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ORIGINAL RESEARCH

ASSOCIATION BETWEEN THE FUNCTIONAL MOVEMENT SCREEN AND INJURY DEVELOPMENT IN COLLEGE ATHLETES

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ABSTRACT

Background: As the number of sports participants continues to rise, so does the number of sports injuries. Establishing a valid method of identifying athletes at elevated risk for injury could lead to intervention programs that lower injury rates and improve overall athlete performance. The Functional Movement Screen (FMS)™ is an efficient and reliable method to screen movement patterns during the performance of specific tasks. The purpose of this study is to explore the association between pre-season FMS TM scores and the development of injury in a population of collegiate athletes

Study Design: Descriptive epidemiology study

Methods: FMS™ scores were obtained for 160 collegiate athletes and injury development was tracked throughout the season. These athletes were both male and female and participated in contact and non-contact sports. Redundancies were utilized with injury data collection, including medical record reviews and interviews with team athletic trainers, to ensure that all injuries requiring medical attention were captured. At the conclusion of the season, a logistic regression analysis was performed to determine which combination of factors best predicted injury.

Results: Athletes with an FMS™ composite score at 14 or below combined with a self-reported past history of injury were at 15 times increased risk of injury. A positive likelihood ratio of 5.8 was calculated which improved the probability of predicting injury from 33% pretest to 74% posttest.

Conclusions: This study adds to the growing body of evidence demonstrating a predictive relationship between FMS™ composite scores and past history of injury with the development of future injury

Level of Evidence: 3, Non-random prospective cohort design

Keywords: Functional Movement Screen™, Injury prediction, Sports Injury

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INTRODUCTION

Student participation in National Collegiate Athletic Association (NCAA) athletics continues to increase annually. Since 1988, the number of female college athletes increased by 80% and the number of male athletes by 20%.[1] As the number of collegiate athletes continues to rise, there is a corresponding increase in the number of sports injuries. Over a 16 year period, the rate of injury during NCAA sports participation consistently ranged from 15-20%.[1] The results of some studies indicate that up to 63% of athletes with a past history of injury are at risk for recurrent injury.[2] The recurrent injury is often more significant and typically results in a longer period away from sports participation.[3] This cycle of injury, and resultant lost playing time, negatively impacts an athlete's ability to compete during a limited window of eligibility.[4] Establishing a valid and field expedient method of identifying athletes at elevated risk for injury could lead to intervention programs that lower injury rates and improve overall athlete performance.

There is minimal evidence supporting the use of subjective or objective findings as a method to identify athletes at increased risk of injury. While several studies identify past history of injury as a risk factor for future injury, reported recurrence rates ranging from 12-63% indicates that this factor lacks precision.[2,5-8] This lack of accuracy adversely affects the selection of an intervention population. There is also evidence that questions the validity of a self-reported history of injury and indicates that recall accuracy beyond a 12-month period is limited.[9] In a systematic review concerning the prevention of ACL injuries, there is a demonstrated value to a prophylactic neuromuscular training program.[10] However, the numbers-needed-to-treat analysis indicates that over 100 athletes need to be trained in order to prevent just one ACL injury.[10] Utilizing a screening exam to identify athletes at risk for injury would ensure that preventative training is applied to the correct population.

The Functional Movement Screen (FMS)™ is an efficient and reliable method to screen movement patterns during the performance of specific tasks.[11-15] While some screening methods require advanced training, certification or a period of familiarization, the FMS™ is a reliable screening method even when administered by novice examiners.[14-16] Test-retest analysis of the FMS™ demonstrates good reliability when utilizing the same team of examiners.[17] A screening test by definition is intended for asymptomatic populations to identify those in need of further assessment. The FMS™ may be able to identify those at risk of injury and therefore those athletes that might benefit from a professional assessment to establish the underlying cause of any movement dysfunction. Several studies have demonstrated a predictive relationship between FMS™ composite scores and the risk of injury.[18-20]

Kiesel et al concluded serious injury in professional football could be predicted from the results of a preseason FMS™.[19] An FMS composite score of 14 or less provided maximal sensitivity and specificity. The retrospective nature of this study, failure to report reliability, use of a broad operational definition of injury and the utilization of all male professional athletes significantly limits internal and external validity. Chorba et al utilized a broader injury definition when exploring the relationship between FMS™ score and injury risk in a cohort of female collegiate athletes.[18] Once again, FMS™ composite scores of 14 or less correlated with injury development in female collegiate athletes without a history of anterior cruciate ligament reconstruction. The use of only females limits the generalizability of this study and the low number of subjects (n = 38) threatens the accuracy of this correlative relationship. O'Connor et al analyzed injury rates in 874 male Marine Corps officer candidates utilizing the FMS™.[20] Injuries were captured based on entries in the electronic medical record. Similar to previous studies, their results suggested that an FMS™ score of 14 or less provided the maximum level of sensitivity and specificity when testing for risk of injury. One downside of this study is that only 10% of the subjects screened scored at the critical level of 14 or below. This indicates that the large study population may not be representative of the normal population or that the screeners utilized a more generous scoring standard than previous studies. This study also relied on injury data collected during a formal medical examination. This requires accurate documentation and coding performed by healthcare providers not involved or familiar with the study protocol. This cohort is also unique in that they were enrolled in a training program with a set completion date. Presenting to a healthcare provider with an injury may delay course completion and result in being recycled into the next class. As a result, there may be a lack of injury reporting if physical function was not significantly limited.

The FMS™ is a relatively inexpensive and time efficient means of screening military and athletes that may identify those at risk for injury and require further assessment. Previous studies demonstrate moderate to good interrater and intrarater reliability of the FMS.[13] The purpose of this study was to explore the association between pre-season FMS scores and the development of injury in a population of collegiate athletes. The hypothesis was that a history of previous injury and low FMS composite score, both individually and in combination, would accurately predict future injury risk.

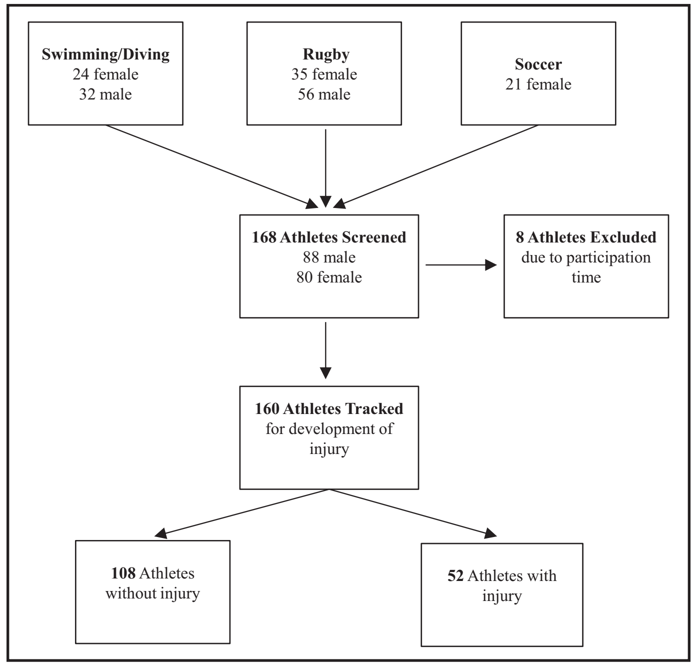

Figure 1. *Subject flowchart*

METHODS

Approval for this study was obtained through the Keller Army Community Hospital Institutional Review Board. All participants provided written informed consent and completed a brief questionnaire prior to the FMS™. One hundred, sixty-eight collegiate athletes competing in a variety of NCAA Division I and club sports volunteered for participation in this study. The participant flow chart is displayed in Figure 1. All athletes performed the complete seven test FMS™ and received individual scores for each test as well as an aggregate score. Five of the FMS™ tests require grading the right and left sides separately. The lowest score obtained was used for aggregate calculation and any evidence of asymmetry was noted for each test. Injuries were tracked throughout the season with the help of the athletic training staff, medical records review and the Cadet Injury and Illness Tracking System (CIITS). All injuries related to sports or physical education classes are entered into the CIITS. Every attempt was made to thoroughly account for injuries that required the attention of medical staff. The sports chosen for this study consisted of rugby, soccer, swimming, and diving. Both genders were included from each sport with the exception of soccer where only the women's team was screened.

INCLUSION AND EXCLUSION CRITERIA

Athletes were included if they were between the ages of 17-22 and medically cleared for full participation in athletic activities. Exclusion criteria included any recent injury or surgical procedure that precluded full participation in collegiate level sports. To control for exposure, athletes that averaged less than three hours per week in sports participation were excluded.

For this study, injury was defined as any musculoskeletal pain complaint, on or off the field of competition, that met all of the following criteria: (1) the injury was associated with athletic participation; (2) the injury required consultation with a certified athletic trainer, physical therapist, or physician; and (3) the injury resulted in modified training for at least 24 hours or the injury required protective splinting or taping for continued sports participation. Regular follow ups with the certified athletic trainers assigned to the respective sports occurred in order to track and monitor the playing status of each previously screened athlete. At the conclusion of the season all injuries were recorded through discussion with the athletic trainer, review of the medical record and review of CIITS.

FUNCTIONAL MOVEMENT SCREENING

The FMS™ is an objective screening tool consisting of seven movement tests. Each subject completed all seven tests in random order. The randomization was accomplished by placing athletes at open stations in no particular order. The tests consist of the hurdle step, deep squat, in-line lunge, shoulder mobility, active straight leg raise, rotary stability and stability push up. Test scores ranged from 0-3 for each test with the highest total composite score being 21. Asymmetry measures were also collected for the five tests that measured scores for each individual side. All participants performed each movement up to three separate times with the highest score of the three movements used for scoring. The screening examination is described in excellent detail in other publications and the reader is encouraged to reference these studies for more information.[15]

Interrater reliability was controlled by utilizing the same team of examiners for each FMS™ session. This means that the same individual examiner instructed and graded the same individual component of the FMS™ for each athlete in this study. Previous research has demonstrated good interrater reliability utilizing the FMS™ when the same examiner is administering the screen.[16,17] Repeat screenings were conducted on a portion of the subject population to establish the intrarater reliability of the screening method. An intraclass correlation coefficient (ICC^{2,1}) value with confidence intervals was calculated for composite FMS™ scores from day one to day two utilizing the same team of investigators.[21] The examiners were all licensed physical therapists with specialist certification in orthopedics or sports physical therapy from the American Board of Physical Therapy Specialties. For this study, reliability was ranked based on the following criteria: excellent (0.90 – 0.99), good (0.75 – 0.89), moderate (0.50 – 0.75), and poor (0.00 – 0.50).[22] Each examiner underwent a limited amount of functional movement training consisting of classroom instruction, laboratory instruction and practice screening on other athletes not enrolled in this study. Examiners also reviewed the relevant literature related to functional movement.

DATA ANALYSIS

The mean was utilized as a measure of central tendency to evaluate differences in composite FMS™ scores between the injured and uninjured groups. A paired t-test was performed to determine if this group difference approached statistical significance. 2x2 contingency tables were created to evaluate the utility of the FMS™ as a diagnostic test where a composite score threshold indicates the development of injury. To determine the threshold value, a receiver-operator characteristic (ROC) curve was calculated plotting sensitivity versus 1-specificity. For the threshold value, the value chosen provided the best balance of maximizing sensitivity while minimizing 1-specificity. Several conditions were analyzed including composite FMS™ score, history of past injury and a combination of composite score with history of past injury. Odds ratios, sensitivity, specificity, and likelihood ratios were calculated for each of these conditions. Using an actual pre-test probability consistent with the cohort and the likelihood ratios, the resultant impact on post-test probability was examined.

To explore the value of FMS™ results as a predictor of injury risk, logistic regression models were fit. To determine which predictor variables to include in the model, possible predictors allowed included: scores for the individual FMS™ component tests, presence of an asymmetry, the FMS™ composite score and past history of injury. Data analysis was performed using R Core Team 2013 (R Foundation; Vienna, Austria).

RESULTS

One hundred sixty athletes were ultimately included in the final data analysis. Injury data from eight athletes were not included as their sports participation did not meet the three hours per week minimum. Out of the 160 athletes screened, 52 athletes sustained some type of injury during the competitive season requiring the attention of the medical staff. The mean FMS™ composite score for the injured group was 13.6 while the mean FMS™ composite score for the uninjured group was 15.5. Comparing these means with an independent t-test resulted in a p-value ≤ 0.05 indicating a statistically significant difference between the two groups. The ICC (2,1) value for test-retest reliability from Day 1 to Day 2 was 0.87, indicating good intrarater reliability.

Sensitivity and specificity were calculated based on FMS™ score. The ROC curve analysis demonstrated that a composite FMS™ score of 14 or less should be used as the threshold to find the best balance of sensitivity and specificity (i.e., maximize true positives while minimizing false positives). To examine the utility of FMS™ as a diagnostic test, 2x2 contingency tables were examined at composite score thresholds of 13 and 14, with and without history of past injury. Table 1 shows sensitivity, specificity, predictive values, likelihood ratios, and post-test probabilities for a variety of test conditions. Maximal sensitivity was obtained using history of past injury alone as the diagnostic, but the positive predictive value was the lowest. Maximal specificity and positive predictive value were obtained when a composite FMS™ score of 13 or below was combined with history of past injury, but the percentage of falsely negative results was undesirably large at 63.5% (only 24 of the athletes met these criteria, all but five sustained an injury). A composite FMS™ score of 14 or below provided the best balance of sensitivity and specificity. Including the history of past injury resulted in a minimal reduction in sensitivity but large improvement in specificity. The likelihood ratio nomogram in Figure 3 visually depicts the resultant impact on post-test probability of developing an injury in the group of athletes with an FMS™ score of 14 or below combined with a past history of injury. With the given pre-test probability of injury in the study population of 33%, the calculated likelihood ratio of 5.88 increases the post-test probability of injury to 74%.

Prior to exploring the predictive capability of the data, it was first established that a relationship exists between FMS™ composite score and injury. The scatterplot in Figure 2 demonstrates a strong correlation between FMS™ composite score and development of injury ($r = -0.90$). The coefficient of determination value of 0.82 indicates a strong linear association between development of injury and FMS™ composite score.

The logistic regression models generated odds ratios (ORs) comparing the predictive power of FMS™ composite scores with and without history of previous injury (Table 2). The odds ratio of 5.61 (2.73, 11.51) for the FMS™ score 14 or less demonstrates that an athlete with a composite score of 14 or less has more than five times greater chance of injury than an athlete with a composite score of 15 or higher. Including history of past injury increases the odds ratio to 15.11 (6.60, 34.61). This is interpreted as an athlete with an FMS™ score of 14 or less and a history of past injury has more than 15 times greater chance of injury than an athlete with a composite score of 15 or higher and no past history of injury.

DISCUSSION

The results of this study indicate that athletes with an FMS™ composite score of 14 or less combined with a self-reported history of previous injury are at a 15 times increased risk for injury compared to athletes scoring higher on the FMS™. The ICC value indicates that this screening can be reliably performed with the same group of examiners after undergoing a limited amount of training. This is the first prospective study examining a large cohort of athletes, both male and female, involved in a variety of contact and non-contact sports. Unlike previous studies, a broad injury definition was utilized to fully capture the impact that injuries have on medical resources and athlete performance.

The finding of a low FMS™ composite score being predictive of injury risk is consistent with the findings of other published studies, however, the results of this present study are more generalizable to a larger sector of the athletic population. Athletes of both genders were screened and followed through

Table 1. *Sensitivity and Specificity Calculations*

	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	Post-test Probability	Change from Pre-test Probability
FMS™ ≤ 14	67%	73%	2.51	0.45	55%	22%
FMS™ ≤ 14 with past history of injury	65%	89%	5.88	0.39	74%	41%
FMS™ ≤ 13	52%	90%	5.1	0.54	71%	38%
FMS™ ≤ 13 with past history of injury	37%	95%	7.89	0.66	79%	46%
Past history of injury alone	72%	57%	1.67	0.49	45%	12%

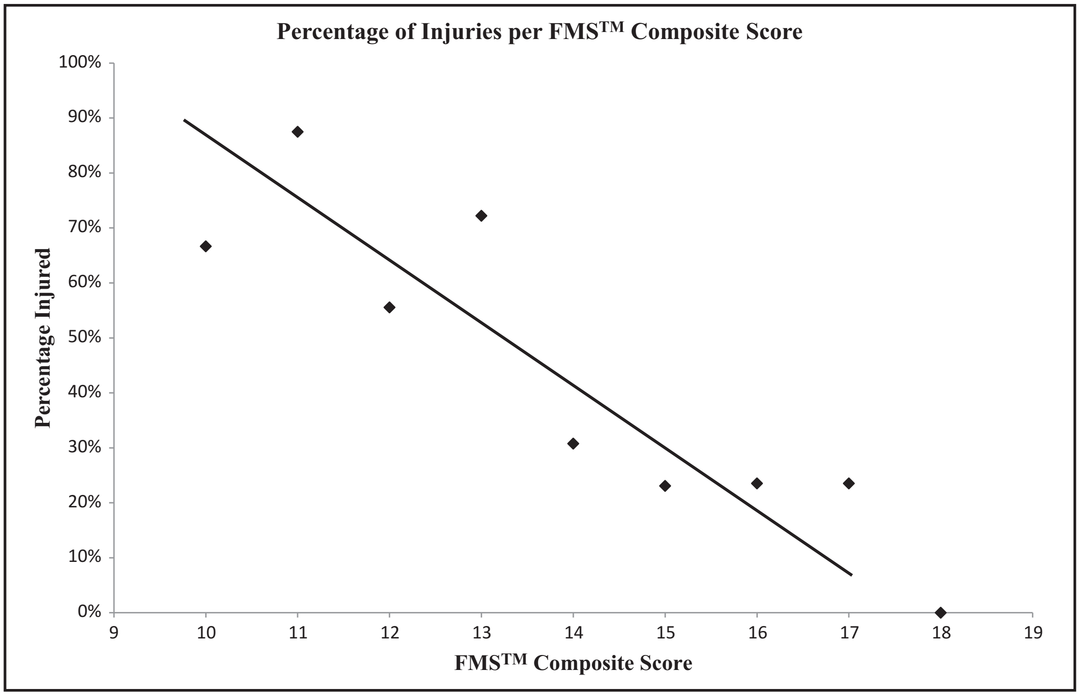

Figure 2. *FMS scatterplot.*

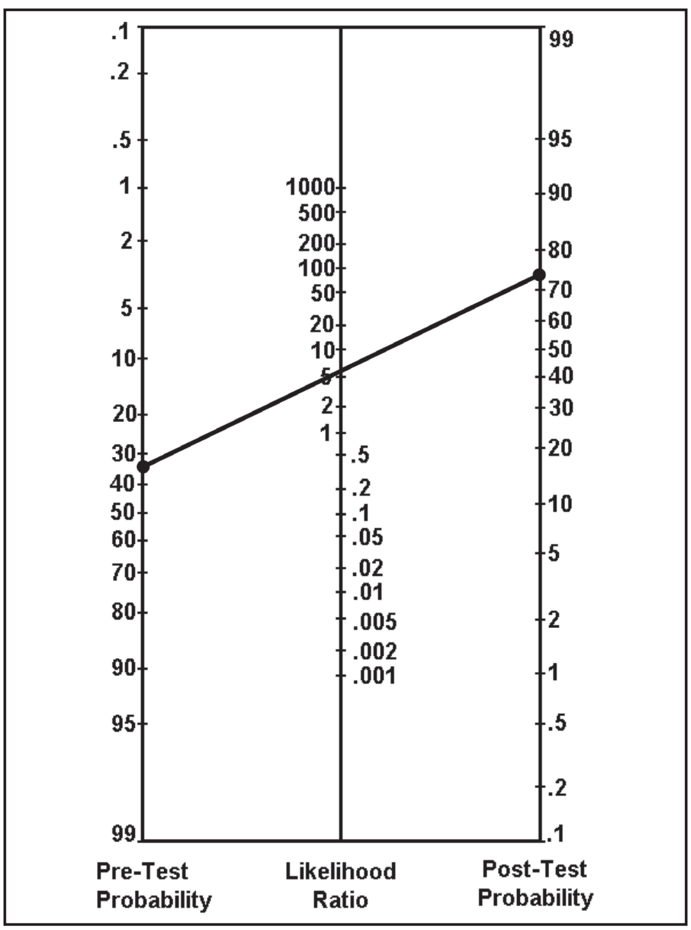

Figure 3. *Likelihood ratio nomogram.*

Table 2. *Odds Ratios and Confidence intervals*

	Odds Ratio	95% Confidence Interval
FMS ≤ 14	5.61	2.73, 11.51
FMS ≤ 14 with past history of injury	15.11 *	6.60, 34.61
FMS ≤ 13	9.52 *	4.16, 21.79
FMS ≤ 13 with past history of injury	11.86 *	4.11, 34.24
Past history of injury alone	3.45	1.70, 7.03

* = statistically significantly different from reference group of past history of injury alone

a season of contact and non-contact sports. Previous studies have looked at cohorts of professional football players, female college basketball players or male Marine Corps Officer Candidates.[18-20]

Other studies have utilized a more narrow definition of injury and only captured athletes that were removed from competition for at least three weeks.[19] By broadening the definition of injury, injuries can be captured that not only limit playing time but also require the attention of the medical staff. A broad injury definition also allows the capture of injuries that may affect movement patterns and alter peak performance but not result in a significant loss of playing time.

Redundancies in data collection were utilized to ensure that all injuries were fully captured. Each team athletic trainer was interviewed, medical records were screened and the United States Military Academy specific injury tracking system was checked to ensure all injuries were thoroughly identified and recorded. Previous studies have utilized larger subject populations but relied on a medical visit, accurate documentation and accurate visit coding to obtain information regarding sample injuries.[20] Because this sample population is highly motivated to complete required military training without delay, it is possible that some injuries went unreported so candidates were able to graduate on time.

This study is not without limitations and these should be considered carefully when interpreting and applying these research findings. This is a descriptive investigation demonstrating a relationship between low FMS™ scores and injury development. These results do not suggest that faulty movement patterns as measured by the FMS™ are a cause of injury. Athletic exposure was not thoroughly controlled for. While athletes that did not meet the three hours per week of athletic activity required for inclusion were eliminated, further delineation regarding how many hours each athlete spent participating in their sport was not performed. The possibility exists that increased practice and playing time, associated with a starting position, is also predictive of injury. A broad injury definition was utilized in this study. Some readers may question the importance of injuries that do not result in lost playing time. Capturing injuries that impact medical resources and adversely affect performance were considered important for this study. Lastly, the FMS™ was performed prior to the competitive season. Repeating the screening exam at different intervals during the competitive season and at the end of the season might be useful to determine if movement patterns change as the season progresses.

The results of this study have many practical clinical applications. Identifying individuals at risk for injury can lead to intervention strategies that address fundamental movement patterns and potentially decrease injury risk. In addition to identifying athletes at risk for injury, movement screening may also play a role in determining when an athlete can safely return to sport with a lower risk of re-injury. Given that past history of injury continues to be a risk factor for future injury, there is a need for tests and measures to help guide clinicians when making return to play decisions. Currently there is no consensus regarding what factors need to be addressed to safely return an athlete to sports participation after injury.[23] Full sports participation requires the integration of upper and lower extremity motion, strength and motor control. The FMS™ is a unique screening tool that integrates all of these components reliably in a short amount of time.[11,13,15] The FMS™ demonstrates adequate predictive power for the development of future injury and integration of this screening test into return to play guidelines should be considered.

CONCLUSION

This study adds to the growing body of evidence demonstrating a predictive relationship between FMS™ composite scores and the development of injury. These study findings are consistent with previous studies that demonstrate that an FMS™ score ≤14 is associated with increased risk of injury. For maximal predictive power, an FMS™ score ≤14 combined with a history of previous injury provides the greatest indicator of future injury risk. The difference between a composite FMS™ score of 13 or 14 can be very minimal and how to approach the cutoff for potential intervention is completely up to the coaching and medical staff. Given the large numbers on some sports teams, coaches may consider focusing their screenings on those athletes who report a past history of injury. Future research should focus on interventions that improve FMS™ scores and determine if this improved movement results in a lower risk of injury. Other areas of interest include determining the length of time required to significantly change the FMS™ composite score and the stability of those changes over time.

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