heel lift, a score of two is awarded. When one or more of the criteria are not achieved despite the modification, a score of one is earned.

Hurdle Step

The hurdle step is tested by positioning the subject with feet together and toes touching the base of a hurdle. The hurdle should be adjusted to the height of the tibial tuberosity, defined as the distance from the ground to the anatomical marker. The dowel is held with both hands resting on the shoulders behind the neck. The individual then executes a step over the hurdle, touching their heel to the ground, and then returning to the starting position. Eye contact must be maintained at the horizon and not down to the hurdle. After a maximum of three attempts, a score of three is recorded if the individual is able to clear the hurdle while maintaining the hips, knees, and feet aligned in the sagittal plane, dowel aligned in the frontal plane, and minimal flexion of the spine. If any of the above-mentioned criteria are not achieved, but the hurdle is cleared and balance is maintained, a score of two is awarded, whereas contact with the hurdle or loss of balance earns a one.

In-line Lunge

The in-line lunge is tested by first measuring the height of the tibial tuberosity (defined above) and then placing one foot at the end of a 2-inch by 6-inch board. The heel of the contralateral foot is placed on the board at the distance corresponding to the height of the tibial tuberosity (distance measured from the toe of the back foot to the heel of the front foot). The subject then holds a dowel along the spine, with the hand ipsilateral to the back foot securing the rod at the cervical spine and the contralateral hand securing the rod at the lumbar spine. It must be in contact with the head, thoracic spine, and sacrum. The subject then lowers the back knee until it touches the board and immediately returns to the starting position. After a maximum of three attempts, a score of three is recorded if the individual is able to contact the board with their knee while maintaining sagittal alignment of both feet, upright and sagittal alignment of the trunk, and three points of contact with the dowel throughout the movement. If any of the above-mentioned criteria are not achieved, but the lunge is attempted and balance is maintained, a score of two is recorded. A one is earned if balance is lost or the starting position cannot be obtained.

Shoulder Mobility

Measurements of shoulder mobility are evaluated by first measuring the length of the subject's hand from the distal palmar wrist crease to the tip of the third digit. While standing in an upright posture, both hands are clinched in a fist and in one smooth motion, they are placed and maintained on the back as close as possible. This is achieved by maximally internally rotating, adducting and extending one shoulder while maximally externally rotating, adducting and flexing the contralateral shoulder. The evaluator measures the distance between the two closest bony prominences of the fists. If after a maximum of three attempts, the distance measured is within one hand-length, a score of three is recorded, a two if the measurement is within one and one-half hand-lengths, and a one is if the measurement is greater than one and one-half hand-lengths.

Active Straight Leg Raise

Evaluation of the active straight leg raise begins in the supine position with head on the floor, arms by the side, palms up, both feet together, and ankles dorsiflexed to 90 degrees. A 2-inch by 6-inch board is placed under both knees, and the mid-point between the subject's anterior superior iliac spine and mid-point of the patella is identified. A dowel is placed at this location, perpendicular to the ground. The test leg is then lifted in the sagittal plane while maintaining an extended knee and dorsiflexed foot position. A valid test requires that the contralateral limb does not rotate and the knee must remain in contact with the board. After maximal hip flexion is achieved, the position of the medial malleolus of the test limb is measured in relationship to the contralateral knee and dowel. Movement of the medial malleolus past the dowel towards the subject's head earns a three, and a two corresponds with the medial malleolus passing the contralateral knee but not the dowel. If the medial malleolus fails to pass the contralateral knee, the score is reduced to a one.

Trunk Stability Push-Up

The trunk stability push-up commences in the prone position with feet together and the hands placed shoulder width apart. Male subjects start with the hands in-line with the top of the head and continue by lowering them to the chin if necessary, whereas female subjects commence with the hands at chin level and lower them to the clavicle if necessary. One push-up is executed with the body elevating as a unit and no lag in the lumbar spine, followed by returning to the starting position while maintaining the same movement criteria and hand positioning. Males earn a three if the criteria are maintained with hands at head-level, and females with hands at chin-level. A score of two corresponds with successful completion of the criteria while hands are kept at chin-level (males), and clavicle-level (females), and a score of one is consistent with failure to maintain the second position.

Rotary Stability

The test begins in the quadruped position with shoulders and hips flexed to 90 degrees, and a board is placed between the hands and knees of the subject. The hands (palmar aspect) and knees are in contact with the ground, directly below the shoulders and hips, respectively, with the ankles dorsiflexed. One hip and knee is extended while flexing the shoulder and extending the elbow of the ipsilateral limb. While maintaining the elevated appendages in-line with the board, and the trunk in-plane with the board, an attempt is made to contact the ipsilateral knee and elbow over it, followed by a return to the extended positions. Completion of the task within the required criteria earns a score of three. In case of failure, the task is repeated in the diagonal with opposite arm and leg raised. A score of two corresponds to completion of the diagonal task within the required criteria, whereas the subject earns a one if he/she is not able to complete the diagonal task within the required criteria.

Research Studies

Reliability Studies

Subjects

The subjects for this study (N = 8) were Certified Athletic Trainers who volunteered their participation as evaluators in the injury prediction study. They were trained to execute and rate the FMS by the primary investigator who had previously been instructed at an FMS seminar (Perform Better; Los Angeles, CA). The process began with an introduction DVD (http://functionalmovement.com) and grading rubric (Appendix 1) given to the evaluators to gain exposure to the principles of the FMS. Subsequently, a group training session of two hours that included a review of the individual tests in the FMS (i.e. proper set up, execution, and scoring criteria of the tests) was used. After completion of this session, each evaluator carried out a complete FMS while the primary investigator provided corrective feedback on the execution of the tests.

A sample of fifteen college-aged subjects (eleven males, four females; age: 24.7 years; height: 165.87cm; weight: 73.07kg) volunteered to perform the movements of the FMS while being video taped from a frontal and sagittal view. Prior to participation, each subject signed a consent form and agreement for videotaping approved by the Human Subjects Compliance Committee at the University of Oregon. (Appendices 2 & 3) Each participant was instructed in the performance of all test movements by the primary investigator to ensure a standardized explanation. The videos were compiled by the primary investigator and one repetition of each movement was presented to the evaluators. The evaluators scored the video performances on a written score sheet

(Appendix 4) two times with a two-week interval between sessions. After the sessions, their scores were given to the primary investigator with whom they were kept confidential and ultimately transcribed into Excel and transferred to SPSS for data analysis.

Data Analysis

Inter-rater Reliability Study

Inter-rater reliability for the group of eight subjects was tested using an inter-item correlation matrix, in which the scores of each evaluator are compared to the scores of each other evaluator. The dependent variables (8) included each movement of the FMS (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability) and the FMS score. For movements divided for right and left, the composite score (lower of the two net scores, as used in the FMS total) was used in determining inter-rater reliability for the movement. Scores for each test were analyzed from the first video scoring session with the evaluator serving as the independent variable (8). Statistical analyses were run using SPSS 13 Grad Pack for Mac OS X. With this type of analysis, the scores of the evaluator are compared individually to each of the others (Ex. 1-2, 1-3, 1-4, 2-3, 2-4, etc.). In order to evaluate the reliability for each test, the median reliability coefficient was calculated for each Athletic Trainer and the median of the medians was calculated for the entire group. The median reliability coefficient was defined as the score that separated the higher and lower halves for the inter-rater reliability pairings. (Table 2.1) This value was used instead of the mean value in order to protect the outcomes from skewed results or outliers. Furthermore, the median of the medians (middle score of all evaluators' inter-rater reliability) was used to report the performance for the group of evaluators. This allowed the primary investigator to evaluate the degree of agreement across individuals and the group. Median reliability coefficients were calculated using Microsoft Excel 2008 for Mac.

Table 2.1: Example Calculation for Median Reliability Coefficient

Pairings	1-2	1-3	1-4	1-5	1-6	1-7	1-8
Score	0.78	0.83	0.85	**0.88**	0.90	0.90	0.94

Note. The reliability coefficient of 0.88 is the median score because it splits the inter-rater reliability scores into high and low halves

Intra-rater Reliability Study

Intra-rater reliability for each subject was tested using an intraclass reliability coefficient, which evaluates the degree of consistency for each rater scoring the FMS over time. The dependent variables (8) were each movement of the FMS (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability) and the FMS score. For movements divided for right and left, the composite score (lower of the two net scores, as used in the FMS total) was used in determining intra-rater reliability for the movement. The independent variable (1) was time (session one and two). Intra-rater reliability for each evaluator was run using SPSS 13 Grad Pack for Mac OS X. The median reliability coefficient (middle score for the group) was then calculated for each movement and the FMS scores (Microsoft Excel 2008 for Mac). This value permitted the primary investigator to evaluate the level of agreement across individuals for each test without the scores being influenced by skewed results or outliers.

Interpretation of Data

Generally, there are no universally applicable standards as to how high scores must be to constitute acceptable reliability, and the use of the scores typically dictates the minimum level that must be met (Shrout & Fleiss, 1979; Eliasziw, Young, Woodbury, & Fryday-Field, 1994; Hayen, Dennis, & Finch, 2007). For example, reliability scores for screening purposes are commonly considered appropriate at much lower levels than for outcomes that will directly influence the choice of treatment for a patient (Downing, 2004; Hayen et al., 2007). However, it is important to carefully pre-determine the acceptable level in order to have confidence that a group is consistent in scoring the required tests. In this study, a cutoff of 0.80 on the FMS score was used to exclude evaluators from the injury prediction study. Scoring above 0.80 was considered acceptable reliability, whereas scores below 0.80 resulted in exclusion from the study because the evaluator's performance may not be adequate for screening purposes relative to the needs of the study. As stated above, these values correspond to the level of consistency for the scores that were recorded, as compared between and within each evaluator.

Injury Prediction Study

Subjects

The subjects for this study (N = 112) included 52 male and 60 female basketball players from participating high schools in the 4J (Eugene, OR) and Springfield (Springfield, OR) school districts. Prior to participation, each subject or, for minors, their legal guardian signed a consent form approved by the Human Subjects Compliance Committee at the University of Oregon. (Appendix 5) Fifteen of the subjects who participated were at the freshman level, 37 at the junior varsity level, and 60 at the varsity level. None of the subjects had internal or external appliances in the extremities (i.e.: rods, joint replacement, prosthetic) or an injury status that prevented full participation in school-sanctioned basketball practices or games.

Each subject completed a demographic information form that included their name, age, gender, year-in-school, previous musculoskeletal injuries, school name, team level, years-of-participation in basketball, projected player status (starter, second-string), and projected position. (Appendix 6) All information was self-reported and collected prior to the screening process.

Functional Movement Screen Rating

The FMS was administered by a team of Certified Athletic Trainers that had completed the inter-rater and intra-rater reliability study and scored 0.80 or greater on the FMS score (see Results section). Each subject was screened prior to a school-sanctioned basketball practice or at a mutually agreeable time outside of practice. No testing was administered immediately following a basketball practice, competition, or strength and conditioning session to limit the impact of potentially confounding variables such as muscular fatigue, lack of flexibility or soreness on the testing. All scoring was conducted live by individual evaluators and transcribed on a written score sheet (Appendix 4). Asymmetries were recorded as the difference between the scores recorded for right and left movements (Ex: Hurdle step right = 1, hurdle step left = 3. Asymmetry recorded), whereas weighted asymmetries were designated as the total difference between those measurements (Ex: Hurdle step right = 1, hurdle step left = 3. Weighted asymmetry of 2 recorded). The latter were calculated to determine if the degree to which a movement was asymmetrical was a better predictor than unweighted asymmetries. FMS and asymmetry scores were transcribed into Excel and transferred into SPSS for data analysis.

Injury Data

Injury and time-loss data were collected throughout the duration of the 2008-2009 high school basketball season by Certified Athletic Trainers employed by the participating high schools using a Daily Injury Report Form. (Appendix 7) Classification was made by:

- Date of injury
- Date of return-to-full-participation
- Injured body part
- Injured side
- Type of injury
- Diagnosis
- Occurrence of previous injury
- Cause of injury (overuse or acute)
- Time of injury (practice or competition)
- Non-contact vs. contact
- Type of contact

Injuries utilized in this study were limited to those classified as neuromusculoskeletal impairments reported to and/or recognized by the school's coaching staff or Certified Athletic Trainer. Injuries were excluded if they did not occur during a school-sanctioned practice or game, were unrelated to training or competition, or were caused by contact with a ball, another player, the floor, or any combination of the above. The latter were recorded nonetheless so that the primary investigator could evaluate the type of contact and determine proper use of the exclusion criteria. Injury data collection began on the day of the FMS testing and was concluded on the last day of competition for each team.

Data Analysis

A one-way analysis of variance was performed to verify that no significant differences existed between boys' and girls' FMS scores so that data from both groups could be pooled for injury prediction analyses. The dependent variable (1) was the FMS score with gender serving as the independent variable (2). Furthermore, to rule out type of injury (acute and chronic) as a potentially confounding variable, the FMS total scores for those sustaining acute versus chronic injuries were compared using a one-way analysis of variance to indentify if there were significant differences between the groups. No differences would indicate that type of injury was not a confounding variable in this study and the data could be pooled.

Previous research (Kiesel, Plisky, & Voight, 2007) utilized a receiver-operator characteristic (ROC) curve to determine a cutoff score on the FMS that maximized sensitivity (the percentage of injured athletes that were predicted by the FMS) and specificity (the percentage of uninjured athletes that were predicted by the FMS). This cutoff was then used with the same data set in order to evaluate the efficacy of the cutoff, despite the fact that this practice often overestimates the findings as compared to using the cutoff with a unique, prospective sample of subjects (Kiesel et al., 2007). Therefore, the previously identified score of fourteen was utilized for our study.

Chi-square determined the predictive capacity of the FMS score cutoff of 14 out of 21 to identify basketball athletes that became injured. The dependent variable (1) for this analysis was injury (injured, not injured), whereas the independent variable (1) was FMS score (14 and below, 15 and above). The subjects were divided into a 2x2 contingency table for the chi-square test with column one assigned to subjects that scored 14 or above on the FMS and column two containing those subjects with lower scores. Row one included subjects that were not injured during the season and row two, those that were. If the FMS was able to perfectly identify at-risk subjects, all participants would fall into two cells: the cell for row one/column one would include all subjects that scored above 14 or greater and, therefore, did not become injured, whereas row two/column two would contain the remainder of the subjects that scored lower and were injured.

Logistic regression isolated demographic variables and components of the FMS in order to determine their predictive capacity for identifying injury-prone athletes. This tool identifies a combination of independent variables that best predict membership in a particular group, as measured by a categorical dependent variable (Mertler & Vannatta, 2005). The categorical dependent variable was injury (injured, not injured) measured against the independent variables (11) gender, level (Freshman, Junior Varsity, Varsity) each movement of the FMS (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability), the number of asymmetries, and weighted asymmetries. The goal was to determine if the independent variables listed above could predict if an athlete was vulnerable to injury, either individually or grouped.

Although research indicates that previous injury is a significant risk factor for repeat injury (Emery et al., 2005), the methods for collecting this type of data relied upon the memory of the subjects and/or their parents to accurately report the athlete's history of injury. After reviewing the data, the replies were incomplete and lacking details. For this reason, previous injury data was not included in the logistic regression model. However, we were able to obtain complete data regarding the history of those athletes that became injured during the season, as reported by the school's Athletic Trainer. This data was analyzed using a one-way analysis of variance to determine if there were significant differences between the FMS total scores of the subjects that sustained new versus recurring injuries.

CHAPTER III

RESULTS

Reliability Studies

Table 3.1 displays the minimum and maximum scores for the group of 15 subjects performing the FMS, as rated by the Athletic Trainers participating in the reliability studies.

Table 3.1: Values for Functional Movement Screen of Reliability Study Participants

Source	min	max
Deep Squat	0	3
Hurdle Step	1	3
In-line Lunge	0	3
Shoulder Mobility	0	3
Active Straight Leg Raise	1	3
Trunk Stability Push Up	1	3
Rotary Stability	0	2
Score	10	18

Note. n = 15

Inter-rater Reliability Study

The median inter-rater reliability coefficient was considered acceptable (greater than 0.80) for all of the individual tests except for the rotary stability test (0.73). However, our evaluation of FMS total scores, which included the latter test, yielded acceptable reliability, indicating that, for the screening as a whole, evaluators are able produce FMS scores similarly to their peers. (Table 3.2) Since Kiesel et al. (2007) proposed that the composite FMS score is the primary indicator of injury risk, its reliability score was used to determine the cutoff for exclusion as a rater in this study. All evaluators scored above 0.80 and were included. However, the results for the rotary stability test should be considered with caution when interpreting results derived from that test individually.

Table 3.2: Inter-rater Reliability Results

Source	min	max	median of medians
Deep Squat	0.84	0.91	0.90
Hurdle Step	0.75	0.90	0.84
In-line Lunge	0.86	0.95	0.88
Shoulder Mobility	0.97	0.97	0.97
Active Straight Leg Raise	0.85	0.92	0.90
Trunk Stability Push Up	0.77	0.87	0.84
Rotary Stability	0.66	0.81	0.73
FMS Total Score	0.89	0.92	0.90

Note. $n = 8$

Intra-rater Reliability Study

The median intra-rater reliability coefficient was considered acceptable for all of the tests and FMS score, indicating that evaluators are able to score the FMS consistently over time. (Table 3.3)

Table 3.3: Intra-rater Reliability Results

Source	min	max	median
Deep Squat	0.75	1.00	0.92
Hurdle Step	0.64	1.00	0.85
In-line Lunge	0.86	1.00	0.92
Shoulder Mobility	0.93	1.00	0.97
Active Straight Leg Raise	0.69	1.00	0.88
Trunk Stability Push Up	0.71	1.00	0.88
Rotary Stability	0.50	1.00	0.82
FMS Total Score	0.86	0.95	0.88

Note. $n = 8$

Injury Prediction Study

Demographics

The subjects for this study (N = 112) included 52 male and 60 female basketball players from participating high schools in the 4J (Eugene, OR) and Springfield (Springfield, OR) school districts. Fifteen of the subjects participated at the freshman level, 37 at the junior varsity level, and 60 at the varsity level. The minimum, maximum, mean and standard deviation for each of the FMS movements and final scores can be found in Tables 3.4 and 3.5, which are sub-divided for boys and girls. A comparison of their performances can be found in Table 3.6 and Figures 3.1 and 3.2, which show that the effect of gender on FMS score was not significant, $F(1, 110) = 0.29, p > .05$. This indicates that there is no significant difference in the FMS score between boys and girls and consequently, the injury results for this study can be pooled in a single group.

Table 3.4: Values for Functional Movement Screen Tests and Final Score for Boys

Source	min	max	*M*	*SD*
Deep Squat	1	3	1.62	0.56
Hurdle Step	1	3	1.83	0.43
In-line Lunge	1	3	2.21	0.61
Shoulder Mobility	1	3	2.62	0.72
Active Straight Leg Raise	1	3	2.48	0.64
Trunk Stability Push Up	1	3	1.83	0.79
Rotary Stability	1	3	1.88	0.65
Total Score	10	20	14.46	2.13

Note. n = 52

Table 3.5: Values for Functional Movement Screen Tests and Final Score for Girls

Source	min	max	*M*	*SD*
Deep Squat	1	3	1.68	0.57
Hurdle Step	1	3	1.88	0.45
In-line Lunge	1	3	2.23	0.59
Shoulder Mobility	2	3	2.90	0.30
Active Straight Leg Raise	1	3	2.67	0.57
Trunk Stability Push Up	1	3	1.43	0.65
Rotary Stability	1	3	1.87	0.57
Total Score	10	20	14.67	1.91

Note. $n = 60$

Table 3.6: One-Way Analysis of Variance Summary Table for the Effects of Gender on FMS Score

Source	*df*	*SS*	*MS*	*F*
Gender	1	1.17	1.17	0.29
Error	110	446.26	4.06	
Total	111	447.43		

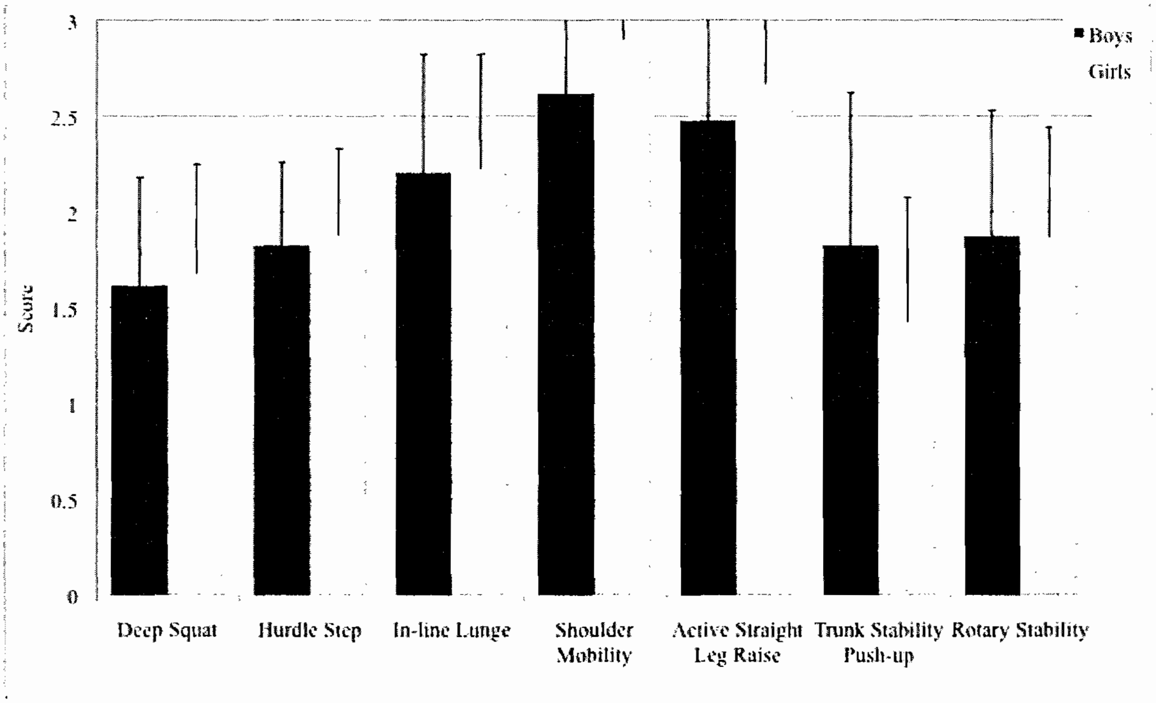

Figure 3.1: Comparison of FMS Movement Scores for Boys and Girls

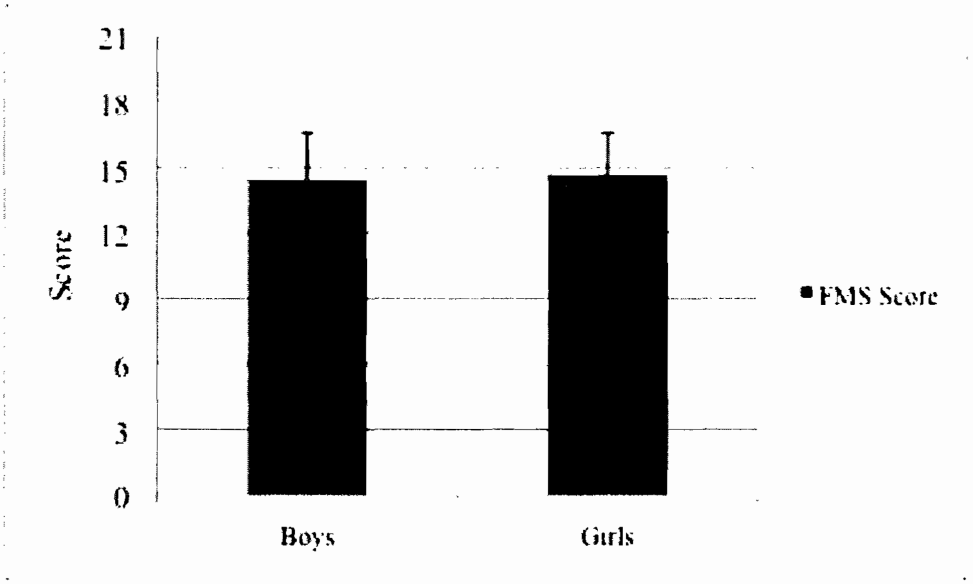

Figure 3.2: Comparison of FMS Scores for Boys and Girls

Five of the seven FMS tests are divided for right and left, and provide potential areas for movement asymmetries (defined as a difference in test scores between the right and left). The average number of asymmetries for boys was one, whereas girls had less than one. (Tables 3.7 and 3.8) There was little difference between the means for asymmetries and weighted asymmetries (see Methods for definition), and therefore, these calculations may be redundant for future studies.

Table 3.7: Functional Movement Screen Asymmetries for Boys

Source	min	max	*M*	*SD*
Asymmetry	0	3	1.00	0.77
Weighted Asymmetry	0	3	1.10	0.85

Note. n = 52

Table 3.8: Functional Movement Screen Asymmetries for Girls

Source	min	max	*M*	*SD*
Asymmetry	0	3	0.83	0.83
Weighted Asymmetry	0	3	0.82	0.83

Note. n = 60

Injuries

Thirty-two non-contact neuromusculoskeletal injuries were reported during the season. The majority of injuries affected the lower extremities (27), whereas only two affected the upper extremity and three impacted the trunk. (Table 3.9) The volume of injuries to the lower extremity compared to the upper extremities and trunk was greater than has been reported by Rechel et al. (2008), studying a subset of high school basketball players. However, that study included contact injuries, which would have likely increased the number of reported injuries to the upper extremity and trunk. Twenty-six of the injuries occurred during a practice session (81%) and six (19%) during games. These findings are significantly skewed towards practice compared to previous research (Rechel et al., 2008), which showed that there is only a difference of 2.6 to 10.6 percent between practice and competition, with more injuries occurring during games for girls. Thirteen of these injuries were sustained by boys, nine of which were chronic in nature and four could be attributed to acute mechanisms. Nineteen injuries were sustained by girls, thirteen of which were chronic and six acute. The total amount of time lost from these injuries was 61 days for both boys and girls, totaling 122 days of time-loss for the study.

Table 3.9: Number of Injuries by Region

Region	Number
Foot & Ankle	6
Leg	8
Knee	5
Thigh & Groin	6
Hip	2
Low back	3
Shoulder	1
Forearm	1

The mean FMS total scores for those sustaining acute or chronic injuries were 13.90 ($SD = 2.03$) and 14.64 ($SD = 1.50$), respectively. Results for the comparison of the FMS total scores between athletes sustaining acute versus chronic injuries can be found in Table 3.10, which shows that the effect of injury type on FMS score was not significant, $F(1, 30) = 1.33, p > .05$. This indicates that there is no significant difference between the FMS scores of those suffering injuries as the result of acute versus chronic mechanisms, and therefore, this data was pooled into a single group.

Table 3.10: One-Way Analysis of Variance Summary Table for the Effects of Injury Type on FMS Score

Source	*df*	*SS*	*MS*	*F*
Injury Type	1	3.73	3.73	1.33
Error	30	83.99	2.80	
Total	31	87.72		

Injury Prediction with Cutoff Score of 14

Utilizing the cutoff score below 14 to categorize athletes, 76 subjects scored above the benchmark and 36 scored below. Data analysis revealed that the commonly-used FMS cutoff score of less than 14 out of 21 was not significantly related to the likelihood of sustaining an injury, χ^2 (1, n = 112) = 0.03, $p > .50$. (Table 3.11) In fact, the FMS displayed very poor ability to predict at-risk athletes as a greater percentage of those scoring fourteen or higher became injured (24%) compared to those below the cutoff (22%). This contradicts the assertation of a cutoff identifying vulnerable athletes because a greater percentage of athletes scoring above 14 became injured compared with the group that was expected to have a greater risk of injury. Furthermore, analyses of higher and lower cutoff scores indicated that no other cutoff could accurately predict an increased risk of injury. (Tables 3.12-3.15)

Table 3.11: Chi-square Results with Cutoff of 14

Injury	FMS Score	
	< 14	14+
No Injury	28	58
One or more injuries	8	18

Note. $n = 112$

Table 3.12: Chi-square Results with Cutoff of 12

Injury	FMS Score	
	< 12	12+
No Injury	4	82
One or more injuries	1	25

Note. $\chi^2 (1, n = 112) = 0.30, p > .50$

Table 3.13: Chi-square Results with Cutoff of 13

Injury	FMS Score	
	< 13	13+
No Injury	12	74
One or more injuries	3	23

Note. $\chi^2 (1, n = 112) = 0.10, p > .50$

Table 3.14: Chi-square Results with Cutoff of 15

Injury	FMS Score	
	< 15	15+
No Injury	41	45
One or more injuries	14	12

Note. χ^2 (1, n = 112) = 0.30, p > .50

Table 3.15: Chi-square Results with Cutoff of 16

Injury	FMS Score	
	< 16	16+
No Injury	56	30
One or more injuries	20	6

Note. χ^2 (1, n = 112) = 1.28, p > .10

Injury Prediction with Logistic Regression

In order to determine if a subset of demographic variables, FMS movements and asymmetrical movements could more accurately predict injury risk, logistic regression was used (see Methods, pg. 39). Data analysis revealed that none of the predictors were significant, either in isolation (Table 3.16) or in combination ($df = 11, p > .10$).

Table 3.16: Logistic Regression for Predictors in Isolation

Predictors	β	*p*
Gender	0.55	1.74
Level	-0.91	0.40
Deep Squat	0.39	1.48
Hurdle Step	0.56	1.75
In-line Lunge	-0.81	0.45
Shoulder Mobility	-0.72	0.49
Active Straight Leg Raise	-0.14	0.87
Trunk Stability Push Up	0.10	1.11
Rotary Stability	-0.29	0.75
Asymmetries	0.11	1.12
Weighted Asymmetries	-0.51	0.60

Note. $df = 11$

Previous Injury

The prevalence of injury was equally divided between new injuries and recurrences with mean FMS total scores of 14.21 ($SD = 1.81$) and 14.42 ($SD = 1.62$) for each group, respectively. Results for the comparison of the FMS total scores between athletes sustaining a new or recurring injury can be found in Table 3.17, which shows that the effect of previous injury on FMS score was not significant, $F(1, 24) = 0.89$, $p > .05$. This indicates that there is no significant difference for the FMS scores of newly versus previously injured athletes.

Table 3.17: One-Way Analysis of Variance Summary Table for the Effects of Previous Injury on FMS Score

Source	*df*	*SS*	*MS*	*F*
Previous Injury	1	0.27	0.27	0.89
Error	24	71.27	2.97	
Total	25	71.54		

CHAPTER IV

DISCUSSION

Statement of the Problem

It has long been the responsibility of the sports medicine team of physicians, athletic trainers, physical therapists, and strength and conditioning coaches to ensure the safety of those participating in sport. Their involvement in the well-being of athletes varies based upon the setting, but each of these individuals has an integral part in the process. The current model of health care and advances in medical science are strongest in their response to injury. That is, once an injury occurs, there are many theories and techniques available that contribute to its accurate diagnosis and management. With respect to musculoskeletal pathology, there are often efforts to reduce the likelihood of reinjury by correcting biomechanical deficiencies in range of motion, strength or movement patterns. However, there is scant information available as to how to intervene prior to the occurrence of an injury so that the event is prevented before it ever happens.

The number of athletes that participate in sport, ranging from recreational involvement to high-level competition, and the wide spectrum of injuries that occur, suggests that any attempt to develop prevention protocols would be daunting. In addition, practicality would require a streamlined and standardized approach for their implementation. Within organized athletics, this effort could be simplified because many schools, clubs and teams employ sports medicine professionals who work specifically with the athletes to monitor the incidence of injury and manage their rehabilitation. Consequently, they are well placed to develop, implement and test promising injury prevention models. At the elite level, preventing injuries is economically desirable as it helps to ensure that highly paid athletes remain active for competition. Despite only anecdotal evidence and limited research supporting various methods of identifying athletes that are at risk of becoming injured, some institutions and teams have already hired personnel that are specifically charged with the duty of executing injury prevention programs. Although this forward thinking attitude towards injury prevention warrants praise, the methods such groups employ to design prevention programs are rarely grounded on strong, evidence-based practice. This gap between evidence and practice is what prompted the research described here.

The focus of the study was evaluation of the reliability and validity of the Functional Movement Screen (FMS) (http://functionalmovement.com), a battery of tests developed in 1995 that relies upon common, basic movements to identify athletes that are at an elevated risk of injury. The FMS was constructed around seven basic movement patterns that were deemed to represent foundational actions of many sport maneuvers. The tests devised by its creators measure mobility and stability for the upper and lower extremities, as well as the trunk. Three stance positions form the core of the FMS and are designed to challenge the whole body while standing upon various bases of support. They include a symmetrical foot position during the deep squat, a split stance for the in-line lunge, and a single leg stance in the hurdle step. Core stability, defined as the capacity to resist motion about the trunk, is required during the deep squat, in-line lunge, trunk stability push-up and rotary stability movements, whereas mobility of the upper extremities is tested in the deep squat and shoulder mobility maneuvers. Although the justification for the choice of these tests is logical, they were nonetheless chosen based solely upon the clinical experience of sports medicine practitioners in the absence of any research to validate the inclusion of each movement. Furthermore, no evidence has yet been published to establish the screen's reliability and only one study to-date supports the developer's assertion that a cutoff score of 14 out of 21 on the FMS is a reliable predictor of injury. Despite the paucity of information and support for its design, the FMS has been widely accepted in clinical practice, likely due to its simple, practical and systematic protocol for executing the screen, as well as its delineated, ordinal scoring system that enables practitioners to easily translate evaluation of movement into numerical scores.

A subset of high school basketball athletes from the Eugene and Springfield, OR region were evaluated with the FMS and followed throughout a single season to determine if the test, and its widely-used numerical cutoff standard, demonstrated the same predictive ability as that previously observed in professional football players (Kiesel et al., 2007). This subset of athletes was chosen because the successful application of the FMS to this population could have a profound impact on sports in the United States. That is, seven million high school students participate yearly in various sports (Rechel et al., 2008), whereas professional football players number less than 1,700 nationwide (http://www.nfl.com). Furthermore, a high volume of injuries occurs in this age group (Rechel et al., 2008) and basketball is a sport in which upper and lower extremities movements are common, which should fit well into the testing paradigm of the FMS.

Reliability

Prior to the implementation of the FMS in a clinical or research setting, it is incumbent upon the users to establish adequate reliability, across and within a subset of evaluations, in scoring the tests. In essence, this means that the scoring performance on the FMS movements should be able to be executed rapidly and efficiently, over time and between evaluators, with consistent results. Without adequate reliability, attempts to establish the validity of the FMS, with respect to injury prevention, cannot be performed with any confidence and the outcomes of any attempts to do so in the absence of such data must be viewed with caution. In addition, because the intent of the FMS is to screen a large population of athletes, questions about practicality surface. This study was designed using eight evaluators to efficiently screen subjects and minimize the impact of such data collection on the teams' practice time. However, if use of multiple evaluators was deemed untenable, reliance on a smaller number of personnel or, worse yet, a single rater, would most certainly diminish efficiency and practicality.

The reliability study for this research tested eight Athletic Trainers' ability to score the FMS tests consistently across multiple trials and evaluators. Fifteen subjects (see Methods for demographics) were instructed on how to perform the FMS movements by the primary investigator and subsequently video taped from the front and side while they executed each test. The videos were then compiled and randomly presented to the team of evaluators for scoring. Because the composite score is the primary predictor of injury and the focus of this investigation, it was used as the reliability standard for including or excluding raters for this study. Results indicate that, in all subjects, an acceptable reliability coefficient of greater than or equal to 0.80 was achieved across and within evaluators in obtaining FMS scores. (Tables 3.2 and 3.3) Thus, each rater was included in the study of validating injury prediction. The data also show that all of the tests could be scored individually with adequate reliability over time, whereas the rotary stability test was found to be the only test that was not reliable between raters.

The results from the rotary stability test are noteworthy and should generate caution. The lack of consistency in evaluating the movement might well be related to the anatomical position of the subject and its complexity as the test is performed low to the ground with many variables to assess. Scoring is further complicated by the fact that it is not possible to evaluate all aspects of the test in a single trial or from a single viewing location, requiring the subject to repeat the test several times. Due to the fact that subjects were required to perform repeated trials, inconsistent performances are a possibility as they attempt to execute the test while maintaining stability. Furthermore, this test presented the greatest instructional challenge on proper execution since the quadruped, unilateral movement required to earn a score of three is a complex movement.

In general, the well-defined movement criteria and scoring rubric are a strength of the FMS; however, the rotary stability test may need further development to improve the consistency of the movement scoring or it may be best to drop it and seek an alternative method to assess the parameters it targets. It must be noted that these data are the first published reliability study for the FMS. In light of the results, further research should be conducted to specifically address the use of the rotary stability portion of the FMS to determine if its inclusion compromises the overall screening procedure. Furthermore, future research should attempt to design a real-time scoring scenario to ensure that the reliability of the tests are evaluated as they would be scored in a real-life setting. The 2-D nature of the video scoring design, although practical, may have over-simplified the evaluations and enhanced the screen's reliability.

FMS Performance

Once inter-rater and intra-rater reliability of scoring the FMS were established, the primary goal was to answer the question: can the FMS accurately predict athletes that are most vulnerable to becoming injured? Thus, FMS and injury data were collected throughout the duration of a single basketball season. For this subset of high school basketball athletes, there were no significant differences in the FMS score for boys and girls (Table 3.6), which allowed the researchers to pool the injury data. It should be noted that the group means for two of the tests, the shoulder mobility and active straight leg raise, were greater than the rest of the movements. These tests are designed to evaluate mobility of the upper and lower extremities, and, in this young population, the subjects routinely displayed sufficient range of motion to score high on these tests. (Tables 3.4 and 3.5, and Figure 3.1) In contrast, the high school athletes displayed a trend for low scores on the deep squat (mean score of 1.62 and 1.68 for boys and girls respectively), which evaluates the greatest number of joints moving simultaneously and requires mobility in the ankles, knees, hips, thoracic spine and shoulders while stabilizing extraneous motion in the knees and trunk. The complexity of this motion may have caused both genders to score low. Furthermore, as noted in clinical practice, the deep squat is typically one of the most difficult movements across all ages. (Unpublished observation) Finally, girls scored the lowest for the group in any test with the trunk stability push-up (mean score of 1.43), a test that demands upper extremity and core strength.

Injuries

The frequency of injury in this study exceeded the findings from the general high school athletic population (Rechel et al., 2008), in that twenty-nine percent of the basketball athletes became injured during the basketball season compared to twenty percent in the previous study. In addition, the volume of injuries that were sustained during practice compared to games was greater than the previous basketball population studied by Rachel, et al. (2008). This may well be simply related to the frequency of practices versus games during a basketball season, although this explanation does not account for the difference noted in the previous research. Anecdotally, there were several early-season, overuse injuries sustained by athletes as they transitioned from other sports like football, cross-country and volleyball, which could have influenced the volume of injuries noted in the pre-season basketball practices. However, a comparison of FMS scores for those suffering acute versus chronic injuries indicates that there is no difference between the groups (Table 3.10) and suggests that type of injury is not a confounding variable in this study. In any case, for boys and girls alike, the majority of injuries affected the lower extremity, a finding that is consistent across a wide range of sporting activities (Murphy et al., 2003; Rechel et al., 2008).

It should be noted that, although it is recommended to report injury using exposure data (Fuller et al., 2006), the logistics of this study prevented participation data from being accurately collected. The researchers originally planned for each team's head coach to record daily participation numbers, but compliance was lacking and the data set was incomplete. Future studies should design an instrument for tracking this data through the attending medical staff or post-season analysis of athletes' medical charts in order to determine time-loss, and thus, participation.

Injuries included in this study were limited to those evaluated by the institution's athletic trainer, sustained during a school-sanctioned basketball event, and void of any contact with the ball, another player, the floor (with the exception of the feet) or any other object in the gymnasium. In contrast with the professional football study, these criteria resulted in inclusion of less severe injuries that occurred during basketball and did not require any time-loss. This would result in more liberal inclusion of certain types of injuries that might alter the FMS's sensitivity compared to the previous study. A self-reporting system for the athletes to volunteer additional injuries that were not reported to the athletic trainer was not used, although it may have captured an even greater number of injuries due to the common underreporting of injuries that characterizes high school athletes. This decision was made, as inclusion of this population would have compromised the quality of data by relying on the memory and maturity of the athletes in their responses.

The professional football study (Kiesel et al., 2007) identified athletes that became injured from both contact and non-contact mechanisms, whereas our study was limited to non-contact injuries. The justification for that course of action was that, we believed that although a good performance on the FMS tests is consistent with a high level of mobility and stability, it is unclear how those qualities could positively assist an individual in avoiding a contact injury. It may be theorized that increased mobility and stability could help an athlete avoid contact or tolerate greater impact forces against the body. However, we chose to exclude such injuries so as to eliminate any contribution from those that occurred from random encounters on the court. Confirming this decision, one athlete practiced for only two days during the season and sustained a finger fracture on each of those days, causing her to miss the entire season. The relationship between these types of injuries and the FMS could not be rationalized, and therefore, they were excluded in their entirety.

FMS Injury Prediction

The previous research with professional football players (Kiesel et al., 2007) shows that athletes who score below 14 out of 21 are eleven times more likely to sustain an injury that results in greater than three weeks of missed participation. In the current study, utilizing the cutoff score below fourteen to categorize athletes, seventy-six subjects scored above and thirty-six scored below the accepted value. Twenty-four percent of the athletes who scored fourteen or above became injured, whereas twenty-two percent testing below fourteen sustained an injury. (Table 3.11) These data clearly contradict the previous assertation (Kiesel et al., 2007) that a cutoff of fourteen identifies vulnerable athletes. In an attempt to determine if a different cutoff score could more accurately discriminate within this population, the value was altered to higher and lower scores and the chi-square analysis was repeated. (Tables 3.12-3.15) It can be seen that, in all comparisons, no alternative cutoff could be found that was able to identify at-risk athletes.

While the FMS score was not successful in identifying vulnerable high school basketball players, it might be possible that combinations of demographic information (gender and level), the scores from FMS movements, and asymmetrical movements (different score for right and left limbs) could actually prove more useful in injury prediction than the FMS score alone. To this end, a logistic regression model was used, which employs a combination of independent variables that best predict membership in a particular group, as measured by a categorical dependent variable, in this case, injury (Mertler & Vannatta, 2005). For example, anatomical and movement asymmetries have previously been identified by several authors as potential indicators of injury risk (Knapik et al., 1991; Baumhauer et al., 1995; Nadler et al., 2001; Plisky, Rauh, Kaminski, & Underwood, 2006). The theory is that uneven stresses applied to the body during asymmetrical movement lead to chronic injuries and/or predispose an individual to an acute injury during landing or pivoting maneuvers (Plisky et al., 2006).

Despite the historical connection between asymmetries and injury, our results failed to identify any of the variables included in the model as significant predictors of injury, either alone or in combination with any other parameter. Similarly, Burton (2006), a developer of the FMS, found that FMS movement asymmetries were not significant predictors of injury in a population of firefighters. Furthermore, while past authors (Murphy et al., 2003; Emery et al., 2005; Caine et al., 2008) have indicated that a history of previous injury is a significant predictor of future injury, a comparison of the FMS scores for those sustaining a new versus recurring injury displayed no significant differences between the groups (Table 3.17), which suggests that previous injury was not a significant predictor of injury.

Collectively, our results provide the first evidence that, despite the fact that anecdotal, clinical findings have led to widespread adoption of functional screening, the FMS is not in any way a viable evaluation tool for identifying high school athletes throughout a basketball season as being at high risk for injury. Our data do not rule out the potential value of the FMS in other sport or recreational settings, as our protocols were quite specific to the studied population. As described previously (see Introduction, pg. 12), past efforts to identify tests that are predictive of injury have yielded conflicting results and this study introduces similar disparity with the professional football study (Kiesel et al., 2007). Furthermore, the definition of injury was more inclusive than the previous FMS study (Kiesel et al., 2007), and may have introduced too much variability and/or captured injuries that were unrelated to performance on the FMS, thus limiting the screen's ability to accurately identify at-risk athletes. However, activities in each test seem to fail to replicate the high forces and velocities that are produced during actual practice or competition, which may contribute to our inability to find any positive correlations. That is, the physical demands of various sports are extremely variable and a single battery of tests may simply be insufficient to accurately predict the level of risk across a broad spectrum of athletes. For example, football and basketball have great dissimilarity in levels of contact, movements, playing surfaces, equipment, goals for the sport, etc. that may easily account for the disparity in findings between the two studies.

Over several decades, many researchers have attempted to identify risk factors for injury (Godshall, 1975; Knapik et al., 1991; Twellaar et al., 1997; Murphy et al., 2003); however, meaningful success in this area has been elusive. The complexity of injury (mechanisms, predisposing conditions, fatigue, psychosocial factors, etc) may simply be too great to allow any one test, screen or other collection of predictive variables to consistently predict injury. The answer may lie in creating a battery of tests that is sport-specific so that the uniqueness of each activity can be properly evaluated. However, despite the difficulties facing individuals who seek progress in this area, the effects on the lives of those injured, the associated health care costs, long-term disability, and the loss of physical vitality call for more extensive investigation into the utility of screening methods, and/or the identification of other variables, or combination thereof, that may predict injury more accurately. As players get larger, faster and stronger, the stress put on them will likely raise the prospect of injury. Advances in treatment alone will not be sufficient to meet the needs of athletes and society in the decades to come.

APPENDIX A

FUNCTIONAL MOVEMENT SCREEN SCORING RUBRIC

Movement	III	II	I
Deep Squat	• Upper torso parallel with tibia or toward vertical • Femur below horizontal • Knees aligned over feet • Dowel aligned over feet	* Add heel raise • Same criteria as score of III	• Unable to perform movement properly with heel raise
Hurdle Step	• Hips, knees & ankles aligned in sagittal plane • Erect posture maintained	• One or more of scoring criteria for III is not performed	• Contact between foot & hurdle • Loss of balance
In-line Lunge	• Dowel contacts remain with head, T-spine & L-spine • Dowel & feet aligned in sagittal plane • Knee touches board	• One or more of scoring criteria for III is not performed	• Loss of balance
Shoulder Mobility	• Fists are within one hand length	• Fists are within 1 ½ hand lengths	• Fists are not within 1 ½ hand lengths
Active Straight Leg Raise	• Ankle passes mid-thigh point	• Ankle between knee & mid-thigh	• Ankle does not pass knee
Trunk Stability Push-up	• Males: 1 rep; thumbs aligned with top of forehead • Females: 1 rep; thumbs aligned with chin	• Males: 1 rep; thumbs aligned with chin • Females: 1 rep; thumbs aligned with clavicle	• Males: unable to achieve score of II • Females: unable to achieve score of II
Rotary Stability	• Performs unilateral repetition • Spine parallel to board • Knee & elbow touch over board	• Performs diagonal repetition • Same criteria as III	• Unable to perform diagonal repetition

* FMS created by: Gray Cook, PT, OCS, CSCS & Lee Burton, PhD, ATC, CSCS
** Note: Pain = 0

APPENDIX B

INFORMED CONSENT FORM RELIABILITY STUDY

INFORMED CONSENT

Reliability of Scoring the Functional Movement Screen and Y-balance Test

You are invited to participate in a graduate research study conducted by Eric Sorenson, from the University of Oregon's Department of Human Physiology. I hope to learn about the reliability of sports medicine professionals scoring the functional movement screen and Y-balance test. The results from this study will contribute to the completion of my doctoral dissertation.

If you decide to participate, you will be asked to attend the testing session at (testing location) on (date) at (time). You will be measured for height and weight, and your age will be recorded. You will then be tested for your ability to perform basic movements that are a part of a functional movement screen. Movements included in the screen are a:

1. Deep squat without weight
2. Lunge
3. Hurdle step – stand on one leg; step over an obstacle
4. Straight leg raise – laying on back; raise leg towards sky
5. Shoulder flexibility test – touch both hands as close as possible on back
6. Push-up
7. Core stability test – positioned on hands and knees; touch elbow and knee together
8. Y-balance test – stand on one leg; reach out other foot towards three targets
    a. Following the Y-balance test, you will be asked to lie on a table in order to have your leg length measured. The measurement will be taken from your hip to your ankle using a tape measure.

You will be asked to bring shorts, a short-sleeved shirt, and athletic shoes to the day of testing. All testing will take approximately thirty minutes. Evaluation of your screen will be performed by 6-10 Certified Athletic Trainers and Physical Therapists. Movements 1-7, as listed above, will be scored simultaneously by all of the evaluators. Movement 8, the Y-balance test and leg measurements, will be conducted by each evaluator individually.

You will also be video taped from the front and side during your functional movement screen (movements 1-7 as listed above). This information will be used by the evaluators to score your movements several times following the live scoring session. We will use this method of scoring to test the evaluators' consistency with scoring your movements. Furthermore, the videos may be used in professional presentations and conferences. Your identity will remain confidential, but your face will be visible on the video.

There are minimal risks involved in this study but precautions will be taken to minimize the possible risk. All the functional movement tests will be within a normal range of motion and speed. You will be under complete control over the amount of movement produced during each of the tests. The investigator will monitor you at all times for any discomfort associated with the activities. Data collection will stop if an activity is causing undesired discomfort.

This study hopes to add to the body of knowledge available regarding the consistency of sports medicine professional with scoring functional movements. However, I cannot guarantee that you personally will receive any benefits from this research.

Your participation is voluntary. Your decision whether or not to participate will not affect your relationship with the University of Oregon or the Department of Human Physiology. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

You are advised to go the University's Student Health Center if you become injured. You will be held responsible for any treatment costs in the case that you are injured.

If you have any questions, please feel free to contact Eric Sorenson at (541) 206-2586, esorens1@uoregon.edu, or his faculty advisor Dr. Gary Klug at (541) 346-4181. If you have questions regarding your rights as a research subject, contact Human Subjects Compliance, University of Oregon, Eugene, OR 97403, (541) 346-2510.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time, discontinue participation without penalty, and that you are not waiving any legal claims, rights or remedies. It also indicates that I have received an adequate description of the purpose and procedures for videotaping during the course of the proposed research study. I give my consent to be videotaped during participation in the study, and for those videotapes to be viewed by persons involved in the study, as well as for use in professional presentations and conferences as described to me. I understand that my face may be visible on the tape, but that all information will be kept confidential and will be reported in an anonymous fashion, and that the videotapes will be kept indefinitely. I further understand that I may withdraw my consent at any time.

____

Subject's Name

________________________________ ________________

Subject's Signature Date

APPENDIX C

AGREEMENT FOR VIDEOTAPING

AGREEMENT FOR VIDEOTAPING

I have received an adequate description of the purpose and procedures for videotaping sessions during the course of the proposed research study. I give my consent to be videotaped during participation in the study, and for those videotapes to be viewed by persons involved in the study, as well as for use in professional presentations and conferences as described to me. I understand that my face may be visible on the tape, but that all information will be kept confidential and will be reported in an anonymous fashion, and that the videotapes will be kept indefinitely. I further understand that I may withdraw my consent at any time.

Print Name____

Signature of participant________________________________ Date_________

APPENDIX D

FUNCTIONAL MOVEMENT SCREEN SCORING SHEET

Subject		
Test	Raw Score	Final
1Deep Squat		
2Hurdle St R		
2Hurdle St L		
3Lunge R		
3Lunge L		
4Sh Mob R		
4Sh Mob L		
Impinge R		
Impinge L		
5ASLR R		
5ASLR L		
6Push up		
Extension		
7Quad R		
7Quad L		
Flexion		

* Note: This table had to be modified for publication. Three columns of the table above were used on the actual scoring sheet.

APPENDIX E

INFORMED CONSENT FORM INJURY PREDICTION STUDY

INFORMED CONSENT

Functional Movement Screen and Y-balance as Predictors of Injury in High School Athletes

You are invited to participate in a graduate research study conducted by Eric Sorenson, from the University of Oregon's Department of Human Physiology. I hope to learn about the ability of a functional movement screen to identify athletes that are at risk of injury. The results from this study will contribute to the completion of my doctoral dissertation.

If you decide to participate, you will be asked to complete a demographic information form indicating your age, gender, year-in-school, previous musculoskeletal injuries (self-reported), school name, sport, team level (varsity, junior varsity, etc), years-of-participation, projected player status (starter, second-string, etc), and position. (**See attached**) Next, you will be measured for your height and weight, and your ability to perform basic movements that are a part of a functional movement screen. Movements included in the screen are a:

1. Deep squat without weight
2. Lunge
3. Hurdle step – stand on one leg; step over an obstacle
4. Straight leg raise – laying on back; raise leg towards sky
5. Shoulder flexibility test – touch both hands as close as possible on back
6. Push-up
7. Core stability test – positioned on hands and knees; touch elbow and knee together
8. Y-balance test – stand on one leg; reach out other foot towards three targets
    a. Following the Y-balance test, you will be asked to lie on a table in order to have your leg length measured. The measurement will be taken from your hip to your ankle using a tape measure..

You will be asked to bring shorts, a short-sleeved shirt, and athletic shoes to the day of testing. All testing will take approximately fifteen minutes and will be conducted as a part of your typical training session with your team.

During the course of your athletic season, your coach will keep track of the number of athletes participating in a competition or practice for each day. Your name will not be included in these records. In the circumstance that you may become injured as a part of your participation with your sport, your coach and athletic trainer will fill out an injury report form. This form will include information about your injury, including the date of injury, date that your return to full participation, injured body part, type of injury (sprain, strain, fracture, etc), diagnosis, whether you have had a similar injury to the same area in the past, when the injury occurred (practice or competition), and the cause of injury. The injury report form will contain your name, but this information will remain in a locked filing cabinet. With your permission, the injury report form will be made available to me for analysis. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Subject identities will be kept confidential by a coding system known only by the investigator.

There are minimal risks involved in this study but precautions will be taken to minimize the possible risk. All the functional movement tests will be within a normal range of motion and speed. You will be under complete control over the amount of movement produced during each of the tests. The investigator will monitor you at all times for any discomfort associated with the activities. Data collection will stop if an activity is causing undesired discomfort.

This study hopes to add to the body of knowledge available regarding the ability of functional movement screens to identify athletes that are at-risk of injury. However, I cannot guarantee that you personally will receive any benefits from this research.

Your participation is voluntary. Your decision whether or not to participate will not affect your relationship with the (specified school district) or (specified school). If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

You are advised to notify your team's coach, athletic trainer or school nurse if you become injured during the testing or over the course of the season. You will be held responsible for any treatment costs in the case that you are injured.

If you have any questions, please feel free to contact Eric Sorenson at (541) 206-2586, esorens1@uoregon.edu, or his faculty advisor Dr. Gary Klug at (541) 346-4181. If you have questions regarding your rights as a research subject, contact Human Subjects Compliance, University of Oregon, Eugene, OR 97403, (541) 346-2510.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time, discontinue participation without penalty, and that you are not waiving any legal claims, rights or remedies. It also indicates that you are willing to release injury information to Eric Sorenson during the 2008-2009 school year. This information will not include any past medical information, except for musculoskeletal injury information, which you volunteer during on the demographic information form.

____

Subject's Name

__________________________________ ________________

Subject's Signature Date

____

Parent's Name (if subject is under 18 years old)

__________________________________ ________________

Parent's Signature (if subject is under 18 years old) Date

APPENDIX F

DEMOGRAPHICS FORM

Name:

____

Birth Date (Month/Day/Year): ______________________________

Gender: Male Female

Year in school: FR SO JR SR

Team Level: FR JV Varsity

Projected status: Starter Second-team Third-team

Position(s):

____

Number of years playing this sport: ______________

Previous Injuries:

Month/Year	R/L Body part	Type of Injury	Surgery? Y/N
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______
________	__________	________________	_______

APPENDIX G

INJURY REPORT FORM

Date of Injury: ____________ **Date of return to full participation:** ____________

Injured body part

☐ head/face
☐ neck /cervical spine
☐ sternum/ribs/upper back
☐ abdomen
☐ low back/sacrum/pelvis

☐ shoulder /clavicle
☐ upper arm
☐ elbow
☐ forearm
☐ wrist
☐ hand/finger/thumb

☐ hip/groin
☐ thigh
☐ knee
☐ leg/Achilles tendon
☐ ankle
☐ foot/toe

Injured body part

☐ right ☐ left ☐ not applicable

Type of Injury

☐ concussion
☐ fracture
☐ other bony injury
☐ dislocation
☐ sprain

☐ lesion of meniscus or cartilage
☐ muscle strain/cramp
☐ tendon injury/bursitis
☐ dental injury
☐ other (please specify)

☐ hematoma/contusion
☐ abrasion
☐ laceration
☐ nerve injury

____

Diagnosis

____

Has the player had a **previous injury** of the same type at the same location (i.e. this injury is a reoccurrence)? ☐ yes ☐ no

If **Yes**, specify the date of player's return to full participation from the previous injury:

____

Was the injury caused by **overuse** or **trauma**? ☐ overuse ☐ trauma

When did the injury occur? ☐ training ☐ game

Was the injury caused by **contact**? ☐ no
☐ yes, with another player ☐ yes, with the ball ☐ yes, with other object:

____

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