CAN SERIOUS INJURY IN PROFESSIONAL FOOTBALL BE PREDICTED BY A PRESEASON FUNCTIONAL MOVEMENT SCREEN?

Kyle Kiesel, PT, PhD, ATC, CSCS[a]
Phillip J. Plisky, PT, DSc, OCS, ATC[a]
Michael L. Voight, PT, DHSc, OCS, SCS, ATC[b]

ABSTRACT

Background. Little data exists regarding injury risk factors for professional football players. Athletes with poor dynamic balance or asymmetrical strength and flexibility (i.e. poor fundamental movement patterns) are more likely to be injured. The patterns of the Functional Movement Screen™ (FMS) place the athlete in positions where range of motion, stabilization, and balance deficits may be exposed.

Objectives. To determine the relationship between professional football players' score on the FMS™ and the likelihood of serious injury.

Methods. FMS™ scores obtained prior to the start of the season and serious injury (membership on the injured reserve for at least 3 weeks) data were complied for one team (n = 46). Utilizing a receiver-operator characteristic curve the FMS™ score was used to predict injury.

Results. A score of 14 or less on the FMS™ was positive to predict serious injury with specificity of 0.91 and sensitivity of 0.54. The odds ratio was 11.67, positive likelihood ratio was 5.92, and negative likelihood ratio was 0.51.

Discussion and Consclusion. The results of this study suggest fundamental movement (as measured by the FMS™) is an identifiable risk factor for injury in professional football players. The findings of this study suggest professional football players with dysfunctional fundamental movement patterns as measured by the FMS™ are more likely to suffer an injury than those scoring higher on the FMS™.

Key words: Functional Movement Screen, injury prediction

CORRESPONDENCE:

Kyle Kiesel
Wallace Graves Hall 206
University of Evansville
Evansville, IN 47722
Kk70@evansville.edu
Phone: (812) 479-2646
Fax: (812) 479-2717

[a] ProRehab PC
Evansville, IN

[b] Belmont University
Nashville, TN

INTRODUCTION

Participation in football is one of the leading causes of sport related injury with over 500,000 injuries occurring per year in high school and collegiate football.[1] To date, the injury rate for professional football has not been reported in the literature; but, the injury rate for high school and collegiate football ranges from 1.3 to 26.4 per 1000 athletic exposures (18.4-51.7 injuries per 100 players).[1-5] Although limited published reports exist on injury risk factors for professional football players,[6] researchers have prospectively identified risk factors for injury in high school and collegiate levels of competitive football. These risk factors include previous injury,[2,7] body mass index,[7-9] body composition (percent body fat),[9] playing experience,[2] femoral intercondylar notch width,[10] cleat design,[11] playing surface,[6] muscle flexibility,[12] ligamentous laxity,[12] and foot biomechanics.[13,14] Although these risk factors have been examined individually, injury risk is likely multifactorial.[15-17] The dynamic interplay of risk factors during sport and their relationship to injury, needs additional investigation. Furthermore, evaluation of isolated risk factors does not take into consideration how the athlete performs the functional movement patterns required for sport.

Recently, researchers have utilized movement examinations that involve comprehensive movement patterns to predict injury.[18] Pilsky et al[18] hypothesized that tests assessing multiple domains of function (balance, strength, range of motion) simultaneously may improve the accuracy of identifying athletes at risk for injury through pre-participation assessment. The Functional Movement Screen (FMS™) is a comprehensive exam that assesses quality of fundamental movement patterns to identify an individual's limitations or asymmetries. A fundamental movement pattern is a basic movement utilized to simultaneously test range of motion, stability, and balance.[19,20] The exam requires muscle strength, flexibility, range of motion, coordination, balance, and proprioception in order to successfully complete seven fundamental movement patterns. The athlete is scored from zero to 3 on each of the seven movement patterns with a score of 3 considered normal. The scores from the seven movement patterns are summed and a composite score is obtained. The intra-rater reliability of the composite score (which was used in the analysis for this study) for the FMS™ is reported to have an ICC value of 0.98.[21]

Additional information regarding the development and uses of the FMS™ was documented by Foran,[22] Cook,[23] and recently published journal articles.[19,20]

Mobility and stability extremes are explored in order to uncover asymmetries and limitations. The scoring system was designed to capture major limitations and right-left asymmetries related to functional movement. Additionally, clearing tests were added to assess if pain is present when the athlete completes full spinal flexion and extension and shoulder internal rotation/flexion.

The seven tests utilize a variety of basic positions and movements which are thought to provide the foundation for more complex athletic movements to be performed efficiently. The Appendix includes pictures of and detailed scoring criteria for each of the seven tests which compose the FMS™. The seven tests are: 1) the deep squat which assesses bilateral, symmetrical, and functional mobility of the hips, knees and ankles, 2) the hurdle step which examines the body's stride mechanics during the asymmetrical pattern of a stepping motion, 3) the in-line lunge which assesses hip and trunk mobility and stability, quadriceps flexibility, and ankle and knee stability, 4) shoulder mobility which assesses bilateral shoulder range of motion, scapular mobility, and thoracic spine extension, 5) the active straight leg raise which determines active hamstring and gastroc-soleus flexibility while maintaining a stable pelvis, 6) the trunk stability push-up which examines trunk stability while a symmetrical upper-extremity motion is performed, and 7) the rotary stability test which assesses multi-plane trunk stability while the upper and lower extremities are in combined motion.

The relationship between the FMS™ score and injury risk has not been previously reported. Therefore, the purpose of this study was to examine the relationship between professional football players' score on the FMS™ and the likelihood of a player suffering a serious injury over the course of one competitive season.

METHODS

The strength and conditioning specialist associated with the team studied had extensive experience (11 years) as a professional football strength and conditioning specialist and utilized the FMS™ as part of pre-season physical per-

formance testing prior to the 2005 season. All players who attended training camp were tested on each of the seven tests of the FMS (as described in the Appendix) each year. The composite score for each player was then variable analyzed in this retrospective study.

In order to protect the identity of the subjects, only limited injury information and FMS™ data were available to the authors for analysis, which is why common demographic data routinely reported in most studies are not included. In addition, the authors agreed with the professional football team not to state the name of the team in any subsequent publications.

The sample included only those players who were on the active roster at the start of the competitive season (n = 46) and the surveillance time for the study was one full season (approximately 4.5 months). Membership on the injured reserve and time loss of 3 weeks was utilized as the injury definition. This operational definition of injury ensured the player was placed on the injured reserve due to a serious injury. The study was approved by the University of Evansville Institutional Review Board.

Data Analysis

To determine if a significant difference existed in composite FMS scores between those injured and those who were not injured, a dependent t-test was performed with significance set at the p< 0.05 level. To determine the cut-off score on the FMS™ that maximized specificity and sensitivity a receiver-operator characteristic (ROC) curve was created. In this context, the FMS™ can be thought of as a special test used to determine if a player is at risk for a serious injury. An ROC curve is a plot of the sensitivity (True +'s) versus 1-specificity (False +'s) of a screening test. Different points on the curve correspond to different cut-off points used to determine at what value a test is considered positive.[24] The test value (FMS™ score) which maximizes both True +'s and controls for False +'s is identified on the ROC curve as the point at the upper left portion of the curve. Once the cut-off score was identified, a 2 x2 contingency table was created dichotomizing those who suffered an injury and those who did not, and those above and below the cut-off score on the FMS™.

Simple odds ratios, likelihood ratios, sensitivity and specificity were then calculated. Post-test odds and post-test probability were calculated according to the formula provided, which allowed for the estimation of how much an individual's FMS™ score influenced the probability of suffering a serious injury.

At the start of the season, a probability (pretest probability) existed for suffering a serious injury. To determine how much the probability of serious injury increased when a player's score is below the cut-off score (magnitude of the shift from pre-test to post-test probability), the post-test probability was calculated utilizing a 3-step calculation process as described by Sackett et al.[25] The positive likelihood ratio (+LR) value is the value associated with the special test utilized. In this case, the special test is the FMS™ and is considered negative for a given subject when their score is above the cut-off score determined by the ROC curve. The FMS™ scale is considered positive if a given subject's score is equal to or below the cut-off score determined by the ROC curve. The calculation is as follows:

1. Convert the pre-test probability to odds:
$$Pre\text{-}test\ odds\ =\ \frac{pre\text{-}test\ probability}{1 - pre\text{-}test\ probability}$$

2. Multiply the odds by the appropriate +LR value:
$$Pre\text{-}test\ odds\ X\ +LR\ =\ post\text{-}test\ odds$$

3. Convert the post-test odds back to probability:
$$\frac{post\text{-}test\ odds}{post\text{-}test\ odds\ +\ 1}\ =\ post\text{-}test\ probability$$

Pre-test probability is synonymous with the prevalence of the disorder. In this case it would be the probability (at the start of the season) of a player suffering a serious injury as defined. In the absence of published data, an estimation of prevalence was made.[26] Since no injury rate data was available for professional football, a conservative prevalence of 15% was used based on previous high school and collegiate injury surveillance studies and expert opinion.[1-5]

RESULTS

The subjects were professional football players who made the final team roster before the start of a competitive sea-

Figure. Receiver-operator characteristic (ROC) curve for the FMS composite score and injury status.
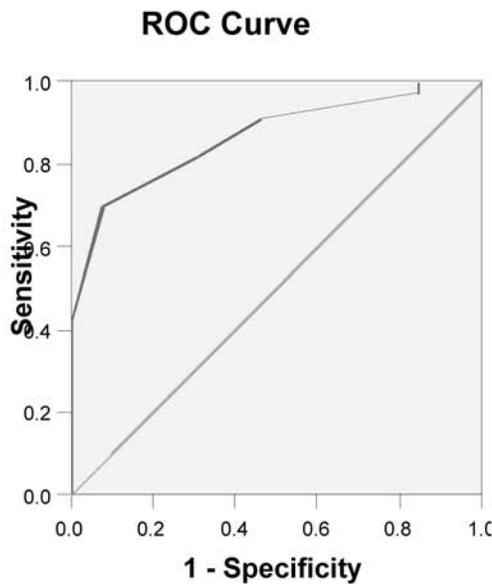
Coordinates of the ROC Curve

Test Result Variable(s): FMS

FMS	Sensitivity	1 - Specificity
10.0000	1.000	1.000
12.0000	1.000	.846
13.5000	**.970**	**.846**
14.5000	**.909**	**.462**
15.5000	.818	.308
16.5000	.697	.077
17.5000	.424	.000
18.5000	.242	.000
20.0000	.000	.000

Coordinates of the ROC curve showing that the FMS composite score value which corresponds best with the upper left hand portion of the curve is between 13.5 and 14.5 justifying the cut-point determination of 14.

son. The mean (SD) FMS™ score (highest possible score is 21) for all subjects was 16.9 (3.0). The mean score for those who suffered an injury was 14.3 (2.3) and 17.4 (3.1) for those who were not injured. A t-test revealed a significant difference between the mean scores of those injured and those who were not injured (df = 44; t = 5.62; $p < 0.05$).

Upon analysis of the ROC curve (Figure) and corresponding table of sensitivity and specificity values, it was determined that an FMS™ score of 14 maximized specificity and sensitivity of the test. Specifically, the point is chosen so that the test correctly identifies the greatest number of subjects at risk (true positives) while minimizing incorrectly identifying subjects not at risk (false positives). On a ROC curve, this point is usually at the left uppermost point of the graph[27] (the point where the curve turns). Using this value, subjects were dichotomized into groups with a score of 14 as well as by injury status (Table). This cut-off score represents a sensitivity of 0.54 (CI95 = 0.34-0.68) and specificity of 0.91 (CI95 = 0.83-0.96). The odds ratio was 11.67 (CI95 = 2.47-54.52), positive likelihood ratio 5.92 (CI95 = 1.97-18.37), and negative likelihood ratio 0.51 (CI95 = 0.34-0.79).

The odds ratio of 11.67 can be interpreted as a player having an eleven-fold increased chance of injury when their FMS™ score is 14 or less when compared to a player whose score was greater than 14 at the start of the season. The post-test probability was calculated to be = 0.51. That is to say, if an athlete's score on the FMS™ was 14 or less, their probability of suffering a serious injury increased from 15% (pre-test probability of 0.15) to 51% (post-test probability of 0.51; CI95 = 0.25-0.76).

DISCUSSION

Sports physical therapists, athletic trainers, and

Table. *2x2 contingency table indicating if an athlete's FMS score was above or below the cut-off point and if they had suffered serious injury.*

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

strength and conditioning specialists using the FMS™ in professional football have casually observed that players with lower scores were more likely to be injured. Basic statistical procedures were used to test this observation. Those players with a score of less than 14 were found to have a substantially greater chance of membership on injured reserve over the course of one competitive season than those scoring greater than14.

To estimate the value of the FMS™ as a diagnostic test to predict the likelihood of injury, the purpose of the tests such as the FMS™ was considered. It was important to maximize the test's ability to rule in the potential disorder (injury), or in other words, to maximize the test's specificity. Higher specificity increases the ability to use the test to recognize when the disorder is present. That is, a highly specific test has relatively few false positive results and speaks to the value of a positive test.[28] The reverse is true when a given diagnostic test has high sensitivity. Because the FMS™ in this study was shown to be highly specific (0.91) for suffering a serious injury, the test can be used to rule in the condition studied. The sensitivity was 0.54, so the test offers limited capability to rule out the condition.

To consider how this information can be applied to an individual athlete, the shift from pre to post-test probability was calculated. Accurate estimation of the prevalence (pre-test probability) of a given disorder when attempting to determine the magnitude of the shift from pre to post-test probability when using the positive likelihood ratio of a special test is critical. If too high of a value is used, it will artificially inflate the magnitude of the shift and imply the special test (in this case the composite FMS™ score) is more powerful than it really is. A conservative prevalence rate (15%) was used to control for this potential error. In the absence of published data, professional football injury rates were discussed with professional football sports medicine personnel, who indicated that 15% was on the low end of what they would expect over the course of one competitive season.

The findings of this report suggest that athletes with dysfunctional fundamental movement patterns (as measured by lower scores on the FMS™) are more likely to suffer a time-loss injury, but can not be used to establish a cause-effect relationship. Some additional limitations of this study should be noted. Because this review only considered data from one team, selection bias is a limitation. Furthermore, the same data set that was used to determine the ROC curve cut-off score was used to test the cut-off score in the prediction model. Using the same data to determine cut-off score and evaluate those cut-off scores as predictive is more likely to demonstrate meaningful findings than when using cut-off scores determined with different data. Ideally, a cut-off score should be established from a separate prospective study, and then that value is applied to the prediction model to prevent inflation of the post-test probability and odds ratio.

Another limitation of the study was that only those on injured reserve for at least 3 weeks were used as the definition of an injury. These criteria may not have captured injuries that were meaningful, but were not of long enough duration to place the athlete on the injured reserve.

Future research should be conducted in a prospective manner that includes detailed injury surveillance and a more robust injury definition. Having access to data on multiple variables (such as previous injury) not available for this study would allow researchers to build a regression equation that predicts those who will suffer a time loss injury. Based on this retrospective analysis, the authors suggest including the FMS™ score in the model by using the individual test scores in addition to the composite score. With this detailed information, it may be possible to specifically identify factors (previous injury, deep squat score, lunge score) that contribute most to injury risk and then focus injury prevention efforts on modifiable factors such as dysfunctional movement.

CONCLUSION
Fundamental movement patterns such as those assessed by the FMS™ can be easily tested clinically. This retrospective descriptive study demonstrated that professional football players with a lower composite score (<14) on the FMS™ had a greater chance of suffering a serious injury over the course of one season.

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Appendix. *The scoring criteria and descriptions of the 7 tests of the FMS™.*

1. Deep Squat

The subject will assume the starting position by placing his/her feet shoulder width apart with the feet in line with the sagital plane. The dowel will be held overhead with the shoulders flexed and abducted and the elbows extended. The subject will squat down with the heels on the floor and head and chest facing forward. If a score of III is not accomplished, the subject will be asked to perform the test with a 2x6 board under their heels. If this allows for a completed squat a II is given. If the subject still cannot complete the movement a I is scored.
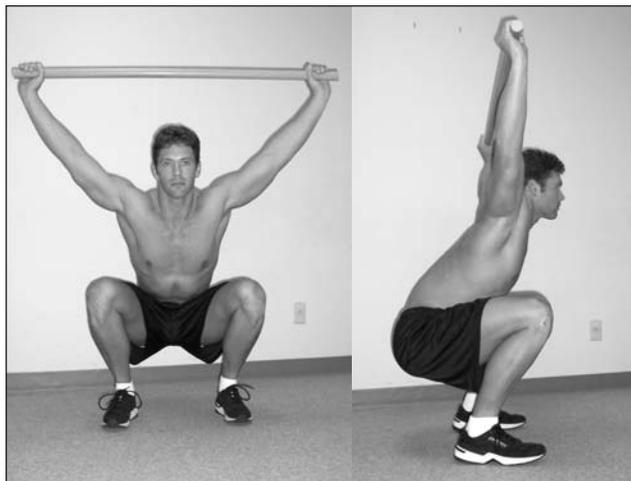
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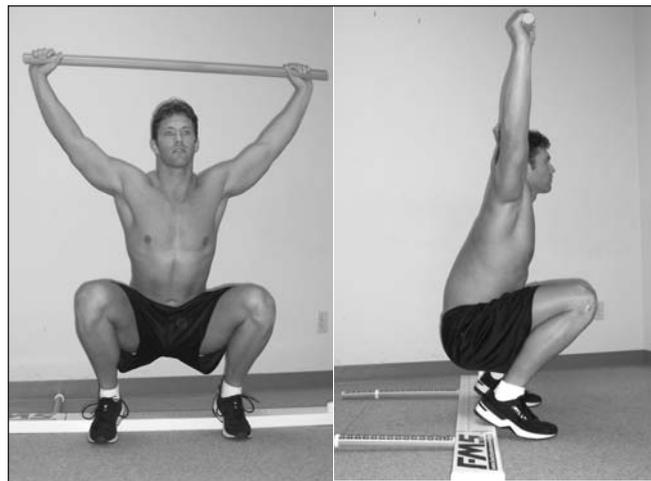
II

I

2. Hurdle Step

For the hurdle step the subject will align their feet together with the toes touching the base of the hurdle, which is then adjusted to the height of the subject's tibial tuberosity. The dowel will be positioned across the shoulders, just below the neck. The subject will be instructed to slowly step over the hurdle and touch their heel to the floor while the stance leg remains in extension. The moving leg is then returned to the starting position. A III is scored if one repetition is completed bilaterally, a II if the subject compensated in some way by twisting, leaning or moving the spine, and a I if loss of balance occurs or contact is made with the hurdle.

III

II

I

3. In-line lunge.

The length of the subject's tibia will be measured from the floor to the tibial tuberosity. The subject will then be instructed to place the end of his/her heel on the end of the 2x6 board. Using the tibia length a mark is made on the board from the end of the subject's toes. The dowel is held behind the back in contact with the head, thoracic spine, and sacrum. The hand that is opposite the front foot should grasp the dowel at the cervical spine and the other hand at the lumbar spine. The subject will then place the heel of the opposite foot at the measured mark on the board, and the back knee will be lowered enough to touch the board behind the heel of the front foot. A III is given for a successfully completed repetition, a II for compensation and a I for incompletion or loss of balance.


III

II

I

4. Shoulder Mobility

The subject's hand will first be measured from the distal wrist crease to the tip of the third digit. The subject will then be asked to make a fist with each hand. The subject will be instructed to assume a maximally adducted, extended and internally rotated position with one shoulder and a maximally abducted, flexed and externally rotated position with the other so that the fists are located on the back. The distance between the two fists on the back at the closest point will be measured. A III is given if the fists are within one hand length, a II if the fists are within 1 ½ hand lengths, and a I if the fists fall outside this length. At the end of this test a clearing exam is administered. The subject will place his/her hand on their opposite shoulder and attempt to point the elbow upward. If pain results from this movement using either shoulder a score of zero is given for the entire shoulder mobility test.

III
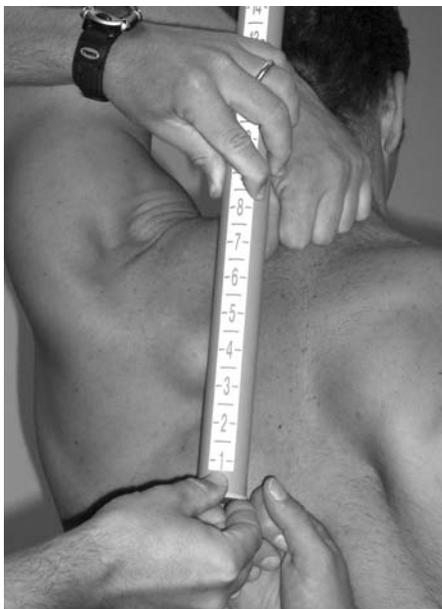
II

I

Clearing Exam

5. Active Straight Leg Raise

The starting position for the active straight-leg raise requires the subject to lie supine with the arms in an anatomical position and head flat on the floor. The 2x6 board is placed under the knees, and the anterior superior iliac spine (ASIS) and mid-point of the patella are identified. Using those two landmarks a mid point on the thigh is found. The dowel is placed on the ground perpendicular to this position. The subject will be instructed to lift the test leg with a dorsiflexed ankle and extended knee while keeping the opposite knee in contact with the board. If the malleolus of the raised leg is located past the dowel than a score of III is given. If the malleolus does not pass the dowel then the dowel is aligned along the medial malleolus of the test leg, perpendicular to the floor. If this point is between the thigh mid point and patella, a II is scored. If it is below the knee a I is received. The test should be performed bilaterally.

III

II

I

6. Trunk stability push-up

The subject will begin in a prone position with both feet together. The hands will be placed shoulder width apart with the thumbs at forehead height for males and chin height for females. With the knees fully extended and the feet dorsiflexed the subject should perform one push-up in this position with no lag in the lumbar spine. By completing the push-up a score of III is given. If the subject cannot perform the push-up the hands are lowered, with the thumbs aligning with the chin for males and the clavicles for females. If a push-up is successful in this position a score of II is given; if not, a I is scored. At the end of this test a clearing exam is given. The subject should perform a press-up in the push-up position. If there is pain associated with this motion a score of zero is given for the entire test.

III

II

I

Clearing Exam