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The Functional Movement Screen as a Predictor of Injury in National Collegiate Athletic Association Division II Athletes

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Context: The Functional Movement Screen (FMS) is a tool used to assess the quality of human movement. Previous FMS researchers reported a difference between the comprehensive and individual FMS test scores of injured and uninjured participants.

Objective: To evaluate the accuracy of the FMS for predicting injury in National Collegiate Athletic Association Division II athletes and to evaluate how an injury definition may affect the prognostic values.

Design: Cross-sectional study.

Setting: University preparticipation examinations.

Patients or Other Participants: A total of 257 collegiate athletes (men = 176, women = 81) between the ages of 18 and 24 years.

Main Outcome Measure(s): The athletes were prospectively screened with the FMS and monitored for subsequent injury. The ability of the FMS to accurately predict musculoskeletal injuries, overall injuries, and severe injuries was determined.

Results: The receiver operating characteristic curve provided the FMS cut score of ≤15 for the study sample. The areas under the curve were 0.53, 0.56, and 0.53 for musculoskeletal injury, overall injury, and severe injury, respectively. Sensitivity was 0.63 (0.62, 0.61, 0.65), whereas specificity was below 0.50 (0.49, 0.49, 0.45) for all 3 injury definitions of musculoskeletal injury, overall injury, and severe injury, respectively. Relative risk was 1.25 for musculoskeletal injuries, 1.24 for overall injuries, and 1.45 for severe injuries.

Conclusions: The overall prognostic accuracy of the FMS offered a slightly better than 50/50 chance of correctly classifying those most at risk for injury. As such, the FMS did not provide discriminatory prediction of musculoskeletal injury, overall injury, or severe injury in National Collegiate Athletic Association Division II athletes. Using the identified optimal cut score produced inadequate validity, regardless of the injury definition. We recommend using the FMS to assess movement quality rather than as a standalone injury-prediction tool until additional research suggests otherwise. Clinicians screening for injury risk should consider multiple risk factors identified in the literature.

Key Words: sports injuries, musculoskeletal injuries, severe injuries

Key Points

- The Functional Movement Screen had limited prognostic ability to accurately identify National Collegiate Athletic Association Division II athletes who might be at risk of injury.
- The Functional Movement Screen was unable to discriminate among injury classifications, and changes in the reference standard (injury definition) produced minimal changes in the prognostic ability. Further research is needed.

The Functional Movement Screen (FMS) is a physical examination used to measure essential movement patterns in a practical and dynamic way. As designed, its purposes were to (1) identify body asymmetries, (2) assess mobility and stability within the kinetic chain of whole-body movements, and (3) detect poor-quality movement patterns.[1–3] Applications of the FMS include screening for the possibility of future injury and establishing a baseline of movement proficiency to allow for comparisons after performance training, treatment, and rehabilitation.[1–3]

Prior researchers[4–10] indicated that the FMS might be able to identify those athletes most at risk for injury. Those reports demonstrated differences between injured and uninjured participants in comprehensive FMS scores and individual FMS test scores (eg, deep squat). However, a recent systematic review and meta-analysis[11] brought into question the ability of the current body of research to effectively evaluate the predictive validity of the FMS. The FMS was more specific (0.85; 95% confidence interval [CI] = 0.77, 0.91) than sensitive (0.24; 95% CI = 0.15, 0.36), with a positive predictive value (PV+) of 0.42 (95% CI = 0.23, 0.64) and a negative predictive value (PV–) of 0.72 (95% CI = 0.67, 0.76). The area under the curve (AUC) was 0.58 (95% CI = 0.42, 0.77), the positive likelihood ratio (LR+) was 1.65 (95% CI = 1.3, 2.0), and the negative likelihood ratio (LR–) was 0.87 (95% CI = 0.82, 0.92). In short, the high specificity (sp) indicated the FMS positively categorized uninjured athletes who were at low risk, but significant threats to validity included inconsistent data-analysis methods, methodologic limitations, and inconsistent injury definitions that may have limited the prognostic validity of prior reports. The previous use of an inconsistent reference standard (ie, injury definition) in the FMS literature may have limited our understanding of the test's ability to assess risk.[11]

Therefore, the purpose of this current research project was to examine the prognostic accuracy of the FMS in predicting injury in National Collegiate Athletic Association (NCAA) Division II athletes and to evaluate how variations of the reference standard (ie, musculoskeletal injury [MI], overall injury [OI], and severe injury [SI]) may affect the prognostic values and accuracy of the FMS.

METHODS

Study Design

This cross-sectional study was approved by the institutional review boards of Rocky Mountain University of Health Professionals and Northwest Missouri State University.

Participants

For inclusion in the study, each participant was required to (1) be a current athlete enrolled in the home institution of the lead researcher (B.D.), (2) complete the entire 2013–2014 season as a member of his or her respective team, and (3) be uninjured and fully able to play at the start of the athletic season. Any recruit who failed to meet these previously stated criteria was excluded from the study.

Procedures

Potential study participants were solicited through an informative presentation arranged by the primary researcher with athletics department coaching staff at his institution. All student-athletes were solicited to participate in the study. Before enrolling in the study, all volunteers were briefed regarding potential risks and benefits. Athletes who wished to participate signed an informed consent form and completed a brief survey regarding demographic data and collegiate injury history.

The strength and conditioning and athletic training staffs were solicited to assist the research team with data collection. Before the study, staff personnel were given a list of those student-athletes who provided informed consent. The staffs were briefed on research methods and data-collection procedures.

Functional Movement Screen training was required for all personnel assisting the strength and conditioning staff with administering the test as part of the preparticipation physical examination. Functional Movement Screen training was conducted by the primary researcher, a certified athletic trainer (AT) and instructor of biomechanics, and the head strength and conditioning coach. Both were FMS certified and had 4 years of experience using FMS as part of the university preparticipation screening. Training for the personnel administering the FMS consisted of a slide presentation with instruction in FMS methods, data recording, and scoring and hands-on practice.[1–3] In all, 5 members of the FMS administration team were officially certified to administer the FMS, and 8 others were trained in house. The members of the FMS administration team were ATs, assistant strength and conditioning coaches, and 2 doctoral-level instructors from the university's Department of Health and Human Services.

Functional Movement Screen

The FMS was prospectively administered at the start of the 2013 school year as part of the preparticipation screening required of all student-athletes. Approximately 325 athletes were screened at 8 stations in 5 sessions; the first station was a check-in and checkout station. Functional Movement Screen scores were recorded on standardized forms and collected by the head strength and conditioning coach. The primary author monitored 1 station but was blinded to the athletes' comprehensive scores until the end of the study.

Injury Data

Injury data were collected and compiled by the university athletic training staff. Each day, staff ATs documented each athlete who reported an injury, the specific injury diagnosis, and the athlete's practice status as *full go*, *as tolerated*, *limited practice*, or *no practice*. An injury was documented in the dataset only when an athlete's practice status was categorized as *limited* or *no practice*. Minor conditions that did not alter the athlete's ability to practice or compete were not counted as an injury in the dataset or during the data analysis. Only practice- and competition-related injuries were included. For this research project, *injury* was defined as an altered state of practice or competition, and *SI* was defined as an altered state of practice or competition that lasted for at least 3 weeks. In the dataset, all athletic-related injuries were classified as either MI or OI. The OI category was designed to include all potential injuries sustained during athletic practice or competition that might not be captured in the traditional musculoskeletal category, such as concussion. Any condition, such as illness, that might have altered an athlete's participation status was excluded from the dataset. Any athlete who exhibited active injury symptoms that prevented full participation at the start of his or her athletic season was excluded from the study. In addition, all participants with preexisting conditions were excluded from the dataset. For example, if the athlete had a history of shoulder instability dating from the previous year and the condition recurred during the study period, he or she was not included in the dataset. Data from any athlete who did not complete the entire season as an active member of a collegiate team and any incomplete or indeterminable data regarding the index test or reference standard were excluded from the dataset. After the data were collected and the dataset constructed, we determined the accuracy of the FMS in predicting MI, OI, and SI.

Statistical Analysis

At the end of the study period, FMS scores (collected from the strength and conditioning staff) and injury data (collected from the athletic training staff) were compiled in an Excel (version 2010; Microsoft Corp, Redmond, WA)

Table 1. Demographics and Baseline Characteristics of Participants

Measure	Participants (N = 257)		
	All	Injured	Uninjured
Musculoskeletal injury			
Year in school	Mean = 2.33		
First	94	36	58
Second	62	25	37
Third	44	23	21
Fourth	38	19	19
Fifth	18	13	5
Sixth	1	1	0
Sex			
Men	176	92	84
Women	81	25	56
Height, cm	180.2	181.8	178.7
Weight, kg	85	90	80.7
Average Functional Movement Screen score	15.13	14.99	15.25
Overall injury			
Year in school	Mean = 2.33		
First	94	37	57
Second	62	26	36
Third	44	24	20
Fourth	38	23	15
Fifth	18	13	5
Sixth	1	1	0
Sex			
Men	176	95	81
Women	81	29	52
Height, cm	180.2	181.5	178.9
Weight, kg	85	89	81.1
Average Functional Movement Screen score	15.13	14.91	15.34
Severe injury			
Year in school	Mean = 2.33		
First	94	6	88
Second	62	5	57
Third	44	4	40
Fourth	38	4	34
Fifth	18	1	17
Sixth	1	0	1
Sex			
Men	176	16	160
Women	81	4	77
Height, cm	180.2	181.3	180.1
Weight, kg	85	86	84
Average Functional Movement Screen score	15.13	15	15.14

spreadsheet and analyzed using SPSS (version 20; IBM Corp, Armonk, NY).[11] Data analysis consisted of descriptive statistics; receiver operating characteristic (ROCs) curve and AUC; and logistic regression to determine sensitivity (sn) and sp, LR+ and LR–, PV+ and PV–, odds ratios (ORs), and relative risk (RR) and perform χ^2 analysis.

RESULTS

Descriptive Statistics and Demographics

The participants were 257 collegiate athletes (men = 176, women = 81), ranging from first-year freshmen to sixth-year seniors between the ages of 18 and 24 years. The players' sports were football (n = 104), volleyball (15), baseball (n = 34), softball (n = 13), men's basketball (n = 11), women's basketball (n = 10), women's soccer (n = 15), men's tennis (n = 3), women's tennis (n = 6), men's track and field (n = 23), and women's track and field (n = 23). In all, 117 athletes sustained MIs during the study, while 140 remained uninjured. The OI total was 124 (133 were uninjured), and the SI total was 20 (237 were not severely injured; Table 1).

Table 2. Frequencies of Functional Movement Screen Total Scores

Total Score	No. of Athletes
7	1
10	1
11	9
12	13
13	32
14	38
15	50
16	50
17	34
18	14
19	11
20	4
Total	257

Receiver Operating Characteristic Curve and Area Under the Curve Analyses

We first calculated the ROC curve to determine the most appropriate cut score for each injury definition. A score of 15 maximized both sn and sp. Other cut scores ranging from 14 to 17 have been used by previous researchers.[4–9,12,13] The SPSS outputs for sn and sp are calculated in 0.5 increments and indicated that 14.5 (sn = 0.402, sp = 0.664) and 15.5 (sn = 0.615, sp = 0.486) were the 2 scores that maximized both sn and sp; therefore, we selected 15. In addition, 15 was the mean FMS score of the study sample and was the first FMS score noted during ROC curve analysis with an sn of more than 0.500 for all 3 injury definitions. As a result, 15 was established as the most suitable score to further analyze all 3 injury definitions (Table 2).

With the cut score established, we then determined the number of athletes who scored at or below the cut score and examined those athletes who sustained injuries. In all, 118 men scored at or below the cut value, whereas 58 scored higher. A total of 26 women scored at or below the cut value, whereas 55 scored higher ($P \leq .001$). For MI, of the athletes who scored at or below the cut value, 72 sustained an MI, and 72 did not sustain an MI. Of the athletes who scored higher than the cut value, 45 sustained an MI, whereas 68 did not sustain an MI. For OI, of the athletes who scored at or below the cut value, 76 athletes sustained injuries, whereas 68 did not sustain injuries. Of the athletes who scored higher than the cut value, 48 sustained injuries, and 65 did not sustain injuries. For SI, 13 of the athletes scored at or below the cut value, whereas 131 did not sustain SIs. In addition, of the athletes who scored higher than the cut value, 7 sustained SIs, whereas 106 did not sustain SIs (Table 3).

Table 3. Functional Movement Screen (FMS) Cross-Tabulation for Each Injury Category

Score	Musculoskeletal Injury	No Musculoskeletal Injury	Total
FMS+ (≤ cut score)	72	72	144
FMS– (> cut score)	45	68	113
Total	117	140	257
	Overall Injury	No Overall Injury	Total
FMS+ (≤ cut score)	76	68	144
FMS– (> cut score)	48	65	113
Total	124	133	257
	Severe Injury	No Severe Injury	Total
FMS+ (≤ cut score)	13	131	144
FMS– (> cut score)	7	106	113
Total	20	237	257

Once the cut score for the study sample was established and athletes and injuries categorized, diagnostic values were calculated for sn, sp, PV+ and PV–, LR+ and LR–, ORs, and RR. We then checked to see if the observed pattern of injury classification differed when comparing those who scored above versus those who scored at or below the cut value to determine the diagnostic accuracy of the FMS for MI, OI, and SI.

For predicting MI, the FMS had an sn of 0.62, sp of 0.49, and AUC of 0.544. The PV+ was 0.50, and PV– was 0.61. The LR+ was 1.21, and the LR– was 0.79. For predicting OI, the FMS with a cut score of 15 resulted in weaker sn (0.61), with the same sp as for MI (0.49). The AUC was slightly better (0.56), while producing similar results for the PV+, PV–, LR+, and LR–. For predicting SI, the FMS with a cut score of 15 resulted in increased sn (0.65) and the same sp (0.49) as for MI and OI. The AUC for SI was the lowest of all 3 categories (0.53), while the PV+ decreased to 0.09 and PV– increased to 0.94.

For MI, the OR was 1.5, RR was 1.25, and no difference between MI and FMS cut scores ≤15 was detected (P = .067). For any injury, the OR was 1.5, RR was 1.2, and again, no relationship was detected between OI and FMS scores ≤15 (P = .065). For SI, the OR was 1.5, RR was 1.24, and χ^2 analysis was nonsignificant (P = .274). All results including CIs are shown in Table 4.

DISCUSSION

The purpose of our study was to examine the prognostic accuracy of the FMS for predicting injury among an NCAA Division II athlete population. In addition, we sought to examine the influence injury definition may have had on the diagnostic values by conducting statistical analyses with 3 injury definitions: MI, OI, and SI.

Our AUC score findings (MI = 0.544, OI = 0.561, SI = 0.534) were consistent with those from the O'Connor et al[8] study and our meta-analysis.[11] O'Connor et al established the AUC for the injury classifications of any injury (0.58), overuse injury (0.52), and serious injury (0.53) of the FMS to be slightly better than chance in predicting injury in each of the 3 categories. Our meta-analysis results[11] established the comprehensive AUC of the included FMS literature at 0.587. Based on the results of these 3 studies, we can establish that the FMS was slightly better than chance in predicting injury.

Like O'Connor et al,[8] we examined prognostic values for the different injury definitions. Both studies, regardless of the variations in injury definitions, resulted in a fairly consistent grouping of results for sn and sp. The FMS was less sensitive and more specific with all 3 injury definitions (any injury = 0.45 and 0.78, overuse injury = 0.12 and 0.90, and serious injury = 0.11 and 0.93, respectively), whereas we found the FMS to be more sensitive than specific in all 3 categories (MI = 0.62 and 0.49, OI = 0.61 and 0.49, and SI = 0.65 and 0.45, respectively). We expected minimal statistical differences between MI and OI, as the true positive rate increased by only 4 when OI was included versus a strict MI definition. Although the effect was limited, the addition of 4 true positives for any injury category lowered the diagnostic sn while slightly improving the AUC (Table 3). The additional 4 injuries were all head injuries. When a strict injury definition of *severe* was used, FMS sn increased but AUC decreased. These results may imply that, regardless of injury definition, the FMS was unable to discriminate among injury classifications, and the differences in the reference standards produced minimal changes in prognostic values.

Our findings refute those of O'Connor et al[8] and our meta-analysis,[11] both of which demonstrated the FMS to have lower sn and higher sp. The current data indicate that the FMS was more sensitive than specific. In this case, the FMS accuracy for correctly identifying the true-positives (those who scored ≤15 and sustained an injury) in our study sample was 63%. Moreover, the test functioned below 50% in identifying the true-negatives (sp): those who

Table 4. Diagnostic Values of the Functional Movement Screen for Predicting Musculoskeletal, Overall, and Severe Injury

Item	Injury, Value (95% Confidence Interval)		
	Musculoskeletal	Overall	Severe
Sensitivity	0.62 (0.52, 0.70)	0.61 (0.53, 0.69)	0.65 (0.43, 0.81)
Specificity	0.49 (0.41, 0.57)	0.49 (0.41, 0.57)	0.45 (0.39, 0.51)
Positive predictive value	0.5 (0.44, 0.56)	0.53 (0.47,.59)	0.09 (0.06, 0.13)
Negative predictive value	0.61 (0.55, 0.67)	0.58 (0.51,.64)	0.94 (0.91, 0.97)
Positive likelihood ratio	1.21 (0.97, 1.5)	1.2 (0.97, 1.49)	1.18 (0.83, 1.7)
Negative likelihood ratio	0.78 (0.59, 1.03)	0.79 (0.6, 1.1)	0.78 (0.4, 1.4)
Area under the curve	0.544 (0.47, 0.61)	0.561 (0.49, 0.63)	0.534 (0.41, 0.66)
Odds ratio	1.511 (0.918, 2.48)	1.513 (0.922, 2.48)	1.503 (0.579, 3.9)
Relative risk	1.256 (0.95, 1.66)	1.242 (0.95, 1.61)	1.457 (0.601, 1.04)
χ^2 Result	0.067	0.065	0.274

Table 5. Comparison of Sensitivity, Specificity, and Area Under the Curve Findings for Predicting Injury From the Functional Movement Screen Related Research

Item	Current Study[a]	O'Connor et al[8]	Dorrel et all[11b]
Sensitivity			0.24
Any injury	0.61	0.45	
Musculoskeletal injury	0.62	NA	
Overuse injury	NA	0.12	
Severe or serious injury	0.65	0.11	
Specificity			0.85
Any injury	0.49	0.78	
Musculoskeletal injury	0.49	NA	
Overuse injury	NA	0.9	
Severe or serious injury	0.45	0.93	
Area under the curve			0.58
Any injury	0.561	0.58	
Musculoskeletal injury	0.544	NA	
Overuse injury	NA	0.52	
Severe or serious injury	0.534	0.53	

Abbreviation: NA, not applicable.

[a] National Collegiate Athletic Association Division II athletes.

[b] Systematic review and meta-analysis.

scored >15 and never sustained an injury. The interpretation of sn and sp scores and the acceptable level of accuracy for a test to provide valuable information are left to the reader. In the present study, neither sn nor sp produced large, profound results that demonstrated the FMS correctly categorized those at risk for different injury categories.

After ROC curve analysis, we established the FMS cut score of ≤15 and calculated prognostic values for each of the 3 injury definitions. The established cut score was 1 point higher than the cut score of ≤14 used by some previous FMS researchers.[4–8] Other authors have established cut scores of 16[10] and 17.[9] In addition, some investigators used the cut score of 14 because it was established in an earlier study.[6,7] For our study sample of NCAA Division II athletes, the cut score of 15 was the mean score, and it was the first score that established an sn higher than 50%.

We established clear definitions for 3 categories of injury before data collection. During data collection, ATs documented all sport-related injuries in detail so that we could accurately categorize them. Detailed documentation and thorough interviews with staff ATs at the end of the study period allowed us to classify injuries as accurately as possible and exclude injuries that were not sport related. Substantive efforts were made to control for preexisting conditions and to enroll only healthy participants in the study. However, even with this attention to detail and the efforts to promote accurate injury documentation, the process contained multiple opportunities for information to be mishandled or inaccurately documented, which may be a limitation of the study. To ensure blinding of the primary researcher, data were not collected from staff ATs until the end of the study. Although all ATs were knowledgeable and followed the study procedures, limitations exist. One perceived limitation is that we did not account for the cause of injury. During analysis of the injury data, we were unable to distinguish between injuries sustained as a result of external contact versus the movement-quality variables the FMS was designed to detect. Future researchers may wish to keep more detailed data that allow the injury inclusion criteria to be more or less stringent. As well, investigators may find it helpful to determine the prognostic accuracy of the FMS for injuries in contact and noncontact sports to determine if the prognostic ability is enhanced. Another perceived limitation of the study is that we did not consider sex differences related to the predictive validity of the FMS.

Furthermore, we did not examine how each individual's FMS score might have contributed to the overall comprehensive score and the influence each FMS assessment might have had on the prognostic accuracy. Determining the individual contribution of each FMS test may allow for the development of a more efficient and accurate assessment. Researchers[13] who examined the internal consistency and factor structure of FMS scores through analysis of the Cronbach α and exploratory factor analysis determined that the interpretation of a summed FMS score was unclear and that the results of the 7 individual assessments were not interrelated. Exploratory factor analysis indicated that the FMS scores lacked internal consistency and a coherent empirical structure and might represent 7 independent tests. In another study[14] assessing internal consistency, the α value was higher with increased internal consistency among the individual FMS tests, so the total FMS score may be more meaningful in a wider spectrum of adults. Additional authors[15] noted that summary FMS scores of ≤14 did not predict injury but that athletes who had individual FMS test scores of 1 or asymmetry were 2.73 times more likely to sustain injury than those who did not. These results reinforce our findings and provide a platform for future researchers to examine aspects of the individual FMS test scores and asymmetry.

Implications from this study are offered with caution as our results contradict those of earlier researchers to some extent. In particular, the current results lack a clear indication that the FMS was a valid predictor of injury or an effective risk-assessment tool from a statistical perspective.

However, several notable implications should be discussed. First, our findings raise questions regarding the tendency to describe the FMS as a predictor of injury or a risk-assessment tool. We assert that in its current form, the FMS is better described as an assessment of the quality of human movement. Future investigators should examine and work to improve the predictive ability of the FMS.

Second, sn and sp should be examined within the context of a test. The FMS was designed to serve as a baseline before training to identify poor movement patterns, asymmetry, and those at risk.[2,3] In regard to the FMS, we believe that the focus should be on sn when screening for the risk of injury. A test with high sn will accurately identify those at risk who sustain injuries.

We did not observe clear distinctions in accuracy based on injury definitions. Therefore, we advise that practitioners use a definition that is most relevant to the targeted sample and the context of their sports or activity levels. Developing a cut score specific to the targeted population may be a more critical factor to consider and is highly recommended.

Future researchers using the FMS as an injury-prediction tool should examine how to improve its accuracy, namely the sn, sp, and overall AUC. This cannot be accomplished unless methods and statistics relevant to prognostic accuracy are used and reported. In addition, future authors need to address the multiple factors that contribute to injury risk (not just movement quality) and the effects of individual FMS scores and asymmetry. Considering the FMS results in conjunction with known risk factors may improve screening performance. For example, Bushman et al,[14] using logistical regression, identified smoking, 2-mile run time, and an FMS score of $\leq$14 as risk factors for injury in physically active male soldiers. Even though the risk of injury was associated with a poor FMS score, the prognostic ability of the FMS still demonstrated a low AUC, PV+, and sn.[14]

In conclusion, the FMS is an assessment tool designed to screen movement patterns. Previous investigators sought to determine if the FMS was capable of predicting injury. Our results indicated that, regardless of the injury definition, the FMS scores demonstrated above-average sn and below-average sp, with an average overall AUC. The ORs and RRs reflected a minimally increased risk of injury for those athletes who scored $\leq$15. The χ^2 analysis showed a nonsignificant relationship between FMS scores of $\leq$15 and injury in any category. Clinicians should be cautious when using the FMS as an injury-prediction tool; however, the FMS may support efforts to target deficits that could increase injury risk or reflect inadequate recovery from a prior injury. Future researchers should examine ways to optimize and improve the prognostic accuracy of the FMS.

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