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ORIGINAL RESEARCH

USE OF A FUNCTIONAL MOVEMENT SCREENING TOOL TO DETERMINE INJURY RISK IN FEMALE COLLEGIATE ATHLETES

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ABSTRACT

Background. Athletes often utilize compensatory movement strategies to achieve high performance. However, these inefficient movement strategies may reinforce poor biomechanical movement patterns during typical activities, resulting in injury.

Objectives. This study sought to determine if compensatory movement patterns predispose female collegiate athletes to injury, and if a functional movement screening (FMS™) tool can be used to predict injuries in this population.

Methods. Scores on the FMS™, comprised of seven movement tests, were calculated for 38 NCAA Division II female collegiate athletes before the start of their respective fall and winter sport seasons (soccer, volleyball, and basketball). Seven athletes reported a previous history of anterior cruciate ligament reconstruction (ACLR). Injuries sustained while participating in sport activities were recorded throughout the seasons.

Results. The mean FMS™ score and standard deviation for all subjects was 14.3 ± 1.77 (maximum score of 21). Eighteen injuries (17 lower extremity, 1 lower back) were recorded during this study. A score of 14/21 or less was significantly associated with injury ($P = 0.0496$). Sixty-nine percent of athletes scoring 14 or less sustained an injury. Odds ratios were 3.85 with inclusion of all subjects, and 4.58 with exclusion of ACLR subjects. Sensitivity and specificity were 0.58 and 0.74 for all subjects, respectively. A significant correlation was found between low-scoring athletes and injury ($P = 0.0214$, $r = 0.76$).

Discussion: A score of 14 or less on the FMS™ tool resulted in a 4-fold increase in risk of lower extremity injury in female collegiate athletes participating in fall and winter sports. The screening tool was able to predict injury in female athletes without a history of major musculoskeletal injury such as ACLR.

Conclusion. Compensatory fundamental movement patterns can increase the risk of injury in female collegiate athletes, and can be identified by using a functional movement screening tool.

Key Words. female athlete, sports injury, Functional Movement Screen™, injury risk factors

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INTRODUCTION

A variety of intrinsic factors predisposing athletes to injury have been documented in the literature, including agonist/antagonist muscle ratios for strength and endurance, structural abnormalities, female gender, pre-training fitness level, and history of prior musculoskeletal injury.[1-3] More recently, neuromuscular control,[4-6] core instability,[7-9] and contralateral muscular imbalances[10-16] have been suggested as other important intrinsic risk factors for injury. Contralateral imbalances may also present after injury has already occurred, resulting in muscular inhibition, compensatory strategies, or both.[11] Much of the published literature on causative and contributing factors to sports injuries are retrospective, as well as demonstrate inconsistencies in definitions, populations, and methodology. In addition, many studies focus on impairments surrounding a single joint or involving individual muscles.

In an effort to bridge the gap between the pre-participation medical screening and performance testing, Gray Cook et al[17] developed the Functional Movement Screen™ (FMS™). The FMS™ consists of seven movement tests that are intended to quickly and easily identify restrictions or alterations in normal movement. According to Cook et al,[17-19] the tool was designed to challenge the interactions of kinetic chain mobility and stability necessary for performance of fundamental, functional movement patterns. Such movements require controlled neuromuscular execution in a variety of occupational and athletic tasks. By adopting inefficient movement strategies, individuals may reinforce poor movement patterns that, despite achieving high performance, may eventually result in injury.

Few studies[7,19,20] have formally investigated the use of the FMS™ and its ability to predict injury in the athletic population. Peate et al[7] studied the correlation between FMS™ performance and history of prior injury, as well as the impact of core stabilization intervention on injury rates and lost work time in 433 firefighters. After adjusting for the age of subjects and dichotomizing to either passing (score >16/21) or failing (score < 16/21), the odds of failing the FMS were 1.68 times greater in firefighters with previous history of any injury. In an unpublished manuscript, Burton[19] incorporated the FMS™ in testing of 23 firefighter candidates entering 16 weeks of firefighter academy training. Although results of this study could not determine the ability of the FMS alone to predict injury or performance due to a small sample size, a relationship did exist between using the FMS combined with selected performance tests to identify injury predisposition. Kiesel et al[20] examined the relationship between FMS™ scores of 46 professional football athletes and the incidence of serious injury. Results of the study concluded that a score of 14 or less on the FMS was associated with an 11-fold increase in the chance of injury and a 51% probability of sustaining a serious injury over the course of one competitive season.

While considering these promising results, none of these studies have implemented the FMS™ as a screening tool for female athletes despite consistently higher injury rates in this group. Therefore, the purpose of this study was to determine if compensatory movement patterns predispose female collegiate athletes to injury, and if the Functional Movement Screen™ could be used to predict injury in this population over the course of one competitive season.

METHODS

Thirty-eight female student-athletes (mean age 19.24$\pm$1.20 years) participating in women's collegiate soccer, volleyball, and basketball at an NCAA Division II institution during the 2007-2008 season volunteered for the study. An exclusively female population was selected in order to potentially observe a higher number of injuries, as females frequently experience increased injury rates compared to males in sport.[9, 21,22]

Inclusion criteria for this study included females 18-26 years old who had not sustained an injury within the previous 30 days that prohibited full participation in preseason practice and/or conditioning programs. Exclusion criteria included an injury sustained within the 30 days preceding testing that excluded the athlete from participating in practice and/or competition, or recent surgical intervention that limited the athlete's participation in sport due to physician-imposed restriction.

Prior to commencement, approval for the study was obtained through the University of Findlay's Institutional Review Board. All participants were asked to provide informed consent and fill out a medical history form prior to their involvement in the study. A preliminary pilot study was performed to examine the inter-rater reliability between the lead investigator and an independent scoring investigator who scored subjects based upon video recording of their respective testing sessions.

Subjects were tested within two weeks of the beginning of their respective competitive sport seasons. Subjects were asked to perform a series of movements using directions for testing as described by the authors of the FMS™.[17,18,23] Testing was conducted by two investigators experienced in using the FMS™ in daily practice and scored by the lead investigator, and via video recording by an independent investigator (based on the criteria described by Cook et al).[17,18,23] The FMS™ consists of seven movement tests, described by Cook et al,[17,18,23] that include: Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-Up, and Rotary Stability.

Injuries sustained by each subject during in-season practices and competitions were reported. Weekly follow-up with the certified athletic trainers overseeing the respective sports of the subjects were used to track and monitor any injuries that occurred. The definition of injury that was utilized for the purpose of this study was a musculoskeletal injury that met the following criteria: (1) the injury occurred as a result of participation in an organized intercollegiate practice or competition setting; (2) the injury required medical attention or the athlete sought advice from a certified athletic trainer, athletic training student, or physician.

Data Analysis

Interrater reliability between the lead investigator and an independent scoring investigator was determined in a pilot reliability study of eight University student volunteers (5 female, 3 male). The investigators were licensed physical therapists with clinical practice emphasis in orthopaedic rehabilitation. The investigators reviewed the FMS™ instruction manual and watched the accompanying instructional videos prior to scoring study participants. The lead investigator and the independent investigator scored each subject separately via digital video recording. Model 2 intraclass correlation coefficients (ICC) were calculated for each test of the FMS as well as the composite FMS score

For this study, a cut-off score on the FMS of 14 (maximum score = 21) was utilized to determine relationships between lower FMS score and injury. Kiesel et al[20] utilized a receiver-operator characteristic (ROC) curve to determine a cut-off score of 14 that maximized both sensitivity and specificity. To maintain consistency with Kiesel et al's findings, the same cut-off score was employed in this study for data analysis. A 2 x 2 contingency table was created, dichotomizing those above and below the predetermined cut-off composite score on the FMS, and those who incurred an injury from those who did not. A Fisher's exact test with a one-tailed p value of < 0.05 was performed. The Fisher's exact test was chosen due to its ability to calculate a more exact P value with smaller sample sizes than a Chi-square test.[24] Sensitivity, specificity, odds ratios and likelihood ratios with confidence intervals set at 95% (CI95) were also calculated. Correlation and regression analysis was used to establish whether the relationship between the composite FMS score and injury was strong enough to utilize the FMS as a predictor of sustaining a reportable injury. The ability to predict outcomes or characteristics that may predispose an athlete to sustaining an injury can be useful both clinically and in applied settings.

Table 1. *Summary of Subject Descriptive Data*

	# Subjects (n)	Age (yrs)	Ht (cm)	Wt (kg)
All subjects	38	19.24 (± 1.20)	172.29 (±8.51)	67.45 (±9.58)
Soccer	15	18.93 (±1.10)	166.45 (±6.14)	61.64 (±5.64)
Volleyball	11	18.91 (±1.04)	174.68 (±7.39)	69.01 (±7.96)
Basketball	12	19.92 (±1.24)	177.38 (±8.09)	73.30 (±11.16)

Table 2. *ICC Values for Inter-rater Reliability.*

Test	*ICC value*
Squat	0.873
In-Line Lunge	0.774
Hurdle-Step	0.774
Shoulder Mobility	1.000
Active SLR	1.000
Trunk Stability Push-Up	0.974
Rotary Stability	0.851
Composite FMS™ Score	**0.976**

RESULTS

Descriptive subject data including age, height, weight, and sport participation for all subjects is presented in Table 1. Interrater reliability between the lead investigator and an independent scoring investigator were determined via intraclass correlation coefficients (ICC), displayed by test in Table 2.

The mean FMS™ score and standard deviation (SD) for all subjects (n = 38) included in the study was 14.3 $\pm$ 1.77 (maximum score of 21). For those individuals that sustained an injury, the mean FMS score was 13.9 $\pm$ 2.12, while those who did not sustain an injury had a mean score of 14.7 $\pm$ 1.29. Of those individuals who had a composite FMS score of $\leq$14 (n = 16), 68.75% of those individuals sustained an injury throughout their respective competitive season. Additionally, 81.82% of subjects who scored at or below 13 and 48.28% of subjects who scored at or below 15 sustained injuries. Average FMS™ scores for subjects in their respective sports along with number of injuries are reported in Table 3.

Utilizing the cut-off score of 14, as described by Kiesel et al, a 2 x 2 contingency table *(Table 4)* was produced that was utilized to determine a sensitivity of 0.579 (CI95 = 0.335 to 0.798); specificity of 0.737 (CI95 = 0.488 to 0.909); positive likelihood ratio of 2.200 (CI95 = 0.945 to 5.119); and an odds ratio of 3.850 (CI95 = 0.980 to 15.130). Those with an FMS score of $\leq$14 were found to be significantly more likely to sustain an injury (Fisher's exact test, one-tailed, P = 0.0496). A strong correlation existed between injury and FMS™ score (r = 0.761, P = 0.021). Linear regression analysis for the data from all subjects (n = 38) produced results (P = 0.0748, r = -0.7676, r^2 = 0.5892) that did demonstrate a statistically significant relationship between FMS™ score and risk of injury. Non-linear regression analysis also did not produce significant results that would allow the use of the FMS™ to predict injury in this sample of female collegiate athletes.

Further analysis of the data revealed a strong correlation (r = 0.952, P = 0.0028) between composite FMS score and lower extremity injury when the shoulder mobility test was removed from the calculation of the composite FMS™ score for all subjects (n = 38). This resulted in a maximum FMS™ score of 18 from six tests (e.g., Squat, Hurdle-Step, In-Line Lunge, Active Straight Leg Raise, Trunk Stability Push-Up, and Rotary Stability).

Data analysis with exclusion of subjects with a previous history of ACL injury (n = 31) revealed similar findings to results of the entire study sample. The mean FMS™ score and standard deviation (SD) for the non-ACL subjects (n = 31) was 14.0 $\pm$ 1.76. For those individuals that sustained an injury, the mean FMS™ score was 13.6 $\pm$ 1.91, while those who did not sustain an injury had a mean score of 14.6 $\pm$ 1.45. Of those individuals who had a composite FMS™ score of $\leq$14 (n = 15), 73.33% of those individuals also sustained an injury throughout their respective competitive season. Furthermore, 81.82% of subjects who scored at or below 13 and 56.0% of subjects who scored at or below 15 sustained injuries. Average FMS™ scores for non-ACL subjects in their respective sports along with number of injuries are reported in Table 5.

The 2 x 2 contingency table for the 31 non-ACL subjects *(Table 6)* produced a sensitivity of 0.647 (CI95 = 0.383 to 0.858), specificity of 0.714 (CI95 = 0.419 to 0.916), positive likelihood ratio of 2.265 (CI95 = 0.921 to 5.568), and an odds ratio of 4.583 (CI95 = 0.994 to 21.127). Those with a FMS™ score of $\leq$14 were found to be significantly more likely to sustain an injury (Fisher's exact test, one-tailed,

Table 3. *Average FMS™ score and number of injuries per sport (n = 38).*

	Average FMS™ Score	# Injuries
Soccer	13.4	8
Volleyball	15.3	5
Basketball	14.6	5

Table 4. *2x2 contingency table for all subjects (n = 38).*

	Injured	
	YES	NO
FMS™ Score ≤ 14	11	5
FMS™ Score ≥ 15	8	14

Table 5. *Average FMS™ score and number of injuries per sport, subjects without history of ACL injuries (n = 38).*

	Average FMS™ Score	# Injuries
Soccer	13.2	8
Volleyball	14.9	4
Basketball	14.3	5

Table 6. *Contingency table for subjects without history of ACL injuries (n = 31).*

	Injured	
	YES	NO
FMS™ Score ≤ 14	11	4
FMS™ Score ≥ 15	6	10

P = 0.0495). A moderate correlation existed between injury and FMS™ score (r = 0.726, P = 0.046). Linear regressions analysis for non-ACLR (n = 31) subjects reached statistical significance (P = 0.0450, r = -0.8214, $r^2 = 0.6748$) demonstrating a relationship between FMS™ score and risk of injury *(Figure 1)*. Non-linear regression analysis did not produce significant results to use the FMS™ as an injury predictor in non-ACL injured subjects. Results of the statistical analyses conducted for this study are summarized in Table 7.

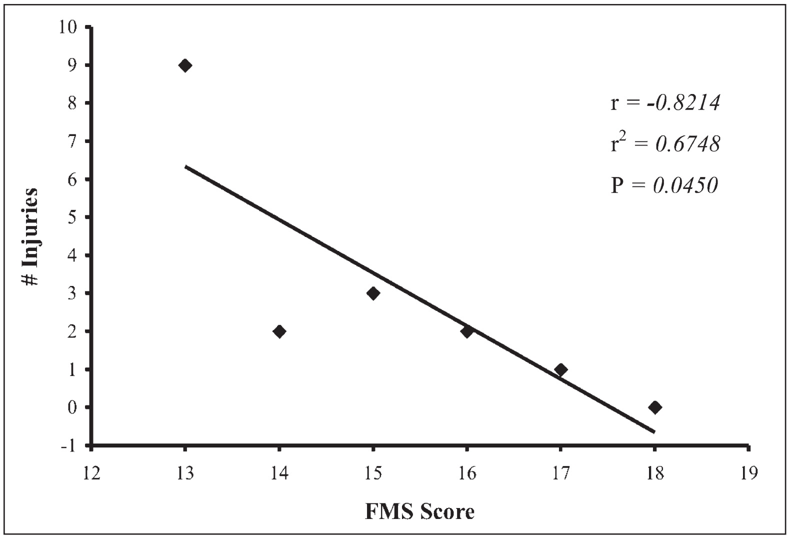

Figure 1. *FMS™ score and injury relationship.*

DISCUSSION

This study was performed to determine if compensatory movement patterns predispose female collegiate athletes to injury, and if the FMS™ could predict injury in the sample population. The hypothesis that compensatory movement patterns were related to injury was supported in the present study. A lower score on the FMS™ was significantly associated with injury, with 69% of those scoring 14 or less sustaining an injury, and experiencing a 4-fold increase in injury risk. The cut-off score of 14 or less that was determined by Kiesel et al[20] was also significant for this study, despite distinct differences in subjects and methodology. Kiesel et al tested professional male football players who, in addition to their elite athlete status, experienced different sport and training demands compared to their female collegiate athlete counterparts. In addition, Kiesel et al limited their data collection to "serious" injury, defined as membership on the injured reserve, and time loss of a minimum of three weeks from normal training and competition.

The authors of the current study chose to adopt a more broad definition of injury for several reasons. First, the authors anticipated that the number of female collegiate athletes available for observation would be less than that studied with a professional football team. Second, the contact but non-collision nature of the represented women's sports studied were thought to be less likely to result in a large number of severe, traumatic injuries more prevalent in a sport such as American football. Third, the authors wanted to include overuse and repetitive microtrauma injuries that may not have been accurately represented under a time-loss injury definition, yet still contribute to compensatory movement patterns and increased risk of more severe musculoskeletal injury. The basis for use of the FMS™ by Cook et al[17] is the hypothesis that repetitive microtrauma caused by adoption of inefficient movement strategies may predispose individuals to musculoskeletal injury. The effects of repetitive microtrauma include overuse pathologies that the athlete is initially able to work through despite his or her symptoms. However, the

Table 7. *Statistical summary.*

	Fisher's Exact Test (*p* value)	Sensitivity (*95% CI*)	Specificity (*95% CI*)	LR	Odds Ratio (*95% CI*)	Spearman Correlation	Adjusted* FMS™ Spearman Correlation	Linear Regression Values
All Subjects (n=38)	0.0496	0.579 (0.335-0.798)	0.737 (0.488-0.909)	2.200	3.850 (0.980-15.130)	r = 0.7608 P= 0.0214	r = 0.9515 P= 0.0028	r = - 0.7676 $r^2 = 0.5892$ P = 0.0748
Non-ACL Subjects (n=31)	0.0495	0.0647 (0.383-0.858)	0.714 (0.419-0.916)	2.265	4.583 (0.994-21.127)	r = 0.7261 P= 0.0458		r = - 0.8214 $r^2 = 0.6748$ P= 0.0450

CI – Confidence Interval ; LR – Likelihood Ratio
*Adjusted FMS™ included all tests except the shoulder mobility test

current study's lack of a longitudinal design spanning multiple sport seasons may decrease its sensitivity to injuries involving repetitive microtrauma that could later progress to a more severe acute injury, easily recognized under a time-loss injury definition.

Of the 38 study participants, seven had previously sustained anterior cruciate ligament injury with subsequent reconstruction (ACLR). This injury represented the most significant type of traumatic injury recorded in participants' past medical history, which could have had a significant impact on FMS™ performance and subsequent injury, and therefore data were analyzed both with and without inclusion of the previously injured subjects. However, significant correlation between an FMSÍ score less than or equal to 14 and sustaining an injury during the season existed with or without inclusion of ACLR subjects, and the average FMS™ score actually dropped slightly in non-ACLR subjects (14.3 +/- 1.77) versus all subjects (14.0 +/-1.76). The odds ratio for injury increased from 3.85 to 4.58 when ACLR subjects were excluded from analysis, demonstrating that a lower FMS™ score in non-ACLR subjects resulted in a higher risk of injury in that group. Although history of previous injury is usually considered a strong predictor of future injury, it is possible that a significant emphasis on lower extremity strength and neuromuscular control was employed in the rehabilitation of subjects post ACLR, and that such training may have positively impacted their FMS™ scores.

The hypothesis that the FMS™ could be used to predict injury in female collegiate athletes was partially supported in the current study. Regression analysis using a linear model was able to establish a predictive relationship between a FMS™ score and the risk of injury, but only for subjects without history of ACLR. When expanded to include all subjects, the linear regression model failed to reach statistical significance, most likely due to a lack of power from a small sample size. The data for the non-ACLR group may have provided better predictive results due to the exclusion of subjects that had suffered serious musculoskeletal injury. As history of previous injury (ACLR) is a strong independent risk factor for future injury, the potential for interaction between FMS™ performance and changes to the neuromusculoskeletal system that may occur after ACLR are unknown in the present study. Further analysis using a non-linear model yielded no predictive capabilities.

The population for this study, a sample of convenience, was limited to fall and winter sports (soccer, volleyball, basketball) that were primarily lower-extremity dominant in nature. Although volleyball players are overhead athletes, the number that participated (n=11) may not have been sufficient to detect upper extremity injuries, as no injuries to the upper extremity were reported.

A trend was noted regarding the performance of the Shoulder Mobility and Trunk Stability Push-Up in female subjects. The majority of subjects (74%, n=28) obtained the highest score of 3 on the Shoulder Mobility test, with many greatly exceeding the required measurements for shoulder/thoracic flexibility indicating joint hypermobility. Conversely, only 5% (n=2) of female subjects scored a 3 on the Trunk Stability Push-Up. As females are more likely to exhibit glenohumeral joint laxity and symptomatic instability[25,26] as well as decreased upper body strength[27] compared to males, these factors are likely influential in upper-extremity focused tests of the FMS™ in female athletes. With exclusion of the Shoulder Mobility test, the remaining FMS™ test cluster demonstrated improved correlation, from 0.761 (P=0.021) to 0.952 (P=0.0028) with the lower extremity/core injuries observed. However, additional removal of the Trunk Stability Push-Up had a negative effect (r=0.698, P=0.136). This demonstrates that the Trunk Stability Push-Up may indeed be more sensitive to core stability issues versus upper extremity strength, via the established connection between core instability and lower extremity injury.[8,9,28,29,30]

A lower score on the FMS™ has previously demonstrated predictive ability in the male athletic population,[20] and was shown to be a predisposing factor for injury in females in the present study. Although this study was only partially successful in establishing a predictive utility for the FMS™ in female athletes, observation of a limited sample size over a single season may not have provided the appropriate framework from which to draw conclusions. Future studies incorporating a larger, more diverse sample of female collegiate athletes, including those participating in upper extremity-dominant sports (e.g. softball, tennis, field events) are warranted in order to determine if the FMS™ can be used to predict injury in a more diverse population of female collegiate athletes. Future studies may also find that certain components of the FMS™ may be used independently to predict injury in various athletic subgroups. However, the concept of energy transfer throughout the kinetic chain underscores the appropriateness of administering the entire test battery within the FMS™, as the complex interaction of core stability with distal extremity control is required in most sporting activities.

CONCLUSION

Compensatory fundamental movement patterns can increase the risk of injury in female collegiate athletes, and can be identified by using the Functional Movement Screen.™ A score of 14 or less on the FMS™ resulted in an approximate 4-fold (3.85-4.58) increase in risk of lower extremity injury over the course of a competitive season in female collegiate athletes participating in fall and winter sports including soccer, volleyball, and basketball. The FMS™ may be able to predict injury in a subgroup of female collegiate athletes without a history of major musculoskeletal injury such as ACL reconstruction.

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