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Predicting Musculoskeletal Injury in National Collegiate Athletic Association Division II Athletes From Asymmetries and Individual-Test Versus Composite Functional Movement Screen Scores

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Context: Functional Movement Screen (FMS) scores of ≤14 have been used to predict injury in athletic populations. Movement asymmetries and poor-quality movement patterns in other functional tests have been shown to predict musculoskeletal injury (MSI). Therefore, movement asymmetry or poor-quality movement patterns on the FMS may have more utility in predicting MSI than the composite score.

Objective: To determine if an asymmetry or score of 1 on an individual FMS test would predict MSI in collegiate athletes.

Design: Cohort study.

Setting: National Collegiate Athletic Association Division II university athletic program.

Patients or Other Participants: A total of 84 Division II rowers, volleyball players, and soccer players (men: n = 20, age = 20.4 ± 1.3 years, height = 1.77 ± 0.04 m, mass = 73.5 ± 4.8 kg; women: n = 64, age = 19.1 ± 1.2 years, height = 1.69 ± 0.09 m, mass = 64.8 ± 9.4 kg).

Main Outcome Measure(s): The FMS was administered during preseason preparticipation examinations. Injury-incidence data were tracked for an academic year by each team's certified athletic trainer via computer software. An *MSI* was defined as physical damage to the body secondary to athletic activity or an event for which the athlete sought medical care, and resulted in modified training or required protective splitting or taping. Composite FMS scores were categorized as *low* (≤14) or *high* (>14). Pearson χ^2 analyses were used to determine if MSI could be predicted by the composite FMS score or an asymmetry or score of 1 on an individual FMS test ($P < .05$).

Results: Athletes with FMS scores of ≤14 were not more likely to sustain an injury than those with higher scores (relative risk = 0.68, 95% confidence interval = 0.39, 1.19; $P = .15$). However, athletes with an asymmetry or individual score of 1 were 2.73 times more likely to sustain an injury than those without (relative risk = 2.73, 95% confidence interval = 1.36, 5.4; $P = .001$).

Conclusions: Asymmetry or a low FMS individual test score was a better predictor of MSI than the composite FMS score.

Key Words: movement patterns, sport injury, risk factors

Key Points

- Division II athletes with composite scores of ≤14 on the Functional Movement Screen were not at greater risk of musculoskeletal injury than those with higher scores.
- The athletes with an asymmetry or a score of 1 on any individual test of the Functional Movement Screen were at 2.73 times greater risk of a musculoskeletal injury than others.

Musculoskeletal injuries (MSIs) are inherent in intercollegiate athletes, with an overall rate of 63.1 per 1000 athlete-exposures for both contact and noncontact injuries.[1] Furthermore, the likelihood of subsequent MSI is high.[2–7] Although our current understanding of injury causation is limited, researchers have identified both extrinsic and intrinsic risk factors for MSI in intercollegiate athletes. *Extrinsic risk factors* are external or environmental factors[8] such as footwear or playing surface. *Intrinsic risk factors* are characteristics of the individual athlete that increase injury disposition,[9] such as inadequate strength or high body mass index. Recent attention has focused on the relationship between athletic injury and intrinsic risk factors, including history of previous injury,[10,11] core dysfunction,[9,12] adiposity,[13] landing and cutting biomechanics,[14] quadriceps : hamstrings ratio,[8] and sex.[14] In populations such as recreational runners,[15] professional American football players,[16] elite track and field athletes,[17] netballers,[18] and high school basketball players,[19] asymmetries in movement patterns have been shown to increase injury risk. Movement-related dysfunctions are of particular interest because they are considered modifiable risk factors that can be targeted by intervention programs, which may decrease injury risk.

Identifying dysfunctional movement patterns that contribute to MSI is an important component in managing active populations.[20] However, in practical terms, this does not come easily. The preparticipation physical examination

(PPE) is the litmus test for identifying conditions that may lead to MSI in athletes. The standard PPE includes a medical and family history, orthopaedic examination (joint and muscle specific), and general medical screen (eg, cardiorespiratory system, vision). The PPE typically does not include any assessment of movement patterns. Therefore, the PPE may fall short in identifying and preventing injuries caused by improper movement patterns. If movement-pattern screening yields substantive information for injury prediction, then it may be a consideration for inclusion in the PPE.

The Functional Movement Screen (FMS) allows for assessment of movement patterns involving strength, mobility, motor control, and core stability.[21] Asymmetries or insufficiencies in 7 fundamental movement patterns are rated on a 4-point scale and summed to provide a score out of 21 possible points. Moderate evidence supports the use of FMS summed scores to predict future injury in athletes. Specifically, National Football League players,[22] National Collegiate Athletic Association (NCAA) Division II female athletes,[23] and Marine officer candidates[24] who scored $\leq$14 points were 1.89, 4.12, and 1.91 times, respectively, more likely to sustain an MSI than those who scored lower. Lehr et al[25] tested an algorithm that used demographic information, previous injury history, presence of pain, and Lower Quarter Y-Balance scores along with FMS scores (composite and individual) to predict MSI in 183 Division III athletes. Participants with moderate or substantial risk, which they delineated as *high risk*, were 3.4 times more likely to be injured (95% confidence interval [CI] = 2.0, 6.0). Thus, researchers and clinicians have adopted the FMS in managing athletic populations. However, the variation in relative risk (RR) in these aforementioned studies should be considered when interpreting FMS results. High specificity but low sensitivity was reported by authors[16,22–26] using composite FMS scores for injury prediction (specificity = 0.71–0.94, sensitivity = 0.12–0.67), which suggests a high number of false-negative results for those scoring >14. Garrison et al[26] noted an increase in specificity (from 0.73 to 0.89) and a reduction in sensitivity (from 0.67 to 0.65) when combining history of previous injury with the composite score in Division I athletes. The use of the composite score may still be questionable. Furthermore, for a composite score on a test composed of individual items to be valid, each individual item is assumed to measure the same latent variable. Factor analysis has been used to test validation in other assessment tools related to athletic injuries, such as the Landing Error Scoring System[27] and the Star Excursion Balance Test.[28] Kazman et al[29] examined the internal consistency and factor structure of the FMS in testing 877 Marine officer candidates and demonstrated a Cronbach α of 0.39; values $\leq$0.60 are considered unacceptable for scales.[30] Exploratory factor analysis revealed very weak correlations between the individual tests ($\leq$0.26). Also, varimax-rotated factor loading revealed 2 components that were significantly higher in 2 factors (pain and no-pain groups): the shoulder-mobility (0.74) and squat tests (0.87). The authors concluded that the FMS composite score cannot be considered a unitary construct. The individual tests were not found to measure a common latent variable; thus, the ability of the FMS composite score to measure injury proneness should be questioned. Furthermore, individual movement patterns are likely more informative than the composite score.

The presence of asymmetries and low scores on individual tests may provide additional injury-predictive value to the FMS, strengthening the usefulness of this tool beyond the summed scores. Of the 7 fundamental movements tested in the FMS, 5 compare movement quality between sides, thereby offering an opportunity to observe movement asymmetry. Wiese et al[31] failed to predict injury risk across a variety of injury stratifications in 144 NCAA Division I American football players using the summed score. They suggested using the FMS within athletic populations to screen for functional asymmetries. Asymmetries in other types of movement tests such as hop tests,[32] lower extremity functional tests,[32] and dynamic balance tests[19] have been associated with athletic injuries. More recently, the presence of asymmetry and low individual test scores on the FMS were identifiable risk factors for time loss due to injury in professional American football players.[16] Low scores on the individual movement tests indicate an inability to complete a basic movement pattern, even with significant compensation. Because functional movement deficiencies may be modifiable intrinsic risk factors, examining them is crucial for constructing appropriate intervention programs. Therefore, the purpose of our study was to assess the predictive value of movement asymmetry and a low individual test score on the FMS by investigating preseason scores and subsequent injury over a competitive season in Division II athletes. We hypothesized that, when compared with the FMS composite score, asymmetry or a score of 1 on an individual test would be associated with a greater likelihood of MSI.

METHODS

Study Design and Participants

In this prospective cohort study, the dependent variable was group (injured, noninjured), and the independent variables were composite FMS score and an asymmetry or score of 1 on any individual FMS test. Participants underwent FMS testing before their competitive seasons as part of the 2012 standard PPE. The study was approved by the university's institutional review board, and written informed consent was obtained from the participants.

A total of 84 NCAA Division II rowers, volleyball players, and soccer players participated (men: n = 20, age = 20.4 $\pm$ 1.3 years, height = 1.77 $\pm$ 0.04 m, mass = 73.5 $\pm$ 4.8 kg; women: n = 64, age = 19.1 $\pm$ 1.2 years, height = 1.69 $\pm$ 0.09 m, mass = 64.8 $\pm$ 9.4 kg) in this study. All were members of an intercollegiate athletic team for the entire competitive season: women's rowing (n = 26), women's volleyball (n = 11), women's soccer (n = 27), or men's soccer (n = 20). All participants were on the official team roster by the beginning of preseason and were medically cleared for activity. Volunteers were excluded if they had an MSI (including orthopaedic surgery) within the past 30 days or signs or symptoms of a concussion or postconcussion syndrome. Most participants had no prior experience with the FMS. We estimate that approximately 10 did have prior experience as part of their curriculum as exercise and sport science majors, but they were not excluded from the study.

Table 1. Functional Movement Screen Scores (N = 84)[a]

Variable	Mean ± SD	Range
Deep squat	1.89 ± 0.64	0–3
Hurdle step	2.21 ± 0.67	1–3
In-line lunge	1.85 ± 0.75	1–3
Shoulder mobility	2.87 ± 0.39	1–3
Active straight-leg raise	2.82 ± 0.43	1–3
Trunk stability push-up	2.16 ± .084	1–3
Rotary stability	2.18 ± 0.39	2–3
Summed score	15.84 ± 1.73	12–19

[a] A score of 3 = movement completed as instructed and free of compensation or pain, 2 = movement completed pain free but with some level of compensation, 1 = unable to complete movement as instructed, and 0 = pain with movement or during a clearing test designed to provoke pain and identify injury.

Functional Movement Screen

Seven members of the sports medicine interdisciplinary team (ie, athletic trainers, physical therapists) with at least 1 year of experience with the FMS before data collection evaluated all functional movement patterns. The primary investigator was level I certified in FMS (3 years' experience) and provided instruction to the other evaluators. Each member evaluated 1 functional movement pattern for all participants in a station approach. The FMS is a comprehensive screen used to identify limitations and asymmetries in 7 fundamental movement patterns: the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability. The protocol for administering the FMS was fully described by Kiesel et al.[33] After each test was administered, the examiner assigned a score of 0 to 3, according to FMS criteria.[33,34] A score of 3 indicated *the movement was completed as instructed and was free of compensation and pain*. A score of 2 indicated *the movement was completed pain free but with some level of compensation*. A score of 1 indicated *the participant could not complete the movement as instructed*. A score of 0 was assigned if *the participant experienced pain during the movement or during a clearing test designed to provoke pain and identify injury*. Only 1 person in our cohort scored a zero and it was on only 1 test, the deep squat. All scores for this athlete were kept in the analysis.

Five of the 7 tests (hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, and rotary stability) are scored independently for the right and left sides of the body. This allows asymmetries to be detected. For example, an individual who scored a raw score of 3 for the in-line lunge on the left leg and a raw score of 2 on the right leg earned a final score of 2 for the in-line lunge. A composite FMS score out of 21 was derived by summing the scores for the individual tests.

The research team set up 8 stations in a gymnasium on the day of the teams' PPEs. One station was designated for check-in and checkout, and the other 7 stations were for each of the 7 FMS tests. At the check-in station, participants were debriefed on the research proposal, provided informed consent, and were issued an FMS recording sheet. They then proceeded to each station, where an evaluator conducted the test. The athletes were asked to perform the movements using test directions as described by the authors of the FMS.[35] Although the time limitation imposed in the PPE process did not allow us to obtain any test-retest reliability values, the FMS is a reliable test,[34,36,37] even among raters with different levels of experience.[38]

Injury Tracking

An *MSI* met the following criteria: (1) the injury occurred as a result of participation in an organized intercollegiate practice, strength and conditioning session, or competition setting; (2) the injury required attention or the athlete sought medical care; and (3) the injury resulted in modified training for at least 24 hours or required protective splinting or taping for continued sport participation.[26] Consequently, this included both contact and noncontact MSIs. Injury evaluations were performed by the staff certified athletic trainers responsible for care of the teams. If necessary, injuries were confirmed through diagnostic imaging and evaluation by the team's primary care sports medicine physician. The athletic trainers documented all injury information (eg, mechanism, body part, diagnosis) using the computer software SportsWare (Computer Sports Medicine Inc, Stroughton, MA). Although we did not control for previous injury history, data from participants with recurrent or ongoing injuries were not included in the analysis because the initial injuries had occurred before the FMS testing. Injuries were tracked for the academic year 2012–2013.

Statistical Analyses

All data were analyzed using SPSS statistical software (version 21; IBM Corporation, Armonk, NY). Descriptive statistics were calculated for summed and individual FMS results. To examine the relationship between potential risk factors and injury, we converted discrete and continuous variables into categorical variables. Composite FMS scores were dichotomized using 14 as the cut point ($\leq$14 versus $>$14),[22–24] and individual scores were examined for asymmetry or a score of 1 (*yes* versus *no*). We used χ^2 statistics to examine the association between injury risk and FMS summed score and between injury risk and an asymmetry or score of 1 on an individual test, with injured or uninjured as the dependent variable for each analysis. An *asymmetry* was defined as 1 or more right-left differences on any of the 5 movements scored unilaterally. Finally, receiver operating characteristic (ROC) curves were calculated to determine the optimal cut-point composite FMS score for predicting MSI. The optimal point on the curve was realized when the true-positive rate (sensitivity) was maximized and the false-positive rate (1 − specificity) was minimized, identifying the point with the highest positive likelihood ratio.

RESULTS

Descriptive statistics for the FMS summed and individual scores are shown in Table 1. Thirty-eight athletes (45.2%) sustained a total of 94 MSIs. Contact and noncontact MSIs represented 30.9% (29 of 94) and 69.1% (65 of 94), respectively, of total MSIs. Lower extremity injuries were the most frequent type in this group. An injury summary by body region and frequency is shown in Table 2.

The association between injury occurrence and summed FMS score, asymmetry, or score of 1 on an individual test is

Table 2. Summary of Injuries by Body Region

Body Region	No. (%)
Lower extremity	64 (68.1)
Trunk	19 (20.2)
Upper extremity	8 (8.5)
Head	3 (3.2)
Total	94 (100.0)

Table 4. 2 × 2 Contingency Table Model for Functional Movement Screen Summed Score and Injury

	Injured?	
Functional Movement Screen Summed Score ≤14?	Yes	No
Yes	10	19
No	28	27

illustrated in Table 3. Athletes with composite scores of ≤14 were no more likely to sustain an injury than those with higher scores: $\chi^2_1 = 2.07$, $P = .15$. The mean summed FMS score for the injured group was slightly lower than that of the uninjured group but not statistically different (15.75 ± 1.79 versus 15.99 ± 1.71, $P > .05$). Using the contingency values in Table 4, we calculated sensitivity (26.3%) and specificity (58.7%) for the composite scores. However, athletes who displayed at least 1 asymmetry or limited movement pattern (score = 1) on any of the individual tests were statistically more likely to sustain an injury than those who did not ($\chi^2_1 = 11.39$, $P = .001$). The RR of injury to this group was 2.73 (95% CI = 1.36, 5.44; $P = .001$), and the odds ratio was 5.27 (95% CI = 1.93, 14.40; $P = .001$). Sensitivity and specificity were 81.5% and 54.3%, respectively (Table 5). Finally, the Figure depicts the ROC curve for the entire sample. The cut-point score was maximized at 16. The RR and odds ratio calculated for participants with scores ≤16 were 0.29 (95% CI = 0.09, 0.91) and 0.58 (95% CI = 0.38, 0.88; $P = .03$), respectively. Results of the ROC curve analysis for FMS composite score in predicting MSI are shown in Table 6.

DISCUSSION

Participation in intercollegiate athletics comes with an inherent risk for injury. Being able to identify modifiable factors related to injury has significant value for athletic health care. We sought to determine the utility of examining limited and asymmetric movement patterns from the FMS as factors that predisposed a collegiate athlete to an MSI. A key finding of this study was that the summed score (≤14) did not predict the occurrence of an MSI but that asymmetry or a limited movement pattern on an individual test did.

Most researchers investigating the usefulness of the FMS to predict injury have assessed the composite score and identified a cutoff score of either 14 points[16,22–24,26,33] or 17 points.[31] With a cutoff score of 14, we found that these Division II athletes were not more likely to sustain an MSI (contact or noncontact) than those with higher scores. The mean summed score of 15.84 ± 1.73 for all athletes was higher than that reported by Chorba et al[23] for a similar group of participants (NCAA Division II females: 14.30 ± 1.77) but lower than that reported for professional American football players (16.9 ± 1.70).[16] Only 29 of 84 (34.5%) of our athletes had scores of ≤14 versus 16 of 38 (42.1%) in the study of Chorba et al,[23] who noted that low FMS summed scores (≤14) did predict injury. The ROC curve analysis determined a cutoff score of 16 for our sample, which is closer to the finding of 17 from Weise et al.[31] The area under the curve was 0.363, which reflected a less than 50% chance of predicting injury with the composite FMS score. Furthermore, the RR associated with this cutoff score was 0.29, indicating that those with composite scores of ≤16 were less likely to become injured. The composite score does not appear to be a good predictor of MSIs for this sample.

Sensitivity and specificity for the composite scores were 26% and 59%, respectively, for all participants. Our results contrast with the calculated sensitivity of 58% and specificity of 74% for the Chorba et al[23] study. Both investigations showed that the FMS composite score was better at ruling in injury when the sum score was ≤14 than it was at ruling out injury when the sum score was >14. Sensitivity in our study increased 81.5% when asymmetries and low scores on individual tests were considered independently of summed scores. Asymmetries or low individual movement test scores in the FMS may be present in athletes who have a composite score >14. This may be a reason for the high number of false-negative results associated with FMS composite scores greater than 14. Another consideration for the low sensitivity and the lower specificity associated with the FMS composite score in our sample is that injury risk is likely multifactorial. Movement dysfunction is likely not the only factor predisposing an athlete to injury. Other variables, such as history of previous injury, training load, body composition, fitness levels, and extrinsic factors, also contribute to MSI risk.[1–7,9–12,27,28,32,39] Investigators[25] who combined FMS scores with Y-Balance scores and a history of previous MSI were able to identify Division III athletes at high risk for noncontact lower extremity injury. Previous authors who reported that a composite score of ≤14 was a predictor of MSI accounted for previous injury[27] or studied different cohorts (professional National Football League athletes,[22,33] females only,[23] or male Marine officer candidates[24]), which may have been responsible for the different outcomes. Furthermore, our definition of MSI needs to be acknowledged. We included MSIs resulting from both contact and noncontact mechanisms, which represented 30.9% (29 of 94)

Table 3. Association Between Injury Risk and Functional Movement Screen Measures

Variable	Variable Range	No.	Odds Ratio (95% Confidence Interval)	*P* Value
Summed score (maximum = 21)	≤14	29	0.51 (0.20, 1.29)	.15
	>14	55	1.00	NA
Asymmetry or score = 1 on individual test	Yes	52	5.27 (1.93, 14.40)	.001
	No	32	1.00	NA

Abbreviation: NA, not applicable.

Table 5. 2 × 2 Contingency Table Model for Asymmetry or Score of 1 on Functional Movement Screen Individual Test and Injury

Asymmetry or Score of 1 on Functional Movement Screen Individual Test?	Injured? Yes	No
Yes	31	21
No	7	25

and 69.1% (65 of 94), respectively, of total MSIs. Our rationale for including both was that not all contact injuries are out of the athlete's control and that he or she may, in part, be in a position to be contacted or to fall because of a faulty underlying movement pattern. For example, a player who falls on an outstretched hand and sprains an elbow while slide tackling in soccer may have asymmetries in the inline lunge and active straight-leg raise that could have put the player at risk. We do not know if dysfunction on the FMS tests is related to proficiency in sport-specific skills such as cutting, running, or landing.

Recent attention has been given to performance on the individual tests that compose the FMS and their relationship to injury.[16,29] Kazman et al[29] showed through measures of internal consistency and factor analysis that the meaning of the summed score is actually unclear because the individual FMS tests do not appear to represent a unitary construct. They suggested that sports medicine professionals focus more on the individual movement scores, as was originally intended by the developers of the screen.[29] This was the aim of our study, to examine the role of asymmetries and limited movement patterns (scores of 1) in the individual movements on injury risk. In a study involving 238 American professional football players over 1 season, Kiesel et al[16] reported that players who had at least 1 asymmetry on the FMS were 1.8 times more likely to sustain an MSI than those who did not. Asymmetries in other functional movement tasks, such as dynamic balance (Star Excursion Balance Test),[19] running biomechanics (eg, step length, impact peak, loading rate),[15] jump-landing biomechanics (knee valgus, knee rotational moments),[40] and single-leg postural stability,[40] have been linked to MSI occurrence. However, these tasks were examined for their predictive ability regarding only lower extremity injuries. When all 7 tests are performed, the FMS involves total body patterns and therefore may be better in predicting a wider range of MSIs.

Our inclusion of limited movement patterns (score = 1) may account for the larger odds ratio (5.27). We included limited movement patterns because we hypothesized that significant impairments must be present to prevent the body from moving through a basic functional movement pattern. Movement dysfunctions in athletic populations have been associated with injury.[41–43] If movement in basic patterns is dysfunctional, then the higher demands of athletic movements may also be impaired and could contribute to injury potential. Additionally, 2 of the individual FMS tests, the stability push-up and overhead squat, are not evaluated for

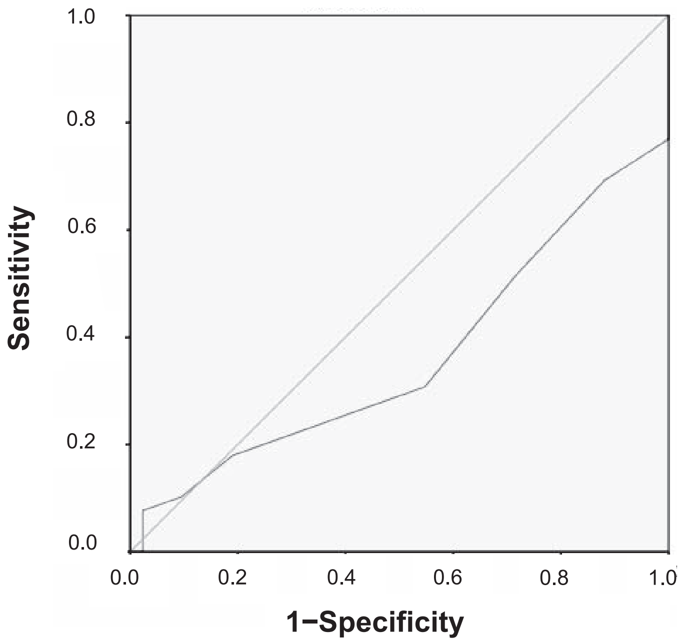

Figure. Receiver operating characteristic curve for summed score and injuries. The straight line denotes the 50/50 reference line, which is approximated by the receiver operating characteristic curve plotted on sensitivity (true-positive rate) over 1 − specificity (false-positive rate) for each score total of the Functional Movement Screen (range, 0–21).

asymmetry, as no side-to-side comparisons are made. Our findings demonstrated that limited basic movement patterns were associated with athletic injury.

This study is not without limitations. First, not including a history of previous MSI as a variable may have affected the generalizability of the results. We had some control over this because we excluded data from participants who were experiencing ongoing or recurrent injuries. However, the role of previous injury history in those who were included is unknown. This limitation may not have detracted from the overall finding that the presence of asymmetric or limited movement patterns on the individual tests are better predictors of MSI than the composite FMS score. Second, the sample size of 84 was small and included athletes from only 3 sports (rowing, soccer, and volleyball) because of time constraints during the PPEs. Thus, the risk estimates should be interpreted with caution in comparison with studies of larger samples. However, as with the previous limitation, this may not have affected the overall finding supporting the usefulness of scores on the individual FMS movement patterns.

Functional movement is the ability to produce and maintain a balance between mobility and stability along the kinetic chain while performing fundamental movement patterns with accuracy and efficiency.[44] The FMS is one method of identifying movement deviations that are base level and, although not sport specific, underlie sport

Table 6. Results From the Receiver Operating Curve Analysis

Receiver Operating Curve Cutoff Point	Area Under the Curve	Standard Area	Area Under the Curve, 95% Confidence Interval	Sensitivity	1 − Specificity
16	0.363	0.063	0.239, 0.486	0.833	0.881

movements and tasks. Identifying movement deviations can be critical not only in recognizing an individual's risk for injury but also in designing intervention programs for that individual. Performance on the FMS appears to be modifiable. For example, Bodden et al[45] and Kiesel et al[33] improved FMS scores (increased the composite score in mixed martial artists and decreased asymmetries in professional American football players, respectively) using a standardized corrective exercise program. The customary precautionary measure for recognizing any preexisting condition that may lead to injury is the PPE. The PPE includes a medical and family history, orthopaedic (joint- and muscle-specific) examination, and general medical screen (eg, cardiorespiratory system, vision) in an attempt to identify conditions that may disqualify the athlete or predispose him or her to injury or illness. However, the PPE may fall short in the identification and prevention of injuries caused by limited functional movements. The FMS can fill that critical gap between the PPE and performance training.

CONCLUSIONS

We examined the presence of asymmetrical or limited (score = 1) movement patterns on the individual tests of the FMS. Division II athletes with summed scores of ≤14 were not at greater risk of MSI than those with higher scores. However, those with an asymmetry or score of 1 on any of the 7 individual FMS tests were at 2.73 times greater risk of MSI. Performance on the FMS is an independent factor that should be considered when assessing injury risk from a multifactorial perspective.

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