A Literature Review of the Functional Movement Screen as a Predictor of Injury in the Sport of Basketball

by
Chad E. Etzel

A PROJECT
Submitted to
Oregon State University
University Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Exercise and Sports Science (Honors Scholar)

Presented May 23, 2012
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AN ABSTRACT FOR THE THESIS OF

Chad E. Etzel for the degree of Honors Baccalaureate of Science in Exercise and Sports Science presented on May 23, 2012. Title: A Literature Review of the Functional Movement Screen as a Predictor of Injury in the Sport of Basketball.

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Athletic activities have always carried an inherent risk for injuries, and basketball is no exception. Basketball is the second most popular team sport in the United States in which 984,777 high school boys and girls participated during the 2010-2011 season. Athletic trainers and strength and conditioning staff are pressured to keep these athletes healthy and playing in games. Injury prevention strategies can reduce the amount of injuries accumulated during a basketball season. One possible injury prevention tool is Gray Cook's Functional Movement Screen (FMS). The FMS is a seven test screen which portrays a brief overview of an athlete's fundamental movement patterns (the quality of an athlete's movements). Poor movement patterns and asymmetries have been associated with injuries. Scholarly research is investigated to identify if the FMS could identify injury susceptible players in the sport of basketball. The literature reviewed reveals mixed results. Some studies identify a possible connection between low FMS scores and injury susceptibility while other literature displays the FMS's inability to predict injury potential. Other research suggests that the FMS may lack the ability to identify injury susceptibility in athletes who have had a previous injury. Overall, the research is too inconclusive to suggest that the FMS should be used as a pre-participation screening tool for the sport of basketball.

Key Words: Functional Movement Screen, basketball, injury, prevention

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I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

_____

Chad E. Etzel, Author

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And thank you to my family for your love and support as I ambitiously pursue my goals. Much of my learning must no doubt be accredited to you.

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To my parents John and Patti, who have always been there for me for all my life.

To my sister Brittney, for all of those great memories and more to come.

To the rest of my family.

I love each of you.

A Literature Review of the Functional Movement Screen as a Predictor of Injury in the Sport of Basketball

Preface

For the last few years I have been chasing a dream of becoming a talent scout for a team in the National Basketball Association. I saw the Honors Thesis as an opportunity to integrate my major of Exercise and Sports Science with my career goal of NBA scouting. The project resulted in an attempt to identify players who were susceptible to injury, rather than an effort to identify future performance potential. However, injury prediction is highly important for talent scouting because a player who does not play due to an injury cannot contribute his talents on the court. This idea came to me as one of my committee members and I discussed possible thesis topics. The Functional Movement Screen (FMS) seemed to be a natural fit for this project since it is widely accepted as an injury prediction tool, but has yet to obtain sufficient scientific support in the domain of basketball. Literature of professional basketball injury incidence is scarce, so studies from high school basketball and other sports will be analyzed to see if the FMS can identify injury susceptibility for basketball players.

SECTION I: INTRODUCTION

The physical nature of athletics has always carried an inherent risk for injuries. Basketball is one of the most popular sports among high school athletics; 545,844 boys and 438,933 girls participated in high school basketball during the 2010-2011 season (The National Federation of State High School Associations). However, a high volume of participants can result in a high number of injuries. Basketball injury rates have been reported as occurring at the rate of 28.3 injuries per 100 boys and 28.7 injuries per 100 girls per season (Wieczorkowski, 2010). Therefore, a combination of these statistics suggests around 154,000 boys and 126,000 girls were injured in basketball practice or competition in the 2010-2011 season.

Furthermore, during the 2010-2011 National Basketball Association (NBA) season, realgm.com reported that at least 132 players had some sort of injury that limited player participation time. An approximate number of 491 different players played in games (realgm.com; nba.com/dleague). In all, approximately 26.9% of all the players participating on an NBA team sustained a reported injury during the season. Since these numbers (at both the high school and professional levels) suggest that approximately one in four players will suffer an injury over a full season, these high injury statistics might be decreased by injury prevention strategies such as pre-participation screen.

At both the amateur and professional level, one of the hindrances of building a consistent team is the unaccountable surprise of injuries. Some professional leagues pay players millions of dollars per year to perform at a high level. The average salary in the 2010-2011 season for an NBA player was approximately $5.15 million

(sports.yahoo.com), and teams must fully pay injured players regardless of the fact that they are not producing in games. Identifying players who are susceptible to injuries can reduce this loss of money as teams are less willing to commit high amounts of money to injury-prone players. Gray Cook's Functional Movement Screen (FMS) might be a tool for identifying players who have high risk for injuries. The FMS is designed to recognize athletes' dysfunctional movement patterns and asymmetries which may lead to injuries.

If the FMS is a valid screen for basketball, then it may be able to identify injury-susceptible players. Prior to the NBA draft, each team holds pre-draft workouts in which the teams invite potential draft picks to display their skills in front of scouts and coaches. NBA talent scouts could obtain FMS scores during pre-draft workouts to use those scores as extra data to assist in draft analysis. For example, if a targeted player has an unsatisfactory FMS score, a team can opt to not draft the player since the player may be likely to suffer an injury. Conversely, a team could still draft a player who has an unsatisfactory score as long as the team puts him through corrective exercises to fix his dysfunctional movement patterns. A valid pre-participation screen could also be used in the high school basketball setting if utilized in conjunction with tryouts. At the high school level, the FMS (if valid) would serve as a tool to help identify which athletes need movement interventions. Two published theses have been done on high school basketball, but no studies have been published by peer-reviewed journals (Sorenson, 2009; Wieczorkowski, 2010). A number of other studies relating the FMS scores and their injury predictability have been completed in a variety of other sports (R. Chorba, D. Chorba, Bouillon, Overmyer, & Landis, 2010; Kiesel, Plisky, Butler, & Kersey,

Publication In Progress; Kiesel, Plisky, & Voight, 2007; Peate, Bates, Lunda, Francis, Bellamy, 2007).

Studying injury incidence in athletics is a complicated issue for a number of reasons. Recognizing what counts as an injury is a difficult task because the word "injury" tends to carry ambiguity. An injury might be characterized by the amount of lost participation time or the amount of medical attention. Also, certain painful inflictions tend to be neglected when they do not fall into the injury definition. For instance, a player with chronic knee pain may play in every game during a season. The athlete would not be considered "injured" if the criteria for an injury requires him or her to miss a game. For this particular project, one must distinguish between contact and noncontact injuries. Most of the studies do not make this distinction, so it is difficult to extrapolate the data to the sport of basketball.

The FMS attempts to identify the athletes who are likely to become injured based on their movement patterns. The screen classifies athletes based on movement minimums by analyzing movement asymmetries and movement dysfunction. Other movement screening tools currently exist and use a variety of methods; examples include the Dartfish video analysis and the Y-balance Test. The FMS has surged in popularity over the years, so it will be the focus of this investigation. In order for the FMS to be an accurate screening tool, it must closely consider the definition of injury, noncontact injuries, and previous injury history.

Section II: THEORY OF THE FMS

Gray Cook designed the FMS to determine if an individual possesses or lacks the ability to perform fundamental movement patterns (Cook, Burton, & Hoogenboom, 2006a). A fundamental movement pattern is the ideal way a body ought to change its position under its own power based on human developmental concepts (Cook, Burton, Kiesel, Rose, & Bryant, 2010, p. 19). Fundamental movement patterns are the building blocks for more complex movement performance and skills; every person's daily activities are built upon fundamental movements. According to Cook, the FMS is "a reliable, seven-step screening system with three clearing tests, designed to rank movement patterns basic to the normal function of active people" and by using the FMS, one can "identify, rate, and rank basic movement limitations and asymmetries" (Cook et al., 2010, p. 17). The FMS consists of seven tests that give a score of 0-3 based on the client's movement patterns. The test scores are then added together to give an overall composite score. More details regarding the scoring of the FMS will be explained in Section III.

Movement Patterns and Movement Screening

Proper daily movement (fundamental movement) is meant to be a building block for all movement; fundamental movement is the foundation of sports-related movement. Therefore, the FMS focuses on pinpointing areas of movement pattern limitations and asymmetries in daily movement rather than identifying deficiencies in sports-related movement (Cook, et al., 2010, p.65). The creators of the FMS contend that athletes who

train poor movement patterns can cause movement deficiencies, which can lead to injury, so fitness professionals should screen athletes to quantify the athletes' movement patterns (Cook, et al., 2010, p.16). Dysfunctional movement is typically attributed to muscle imbalances, habitual asymmetrical movements, improper training methods, and training after incomplete recovery from an injury (Cook, et al., 2010, 67). Defects in fundamental movement can put an athlete at risk for injury in a sports setting. For example, while an athlete may tear a ligament due to trauma, he or she can also injure a ligament due to unnatural stresses (repetitiously poor movements) on the tissue over an extended period of time (Cook, et al., 2010, p. 39). Cook's screen is meant to test basic or fundamental movements to identify if those movements qualify as high risk for injury.

In addition, compensated movements can also result in increased energy expenditure during competition, leading to quicker fatigue (Cook, et al., 2010, p. 39). Sports teams want their athletes moving as efficiently as possible so they can compete at a high level throughout competitive contests. The screen has been accepted into the world of athletics over the last 15 years, but has limited research supporting the creators' claims that the FMS can identify injury susceptibility.

Pre-Participation Movement Screening

Cook suggests that fundamental movement patterns create a neurological foundation for advanced activities and complex skills (Cook, et al., 2010, p. 32). In other words, athletes must have appropriate movement minimums before participating in complex skill activities that can put athletes at risk. If the appropriate movement minimums are not present, the athlete may be at risk for a dysfunctional movement

injury. While a sports physical exam is necessary to rule out serious medical conditions, it may not be sufficient to clear an athlete for competition. A movement screen might be considered for competition-clearing requirements based on the risks injuries pose. The FMS might be able to identify movement compensations and asymmetries to note any potential injury concerns, and then corrections could be made based on these injury risks. The FMS is intended to fill the void between the pre-participation medical examination and the performance-based tests that coaches use to evaluate an athlete's abilities (Cook, et al., 2010, p. 69-70). For example, high school athletes should first receive a physical exam from a doctor, next have their movement patterns screened, and finally complete team tryouts through fitness tests and sports skill tests. Movement screening precedes team tryouts because athletes' fundamental movement patterns provide the foundation of performance and skill movements that are utilized in tryouts and competition. A limitation in fundamental movement patterns might provide the reason an athlete struggles with a particular performance test.

Intervention Programs and Corrective Exercises

When FMS scores are not adequate, an athlete should be assigned an intervention program with corrective exercises to fix the dysfunctional movement patterns (Cook, et al., 2010, p. 229). The goal of corrective exercise is to "resolve or reduce measurable dysfunction within fundamental and functional movement patterns" (Cook, et al., 2010, p. 234). In theory, corrective exercises can undo the consequences of poor training and can help the body improve movement after recovering from an injury. The concept of

corrective exercises is necessary for the FMS because practitioners must be able to improve their clients' inadequate movement scores.

SECTION III: METHODS OF THE FMS

Scoring

The FMS is comprised of seven separate tests, and each test is ranked with a score from zero to three with a high score corresponding to proper movement. A score of three indicates the movement is complete, a score of two demonstrates some level of compensation, a score of one suggests the pattern is incomplete, and a score of zero indicates pain is present (Cook, et al., 2010, p. 81). The clients perform three repetitions of each movement, and the highest score is recorded for their final score. The clients complete five of the seven tests (hurdle step, inline lunge, shoulder mobility, active straight-leg raise, and rotary stability) on both the right and left sides of their body and receive a score for each side. If the scores of the same test differ on both sides of the body, the lower of the two scores is recorded as the total score for that specific test. For example, if the right side receives a three and the left receives a two, then the total score for that test is a two. Note that differing scores indicate an asymmetrical movement pattern and may lead to an injury. The total scores from each individual test are then added together to obtain a composite score. Therefore, a client can receive a minimum composite score of zero (if pain is present in every movement test) and a maximum composite score of 21 (if the client scores a three on every test). An FMS scoring sheet is provided in **Appendix A**.

Clearing Exams

Clearing exams are separate from the tests and are utilized to identify a pain response. The clearing exams include the impingement clearing exam, press-up clearing exam, and posterior rocking clearing exam corresponding to the shoulder mobility test, trunk stability pushup test, and rotary stability test, respectively. Clearing exams are performed after the corresponding movement tests. When pain is present during a clearing exam, a positive (+) is recorded, and the client receives a zero for the total score of that corresponding test. These exams provide additional information on movement dysfunction by using range of motion extremes to identify possible poor mobility and stability (Cook, et al., 2010, p. 85).

Equipment

The required equipment includes a four-foot dowel rod, two smaller dowel rods, a two-by-six board, and an elastic band. This equipment can be obtained through functionalmovement.com or manufactured by the individual rater. A picture of the equipment is provided in **Figure 1**.

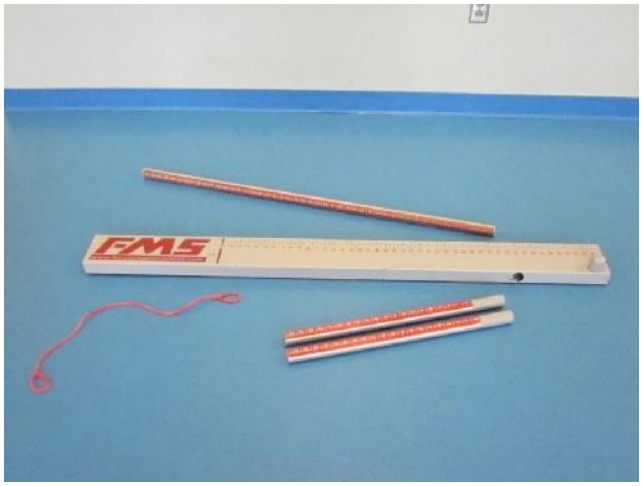

Figure 1 The four-foot dowel rod, two smaller rods, two-by-six board, and elastic band are pictured to the left.

The Seven Tests

The following explains the purposes and implications of each of the seven FMS tests. A written description is provided for the tests and clearing exams. A scoring rubric is listed in **Table 1,** while pictures and scoring details are provided in **Appendix B**.

FMS Scoring Rubric

	III	II	I
Deep Squat	*Upper Torso is parallel with tibia or towards vertical *Femur below horizontal *Knees aligned with the feet *Dowel aligned within footprint	*Upper Torso is parallel with tibia or towards vertical *Femur below horizontal *Knees aligned with the feet *Dowel aligned within footprint	*Upper Torso and tibia are not parallel *Femur is not below horizontal *Knees are not aligned over the feet *Lumbar flexion is noted
Hurdle Step	*Hips, knees and ankles remain aligned in the sagittal *Minimal to no movement is noted in lumbar spine *Dowel and hurdle remain parallel	*Alignment is lost between hips, knees and ankles *Movement is noted in lumbar spine *Dowel and hurdle do not remain parallel	*Contact between and hurdle *Loss of balance is noted
In-Line Lunge	*Dowel contacts remain with L-spine extension *No torso movement is noted *Dowel and feet remain in sagittal plane *Knee touches board behind heel of front foot	*Dowel contacts do not remain with L-spine extension *Movement is noted torso *Dowel and feet do not remain in sagittal plane *Knee does not touch board behind heel of front foot	*Loss of balance is noted
Shoulder Mobility	*Fists are within one hand length	*Fists are within one and a half hand lengths	*Fists are not within one and a half hand lengths
Active Straight Leg Raise	*Ankle/dowel reside between mid-thigh and ASIS	*Ankle/dowel reside between mid-thigh and mid-patella/joint line	*Ankle/dowel reside below mid-patella/joint line
Trunk Stability Push-Up	*Males perform 1 repetition with thumbs aligned with the top of the forehead *Females perform 1 repetition with thumbs aligned with chin	*Males perform 1 repetition with thumbs aligned with the chin *Females perform 1 repetition with thumbs aligned with clavicle	*Males are unable to perform 1 repetition with thumbs aligned with the chin *Females are unable to perform 1 repetition with thumbs aligned with clavicle
Rotary Stability	*Performs 1 correct unilateral repetition while keeping spine parallel to board *Knee and elbow touch in line over the board	*Performs 1 correct diagonal repetition while keeping spine parallel to board *Knee and elbow touch in line over the board	*Inability to perform diagonal repetition

0 - The athlete will receive a score of zero if pain is associated with any portion of these tests or clearance tests. A medical professional should perform a thorough evaluation of the painful area

Table 1 A rubric containing the written descriptions of scoring guidelines for the individual FMS tests.

1. Deep Squat

- *Purpose*: The deep squat displays extremity mobility, postural control, and pelvic and core stability. This movement pattern examines the mobility and stability of the hips, knees, ankles, shoulders, scapular region, and the thoracic spine while the core and pelvis must maintain stability through the entire movement.
- *Description*: The athlete stands straight up with his or her feet slightly wider than the shoulders. He or she then holds the dowel on the head, resulting in 90-degree angle at the shoulder. The athlete then presses the dowel overhead by fully extending the elbows and descends into the deepest possible squat position keeping the heels on the floor with the head and chest facing forward. If the athlete cannot achieve the score of a three, then the two-by six board is placed under the heels and the test is repeated. If the movement is not then completed, the athlete receives a one. Pictures of the test are shown in **Figure 2** and **Figure 3**. Scoring is based on the descriptions provided in **Table 1** and the pictures in **Appendix B**.
- *Implications*: Limited mobility in the upper torso indicates possible poor glenohumeral or thoracic spine mobility. Limited mobility in the lower extremity might lead to poor dorsiflexion of the ankles or poor flexion in the knee or hip. Poor stabilization and control may also lead to a low score (Cook, et al., 2010, p. 90-91).

Figure 2 Deep Squat Anterior View.

Figure 3 Deep Squat Lateral View.

2. Hurdle Step

- *Purpose*: The hurdle step test exhibits step and stride mechanics as well as stability and control in a single-leg stance. Athletes must properly coordinate and stabilize their hips as they lift one foot and bear the load on the other.
- *Description*: The small dowel rods are inserted into the two-by six board approximately 28 inches apart, and an elastic band is spread across the dowels (as seen in **Figure 4**). The vertical height from the floor to the athlete's tibial tuberosity marks how high the elastic band is placed on the inserted dowels. The athlete stands behind the center of the hurdle base with both feet touching each other at toes and heels. The toes should touch the hurdle base. The athlete positions the dowel across his or her shoulders and behind the neck. He or she should then lift one foot above the elastic band and place the heel on the other side of the hurdle, then lift the same foot, and return to starting position. Both sides are scored. Pictures of the test are shown in **Figure 4** and **Figure 5**.

Scoring is based on the descriptions provided in **Table 1** and the pictures in **Appendix B**.

- *Implications*: Poor mobility of the step leg or poor stability of the plant leg can contribute to problems. This test requires relative bilateral, asymmetric hip mobility, and dynamic stability (Cook, et al., 2010, p. 92-93).

Figure 4 Hurdle Step Anterior View.

Figure 5 Hurdle Step Lateral View.

3. Inline Lunge

- *Purpose*: The inline lunge positions the body to experience stresses stimulated during rotation, deceleration and lateral movements. The split stance of the legs and reciprocal pattern in the upper extremity creates a natural counterbalance, which demands spinal stabilization. Mobility and stability is tested in the foot, knee, ankle, and hip along with the flexibility of the latissimus dorsi and rectus femoris. Instead of doing a full lunge, this pattern only contains a descent and return (rather than including an initial step). The initial step is omitted because it would introduce too many variables.

- *Description*: The athlete places his or her feet on the board in a split-squat stance position. The feet are separated by the distance of the vertical height from the ground to the athlete's tibial tuberosity (the measurement obtained from the hurdle step test). The dowel is then placed vertically along the athlete's back touching the head, thoracic spine, and sacrum. The hand opposite the front foot is placed on the rod at the cervical spine and the other hand grips the dowel at the lumbar spine. The athlete then lowers the back knee to touch the board. Pictures of the test are shown in **Figure 6** and **Figure 7**. Movement is executed on both sides and scores are recorded based on the pictures in **Appendix B** and the descriptions in **Table 1**.
- *Implications*: Problems executing the movement can be due to ankle, knee, and hip mobility issues and dynamic stability problems. The thoracic spine may also limit the athlete from completing the movement (Cook, et al., 2010, p. 94-95).

Figure 6 Inline Lunge Anterior View.

Figure 7 Inline Lunge Lateral View.

4. Shoulder Mobility Reach

- *Purpose*: "The shoulder mobility reaching pattern demonstrates the complementary natural rhythm of the scapular-thoracic region, thoracic spine, and

rib cage during reciprocal upper-extremity shoulder movements" (Cook, et al., 2010, p. 96). The pattern examines flexion, external rotation, and abduction in one extremity and bilateral shoulder range of motion, along with extension, internal rotation and adduction in the other.

- *Description*: The hand is measured from the distal wrist crease to the end of the longest finger. The athlete makes fists and puts one fist behind the neck and the other behind the back and tries to touch the fists. The distance between the fists is measured. A picture of the test is shown in **Figure 8**. Movement is executed on both sides and scores are recorded based on the pictures in **Appendix B** and the descriptions in **Table 1**.
- *Implications*: Repetitive overhead throwing can cause limited internal rotation and an incomplete movement. A scapulothoracic dysfunction may result in decreased glenohumeral mobility. The test also requires postural control and core stability.
- *Clearing Exam Description*: The athlete puts a palm on the opposite shoulder and lifts the elbow as high as possible while keeping the palm touching the shoulder. If pain is present a (+) is recorded. (Cook, et al., 2010, p. 96-97). A picture of the impingement clearing exam is shown in **Figure 9**.

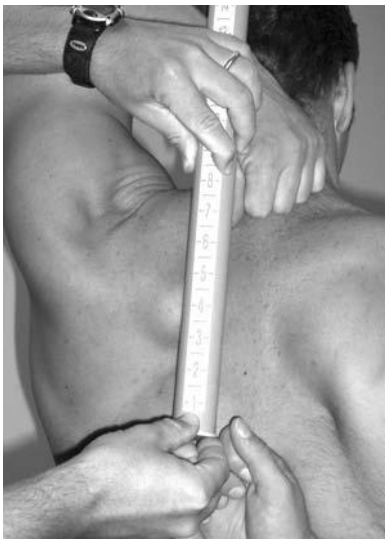

Figure 8 Shoulder Mobility Test (left).

Figure 9 Impingement Clearing Exam.

5. Active Straight-Leg Raise

- *Purpose*: The active straight leg raise identifies core stability, flexed hip mobility, and the available hip extension of the alternate hip. This movement challenges the athlete's ability to dissociate the lower extremities from the stable core.
- *Description*: The athlete lies on his or her back with the soles of the feet perpendicular to the ground, feet touching, and the two-by-six board under the knees. The rater places the dowel perpendicular to the ground midway between the anterior superior iliac spine and the joint line of the knee. The athlete then lifts one leg as far as it can go in the sagittal plane. Head and opposite knee should remain on the floor and toes should remain pointed up. The malleolus must pass the dowel. If it does not, the dowel should be repositioned as shown in the pictures of **Appendix B**. A picture of the test is shown in **Figure 10**. Movement is executed on both sides and scores are recorded based on the pictures in **Appendix B** and the descriptions in **Table 1**.

- *Implications*: Pelvic control must be sufficient for the successful completion of the pattern. Inadequate mobility of the opposite hip may prevent full extension. Poor functional hamstring flexibility may prevent good movement in the hip (Cook, et al., 2010, p. 98-99).

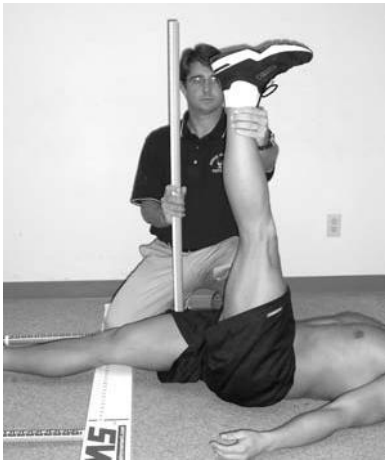

Figure 10 Active Straight-Leg Raise.

6. Trunk Stability Pushup

- *Purpose*: The trunk stability pushup observes reflex core stabilization. A complete movement initiates movements of the upper extremity without allowing movement in the spine or hips.
- *Description*: The athlete lies in a prone position with thumbs at the top of the forehead. The athlete will then perform a pushup from this position lifting the body as one unit. If athletes cannot complete the movement with thumbs starting at the forehead, then they can move the thumbs down to their chin. A picture of the test is shown in **Figure 11**. Scoring is based on the descriptions provided in **Table 1** and the pictures in **Appendix B**.
- *Implications*: Limited performance can be attributed to poor reflex stabilization of the core, compromised upper-body strength, or poor scapular stability. Optimal

start position can be limited by poor hip and spine mobility and may lead to poor performance during the test.

- *Clearing Exam Description*: Athletes perform a press-up in which they push their upper body off of the ground, but keeps their quadriceps on the ground. If pain is present, a (+) is recorded (Cook, et al., 2010, p. 100-101). A picture of the clearing exam is shown in **Figure 12**.

Figure 11 Trunk Stability Pushup.

Figure 12 Press-up Clearing Exam.

7. Rotary Stability

- *Purpose*: The rotary stability movement pattern examines multi-plane pelvis, core, and shoulder-girdle stability along with combined upper and lower extremity movements. It identifies reflex stabilization and weight-shifting in the transverse plane, as well as requiring the execution of coordinated efforts of mobility and stability of fundamental climbing patterns.
- *Description*: The athlete gets on hands and knees with the two-by-six board between opposite hands and knees. Thumbs, knees, and feet should be touching the board. The board should be parallel with the spine, and shoulders and hips should be 90 degrees with respect to the torso. The athlete should then flex one shoulder and extend same-side knee and hip to the horizontal and then touch elbow to thigh while remaining in the sagittal plane. If this movement is not

executed, then the diagonal variation (right arm and left leg or vice versa) is used. Pictures of the test are shown in **Figure 13** and **Figure 14.** Movement is executed on both sides and scores are recorded based on the pictures in **Appendix B** and the descriptions in **Table 1**.

- *Implications*: Poor reflex stabilization and compromised scapular and hip stability can cause limited performance. Inhibited knee, hip, spine, and shoulder mobility can prevent complete execution of the movement.
- *Clearing Exam Description*: The athlete starts on hands and knees and rocks back to touch buttocks to heels and chest to thighs. Hands remain in front of the body stretched out as far as possible. If pain is present, a (+) is recorded (Cook, et al., 2010, p. 102-103). A picture of the clearing exam is shown in **Figure 15**.

Figure 13 Rotary Stability Extension Pattern.

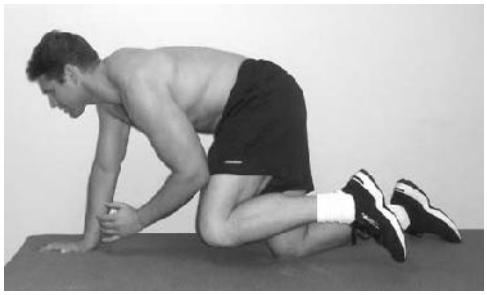

Figure 14 Rotary Stability Flexion Pattern.

Figure 15 Posterior Rocking Clearing Exam.

SECTION IV: FMS VALIDITY

Validity

Test validity must be discussed to know that the results of a measurement are meaningful. Validity is the "soundness of the interpretations of test scores" or the degree to which a test measures what it is supposed to measure (Wood, 2011). In order for a measurement to be valid, it must be both relevant and reliable. This section will investigate the relevancy and reliability of the FMS by examining existing research. Since the FMS is a fairly new screen (set forth in 1995 [Cook & Burton, 2012]), limited research is currently available. However, the current literature seems to indicate the screen's degree of relevancy and reliability (and therefore its validity).

Reliability

Reliability is the ability of a test to detect consistent and precise differences between subjects across test occasions (Wood, 2011). In other words, if the FMS is administered multiple times, reliability is the consistency of scoring over repeated tests. A screen cannot be reliable if scores are not consistent from one rater (intra-rater reliability) or between raters (inter-rater reliability).

A common criticism of the FMS is that one rater may score a movement different than other raters. However, the FMS has been shown to have a high inter-rater reliability (Minick et al., 2010). In the study, researchers videotaped 39 college students performing the FMS. The screen had four raters: two were experts having ten years of

experience using the FMS and two were novices having less than a year of experience using the FMS. The Kappa statistic was calculated between the two sets of raters for each test. The statistic is calculated as a ratio of the times the raters agree, corrected for chance agreement, to the maximum amount of times the raters could agree. The Kappa statistic measures "true" agreement beyond the mathematical chance the scores will agree. The FMS has seven tests, but five of the tests measure both sides of the body, resulting in 12 different raw scores. The five total scores (obtained from the lowest raw score from the five tests which measure both sides of the body: hurdle step, inline lunge, shoulder mobility, active straight-leg raise, and rotary stability) were also compared in the results, so a total of 17 test scores were analyzed for one individual in this study. The total scores have an effect on the statistics, but do not completely duplicate the raw scores. For instance, a subject performs the hurdle step with two different raters giving scores for both sides of the body. One rater records a 3 on both sides while the other rater records a 2 on the right side and a 3 on the left. In this example, the researcher compares 3 scores: the raw score of the right side, the raw score of the left side, and the total score for the hurdle step. Both raters would agree on the left side score, but would disagree on the right side and the total score (since the total score is recorded as the lowest raw score).

The pair of novice raters displayed excellent agreement on 6 of the 17 tests and substantial agreement on 8 of the 17 tests. The pair of experts demonstrated excellent agreement in 4 of the 17 tests and substantial agreement in 9 of the 17 tests, showing more variance than the novice raters. The averaged scores from the paired novice and

paired experts were compared, indicating excellent agreement in 13 of the 17 tests and substantial agreement in one of the tests.

This study concludes that the FMS can be confidently applied when raters use the proper methods. The variance in the scores could be attributed to rater experience, testing protocol, or unclearly defined scoring criteria. Most of the moderate agreement scores tended to be on the inline lunge and rotary stability tests, possibly due to unclear descriptors of midrange performance.

The Minick et al. (2010) study's strong inter-rater reliability was backed up by a recent study (Schneiders, Davidsson, Horman, & Sullivan, 2011). The recent study calculated an Intra-class Correlation Coefficient of 0.971 which represents an excellent agreement between the raters as complete agreement equals 1.0. In addition, researchers noted the raters were in excellent agreement on 12 of the 17 tests, while substantial agreement was found on the other 5 tests. The raters' total amount of years using the FMS is not mentioned, but the raters had the same experience relative to each other.

The previous two studies analyzed only inter-rater reliability, but not intra-rater reliability. Whereas inter-rater reliability examines score agreement between scorers, intra-rater reliability examines score agreement of one scorer with multiple scoring trials of the same tests. A high intra-rater reliability score is received if the rater scores a movement twice (without retaining a memory of the first rating) and scores the movement similarly on both trials. A high intra-rater reliability score can be difficult to obtain when the rater attempts to score 39 videos that are randomized on the second scoring. Currently the only research regarding intra-rater reliability is in a doctoral

dissertation in which both intra-rater and inter-rater reliability was analyzed (Sorenson, 2009) and is noted below.

An investigator created an unofficial FMS training program and trained eight certified athletic trainers to be FMS raters (Sorenson, 2009). The investigator video recorded 15 participants completing the FMS and showed the videos to the athletic trainers who scored the participants twice. There was a two-week break between the scoring trials. The scores were statistically compared for both inter-rater and intra-rater reliability by looking at the median inter-rater and median intra-rater reliabilities. A level of 0.80 agreement was used as the cutoff for determining if the scoring would be acceptably reliable. The median inter-rater reliability coefficient was deemed acceptable as every test fell in the range of 0.84-0.97 except for the rotary stability test (0.73). The FMS composite scores' median inter-rater reliability was 0.90. The investigator determined that the intra-rater reliability was acceptable on all the tests as the median reliability of every test fell in the range of 0.82-0.97. The FMS composite scores' median intra-rater reliability was 0.88. Overall, three studies suggest a high inter-rater reliability and one study suggests an acceptable intra-rater reliability. No studies at this time conflict with this data, so we can conclude that the FMS is a reliable screen.

Relevancy

Relevancy is the closeness of agreement between what a test measures and what it is ideally supposed to measure. The FMS "serves as a tool for risk management. Its role is to pinpoint areas of movement-pattern limitation and asymmetry" (Cook, et al., 2010, p. 65). The FMS's relevancy depends on whether the scores reflect the screen's

purposes: identifying movement-pattern limitation (dysfunctional movement) and asymmetries.

-Dysfunctional Movement: Cook makes an important distinction between movement and motion: “Movement often denotes the act of a functioning body as it changes position under its own power. Motion might represent the available range of flexibility within a single body segment or group of segments…. Normal motion does not guarantee normal movement” (Cook, et al., 2010, p. 19). Movement by definition must be under the athlete’s control, and since all of the seven tests are done under the athlete’s own control, then the FMS measures movement ability rather than just motion. When an athlete cannot complete a designated movement, the athlete will use movement compensations. The FMS identifies these dysfunctional movements since it compares the athlete’s abilities to an objective standard of functional movement. Studies outlining the relevancy of FMS scores and injuries will be addressed in Sections V and VI.

Not only can the FMS indicate dysfunctional movement, it should also allow for movement correction. The creators of the FMS suggest that low scores can be improved (Cook et al., 2010, p. 234). Proof is needed to support that claim in order to suggest the FMS’s relevancy. One study showed an increase in FMS scores when intervention strategies were employed (Kiesel, Plisky, & Butler, 2009). Out of the 62 test subjects, prior to the intervention, 7 subjects had scores above 14, but after the intervention 39 subjects had scores above 14. In addition, 31 subjects were free of asymmetries prior to the intervention while 42 subjects were free of asymmetries after the intervention. These statistics suggest that corrective exercises may cause an increase in FMS composite scores and a decrease in asymmetrical patterns. However, the authors of the study

mention, “further research is required to determine if injury risk is reduced when a player’s score improves beyond the established cut-off of 14 and/or asymmetry is resolved” (Kiesel et al., 2009). The study revealed that FMS scores can be improved through an intervention, but did not determine if the corrected score actually indicates lower risk of injury. This study gives credibility to the principle that poor movement can be fixed through corrective exercises.

-Asymmetries: Five of the seven tests (hurdle step, inline lunge, shoulder mobility, active straight-leg raise, and rotary stability) observe both the right and left sides of the body. If the athlete cannot perform the same movement on one side of the body in a similar movement to the other side of the body, the athlete has an asymmetrical movement pattern for that specific test. The scores reflect these asymmetries, and therefore the FMS is capable of determining asymmetrical movement.

Understanding the origin of the tests might reveal how effective the FMS can be in testing actual movement patterns. In his Pre-Participation Screening article, Cook mentions “the FMS tests were created based on fundamental proprioceptive and kinesthetic awareness principles” (2006a). Also, one studied noted that the FMS test movements are a result of clinical experiences (Sorenson, 2009). Since the FMS was created on the basis of “proprioceptive and kinesthetic awareness principles” and clinical experiences, scientific research is needed in order to support Cook’s claims that the tests are fundamental for all human movement patterns.

Furthermore, the main objective of identifying these “movement-pattern limitation and asymmetry” problems is to identify injury risk. Currently no gold standard assessment exists for poor dynamic balance and asymmetries indicating risk for injuries

(Kiesel, Plisky, Butler, & Kersey, Publication In Progress). Current research suggests poor mobility, stability, core strength, and asymmetries are factors for injuries (Baumhauer et al., 1995; Kiesel et al., PIP; Nadler et al., 2001; Peate et al., 2007). In addition, research suggests that a previous injury may cause decreased proprioceptive input and will eventually alter symmetry, mobility, and stability (Lephart et al., 1997; Neely, 1998; Taimela et al, 1990). Injuries might also cause an athlete to train around a sustained injury resulting in poor movements. The FMS is designed to test these risk factors by measuring movement dysfunction and asymmetries. In all, the FMS should be able to identify any mobility and stability problem regardless of past injury because it attempts to measure dysfunctional and asymmetrical movement patterns. Ultimately, the relevancy of the FMS hinges on its injury predictability. The topic of injury predictability will be explored in the two subsequent sections.

SECTION V: FMS INJURY RESEARCH

Numerous studies have been conducted to see if low FMS scores can identify athletes who are susceptible to injuries. Researchers have studied realms including collegiate athletics, professional athletics, and work place jobs including firefighting and military training. Ultimately, the research question inquires how the FMS applies to basketball players. FMS research regarding basketball is currently limited, so studies from other settings must be utilized. This section investigates studies that discuss the FMS's ability to predict injury risk in domains outside of basketball.

Can Serious Injury in Professional Football be Predicted by a Preseason FunctionaL Movement Screen? (Kiesel, Plisky, & Voight, 2007)

An FMS cutoff score must be established in order to label athletes at risk for injuries. A score of one on any single FMS movement test indicates the athlete cannot complete the movement. The athlete may be at risk for movement injuries attributed to this low scoring movement pattern. As for the composite score, one study calculated the cutoff to be a score of 14 (Kiesel et al., 2007). Other literature typically refers to this study when discussing a previously identified cutoff score (Chorba et al., 2010; Kiesel et al., PIP; Wieczorkowski, 2010). The study's objective was "to determine the relationship between professional players' scores on the FMS and the likelihood of serious injury."

In the study, 46 professional football players were screened prior to a football season. FMS scores were obtained prior to the start of the season, and serious injury was defined as membership on the injured reserve for at least three weeks. A receiver-

operator characteristics curve (ROC) was created to establish a cutoff score. An ROC curve is a plot of true positives versus false positives of a screening test, and the FMS score that maximizes the true positives while minimizing the false positives is the cutoff score.

The score that best maximized true positives and minimized false positives was a composite score of 14. **Table 2** was created based on the players' FMS composite score and injury status during the season. For the athletes that scored 14 or lower, seven sustained a serious injury while three did not. That means 70.0% of those who scored below the cutoff score sustained an injury. Conversely, only six players that scored above 14 suffered a serious injury while the 30 players who had a score greater than 14 were not injured. For those who scored above the cutoff score, only 16.7% of the players were injured. There is clearly a large difference in the rate of injury between the players who scored above the cutoff score and those who scored below it.

FMS score ≤ 14?	Serious Injury?	
	YES	NO
YES	7	3
NO	6	30

Table 2 The relationship between players who sustained or avoided injury and the players' FMS scores.

In this particular study, the FMS seems to be able to predict injury on this team. This study has become the basis for using a cutoff score of 14 on the FMS. Other studies and today's fitness personnel use 14 as the common cutoff score (Chorba et al., 2010; Kiesel et al., PIP; Wieczorkowski, 2010). A cutoff score of 14 falls in an appropriate spot between the FMS's lowest possible score of 0 and its highest possible score of 21;

the score is not unachievable by the general population, nor is it too low to where everyone will pass it (Schneiders et al., 2011).

A limitation with this study is that the investigators used only professional football players as their subjects. Professional football players are only a fraction of the population and the players are typically better conditioned than the average person. Other research must be examined to see if the cutoff score works for alternate populations. In addition, only 46 subjects were used. This small sample size needs other research for support. Also, this study did not address asymmetries, probably due to its focus on establishing a cutoff composite score. The author does not explain why the investigators define serious injury as three weeks; data might change if the criteria for serious injury were adjusted.

Football is a highly contact-oriented sport, so injury rates should be particularly high considering the amount of contact. A bone trauma injury is typically independent of a person's movement patterns because trauma is usually a result of contact. Since poor movement patterns generally do not have an impact on contact injuries – unless movement limitation prevented the avoidance of the contact – the statistics should not include contact injuries while identifying a relationship between FMS scores and injuries. In the Kiesel et al. (2007) study, the researchers never indicated any distinction between contact injuries and noncontact injuries. The effectiveness of the FMS as a tool for injury prediction could have been distorted due to the number of contact injuries in this study. In addition, one would expect injuries to be higher in high contact positions. The researchers do not report injury statistics based on player position.

Functional Movement Test Score as a Predictor of Time-loss during a Professional Football Team's Pre-season (Kiesel, Plisky, Butler, & Kersey, Publication In Progress)

Two of the same primary authors conducted a similar study over the course of a professional football preseason (Kiesel et al., PIP). This research studied how asymmetries and fundamental movement patterns relate to injury over the course of an NFL preseason.

FMS scores were obtained from one team for one year (81 subjects) and from one team for two years (75 subjects the first year, and 76 subjects the second year) and injury data during an NFL preseason was collected. The cutoff score of 14 was used, and the presence of asymmetries was noted. Injury for this study was defined as any practice or competition time missed due to musculoskeletal injury.

The study concluded that there was a significant difference in FMS composite scores between those injured and those who were not. The players who scored 14 or below or recorded an asymmetry had a higher rate of injury. The data suggests that poor fundamental movement patterns and movement asymmetry can be identifiable risk factors for injury. This study seems to have answered the limitation of the small sample size. However, players were tested during the preseason which is a limited time frame. Also, some players may have suffered injuries due to lack of proper conditioning since the preseason is meant to partially provide a simulation of the pace of a regular season NFL game. Overall, the FMS should be able to identify correctable dysfunctional movement. The study correctly notes, "Future research should investigate whether modifying these risk factors results in reduced injury risk." Section IV identified a study that suggests intervention programs can increase the FMS score (Kiesel et al., 2009), but did not exhibit if the corrective exercises led to a decreased injury rate.

In the current section, two studies have given data regarding professional football. Other populations are needed to see if the screen can be used for the general population and other sports. Another point to consider is that this study used a different definition for injury. This time it analyzed any musculoskeletal injury instead of just ones that put a player on the injured reserve for three weeks. This study shares a similar problem to the Kiesel et al. (2007) study in which it did not distinguish between noncontact injuries and contact injures. Again data could be distorted due to the high contact nature of football.

Functional Movement Screening of NCAA Division II Male and Female Athletes (Murphy, 2001)

An author of an academic thesis screened 40 collegiate athletes from a variety of sports (Murphy, 2001). The study examined if FMS scores could identify previous history of musculoskeletal injury. Since previous injury is a risk factor for future injury, uncorrected movements after an injury should theoretically cause an athlete to train compensated movements which would result in a lower FMS score.

The women's sports included basketball, cheerleading, field hockey, middle distance running, softball, soccer, and tennis. The men's sports included football, middle distance running, pole vault, shot put, sprinting, and tennis. The 40 athletes were screened and then surveyed for previous history of musculoskeletal injury within the previous three years. This study did not use a cutoff score for the analysis, but attempted to identify any connections between the FMS scores and previous injuries.

The investigator concluded that the FMS scores "may, at best, have a weak relationship to previous incidence of injury" (Murphy, 2001, p. 51). The study seems to suggest that the FMS scores cannot indicate whether an athlete has had a previous injury.

This is different than future injury prediction, but the results are important because they seem to suggest that the FMS may be only a predictive tool. As mentioned before, injuries can interrupt proprioceptive feedback leading to prevailing movement dysfunction (Lephart et al., 1997). One might then conclude that FMS scores should be lower for those with previous injuries because the athletes would have retrained their movements around the prevailing pain.

This study had a number of limitations. First, it analyzed previous injury in regards to FMS scores rather than predicting future injury from FMS data, so its ability to answer the research question of how the FMS can predict injury in basketball is limited. However, it does suggest that the FMS cannot identify an athlete's previous injury history. One must keep in mind that a small sample size of only 40 athletes was studied. Perhaps if a larger number of the university's athletes were examined, then a better conclusion could be drawn. In addition, a large variety of athletes from different sports were studied. Different sports train athletes in different ways, so movement scores may tend to reflect how athletes are trained. In using a small number of athletes from a variety of sports, the athletes' scores may not be consistent with each other's scores. Perhaps sports-specific movement screens should be created upon the movement involved in competition to reveal possible movement trends in particular sports. The distinction between contact and noncontact injuries is nearly irrelevant in this study since the author analyzed the link between FMS scores and previous injuries, rather than the FMS score and injury predictability.

Use of a Functional Movement Screening Tool to Determine Injury Risk in Female Collegiate Athletes (R. Chorba, D. Chorba, Bouillon, Overmyer, & Landis, 2010)

The next study's researchers attempted to see if the FMS could predict injury for 38 collegiate female athletes among the sports of soccer, volleyball, and basketball (Chorba, et al., 2010). The athletes were screened prior to their seasons, and then injury data was collected over the course of their respective seasons. Injury criteria included any injury that occurred during participation in practice or competition and any injury that required medical attention.

During the study, 18 injuries were recorded (mostly in the lower extremity), and a score of 14 or less was significantly associated with injury. Tables were created similar to the one from the Kiesel et al. (2007) study for all the athletes (**Table 3**) and those who did not have a previous history of ACL injury (**Table 4**). Of all the athletes, 11 of 16 (68.8%) sustained an injury out of those who scored 14 or below, while only 8 of 22 (36.4%) sustained an injury in those who scored above 14.

	Injured	
	YES	NO
FMS™ Score ≤ 14	11	5
FMS™ Score ≥ 15	8	14

Table 3 Relationship between FMS scores and injury occurrences in all subjects.

	Injured	
	YES	NO
FMS™ Score ≤ 14	11	4
FMS™ Score ≥ 15	6	10

Table 4 Relationship between FMS scores and injury occurrences in the group who had no history of previous ACL injury.

The investigator concluded that a score of 14 or less corresponded with a fourfold increase in injury likelihood for those who did not have a previous history of ACL injury. For these athletes, 11 of 15 (73.3%) sustained an injury for those who scored 14 or

below, while 6 of 16 (37.5%) sustained an injury for those who scored above 14. The current study seems to reaffirm the cutoff score of 14 as established by the Kiesel et al. (2007) study. However, the investigators concluded that when the statistics included those who had a previous ACL reconstruction, statistical significance failed. The researchers did indicate that the average FMS score for the 12 female basketball players was a 14.6, and the subjects sustained a total of five injuries. The data does not reveal the relationship between the injury status of the basketball players and their FMS scores, so no conclusions can be made off of this data. This study adds another group to the pool of research by using female athletes and concludes that the FMS could be used to predict injury in the athletes who did not have prior history of major ACL injury. The researchers did not discuss noncontact and contact injuries, yet the distinction between contact and noncontact injury may not apply to these three sports considering that they are much less contact-oriented than football.

The study is limited by the number of athletes (only 38 participated), as a small number participated from three different sports. Also, Chorba et al. (2010) used a different definition of injury than Kiesel et al. (2007) due to the difference in contact natures of the sports. The change in definition is justified considering that the three sports included in the study have less contact than football. However, the difference in the criteria for injury – three weeks missed time on the injured reserve versus any injury in practice or competition that requires medical attention – makes comparisons between the two studies difficult.

Functional Movement Screen Normative Values in a Young, Active Population (Schneiders, Davidsson, Horman, & Sullivan, 2011)

Three of the previous studies appeal to an established cutoff score for injury predictability, but they do not suggest normative FMS values. Normative values allow fitness professionals to compare their clients' scores to ideal scores. Investigators noticed this void in the research and administered the FMS to a population of 209 physically active individuals between the ages of 18 and 40 (Schneiders et al. 2011). All participants had had at least six weeks without a musculoskeletal injury, although 50 subjects reported having recovered from a lower extremity injury suffered in the last six months. The participants were screened using the FMS.

The mean score was 15.7, and there was no statistical significance distinguishing between men and women's composite scores. While the composite scores did not differ significantly, men and women's individual test scores tended to differ based on the test. The females generally did better on the active straight-leg raise and shoulder mobility tests while the males tended to score higher on the trunk stability pushup test. The scores ranged from 11-20, and the 95% confidence interval was 15.4-15.9 meaning that the investigators are 95% confident that the interval of 15.4-15.9 spans the true mean.

Although the study did not test for injury predictability, the investigators suggest the use of a cutoff score of 14 from the Kiesel et al. study (2007) should be used with caution because "of the small sample size and the fact that the target group didn't represent a general athletic population." The numbers from this study can be viewed as valid due to the large sample size, age range of the subjects, and small confidence interval. Overall, the study gives good values of how an average, healthy population should score on the FMS.

The study however does not address the injury predictability of the FMS. It only establishes the average scores of a general population. The mean was significantly lower than the Kiesel et al. (2007) study in which the football players' composite mean was 16.9. However, the higher scores of the players on the football team could be due to their training program intensity. At least from these statistics one may suggest that the football scores (cutoff and average) might not extrapolate to other domains including the sport of basketball.

Core Strength: A New Model for Injury Prediction and Prevention (Peate, Bates, Lunda, Francis, Bellamy, 2007)

Since basketball is a lower contact sport than football, noncontact yet physically demanding professions outside of athletics may provide some extended information on the FMS in regards to basketball. Researchers conducted the FMS on 433 firefighters to identify a correlation between FMS scores and a history of musculoskeletal injury (Peate et al. 2007). An intervention program was later implemented to see if injuries would be reduced from past injury data. The intervention exercises aimed to strengthen core muscles and decrease mechanical load on the musculoskeletal system while performing functionally difficult tasks. These corrective exercises were designed to mimic firefighting tasks.

Compared with a historical control group, the lost time due to injuries went down 62% and the total amount of injuries decreased 42% after the intervention. A correlation was noted between past injury history and FMS score using linear regression. However, using logical regression, firefighters with a history of injury did not have a significant

difference in FMS scores. This study statistically determined that the cutoff score was a score of 16 or below as 69.3% scored higher than 16 and 30.7% scored 16 or below.

Although the researchers never retested the population to see if the corrective exercises increased the FMS scores, this study suggests that the use of corrective exercises can decrease the likelihood of future injuries. An important note is that some of the corrective exercises were specific to the domain of firefighting and could suggest that sport-specific corrective exercises should be utilized. The FMS seemed to have trouble distinguishing between the firefighters with different injury history; this study may uphold the idea that Murphy (2001) set forward in which the FMS scores have trouble in identifying athletes with previous injuries. Considering the low contact nature of this profession, contact injuries are unlikely to skew the data.

The number of participants helps the validity of this study. However, logical and linear regressions disagree in regards to FMS scores and injury history. This study establishes a cutoff score of 16 and is the first to suggest a cutoff score different than 14. Interventions seemed to decrease injury incidence as compared to previous years. The study however is limited to using a large pool of men (94.2% men versus 5.8% women) in an environment that is not an athletic environment, yet one which requires a high amount of physical activity.

Many variables make it difficult to identify a relationship between low FMS scores and injuries. A stumbling block in drawing a summary with these studies is identifying a clear definition for the word “injury” or phrase “serious injury.” One study classifies “serious injury” as only including athletes who were on the inactive list for three weeks (Kiesel et al., 2007). Another study requires a loss of practice or game time

to qualify for an injury (Kiesel et al., PIP). And other research classifies injury as any musculoskeletal problems acquired in competition that required medical attention (Chorba et al., 2010). Another possible criterion for injury would be any significant pain even without missed competition time. In general, the FMS might predict pain will result, but the pain may never be recognized in the statistics if missing competition is a requirement for the pain to be identified as an injury. Since the definition of injury is so ambiguous, it is difficult to come up with a true cutoff score that encompasses all domains.

In addition, the FMS should only be able to predict noncontact injuries. However the data from these studies rarely discriminates between contact and noncontact injuries; the data from these studies might be skewed in the case of the high contact sport of football. While these studies seem to suggest that the FMS can predict those who are susceptible for injuries, some of the studies done in the realm of basketball have been somewhat inconclusive. Overall, the studies seem to suggest that there is a relationship between a low FMS composite score and injury risk. However, the FMS may not be able to identify those with previous injuries (Murphy et al. 2001; Peate et al. 2007) nor predict the future injury susceptibility of those who have suffered a previous lower extremity injury (Chorba et al. 2010).

SECTION VI: FMS INJURY PREDICTION IN BASKETBALL

Currently two studies explore the FMS in a basketball setting, but neither is in a peer-reviewed journal. One study is a Master's thesis and the other is a Doctoral dissertation. These studies give a small sample of how the FMS may work in predicting injuries in basketball.

Functional Movement Screening as a Predictor of Injury in High School Basketball Athletes (Wieczorkowski, 2010)

The investigator of the Master's thesis attempted to identify a significant difference in FMS scores in high school basketball players who would suffer an injury and those who would not during one basketball season (Wieczorkowski, 2010). He also attempted to determine a cutoff for the composite score. A total of 82 boys and girls from junior varsity and varsity teams participated in the study. The investigator separated the participants into three non-mutually exclusive categories: all participants, participants who had a prior lower extremity injury, and participants with no history of lower extremity injury. The investigator qualified injuries as any time lost from participating in competition. An ROC curve was used to determine the cutoff score for all three categories, and a t-test was used to reveal if there was a significant difference in the FMS scores between those who were injured and those who were not injured.

Overall, 20 of the 82 athletes suffered a participation-preventing injury. In the "all subjects" group and the "previous history of lower extremity injury" group, there was no evident difference in FMS scores between those who sustained an injury and those

who did not sustain an injury. The t-test did however reveal a difference in FMS scores between those who sustained an injury and those who did not sustain an injury in the "no previous history of lower extremity injury" group. The ROC curve determined the cutoff scores for the "all subjects" group, the "history of previous lower extremity injury" group, and the "no history of previous lower extremity injury" group were 14.5, 11.5, and 14.5 respectively.

Ultimately, the FMS seemed best at predicting injury in the "no previous history of lower extremity injury" group in which those who scored 14 or below had a 5 times higher chance of getting injured. This study seems to reaffirm the cutoff score of 14, but only for a select population. There is consistency with this study and other studies in regards to the inability of the FMS to predict future injury for the athletes who have sustained a prior injury (Chorba et al., 2010; Peate et al., 2007).

This study did not use corrective measures and does not suggest if scores corrected due to interventions can prevent injury or improve FMS scores. Injuries included any musculoskeletal impairment that required lost time from competition; the study did not take into consideration contact versus noncontact injuries. An important note to be considered is that most colleges and high schools require athletes to get their ankles taped prior to a game but professionals may not. Ankle taping and bracing has been shown to prevent injuries (Wieczorkowski, 2010), and in this particular study the athletes went through the FMS without taping or bracing, yet many of them could have played in games having been taped.

Functional Movement Screen as a Predictor of Injury in High School Basketball Athletes (Sorenson, 2009)

In a doctoral dissertation, an investigator examined the effectiveness of the FMS on 112 high school basketball athletes (both boys and girls) from freshman, junior varsity, and varsity teams (Sorenson, 2009). Injury was defined 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" (38). In essence, noncontact injuries were scrutinized in this study as opposed to all injuries. Once intra-rater and inter-rater reliabilities were established, FMS scores were obtained and injury data was recorded throughout the basketball season. The cutoff score from the Kiesel et al. (2007) study (composite score of 14) was assumed, and previous injury data was not considered due to the lack of available data.

The investigator reported 32 noncontact injuries, with the majority occurring in the lower extremity. The FMS seemed to have a poor ability to predict at-risk athletes, as 24% of those that scored above a 14 sustained an injury, while 22% of those that scored 14 or below suffered an injury. In fact, no cutoff score could accurately predict an increased risk of injury.

This study suggests intra-rater and inter-rater reliabilities for the FMS are acceptable, but implies that the FMS cannot aid in injury prediction. An important note is that this study examined only noncontact injuries instead of all injuries. Since Sorenson (2009) only included noncontact injuries, his data would likely be more relevant to FMS scores because an athlete's fundamental movement patterns are typically

unrelated to contact injuries. However, excluding contact injuries might have limited the data in some way. Sorenson's (2009) study did have a large sample size and a good demographic regarding gender.

The study was limited by the lack of information available on previous injury history. The Wieczorkowski (2010) study determined that there was no significant difference in FMS scores of those who sustained an injury and those who did not record an injury in the "all subjects" group. Perhaps the inability to record previous injury data limited the results of the Sorenson (2009) study. Although Sorenson's (2009) study did address noncontact injuries, perhaps quality of fundamental movement has an impact on the ability to avoid contact. However, the researcher did not report contact injuries, so those injuries cannot be analyzed.

Overall, there seems to be inconclusive evidence that supports the use of the FMS for screening all athletes prior to competition in basketball. For some reason, the FMS could not predict injury in all populations of basketball players. Wieczorkowski (2010) found a relationship between FMS scores and injuries in players who had not had prior history of lower extremity injury, but he found no relationship between the FMS scores and injuries in the "all subjects" group. The investigator determined the cutoff score to be 14 in the population that the FMS could predict injuries. Sorenson could not find a relationship between FMS scores and injuries that occurred in the entire group that participated. Unfortunately, previous injury information was unobtainable for the latter study, so no strong conclusion can be made. However, one can conclude from these two studies that the FMS is not a good predictor for injury in all populations of basketball players.

SECTION VII: DISCUSSION

The sport of basketball has always carried an inherent risk for injuries. This topic is important at both the amateur and professional levels. Movement patterns could be affected in the life of a young player who suffered an injury in high school. Professional teams sometimes spend millions of dollars on players who are forced to sit out of competition due to injuries. There is a clear need to reduce the amount of injuries in basketball for the sake of the athletes and the entertainment product of the professional leagues.

Although other screening tools exist, the FMS was investigated because of its widespread use today. The FMS has been proposed as a way to identify and reduce injury risk. Three studies did conclude that the FMS has a high inter-rater reliability and no literature currently conflicts with these assertions. FMS intra-rater reliability still needs more research, but one study concluded that the FMS has acceptable intra-rater reliability. For the sake of the literature examined, the FMS can be regarded as a reliable screen. The primary purpose of the screen is to identify injury risk through asymmetrical and dysfunctional movement patterns. A cutoff for the composite score then categorizes whether the participant is at risk for injury. Four recent studies have suggested a cutoff score of 14 (Chorba et al., 2010; Kiesel et al., 2007; Kiesel et al., PIP; Wieczorkowski, 2010). Other studies have suggested a different cutoff score (Peate et al, 2007) or the cutoff score of 14 should be used with caution (Schneiders et al., 2011). Even still, others could not find a relationship between injuries and FMS scores (Murphy, 2001; Sorenson, 2009), while others noticed the FMS could more accurately predict injury in a select

population (Chorba, 2010; Wieczorkowski, 2010). An important note is that only one investigator really focused on noncontact injuries (Sorenson, 2009), which is the type of injuries that the FMS would predict. No relationship was found between a low FMS score and injury susceptibility in that study.

Neither of the two basketball studies concluded that the FMS could be a valid injury prediction tool for all subjects. However, Wieczorkowski (2010) concluded that the FMS could predict injuries in the athletes who participated in the sport, but did not have history of a lower extremity injury. Another study suggested the FMS could not identify athletes with previous history of injury (Murphy, 2001), while a different study identified the FMS's injury predictability increased when removing the subjects with prior ACL injuries from the data pool (Chorba, 2010). These findings may suggest that the FMS has a weak ability to identify injury risk in those who have a history of injuries, possibly because previous injury is already a risk factor for future injury.

One of the complications in identifying injury risk is defining the criteria for injury. The studies that have been examined have different interpretations of the term "injury". One study examined "serious injury" in which the definition required players to be on the injured reserve for three weeks in order for the injury to be counted (Kiesel et al., 2007). This would neglect any injury that a player suffered if he was on the injured reserve for time less than three weeks or had an injury but was never placed on the injured reserve. Some studies made their criteria any musculoskeletal damage as a result of competition (Chorba et al., 2010; Sorenson, 2009), while others required missed time from competition to count as injuries (Kiesel et al., PIP; Wieczorkowski, 2010). In addition, one study discussed the difference between contact and noncontact injuries

while most others did not. Unfortunately, the ambiguous definition for injury could have contributed to the mixed results of this literature review. The "Suggested Investigation" segment below suggests an injury nominal ranking system which may answer the one-size-fits-all generalizations found in other studies.

Suggested Investigation

A possible follow-up investigation would be to explore the FMS's ability to predict injury in professional basketball. Researchers should obtain FMS scores and injury data from at least 100 professional players from each the NBA and WNBA over the course of a season. This would provide data at the professional level which is currently missing in the research. The term "injury" would need to be defined more adequately. Accepting a more general definition and adding an injury ranking system would allow different levels of injuries to be analyzed; injury could be defined as any painful musculoskeletal infliction that can limit a player's performance abilities, and a nominal ranking would be assigned based on the injury severity:

- An injury that does not cause an athlete to miss any practice or game time would be assigned a 1.
- An injury that causes an athlete to miss practice time would be assigned a 2.
- An injury that causes an athlete to miss any competition time up to one week would be assigned a 3.
- An injury that causes an athlete to miss competition time from one to three weeks would be assigned a 4.

- An injury that causes an athlete to miss competition time longer than three weeks would be assigned a 5.

The ranking system would be used only for nominal purposes. Separating the severity of the injuries allows the investigator to analyze the FMS's predictability on different levels. Specifications distinguishing noncontact and contact injuries should be established, but contact injuries should not be completely neglected. In addition, previous history of injury information should be recorded. To limit the variables, corrective exercises should not be considered in this investigation, but an FMS posttest should be performed at the end of the season to identify any changes in movement pattern.

Data should be analyzed to see if a cutoff score for the FMS composite scores can be identified to predict noncontact injury at each level for all subjects, subjects without a previous history of injury, and subjects with a previous history of injury. The emphasis on the data analysis should be based upon noncontact injuries, but data from contact injuries should also be collected. Data analysis should also include the FMS cutoff scores for all noncontact injuries (all rankings combined), group cutoff scores for those whose injuries ranked a 2 or above, group cutoff scores for those whose injuries ranked a 3 or above, and group cutoff scores for those whose injuries ranked a 4 or a 5. A researcher would then be able to determine if the FMS injury predictability depends on injury severity. Another possible statistic would be to see if there is a correlation between FMS scores and percentage of missed participation due to injuries (both practice and game time). This would include reoccurrences of a single injury that would cause separate stints of missed participation time.

This study would allow a broad definition for injury to be considered while attempting to identify an FMS cutoff score for injury predictability among multiple levels of injury severity. It would also allow for analysis on noncontact injuries and avoid contact injuries which could skew the data. If injury prediction in professional basketball can be established by the suggested investigation, further research would be needed on other topics such as the effectiveness of corrective exercises on injury prevention, the change in FMS retest scoring after a season without intervention programs, the success of an intervention program on FMS retest scoring, and the ability of ankle taping to prevent movement associated injury.

Conclusion

All in all, the FMS might be able to identify injury risk for basketball participants who do not have a history of lower extremity injury. Questions still remain regarding whether or not high school movement statistics can extrapolate to the professional level considering no research has been completed at the basketball professional level. Research has concluded that corrective strategies can increase FMS scores (Kiesel et al., 2009), and evidence suggests interventions can reduce injuries (Peate, 2007). However, due to the litany of variables in the literature and the lack of depth on the subject, more research is needed to suggest that the FMS should be used for pre-competition screening in basketball.

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APPENDIX A

Functional Movement Screen Scoring Sheet

Scoring Sheet

Name: _____ Date: _____

Age: _____ Height: _____ Weight: _____ Male/Female: _____

Sports Activity/Reference: _____

Hand Dominance: Right / Left Leg Dominance: Right / Left

Test	Raw SC	Final	Comments:
Deep Squat			
Hurdle ST. L			
Hurdle ST. R			
In-Line Lunge L			
In-Line Lunge R			
Should. Mobility L			
Should. Mobility R			
Active Imp. L			
Active Imp R			
ASLR L.			
ASLR R			
TSPU			
EXT			
Rot. Stability L			
Rot. Stability R			
FLX			
Total			

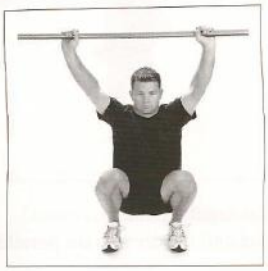
APPENDIX B

Functional Movement Screen Scoring Pictures

APPENDIX 9

FMS SCORING CRITERIA

DEEP SQUAT



3

Upper torso is parallel with tibia or toward vertical | Femur below horizontal
Knees are aligned over feet | Dowel aligned over feet

2

Upper torso is parallel with tibia or toward vertical | Femur is below horizontal
Knees are aligned over feet | Dowel is aligned over feet | Heels are elevated

1

Tibia and upper torso are not parallel | Femur is not below horizontal
Knees are not aligned over feet | Lumbar flexion is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

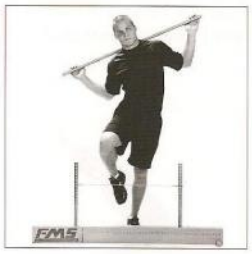
HURDLE STEP

3

Hips, knees and ankles remain aligned in the sagittal plane
Minimal to no movement is noted in lumbar spine | Dowel and hurdle remain parallel

2

Alignment is lost between hips, knees and ankles | Movement is noted in lumbar spine
Dowel and hurdle do not remain parallel



1

Contact between foot and hurdle occurs | Loss of balance is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

INLINE LUNGE

3

Dowel contacts maintained | Dowel remains vertical | No torso movement noted
Dowel and feet remain in sagittal plane | Knee touches board behind heel of front foot

2

Dowel contacts not maintained | Dowel does not remain vertical | Movement noted in torso
Dowel and feet do not remain in sagittal plane | Knee does not touch behind heel of front foot

1

Loss of balance is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

SHOULDER MOBILITY

3

Fists are within one hand length

2

Fists are within one-and-a-half hand lengths

1

Fists are not within one and half hand lengths

The athlete will receive a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.

CLEARING TEST

Perform this clearing test bilaterally. If the individual does receive a positive score, document both scores for future reference. If there is pain associated with this movement, give a score of zero and perform a thorough evaluation of the shoulder or refer out.

ACTIVE STRAIGHT-LEG RAISE

3

Vertical line of the malleolus resides between mid-thigh and ASIS
The non-moving limb remains in neutral position

2

Vertical line of the malleolus resides between mid-thigh and joint line
The non-moving limb remains in neutral position

1

Vertical line of the malleolus resides below joint line
The non-moving limb remains in neutral position

The athlete will receive a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

TRUNK STABILITY PUSHUP

3

The body lifts as a unit with no lag in the spine

Men perform a repetition with thumbs aligned with the top of the head
Women perform a repetition with thumbs aligned with the chin

2

The body lifts as a unit with no lag in the spine
Men perform a repetition with thumbs aligned with the chin | Women with thumbs aligned with the clavicle

1

Men are unable to perform a repetition with hands aligned with the chin

Women unable with thumbs aligned with the clavicle

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

SPINAL EXTENSION CLEARING TEST

Spinal extension is cleared by performing a press-up in the pushup position. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual does receive a positive score, document both scores for future reference.

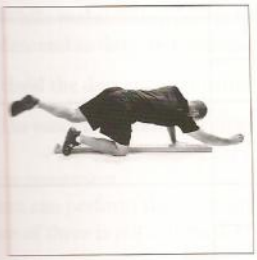
ROTARY STABILITY

3

Performs a correct unilateral repetition

2

Performs a correct diagonal repetition



1

Inability to perform a diagonal repetition

The athlete receives a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.

SPINAL FLEXION CLEARING TEST

Spinal flexion can be cleared by first assuming a quadruped position, then rocking back and touching the buttocks to the heels and the chest to the thighs. The hands should remain in front of the body, reaching out as far as possible. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual receives a positive score, document both scores for future reference.