Musculoskeletal Screening to Identify Female Collegiate Rowers at Risk for Low Back Pain

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Context: Rowers are at risk for overuse injuries, including low back pain (LBP). Defining the utility of screening tests for identifying those at risk for LBP can aid in the development of guidelines for injury prevention.

Objective: To determine if the Functional Movement Screen (FMS) and impairments can identify rowers at risk for developing LBP.

Design: Prospective cohort study.

Setting: Athletic training room.

Patients or Other Participants: A total of 31 National Collegiate Athletic Association Division I, female, open-weight rowers (age = 19.9 ± 1.4 years, height = 163.6 ± 30.8 cm, mass = 84.1 ± 37.63 kg); coxswains were excluded.

Main Outcome Measure(s): We assessed the FMS and 5 impairment measures of the Star Excursion Balance Test, closed kinetic chain dorsiflexion range of motion, and the plank, Sorensen, and sit-and-reach tests before the fall season. Low back pain injuries were tracked by the sports medicine staff. Impairment measures were compared between the injured and uninjured athletes. The FMS cutoff score that discriminated injured from uninjured rowers was determined using a receiver

operating characteristic curve analysis. Impairments were compared between those at a higher versus lower risk of LBP.

Results: Eighteen rowers sustained an LBP injury. No differences in FMS or impairments between groups were demonstrated. The FMS receiver operating characteristic curve analysis cutoff score was 16 points (area under the curve = 0.60, specificity = 0.67, risk ratio = 1.4 [95% confidence interval = 0.91, 2.11]). Rowers with an FMS score \leq 16 had a shorter plank-test time (109.5 ± 60.2 seconds) than those with less risk (175.3 ± 98.6 seconds, mean difference = 65.9 seconds, 95% confidence interval = -129.4, -2.3; P = .043).

Conclusions: Those with an FMS score ≤ 16 had a shorter plank-test hold time, indicating that a lack of core endurance may contribute to the increased risk of LBP in female rowers. An FMS score ≤ 16 indicated a small increased risk (1.4) of developing LBP compared with rowers who had scores >16; however, the FMS is not recommended for widespread screening of female rowers because the risk ratio was relatively small and had a wide 95% confidence interval.

Key Words: crew, evaluation, injury risk, core stability, Functional Movement Screen

Key Points

- The plank test was the only individual impairment measure that differentiated those with an increased risk of low back pain (LBP). Female rowers who scored at or below the Functional Movement Screen cutoff point of 16 had shorter plank-test times than those with less risk.
- A lack of core endurance may be an impairment that, if addressed, could serve as a prevention strategy to reduce LBP in rowers. Identifying at-risk athletes can aid in the development of prevention strategies.
- The increased risk of LPB identified with a Functional Movement Screen score ≤16 was small, with a wide confidence interval. Other potential risk factors related to development of LBP in rowers should be examined.

R owing is a dynamic sport that requires the simultaneous sequencing of both the upper and lower extremities to produce optimal movement of the boat.¹ High levels of physical demands are repetitively placed on the body during training and competition. A rowing athlete will perform the same dynamic movement hundreds of times during a training session and thousands of times during a season.¹ Because of the repetitive nature of the sport, rowing athletes are at risk for chronic overuse injuries. Of these injuries, the most prevalent is low back pain (LBP).^{1–5} Previous studies^{5,6} of elite collegiate and international rowers have shown that 25% to 51% sustained lumbar spine injuries during their careers.

Low back pain is prevalent among rowers and affects sport participation and performance.^{1–7} Numerous intrinsic and extrinsic factors have been reported to be related to LBP: excessive ergometer training, lumbopelvic muscle fatigue, decreased hamstrings length, increased hamstrings muscle stiffness, erector spinae strength asymmetries, low hamstrings: quadriceps ratio, and excessive lumbar flexion.^{1,3–5,8–11} To develop prevention strategies for reducing LBP, potential risk factors need to be assessed before the rowing season and then monitored to determine if they affect the development of LBP over the course of the season. Clay et al⁹ screened rowers before the start of the season using tests for movement deficiencies defined by the Functional Movement Screen (FMS)^{12,13}; rowers with preseason FMS scores of <14/21 had a greater incidence of LBP injuries during the season than those with scores >14/21. The FMS cutoff score of ≤14 was selected to define high- versus low-risk groups based on earlier studies^{14–20}; however, none of the prior studies included rowers. A more optimal FMS cutoff score may identify rowers at risk for LBP.

The FMS composite score (range = 0-21, 21 points = nomovement deficits) has been used to predict the incidence of injury among a variety of sport participants. Earlier investigators¹⁴⁻²⁰ identified FMS cutoff scores of 14 to 17, indicating that athletes with composite scores below these cutoff values were at higher risk of injury during the season. Variance in the reported FMS cutoff scores in these studies was due in part to the diverse populations and injury types examined, as well as the thresholds for sensitivity and specificity values deemed optimal for the cutoff scores. It is unclear if these reported cutoff values of 14 to 17 points can consistently identify rowers at risk of LBP or if 14 points is the optimal cutoff. Moreover, the FMS screen may not identify the specific modifiable impairments related to the increased risk of LBP in rowers. Identifying the physical factors related to injury risk can aid in the development of prevention programs.

Preparticipation examinations are frequently used to identify deficits in strength, flexibility, endurance, and balance that may predispose an athlete to injury. A critical need is to determine if screening tests are helpful to identify those rowing athletes at risk for LBP. Specifically, can movement deficiencies and specific modifiable impairments characterize the risk of LBP in rowers? Defining the impairments related to the risk of LBP will provide important information for developing training and preventive rehabilitation programs aimed at reducing this injury risk. The purpose of our study was to determine the utility of the preseason FMS and impairment measures to identify collegiate female rowers at risk for developing LBP, and in particular, to ascertain if an FMS composite score or impairment measure(s) identified rowers at risk for LBP. We hypothesized that the FMS composite score and impairment measures would identify rowers at risk for LBP and that these rowers would have functional impairment measures that differed from those with less risk of injury.

METHODS

Participants

In a prospective cohort study design, we recruited 35 National Collegiate Athletic Association Division I, female, open-weight rowers (age = 19.7 ± 1.5 years, height = 175.6 ± 7.9 cm, mass = 71.8 ± 15.1 kg, rowing experience = 5.2 ± 2.5 years). Four coxswains were not included, leaving 31 participants. All rowers were screened as part of the preseason testing. This retrospective analysis of data was approved as exempt by the university's institutional review board. Inclusion criteria were (1) freedom from LBP at the time of preseason testing before the fall season and (2) listed on the team roster for the fall season. Exclusion criteria were (1) a history of back surgery, (2) currently receiving treatment for an injury that could limit performance during testing, or (3) coxswain position in the boat (n = 4).

Examiners

We collected data in the university's athletic training facility. Physical therapists and athletic trainers assessed athletes' performance on the 7 FMS tasks and 5 impairment measures defined in the next paragraphs. Before collecting data, the examiners reviewed all testing procedures and FMS scoring criteria. All examiners had previous experience measuring the FMS tasks and impairments addressed in this study.

Procedures

The FMS and 5 impairment measures of the lower extremity Star Excursion Balance Test (SEBT), closed kinetic chain dorsiflexion, plank test, Sorensen test, and sitand-reach test were assessed in each participant before the start of the fall season. The FMS and impairment measures are depicted in Figures 1 and 2, respectively. The trained examiners conducted testing in a station setting. Participants were randomly assigned a starting station and then rotated through the remaining stations.

The FMS uses 7 fundamental movement patterns to identify injury risk: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability. The 7 FMS tasks were performed as described by Cook et al.^{12,13} Each movement pattern is scored on a scale of 0 to 3: 3 = no movement deficits as defined for each test, 2 = mild movement pattern, and 0 = any pain during the test. The FMS total composite score ranges from 0 to 21 points (21 = no movement alteration; movements performed as described). Each task was demonstrated by the examiner at the station and then performed by the participant. The FMS is a reliable test for both interrater and intrarater reliability (intraclass correlation coefficient [ICC] = 0.74-1.00).²¹⁻²⁴

Impairment Measures

Star Excursion Balance Test. The SEBT is a dynamicbalance test shown to be a reliable (ICC = 0.81-1.00) and valid assessment tool for predicting the risk of lower extremity injury.^{25–28} We implemented the procedures described by Plisky et al.²⁷ The participants were instructed to stand on 1 leg with the big toe behind the starting line and hands on hips. They then reached out with their nonweight-bearing limb as far as possible in the anterior direction. For the trial to be recorded, the following criteria had to be met: maintained a single-legged stance, stance foot remained flat and did not lift off the ground, and the nonweight-bearing leg did not touch the ground and was returned to the starting position. Due to time limitations, only the anterior-reach component was measured. We selected this component because it has been shown to be the most predictive of lower extremity injury risk.^{27,28} Three trials were performed bilaterally. To normalize the results among participants, bilateral leg length was measured from the anterior-superior iliac spine to the most distal aspect of the lateral malleolus using a tape measure.



Figure 1. Functional Movement Screen.

Closed Kinetic Chain Dorsiflexion. Dorsiflexion was measured with the participant half kneeling and the heel flat on the ground. As the tibia advanced forward, the maximum dorsiflexion range of motion attained with the heel in contact with the ground was measured using a digital inclinometer. We used the average of 3 trials for data analysis. Dorsiflexion range of motion measured via digital inclinometer is reliable (ICC = 0.82-0.97).^{29,30} Dorsiflexion was identified as a potential risk factor because the feet are locked into shoes built into the boat for rowing. A lack of dorsiflexion may contribute to compensations at the knee and hip and the development of LBP.

Plank Test. As described by Tong et al,³¹ the plank test was performed in multiple stages. First, the participants performed 1 practice trial. Next, they were given a 1minute rest before starting the test. The participant began the test by holding a prone plank position, supporting the body using the forearms and feet (1). The body was positioned parallel to the floor so it remained straight from the head to the heels.³¹ After 60 seconds in this plank position, the participant (2) lifted the right arm off the ground and held this position for 15 seconds, (3) returned the right arm to the ground and lifted the left arm for 15 seconds, (4) returned the left arm to the ground and lifted the right leg for 15 seconds, (5) returned the right leg to the ground and lifted the left leg for 15 seconds, (6) lifted and held the left leg and the right arm for 15 seconds, (8) returned to the basic plank position for 30 seconds, and (9) repeated stages 1 through 9 until she was unable to maintain the prone plank.³¹ These stages were performed continuously with no periods of rest. The examiner recorded the total time and the maximum stage number that each participant completed. This test has demonstrated reliability (ICC = 0.96-0.99) for assessing global core endurance.31

Sorensen Test. As described by Demoulin et al,³² for the Sorensen test, the participants were positioned prone on a table, with the edges of the iliac crest aligned with the edge of the table. The lower body was fixed to the table with straps. The participants were instructed to fold their arms across their chest and to maintain a straight and horizontal position with their upper body. The total time the participant maintained this position was recorded. The Sorensen test assesses core endurance. High test-retest reliability of 0.98 to 0.99 has been reported.³³

Sit-and-Reach Test. As described by Ayala et al,³⁴ the sit-and-reach test required participants to sit on the floor with their legs together and knees on top of half of a foam roller. With the palms down, they were asked to reach forward along a sliding measuring scale to their toes while keeping their knees on the foam roller. The distance each person could reach was recorded to the nearest centimeter, and the average of 3 trials was used for analysis. The sit-and-reach test was used to assess flexibility of the hamstrings and low back extensors. This test has been shown to be a reliable measurement (ICC = 0.92); the results correlate with LBP.^{34,35}

Injury Tracking

All athletes who reported LBP were examined and diagnosed by the team's sports medicine staff, who recorded the details in the Sports Injury Monitoring System (SIMS; FlanTech, Inc, Iowa City, IA). Low back pain-related injury was defined as 1 = occurred as a result of rowing training, 2 = missed at least 1 day of practice or competition due to the LBP injury, and 3 = diagnosed as an LBP-related injury of any lumbar spine muscle, joint, tendon, bone, nerve, or disc or nonspecific. Low back pain injuries that occurred outside of team-related rowing



Figure 2. Impairment measures. Not all stages of the plank test are depicted.

training were excluded. After the fall season, a member of the sports medicine staff compiled all LBP incidence data in a spreadsheet.

Statistical Analysis

Descriptive data for the FMS and all impairment measures were calculated for the total sample. A χ^2 analysis was performed to determine if participants who

had a history of LBP within the past 1 year were more likely to experience LBP during the current season. The rowers were divided into 2 groups by LBP: injured and uninjured. The LBP group was compared on all FMS scores and impairments using independent-samples t tests. The impairments and FMS scores that were different between groups were entered as variables in a multiple regression analysis to determine the ability to predict LBP injury status.

Table 1	Participants'	Demographics	(N = 31)
	Farticipants	Demographics	(11 – 31)

		Mean \pm SD					
Injury Status	Age, y	Height, cm	Mass, kg	Experience, y	in Past 1 y? No.		
Uninjured (n = 13)	19.6 ± 1.1	177.4 ± 4.8	78.2 ± 75.8	5.0 ± 2.7	6		
Low back pain (n = 18)	20.1 ± 1.6	178.0 ± 5.5	75.8 ± 6.7	5.6 ± 2.6	11		

Receiver operating characteristic (ROC) curves were used to determine the optimal FMS composite cutoff score for differentiating those with and without LBP to predict the incidence of reported LBP during the season. The ROC curve was constructed by plotting sensitivity versus 1– specificity for the FMS composite score; the state variable was the rating of injury or no injury. The cutoff point was the value that maximized specificity without sacrificing sensitivity. Using the identified cutoff, the risk ratio was calculated by dividing the cumulative incidence of the rowers with LBP by the rowers without LBP.

Next, the rowers were divided into 2 groups based on their FMS scores, and independent-samples t tests were performed to compare the groups on the 5 impairment measures. This was done to identify the individual impairment measures that differentiated rowers with a higher risk of LBP as determined by the FMS cutoff point from rowers at lower risk. Independent-samples t tests were conducted to determine if the impairment measures differed between the 2 FMS-defined at-risk groups, those who scored above or below the ROC-determined cutoff point. The 5 individual impairment measures (SEBT, closed kinetic chain dorsiflexion range of motion, plank test, Sorensen test, and sit-and-reach test) were compared between the 2 FMS-defined at-risk groups. The level of significance was set at $P \leq .05$ for all tests, and SPSS (version 22; IBM Corp, Armonk, NY) was used for data analyses.

RESULTS

Participant demographics are presented in Table 1. No differences in participant age (95% confidence interval [CI] = -1.6, 0.61; P = .145), height (95% CI = -22.4, 35.2; P = .357), or mass (95% CI = -2.8, 7.5; P = .942) were observed between the injured and uninjured groups. The descriptive statistics for the preseason FMS composite score and impairment measures are reported in Table 2. Eighteen rowers (58%) experienced an episode of LBP during the season, and days missed due to injury ranged from 1 to 200. The χ^2 test indicated that players with a history of LBP in the past year were not more likely to sustain an injury during the current season (P = .667). A total of 17 participants had a history of LBP in the year before testing. The descriptive statistics for the FMS composite score and impairment measures by LBP injured

and uninjured groups are provided in Table 3. Comparisons between the LBP injury-defined groups revealed no differences for the FMS composite score or any of the 5 impairment measures (all P values > .05).

The ROC curve analysis indicated that the injured versus the uninjured groups were differentiated by an FMS composite score of 16 points (area under the curve =0.60, sensitivity = 0.39, specificity = 0.67, positive likelihood ratio = 1.18, negative likelihood ratio = 0.91), which was maximized for specificity. The relative risk was 1.4 (95% CI = 0.91, 2.11), indicating that those with an FMS score ≤ 16 were at 1.4 times higher risk of developing LBP than those with a score >16 points. Rowers with an FMS composite score ≤ 16 had a shorter plank-test time $(109.5 \pm 60.2 \text{ seconds})$ than those at lower risk as defined by a score of >16 points (175.3 \pm 98.6 seconds); mean difference = 65.9 seconds; 95% CI = -129.4, -2.3, P =.043, effect size = 0.81. No other differences were noted in the other 4 impairments between the FMS defined high-risk and low-risk groups. Descriptive data for the 5 individual impairment measures based on FMS-defined at-risk groups using a cutoff score of 16 are presented in Table 4.

DISCUSSION

Health care providers have limited evidence to guide them in selecting movement deficiencies and impairment factors to assess and treat that will limit the development of LBP in rowers. The goal of our study was to determine if FMS movement deficiencies and impairment measures could identify rowers at higher risk of LBP. Secondarily, we also wanted to learn if a cutoff FMS composite score could identify rowers at risk for LBP and whether individual impairment measures differed between rowers with an FMS score that identified a higher versus a lower risk of LBP. Our findings indicate that the FMS can identify those at higher risk (score ≤ 16) of developing LBP over the course of the season. However, an FMS score of ≤ 16 increased the risk of developing LPB by only 1.4, which is a relatively small increase. Caution is warranted when using this FMS cutoff score because of this relatively small increase in risk and the wide CI. We also found that rowers at risk for developing LBP via the FMS cutoff score had less core endurance as shown by a shorter plank-test time than those at lower risk. Perhaps the plank-test time gives us more information to help identify those rowers at risk for

Table 2. Preseason Descriptive Statistics for Functional Movement Screen Composite Score and Impairment Measures in Female Collegiate Rowers, Mean \pm SD

Functional Movement Screen Composite Score (Range = 0-17)	Closed Chain Dorsiflexion Range of Motion, °		Plank	Sorenson	Sit-and-Beach	Star Excursion Balance Test Anterior Distance, % Leg Length	
	Right	Left	Test, s	Test, s	Test, in	Right	Left
13.6 ± 3.2	32.0 ± 4.8	30.7 ± 4.9	122.2 ± 72.2	102.8 ± 43.5	88.6 ± 18.0	88.6 ± 5.2	88.4 ± 6.3

Table 3. The Functional Movement Screen Composite Score and Impairment Measures by Uninjured and Low Back Pain Rower Groups, Mean \pm SD

Iniury	Functional Movement	Closed Chain Dorsiflexion Range of Motion, °		Plank Tost	Sorenson	Sit-and-Beach	Star Excursion Balance Test Anterior Distance, % Leg Length	
Status	(Range = 0-17)	Right	Left	Time, s	Test Time, s	Test, in	Right	Left
Uninjured Low back pain	14.2 ± 3.2 13.2 ± 3.3	$\begin{array}{c} 32.0\pm5.0\\ 32.0\pm4.8\end{array}$	30.5 ± 5.2 30.9 ± 4.8	142.9 ± 88.0 107.3 ± 56.4	91.5 ± 33.8 110.9 ± 48.6	88.7 ± 17.6 88.5 ± 18.7	$\begin{array}{c} 88.3 \pm 6.1 \\ 88.8 \pm 4.6 \end{array}$	89.5 ± 6.2 87.6 ± 6

developing LBP. No other impairment measures assessed in this study were different between the groups of rowers. This absence of difference between the injured and uninjured groups reduces our confidence in using these impairment measurements, other than core endurance, to screen female rowers for the risk of developing LBP.

This is the first study, to our knowledge, that specifically identified an FMS cutoff score that classified female rowers at risk for LBP. Rowers who scored ≤ 16 on the FMS were at 1.4 times greater risk of developing LBP, but this is a relatively small increase. Clay et al⁹ recently examined if FMS scores could predict injury in rowers using a previously determined cutoff score of 14 from field athletes.¹⁴ High-risk rowers (n = 8/29) defined by a score <14 were more likely to experience LBP during the season. Although this cutoff score of 14 did differentiate those who developed LBP, it may not be the optimal value. In the lowrisk group (FMS score >14), 17/29 of rowers had LBP during the season. Clay et al⁹ included coxswains and those rowers who reported LBP in the 6 weeks before the study, whereas we excluded them from our study. Our ROC curve analysis indicated that an FMS score of ≤ 14 had lower specificity than the 16-point cutoff we selected (Table 5). The cutoff point of 16 may be more specific to identify rowers at risk for LBP. However, given the wide CI associated with the increased risk of 1.4, we do not recommend using the FMS as a screening tool until the cutoff score of 16 can be verified in a separate cohort of female rowers to identify those at risk for developing LBP.

The plank test is frequently used by clinicians to globally assess core endurance via the abdominal and back muscles. Previous authors³¹ reported that rectus abdominus, external oblique, and erector spinae muscle activity reached 50% of maximum voluntary isometric contraction during the plank test. The Sorensen test can also be used as an assessment tool to identify impairments in core endurance. In contrast to the plank test, the Sorensen test targets the endurance of the trunk-extensor muscles.³² Although cocontraction of the trunk flexors and extensors occurs during both tests, including both measures in a screening examination can

help to differentiate deficits in the anterior and posterior core musculature. No difference in maximum Sorensen test time between rowers at risk for LBP and those at less risk was observed. It is possible that differences were not observed for this test because of adaptations of the repetitive trunk extension involved in the rowing motion. Muscle-strength and -endurance deficits between the trunk flexors and extensors may contribute to the development of LBP, which is likely multifactorial. Evidence is lacking regarding the multifactorial nature of risk factors that lead to LBP in collegiate rowers, thereby limiting clinicians from effectively preventing these injuries. Only 1 impairment factor was identified in rowers at risk for LBP; therefore, other potential impairment factors should be considered for assessments aimed at preventing LBP. If deficits in modifiable impairments can be determined during the preseason, then at-risk athletes can be identified, and individual interventions can be implemented to address these deficits and decrease the risk of injury. The identification of impaired core endurance in rowers at risk of LBP is beneficial for clinicians because core-endurance exercises can easily be added to a preventive training program. Previous researchers³⁶ noted a reduced risk of LBP in college-aged rowers who pursued a core intervention program focused on endurance. These results are promising because they indicate the ability to implement an intervention program that targets impairment deficits and reduces the incidence of LBP. Thus, if more contributing risk factors can be identified, then interventions can be developed to target the identified deficits and ultimately reduce the incidence of LBP in rowers. It may also be beneficial to look at risk factors that are more rowing specific, such as testing with the legs fixed, as seen in the rowing-movement pattern.

This study had several limitations. The 31 female participants represented a single team of National Collegiate Athletic Association rowers. As a result, these data may not be generalizable to other teams of female rowers. The participant-to-variable ratio for the multiple regression was low (5:1), which may have affected the power to find

Table 4. Impairment Measures by Functional Movement Screen-Defined At-Risk Groups Based on the Receiver Operating Characteristic Curve-Identified Functional Movement Screen Composite Score of \leq 16 and >16, Mean \pm SD

Closed Chain Dorsiflexion Range of Motion, °		Plank Test	Sorensen	Sit-and-Beach	Star Excursion Balance Test Anterior Distance, % Leg Length	
Right	Left	Time, s	Test Time, s	Test, in	Right	Left
31.6 ± 5.1	31.3 ± 4.8	109.5 ± 60.2^{a}	103.5 ± 47.6	87.5 ± 5.9	87.9 ± 5.1	87.9 ± 4.6
$\textbf{33.8} \pm \textbf{2.8}$	28.3 ± 5.1	$175.3\pm98.2^{\mathtt{a}}$	100.0 ± 21.6	92.8 ± 6.6	$89.6~\pm~5.2$	92.8 ± 6.6
	Closed Chair Range of Right 31.6 ± 5.1 33.8 ± 2.8	$\begin{tabular}{ c c c c } \hline Closed Chain Dorsiflexion Range of Motion, ° \\ \hline \hline Right & Left \\ \hline 31.6 \pm 5.1 & 31.3 \pm 4.8 \\ \hline 33.8 \pm 2.8 & 28.3 \pm 5.1 \\ \hline \end{tabular}$	$\begin{tabular}{ c c c c c } \hline Closed Chain Dorsiflexion Range of Motion, ° \\ \hline Right & Left & Plank Test Time, s \\ \hline 31.6 \pm 5.1 & 31.3 \pm 4.8 & 109.5 \pm 60.2^a \\ \hline 33.8 \pm 2.8 & 28.3 \pm 5.1 & 175.3 \pm 98.2^a \\ \hline \end{tabular}$	$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{c} \mbox{Closed Chain Dorsiflexion} \\ \hline \mbox{Range of Motion, }^{\circ} \\ \hline \mbox{Right} \\ \hline \mbox{Left} \\ \hline \mbox{31.6 \pm 5.1 } \\ \mbox{31.3 \pm 4.8 } \\ \mbox{32.8 \pm 2.8 } \\ \hline \mbox{28.3 \pm 5.1 } \\ \hline \mbox{175.3 \pm 98.2^a} \\ \hline \mbox{100.0 \pm 21.6 } \\ \hline \mbox{92.8 \pm 6.6 } \\ \hline \mbox{92.8 \pm 6.6 } \\ \hline Star Ex Balance Anterior $

^a Statistically significant difference $P \leq .05$.

 Table 5.
 Receiver Operating Characteristic Curve Analysis Cut-Points for the Functional Movement Screen Total Score

Functional Movement						
Screen Composite Score	Sensitivity	Specificity				
6	1.00	0				
8	1.00	0.06				
10	0.85	0.11				
11	0.85	0.22				
12	0.77	0.33				
13	0.77	0.44				
14	0.62	0.61				
15	0.46	0.61				
16	0.39	0.67				
17	0.31	0.89				
18	0.15	0.89				
19	0.08	0.94				
20	0.00	1.00				

differences. Many factors must be considered when examining the FMS and impairment data, such as team and individual training and rehabilitation programs. We did not control for these factors, so it is unclear if they affected our findings. Some rowing teams may place greater emphasis on flexibility and core-strengthening protocols; these could influence the incidence of LBP during the season. Our definition of an LBP injury as only 1 day missed from participation due to LBP was broad. Other definitions of injury could be used, such as missing more than 1 day or requiring modified practice, which can change the injury incidence and, thus, predictive results, although we did not show that those with a history of LBP had an increased risk of sustaining LBP. Eleven rowers who sustained LBP during the season had a history of LBP within the past year. A history of injury may still be considered a potential contributing factor to the risk for injury, as many prior investigators have identified a history of injury as indicating a future risk of injury. Future authors should include multiple collegiate teams to assess the generalizability of our findings. In addition, developing a screening test that mimics the functional demands of rowing could better identify athletes at risk for injury. Future studies should track rowing exposure, along with injury prevalence, so that relative risk ratios can be calculated. Researchers should also consider addressing how the core is used during the rowing motion to create screening tools that are sport specific. It is important to point out that our study was only the first step in the process of developing and validating a screening tool to identify the LBP injury risk in rowers.³⁷ The screening battery we used must be validated in a separate cohort of female rowers. After validation, studies are needed to determine the effectiveness of preventive programs aimed at correcting the deficits identified by the screening tool and if correcting the deficits leads to a reduction in injuries.³⁷ These steps will delineate the effectiveness of the screening tool in identifying at-risk rowers and the ability to reduce LBP using targeted interventions in rowers presenting with deficits.

CONCLUSIONS

An FMS composite score of ≤ 16 may indicate a small increased risk of 1.4 for the development of LBP over the rowing season. However, the FMS is not indicated for

widespread use among female rowers, as this cutoff score indicates a relatively small increased risk of developing LBP with an associated wide CI. Specificity was maximized with a score of ≤ 16 to identify those athletes likely at risk for developing LBP. Participants identified as at risk for developing LBP had a shorter hold time during the plank test. Core endurance may be an important deficit to address in a program to reduce LBP in female rowers. Preventive treatments aimed at addressing the coreendurance impairment should be considered. Future investigations are needed to determine if our findings can be validated among a larger cohort of rowers and if coreendurance deficits can be addressed in a program to reduce the injury risk.

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