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Relationship Of Pre-Season Functional Movement Screening On Injury In Division 1 Collegiate Athletes

Zebulon Miller

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RELATIONSHIP OF PRE-SEASON FUNCTIONAL MOVEMENT SCREENING ON INJURY IN DIVISION 1 COLLEGIATE ATHLETES

by

Zebulon Raymond Miller
Bachelor of Science, University of North Dakota, 2014

A Thesis
Submitted to the Graduate Faculty
of the
University of North Dakota
in partial fulfillment of requirements

for the degree of
Master of Science

Grand Forks, North Dakota

May
2016
This thesis, submitted by Zebulon Raymond Miller in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

Dr. Jesse Rhoads
Dr. John Fitzgerald
Dr. Martin Short

This thesis is being submitted by the appointed advisory committee as having met all the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

Dr. Wayne Swisher
Dean of the School of Graduate Studies

April 21, 2016
Date
PERMISSION

Title: Relationship Of Pre-Season Functional Movement Screening On Injury In Division 1 Collegiate Athletes

Department: Kinesiology and Public Health Education

Degree: Master of Science

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Zebulon Raymond Miller
5/14/2016
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ABSTRACT

Introduction: Injury has been seen to have many factors and mechanisms during each individual sport. The functional movement screening (FMS) is a tool that allows for an individual mobility and stability in a fundamentally dynamic movement patterns to show limitations and asymmetries in movement performance based of a seven functional movement patterns and three clearing screens. Researchers have found some evidence that show scoring less than 14 may be related to increase injury. Research Question: Does FMS provide a systematic tool to monitor progress and movement pattern development that identify individuals injury throughout a season? Method: Study design is descriptive research. Obtaining FMS scores prior to the start of the season and assessing the relationship of injury in the athletes. University of North Dakota Athlete (n=84) was recruited during the fall season. The descriptive statistics and correlation data (Pearson’s or Spearman rho) was used in this study. Results of correlation data: Football- FMS lower and U1 Noncontact (r = .27, p = 0.053) soccer- TSscore and L1 contact (r = 0.569, p = 0.34), FMS lower body score and L1 contact (r = 0.6, p=.021), FMS lower and L2 contact (r = -0.5, p = 0.059), FMS upper body score and L1 Noncontact (-0.547, p = 0.043), tennis – no significance; the Chi-Squared analysis did not produce any significant differences when TSscore was binned at 14 or when FMS upper and lower were binned at their midpoints. Conclusion: The FMS is not specific to injury mechanisms and the multiple injury mechanisms that are possible in all different sports. The results from our study do not support the use of the FMS as a screening tool for injuries in colligate
athletes participating in football, soccer and tennis. Mechanisms for injury should be used to develop an approach of a correct prevention programs throughout a college sports program. The key component to the expanding understanding of the traditional biomechanical approach to prevent injury in these athletes is continue to better assessment tool.
CHAPTER
I. INTRODUCTION/LITERATURE REVIEW

The estimated annual total of athletic injuries sustained between 2009-2014 was found to be 210,6754 (Kerr, Marshall, Dompier, Corlette, Klossner, & Gilchrist, 2015). Most of the injuries that happen in college sports occur during a game or practice and affect the lower extremities (53.8% in game and 53.7% in practice) (Hootman, Dick, and Agel, 2007). Screening methods related to injury may be a beneficial tool for support staff to reduce injury rates in athletes. Researchers have been performing studies to evaluate many pre-season tools that support staffs have been using for many years. They have not been able to create a concrete conclusion on one standard screening that is all-inclusive to assess an athlete’s injury.

Researchers have looked at the factors that predispose athletes to injury: an athlete’s pre-training fitness level, agonist/antagonist muscle ratios for strength and endurance, structural abnormalities, being a female, and having prior musculoskeletal injury history (Bahr, and Krosshaug 2005; Devan, Pescatello, Faghri, and Anderson, 2004; Neely, 1998). Additional body mechanisms that also play a role in injury factors include poor movement patterns that individuals develop through limitations or asymmetries, contralateral imbalances, core instability, and muscular imbalance (American College of Sports Medicine, 2013; Cook, 2010; Cook, Burton, and Hoogenboom, 2006; Cook, Burton, Hoogenboom, and Voight, 2014; Cook, Burton, Hoogenboom, and Voight, 2014; Cook, Burton, and Hoogenboom, 2006; Neely, 1998).
Flexibility and range of motion that individuals have are an ever-changing variable as people continue to age. The proposed benefits of healthy range of motion are the following: the reduction in functional decline in movement, reduced tension, reduced injury, relief of muscle pain, stress reduction and improved quality of life (American College of Sports Medicine, 2013; Bahr, 2005; Biagioli, 2007). Training programs should evaluate individuals’ biomechanical movement patterns to bring attention to dysfunction in movement or the compensation that the individual has developed. College athletes must take part in many pre-season examinations such as physicals, athletic trainer assessment, strength & conditioning testing, etc. College athletes have always been examined for the overall health of the athlete as it relates to being able to perform their given skill. We have all this information available for injury, so why is not there an effective preseason tool or system to reduce injury in college athletes. The support staff has grown more focused on how to reduce college athletes’ injury based off the pre-season assessment and examinations that take place.

**Functional Movement Screen Background**

FMS is used to evaluate an individual’s activation of muscles through the complete range of motion and assess areas of weakness and inefficient movement patterns. The research supports that the FMS has reliability for possibly identifying neuromuscular contraction issues and lack of range of motion in a joint (American College of Sports Medicine, 2013; Biagioli, 2007; Cook, 2006; Okada, Huxel, and Nesser, 2011). The FMS was designed to provide fundamental movement patterns that are basic performance on muscle stabilizer, balance, oomotion of individual movement and not a predictor of individual injury (Cook, 2006a, 2006b, 2010, 2014a, 2014b).
From the use of FMS, a physical therapist and athletic trainers have a baseline score to get an athlete back to before allowing them to return to participation. This may help prevent the returning of an athlete to sport before fully healthy. The functional design of the FMS may allow for injury factors to be identified and therefore allow a prevention program to be designed (Cook, 2006a, 2006b, 2010). The fundamental movement patterns that have been designed and utilized for the FMS system allow for joint limitations, bilateral limitations, and asymmetries that may aid in the prevention of injury prior to participation in activities (Cook, 2006a, 2006b, 2010, 2014a, 2014b).

FMS consists of seven fundamental movement patterns that include: a) deep squat, b) active straight leg raise, c) trunk stability push-up, d) rotational stability, e) in-line lunge, f) hurdle step, g) shoulder mobility and three clearing tests. These movement patterns have been studied for accuracy and have been found to have reliability for finding joint limitations and muscle stability issues (Smith, Chimera, Wright, and Warren, 2013). FMS is not designed to be used as a diagnostic tool. The use of the FMS is for prevention of injury and measurement of fundamental movements to collect information to improve or rehabilitate an athlete’s weakness (Cook, 2010).

**Functional Movement Screen Intervention**

Researchers have been able to show that effective intervention programs improve low FMS scores and the results of scoring low on certain movement patterns during the screening. A 7-week offseason corrective exercise program saw an improvement in asymmetrical movement, for 41 individual issues was reduced to 31 individual issues during the post-training evaluation; low FMS scores were shown for the deep squat to have an impact on injury/failure of program. (Kiesel, Plisky, and Butler, 2009). Keisel et al. (2009) reported that a strong predictor of injury/failure in an intervention program was
a low score on the deep squat during the pre-screening. Firefighters (n = 433) were given a FMS and a intervention program was designed to improve flexibility and strength core muscle groups; researchers found that 62% of firefighters were able to reduce lost time due to injury and reduced individual injury by 42%; all base scores of the firefighters’ pre-screening FMS scores may aid in the development of a better program design (Peate, Bates, Lunda, Francis, and Bellamy, 2007).

**Functional Movement Screen Injury**

Researchers have explored the usefulness of the FMS system has to better understand injury and the FMS utility. From an injury viewpoint, Keisel et al. (2007) found that professional football players that performed poorly on the FMS system show an increased predictability of serious injury with a cut-off FMS score between 13.5-14.5. Receiving a poor FMS score has been found to have significant correlation between injuries in the athlete over the course of a season due to performing poor on the individual movement patterns (P= 0.0214, r= 0.76) (Chorba, Chorba, Bouillon, Overmyer, and Landis, 2010).

The impact of score low on a movement during this test could have an overall impact on individual injury of the athlete and their athletic performance. Looking at the predictability of injury based off the athletes’ overall score was found to show no more likely hood if the total score was higher or lower than 14 the relative risk = 0.68, 95% confidence interval = 0.39, 1.19, P = .15 (Mokha, Sprague, Gatens, 2016) An individual with asymmetry or receiving a score of 1 on a movement was 2.73 times more likely to sustain a injury than athletes that received higher than 1(Mokha, Sprague, Gatens, 2016). The FMS has been used to evaluate an athlete’s movement pattern as it relates to athletic coordination and core strength. Chimera et al. (2015) found that male and female division
I athletes scored similar on the deep squat and hurdle step; results also found that the female athletes performed poorly on tasks that involve greater core strength and coordination while performing greater on flexibility and joint mobility movement patterns.

**Functional Movement Screen Reliability**

FMS has been examined for reliability and the system has shown quality as a movement pattern tool. Onate et al. (2012) reported total FMS scores to have good to high inter-rater and moderate-to-high intersession reliability with exception of the hurdle step, when two qualified raters were used to score the screening and the dependent variable used was the total FMS scores. Test-retest and inter-rater reliability was found to show good reliability for the use of one rater, the researchers also saw excellent reliability live-versus-video on the FMS system poor reliability for the inter-rater was also found during this study (K= 0.38) (Shultz, Anderson, Matheson, Marcello, and Besier, 2013).

Research has shown that inter-rater reliability is good reliability (ICC = 0.81-0.91); the raters that were used in this study were physical therapy student and athletic trainers that were all not certified and one rater that was FMS certified (Smith et. al., 2013). Teyhen et al. (2012) reported that inter-rater agreement bases on the score on the FMS were moderate to excellent (Kw = 0.45-0.82) with the use of a group of 8 physical therapy students that were randomly split into two groups of four to increase the variability in the study. Minick et al. (2010) states that novice and expert raters demonstrated excellent agreement on scoring of the FMS assessment. Data supports the FMS to be applied by trained individuals and may assist in identifying individuals that are at risk of injury.
Research Gap

The research has focused a lot of effort testing the reliability of the FMS and the reliability of the scoring scale that is used. The area that has not been looked at closely is the predictability of the FMS when breaking the FMS total score into FMS upper and lower body score to see the impact and power of better assessment of individual athletes injury. Injuries in sports have always shown that female athletes tend to sustain injury more frequently than male athletes in practice and competition. The support staff that college athletes have available to them are physical therapists (PT), athletic trainers (AT), strength and conditioning coaches (SC), etc. The lack of a quality communication has developed between all the many supporting staff that colleges athletes have and has made the development of athletic performance more challenging.

Functional Movement Screening (FMS) has been designed as an aid in the assessment of an athlete’s movement patterns and not a diagnostic tool (Cook, 2010). Greg Cook designed the FMS and the screening the seven fundamental movement patterns that are aimed at assessment of limitation and asymmetries (Cook, 2010). FMS allows for a baseline score for individual movement to be assessed before or after injury. With the use of FMS screening athletes may have pre-existing joint or muscular skeletal limitation that can be seen during a preseason screening that would aid in prevention of injury. FMS also facilitates a baseline measurement of individuals movement pattern that the athlete must accomplish after injury has occurred. The understanding where the FMS system fits or does not fit into the college athlete assessment protocol is yet to completely be determine.
Summary

Factors that have a relationship to the level of injury in athletes include pre-training fitness level, agonist/antagonist muscle ratios for strength and endurance, structural abnormalities, gender differences, having prior musculoskeletal injury history, limitations or asymmetries, contralateral imbalances, core instability, and muscular imbalance (American College of Sports Medicine, 2013; Bahr 2005; Cook, 2006a, 2006b, 2010, 2014a, 2014b; Devan et. al, 2004; Neely, 1998). The multiple factors either play major or minor roles in an individual’s level of injury. The factors that cause injury in sports have developed the need for a screening tool to be designed that allows researchers to evaluate and have better injury predictability. The FMS has shown in research to have value at screening for areas of injury in an individual (Kiesel, Plisky, and Voight, 2007; Cook, 2006a, 2006b, 2010, 2014a, 2014b; Peate, Bates, Lunda, Francis, and Bellamy, 2007). Researchers have been able to find that the FMS system allows for better team injury predictability at moderate significance (Kraus, Schütz, Taylor, and Doyscher, 2014). Researchers have put forth many efforts to test the reliability of the FMS system as well as the rater of the movement patterns. FMS is a simple cost effective screening that is portable and gives the freedom to screen anywhere. FMS evaluates an individual’s core stability as related to balance and the muscular skeletal stability and joint limitation that allows for one part of the injury prevention process in athletes to take place, therefore increasing the ability of those athletes to perform better and less time missed from sport because of injury (Cook, 2010).

Purpose

Individual athletes are required to perform at peak performance for their respective team on week-to-week bases throughout the long seasons. Everyone involved
throughout the athletic department, coaching staff, and athletic trainers is looking at how to best help their athletes get to their individual peak performance every week with as few injuries in that sport as possible. With the high level of injury that takes place within college sports the question of finding a way to prevent these injuries has arisen. Injury data was collected over 16 years for 15 different sports at the division’s 1, 2, and 3, and combine injury for game and practice for division 1 athletes was reported as 86,369 (injury/game exposure 33,535/2,167,846 to injury/practice exposure 52,834/12,600,136) (Hootman, 2007). The significance of this study is to evaluate the relationship in success or unsuccessful use of FMS as being able to predict injury in individual athletes bases off the relationship of scoring high or low on the screening. Establishment of a qualitative measurement screening like the FMS may allow for college athletes’ support staff to have better understanding of the issues and needs of athletes as it relates to improving individual program design for rehab or sports performance training. Research has shown a moderate relationship at successful use as pre-participation screen for a team’s FMS scores (Kraus, 2014). The primary purpose of this study is to look at the correlation between a low FMS score and injuries in athletes over the course of the athletes’ season.

Research Question

Q1: Are FMS scores associated with injury in collegiate athletes competing in fall sports?

Variables

Independent Variable: Functional Movement Screen has 7 movement patterns that are design to identify areas of restrictions in an individual’s joints. The movement patterns that are performed are deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability test. This test is
scored according to how well the movement is performed. The individual will be given a score 0-3 with a perfect score of 21 on the examination.

Dependent Variable: Athlete injury is classification as injury that occurs during the event of a collegiate game or practice. The injury sustained by the athlete would require attention from the one of the certified athletic trainer or team doctor at University of North Dakota. The injury that is sustained will fall into two levels of injury; Level 1 is overuse injury, which includes musculoskeletal pain, stress fractures, tendonitis, bursitis, fasciitis, joint sprain injury, impingement, strain of the muscle due to overuse, shin splints degenerative joint conditions, and retropatellar pain syndrome. Level 2 is traumatic injury, which includes muscle/joint injury such as a strain/sprain due to an acute event, dislocation, fracture, blister, abrasion, laceration, contusions, and concussion.

**Hypothesis**

H₁: Individual that receive a FMS score of 14 or lower will be associated with higher injury compared to individual that receive a FMS score of 14 or higher.
II. METHOD

Participants

Sixty males and twenty-four female collegiate athletes competing in the following: football, soccer and men & female tennis choose to take part in this study. Athletes were recruited to partake in the study by a presentation before team workouts or athlete’s preseason physical examination. Athletes that took part in this study were fall sports teams from the University of North Dakota. The use of these selected teams was done according to what teams that research have use and the convenience of the sample. The reason for convenience sampling is the access to the fall sport athletes at the University of North Dakota. All athletes’ signed an informed consent document after being informed about study participation. Athletes also allowed the University of North Dakota athletic training staff to release injury information for this study (Appendix B). Individual identity was protected during the collection of injury and is completely anonymous throughout the study. All athlete injury information was returned to the athletic training staff at the conclusion of this study. Individuals that were excluded from this study will be athletes that are no longer part of the team or athletes that had a musculoskeletal injury or surgery within the last month; the reason for this exclusion is because of the decrease range of motion and lack of traditional movement patterns of the athlete. The use of fall sport athletes may affect the results due to the shorter season that they are taking part in compared to other longer college sports seasons. Intuitional
research board (IRB) at the University of North Dakota approved the design of the research procedures for this study.

**Procedures**

Athletes completed a single screening session that was approximately 15-20 minutes in duration. After informed consent was obtained, body mass was collected in pounds on a Tanita digital scale (weight was collected with no shoes and lightweight clothes from a standard scale). The height was collected in inches (collected with posterior side of the body against wall, heels together and toes lifted up, and head at neutral position resting against the wall).

Individual raters that are doing the scoring have logged the minimum of 100 hours with the FMS pre-participation system and are certified with the FMS pre-participation system. Gribble et al. (2013) found an athletic training with six months experience to have strong interrater reliability compared to moderate reliability with less than six months experience with the FMS pre-participation screening (ICC =0.946; ICC=0.771). Screening concluded by performing the FMS fundamental movement patterns and receiving a scoring based off of the athletes performance on the following movement patterns deep squat, hurdle step, in-line lunge, shoulder mobility, trunk stability push-up, active straight leg raise, rotary stability, and three clearing test (Cook, 2006, 2010, 2014). At the conclusion of the teams season the data was collected from the preseason screening. The results are inputted into SPSS 23.

Athletes that sustained an injury during the course of their season from training or competition were reported to the University of North Dakota athletic training staff. The athlete’s diagnosis and treatment for injury was completed by the athletic training staff allowing for correct diagnosis and treatment of injury that was sustained by the athlete.
The severity of the injury was designed based off of the two levels of injury. Level 1 is overuse injury, which includes musculoskeletal pain, stress fractures, tendonitis, bursitis, fasciitis, joint sprain injury, impingement, strain of the muscle due to overuse, shin splints, degenerative joint conditions, and retropatellar pain syndrome. Level 2 is traumatic injury, which includes muscle/joint injury such as a strain/sprain due to an acute event, dislocation, fracture, blister, abrasion, laceration, contusions, and concussion. (Lisman, O’Connor, Deuster, and Knapik, 2013; O’Connor, Deuster, Davis, Pappas, and Knapik, 2011).

The mechanism of injury that also needed to be looked at is the element of contact and noncontact types of injuries that are sustained in college sports. Contact injuries have the highest percentage at 58% in games and 41.5% in practice (Hootman, 2007). Contact injuries that are sustained from player contact or other objects such as ball, floor/ground, and sport specific equipment that play a role for each individual sport. Noncontact injuries that are sustained from no direct contact to the area of individuals injury (Agel, Evans, Dick, Putukian, Marshall, 2007; Dick, Ferrara, Agel, Courson, Marshall, Hanley, Reifsteck, 2007; Dick, Putukian, Agel, Evans, Marshall, 2007; Agel, Palmieri-Smith, Dick, Wojtys, Marshall, 2007).

**Functional Movement Screening**

The functional movement screening (FMS) is seven movements that place individuals in positions where stability and mobility must be used to perform movements correctly. When the movement is performed poorly it allows the observer to identify a relationship with that movement limitation or lack of motor unit recruitment that is needed to stabilize movement. The seven movements that are being screened are:
• Deep Squat: dowel is placed overhead will the elbows fully extended with shoulders abducted and flexed with individual squat as low as possible

• Active straight leg raise: position for the individual is supine with arms in anatomical position; individuals’ ankle is flexed and knee is extended as one leg is actively raised as high as individual can while the other leg remains on the ground

• Trunk stability push-up: position is in a prone with knees extended and ankles are dorsiflexed; body should move as one unit without lag in the lumbar spine

• Rotational stability: quadruped position where the individual attempts to touch the elbow to the knee on opposite sides of the body and then on the same side

• In-line lunge: dowel is positioned against the back of the head, thoracic spine, and sacrum as individual performs up to three slow controlled split squats

• Hurdle step: dowel is placed against the shoulders with toes touching the FMS board and then stepping over hurdle touching the heel and then returning to starting position

• Shoulder mobility: individual attempts to place their hands behind their back and move them as close as possible by internal and external rotation.

There are clearing tests that individual also perform for the shoulder impingement, spine extension, spine flexion. Details of all seven movements and clearing test have been published previously (Cook, 2006a, 2006b, 2010, 2014a, 2014b).

FMS seven functional movement patterns are scored on 0-3 scale with a combine score 0-21. If pain is felt during any of the movement patterns or clearing test, an individual receives a score of “0”. The receiving score of “1” is given when the
movement pattern is unable to be performed. Given a score of “2” the rater has seen compensation which allow individual to perform the movement. Receiving a score of “3” is movement performed without any compensation observed. For movements that are performed bilaterally, the lowest of the scores is used when calculating the total FMS score. All seven functional movements are summed to figure out overall FMS score. An individual must be able to score a 14 or higher to pass the screening. If the individual fails to reach 14, this means that the individual may have stiffness, tightness inhibiting their range of motion such as tight internal rotators, tight hamstrings, tight hip flexors or weak trunk musculature, inhibited and tight gluteus muscles, or inefficient core stability as it relates to balance (American College of Sports Medicine, 2013; Cook, 2010).

(Appendix A)

**Statistical Analysis**

The data that was collected will be analyzed through SPSS 23 looking at a correlation data to find any possible significance from the study. The descriptive statistics in this study will be presented as means and standard deviations. Pearson’s moment-product or Spearman rho correlation was used depending on the distribution of the data. The type of correlation that was chosen was a Pearson and Spearman Rho. The reason for choosing this type of correlation successively allows for adding and removing of variables allowing for better strength in finding true significant. This type of correlation will allow for predictability of FMS scores on injury, and it will be utilized to assess the FMS scores. The finding of a relationship between FMS score and injury will only be significance level at alpha (p= 0.05). This relationship does not directly give us causations, but it will allow for a better understanding at how the FMS movement’s given scores relate in athletes movement patterns injury. FMS scores were also binned at 14 to
create a dichotomous variable. Chi-Squared analysis was used to evaluate binned FMS score and when FMS upper score and lower score was binned at their midpoints.
III. RESULTS

The primary aim of this study was to examine the relationship between FMS scores and injury in collegiate athletes. Eighty-four athletes volunteered to participate in the study (n=84). Two were excluded due to leaving the team. The averages of the height and weight of the athletes in this study are the following: males average height (74.0 inches, 233.0 pounds), and the female’s average height was (66.0 inches). The mean total FMS score for football (M =14.13: SD=1.97), soccer (M= 15.85: SD=1.68) and female/male tennis (M=15.00; SD=1.00, M=14.00; SD=3.12) (Table 1). The FMS movements were broken down into a FMS lower body score (deep squat, inline lunge, hurdle step, and active straight leg raise) and FMS upper body score (shoulder mobility, truck stability push-up, and rotational stability) which enable us to see if any significant relationship between level of injury sustained compared to the FMS upper or lower score.

Table 1. Mean/Std. Deviations

<table>
<thead>
<tr>
<th>Sports</th>
<th>Total FMS Score Mean</th>
<th>SD</th>
<th>Total FMS Upper Score Mean</th>
<th>SD</th>
<th>Total FMS Lower Score Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>14.13</td>
<td>1.97</td>
<td></td>
<td>4.02</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>Soccer</td>
<td>15.85</td>
<td>1.68</td>
<td></td>
<td>4.77</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Tennis (Male)</td>
<td>14.00</td>
<td>3.12</td>
<td></td>
<td>4.63</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>Tennis (Female)</td>
<td>15.00</td>
<td>1.94</td>
<td></td>
<td>4.40</td>
<td>0.84</td>
<td></td>
</tr>
</tbody>
</table>
The football team had non-significant relationship between FMS lower vs. upper body level 1 noncontact (r = 0.27, p = 0.053) when running a Spearman Rho, FMS upper body level 1 contact vs. lower body level 1 contact (r=0.482, p=0.0) with the use of a Pearson. The was a non-significant relationship seen for the soccer team when performing Pearson was with the FMS total score vs. lower body level 1 contact (r = 0.569, p = 0.34), FMS lower body score vs. lower body level 1 contact (r = 0.6, p=.021), FMS lower body score vs. lower body level 2 contact (r = -0.5, p = 0.059). A significant relationship found for the soccer team when performing a Spearman Rho was with the FMS upper body score vs. lower body noncontact (-0.547, p = 0.043). Data for the both tennis teams had non-significant results when running a Spearman Rho and Pearson.

Table 2. Summary of Contact/Noncontact

<table>
<thead>
<tr>
<th>Injury Status</th>
<th>Football (n=52)</th>
<th>Soccer (n= 14)</th>
<th>Tennis (n=18)</th>
</tr>
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<tbody>
<tr>
<td>Upper Level 1 Contact (n=20)</td>
<td>19</td>
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<td>1</td>
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<td>Upper Level 2 Contact (n=11)</td>
<td>5</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Upper Level 1 Noncontact (n=11)</td>
<td>9</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Upper Level 2 Noncontact (n=1)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Lower Level 1 Contact (n=23)</td>
<td>22</td>
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<td>0</td>
</tr>
<tr>
<td>Lower Level 2 Contact (n=6)</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Lower Level 1 Noncontact (n=42)</td>
<td>33</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Lower Level 2 Noncontact (n=8)</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Overall (n=122)</td>
<td>96</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td>Not Injured (n=23)</td>
<td>6</td>
<td>1</td>
<td>16</td>
</tr>
</tbody>
</table>
A Chi-Squared analysis was also performed to assess the importance of the receiving of a score of 14 on the FMS. The Chi-Squared analysis did not show any significant differences when FMS total score was binned at 14 or when FMS upper score and lower score was binned at their midpoints. Correlation analysis for the football team compared FMS lower vs. upper body level 1 noncontact; FMS upper body level 1 contact vs. lower body level 1 contact found no significant relationships in the ability to predict an athlete’s injury during the season. The soccer team correlation comparing FMS total score vs. lower body level 1 contact, FMS lower body score vs. lower body level 1 contact, FMS lower body score vs. lower body level 2 contact, and FMS upper body score vs. lower body noncontact had no significant results, but comparing FMS lower body score vs. lower body level 2 contact (r = -0.5, p = 0.059) showed in opposite direction of what we hypothesized.
IV. DISCUSSION

The primary purpose of this study was to look at the correlation between a low FMS score and injuries in athletes over the course of the athletes’ season. Our investigation has found that there was not a relationship between FMS total score and predicting an athletes’ injury over the course of the season. The soccer team correlation comparing FMS scores and contact/non-contact had no significant results, but one significant comparing FMS lower body score vs. lower body level 2 contact \((r = -0.5, p = 0.059)\) showed in opposite directions of what we hypothesized. The results from our investigation do not support using binned FMS scores of 14 to screen for passing or failing by the athlete as related to injury.

The findings in this study compared to current research with the relationship of FMS and predictability of injury. The FMS ability to predict injury during the season was not found in our investigation. These findings agree in part with (Bushnman et. al. 2015) who found that the FMS was not accurate in assessing injury regardless of the injury type. The level 1 or level 2 injuries are more of a challenge to be able to predict because of the severity of the sustained injury is different in every individual. The importance of receiving a passing score of 14 in this study was not found. These results are contrary to the findings of Garrison et al. (2015), which reported that athletes that scored a 14 or higher had a reduced risk of injury compared to those athletes that scored less than 14.
Data has shown that female athlete’s receive a high FMS compared to male athletes. The data found to be significant was the higher score that was sustained by the females the higher the chance injury was seen with FMS lower body score versus injury lower body level 2 contact. The results that were found in this study are conflicting with the results the Chorba et al. (2010) study found on female basketball players. The results showed that the female team sustained upper body level 2 injuries that were sustained was 7 compared to 5 sustained by males. Lockie et al. (2015) found that the college female athletes showed greater overall flexibility in the testing but more flexibility in athletic areas caused females to perform poorly in different performance based movements required in their sport. With female athletes being at an increased chance of injury but scoring higher on the FMS raise the question to whether the increased flexibility in a female athlete is the risk factor or possibly having more mobility in certain movements is detrimental which may increase chance of injury in the athlete.

The findings in this study do not support the use of the FMS as a screening tool for injury in athletes. It is well known that previous injury is one of the most important risk factors in sports. Following an injury sustained by an athlete the body’s movement will be effected such as strength and flexibility in the athletes. The range of motion that is being assessed within the FMS movements does not resemble athlete-based movements that are required for individual sports related performance (Minick et al. 2010; Lockie et al. 2015). The FMS is not specific to injury mechanisms and the multiple injury mechanisms that are possible in all different sports. The key component to the expanding understanding of the traditional biomechanical approach to prevent injury in these athletes is to continue to better our assessment tool.
Limitations and Future
This study is not without limitations and these should be considered carefully and interpreted correctly when applying the finding of this study. A limitation of this study was the sample size (n=84), as this resulted in uneven group sizes, as well as having different sports involved in this study and the many different injury mechanisms that are seen between the sports. The limitation was no tracking of athlete-exposed rates between practice, weights, and games. The chance of any athlete-exposure time plays an important role in elevating athletes’ injury. The injury and repeat injury was also not tracked during this study. Future studies should look into the effect of the FMS on athletic performance and whether correcting the compensation of a low FMS over athlete’s time spent in college have an overall effect on reducing athlete injury. Also, looking at the movements that are the best at assessing the area of injury that is at the highest risk for injury for different sports.

Practical Application
The results in the study show that the FMS does not give the athlete predictable injury during the season. The FMS was not designed to be a comprehensive screening system to predict injury in athletes and our data reflects this. The results from our study do not support the use of the FMS as a screening tool for injuries in colligate athletes participating in football, soccer and tennis. Mechanisms for injury should be used to develop an approach of a correct prevention program throughout a college sports training program. The FMS according to the data would not be a tool to help assist the PT or AT in reducing injury for individual athletes in a college sports training program because it allows the assessment of an athlete’s movement pattern but not related to athletes performance.
APPENDICES
Appendix A

Scoring Functional Movement & Verbal Cues & Movement Instruction

DEEP SQUAT

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

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

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

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

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

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

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

- **Performs a correct unilateral repetition**

- **Performs a correct diagonal repetition**

- **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.
VERBAL INSTRUCTIONS FOR

THE FUNCTIONAL MOVEMENT SCREEN

- The following is a script to use while administering the FMS. For consistency throughout all screens, this script should be used during each screen. The bold words represent what you should say to the client.
- Please let me know if there is any pain while performing any of the following movements.

Deep Squat

Equipment needed: Dowel

Instructions

- Stand tall with your feet approximately shoulder width apart and toes pointing forward.
- Grasp the dowel in both hands and place it horizontally on top of your head so your shoulders and elbows are at 90 degrees.
- Press the dowel so that it is directly above your head.
- While maintaining an upright torso, and keeping your heels and the dowel in position, descend as deep as possible.
- Hold the descended position for a count of one, then return to the starting position.
- Do you understand the instructions?

Score the movement. The client can perform the move up to three times total if necessary. If a score of three is not achieved, repeat above instructions using the 2 x 6 under the client’s heels.

Hurdle Step

Equipment needed: Dowel, Hurdle

Instructions

- Stand tall with your feet together and toes touching the test kit.
- Grasp the dowel with both hands and place it behind your neck and across the shoulders.
- While maintaining an upright posture, raise the right leg and step over the hurdle, making sure to raise the foot towards the shin and maintaining foot alignment with the ankle, knee and hip.
- Touch the floor with the heel and return to the starting position while maintaining foot alignment with the ankle, knee and hip.
- Do you understand these instructions?
Score the moving leg. Repeat the test on the other side. Repeat two times per side if necessary.

**Inline Lunge**

Equipment needed: Dowel, 2x6

Instructions

- Place the dowel along the spine so it touches the back of your head, your upper back and the middle of the buttocks.
- While grasping the dowel, your right hand should be against the back of your neck, and the left hand should be against your lower back.
- Step onto the 2x6 with a flat right foot and your toe on the zero mark. The left heel should be placed at _____________ mark. This is the tibial measurement marker.
- Both toes must be pointing forward, with feet flat.
- Maintaining an upright posture so the dowel stays in contact with your head, upper back and top of the buttocks descend into a lunge position so the right knee touches the 2x6 behind your left heel.
- Return to the starting position.
- Do you understand these instructions?

Score the movement. Repeat the test on the other side. Repeat two times per side if necessary.

**Shoulder Mobility**

Equipment needed: Measuring device

Instructions

- Stand tall with your feet together and arms hanging comfortably.
- Make a fist so your fingers are around your thumbs.
- In one motion, place the right fist overhead and down your back as far as possible while simultaneously taking your left fist up your back as far as possible.
- Do not “creep” your hands closer after their initial placement.
- Do you understand these instructions?

Measure the distance between the two closest points of each fist.

Score the movement. Repeat the test on the other side
Active Scapular Stability (shoulder clearing)

Instructions

- Stand tall with your feet together and arms hanging comfortably.
- Place your right palm on the front of your left shoulder.
- While maintaining palm placement, raise your right elbow as high as possible.
- Do you feel any pain?

Repeat the test on the other side.

Active Straight-Leg Raise

Equipment needed: Dowel, measuring device, 2 x 6

Instructions

- Lay flat with the back of your knees against the 2x6 with your toes pointing up.
- Place both arms next to your body with the palms facing up.
- Pull the toes of your right foot toward your shin.
- With the right leg remaining straight and the back of your left knee maintaining contact with the 2x6, raise your right foot as high as possible.
- Do you understand these instructions?

Score the movement.

Repeat the test on the other side.

Trunk Stability Pushup

Equipment needed: None

Instructions

- Lie face down with your arms extended overhead and your hands shoulder width apart.
- Pull your thumbs down in line with the ___ (forehead for men, chin for women).
- With your legs together, pull your toes toward the shins and lift your knees and elbows off the ground.
- While maintaining a rigid torso, push your body as one unit into a pushup position.
- Do you understand these instructions?

Score the movement.

Repeat two times if necessary.

Repeat the instructions with appropriate hand placement if necessary.

---

**Spinal Extension Clearing**

**Instructions**

- While lying on your stomach, place your hands, palms down, under your shoulders.
- With no lower body movement, press your chest off the surface as much as possible by straightening your elbows.
- Do you understand these instructions?
- Do you feel any pain?

---

**Rotary Stability**

**Equipment needed: 2 x 6**

**Instructions**

- Get on your hands and knees over the 2x6 so your hands are under your shoulders and your knees are under your hips.
- The thumbs, knees and toes must contact the sides of the 2x6, and the toes must be pulled toward the shins.
- At the same time, reach your right hand forward and right leg backward, like you are flying.
- Then without touching down, touch your right elbow to your right knee directly over the 2x6.
- Return to the extended position.
- Return to the start position.
- Do you understand these instructions?

Score the movement.

Repeat the test on the other side.
If necessary, instruct the client to use a diagonal pattern of right arm and left leg.

Repeat the diagonal pattern with left arm and right leg.

Score the movement.

---

**Spinal Flexion Clearing**

**Instructions**

- Get on all fours, and rock your hips toward your heels.
- Lower your chest to your knees, and reach your hands in front of your body as far as possible.
- Do you understand these instructions?
- Do you feel any pain?
Appendix B

Inform consent
Relationship of Pre-season Functional Movement Screening on Injury in Divisions 1 Collegiate Athletes

Zebulon Miller
Master Thesis
Department of Kinesiology and Public Health

You are invited to be in a research study for injury prevention through basic movement patterns at the University of North Dakota. As a student-athlete of one of the fall sports teams, you are able to voluntarily participate in this study. A person who is to participate in the research must give his or her informed consent to such participation. This consent must be based on an understanding of the nature and risks of the research. This document provides information that is important for this understanding. Research projects include only participants who choose to take part. Please take your time in making your decision as to whether to participate. If you have questions at any time, please ask.

The purpose of this research study is to look at the correlation between a low Functional Movement Screen (FMS) score and increased risk of injuries for an individual. FMS scores will also be looked at as a predictor for team injury risk in the different sports. Data from this study could eventually be utilized to design more effective rehab programs and baseline movement scores to have an athlete reach before returning to activity.

Participation in this study will require individuals to perform seven fundamental movement patterns that include deep squat, active straight leg raise, trunk stability push-up, rotational stability (quadruped movement with opposite arm and knee tuck and touching together in the middle of your abdominal area), in-line lunge, hurdle step, shoulder mobility and spinal extension (performed by performing a press-up in the pushup position) and spinal flexion (performed by first assuming a quadruped position, then rocking back and touching the buttocks to the heels and the chest to the thighs). The screening will take approximately 10-15 minutes in the Hyslop gym with control over privacy as much as possible. Nothing else will be required of you for participation in this study. There are minimal foreseeable risks from participating in this project. While there are no direct benefits to your involvement in this research, the involvement of you and others will help Physical Therapists /Athletic Trainers /Strength Coaches to possibly design and develop of more effective performance programs.

You will not have any costs for being in this research study. Further, you not be paid for being in this research study. The University of North Dakota and the research team are receiving no payments from other agencies, organizations, or companies to conduct this research study.

The injury information needed in this study will be obtained from the University of North Dakota athletic training staff. The athletic training staff will classify an injury
you sustain as either a level 1 (overuse injury) or level 2 (traumatic injury). The athletic training staff will then send only the information about level of injury not actual injury information to the researchers protecting the privacy of your medical information. The records of this study will be kept private to the extent permitted by law. In any report about this study that might be published, you will not be identified. Any information that is obtained in this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of the utilization of pseudonyms in all publication. All data, which includes observational documents, will be kept in a locked cabinet. This cabinet will have only one key that is held by one researcher. All computer analysis of data will be kept on one computer, which is password protected.

Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota.

The researchers conducting this study Zebulon Miller. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Dr. Jesse Rhoades at (701) 777-3113.

If you have questions regarding your rights as a research subject, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701) 777-4279. Please call this number if you cannot reach research staff, or you wish to talk with someone else.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Participant’s Name: ______________________________________________________

__________________________________________
Signature of Subject

Date

__________________________________________
Signature of Principal Investigator

Date
Appendix C

FMS Scoring Sheet

<table>
<thead>
<tr>
<th>TEST</th>
<th>RAW SCORE</th>
<th>FINAL SCORE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEEP SQUAT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HURDLE STEP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INLINE LUNGE</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SHOULDER MOBILITY</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>IMPINGEMENT CLEARING TEST</td>
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<td></td>
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<tr>
<td>ACTIVE STRAIGHT-LEG RAISE</td>
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<tr>
<td>TRUNK STABILITY PUSHUP</td>
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<td>PRESS-UP CLEARING TEST</td>
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<tr>
<td>ROTARY STABILITY</td>
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<td>POSTERIOR ROCKING CLEARING TEST</td>
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<tr>
<td>TOTAL</td>
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<td></td>
</tr>
</tbody>
</table>

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

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


