ACAVIS PUBLISHERS

Physiotherapy and Rehabilitation International Journal

Research Article | Volume 2, Issue 1

The Functional Movement Screen as a Predictor of In-Season Injuries in National Adolescent Female Volleyball Players

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Article Info:
Received Date: May 07, 2026
Published Date: June 24, 2026

Citation:
Mathis RA, Taylor JD, Ramey K, Everson R, Everson E. The Functional Movement Screen as a Predictor of In-Season Injuries in National Adolescent Female Volleyball Players. Physiother Rehab Int J. 2026;2(1):1-6.

ABSTRACT

Objectives: The Functional Movement Screen (FMS) is a commonly used tool to determine if an athlete possesses the necessary movement competencies to safely participate in sports. The primary aim of this study was to investigate the FMS as a predictor of adolescent female volleyball player injuries over the course of a season. A secondary purpose was to evaluate changes in FMS scores, along with other physical performance measures, during the season.

Equipment and Methods: This investigation was a prospective observational study. Forty adolescent female volleyball players, ages 13-18 years old, were recruited from a competitive club volleyball program. Subjects participated in a tournament season of volleyball for a period of 20 weeks. Participants completed three performance measures: (1) the FMS, (2) T-test, and (3) Vertical Jump. Performance measures were administered pre-season, mid-season, and post-season. In-season incidences of injuries were also recorded.

Results: Sensitivity, specificity, and receiver operating characteristics (ROC) curve were utilized to examine the strength of the FMS to predict injury. The ROC curve identified a FMS cut score of 15.5. The area under the curve (AUC) was 0.480 (95% confidence interval = 0.282, 0.678; p = 0.84). Sensitivity and specificity were 0.462 and O.440, respectively. Repeated measures analysis of variance at an alpha level of 0.05 was used to evaluate within-group effects. Significant improvements were found in FMS scores, vertical jump, and T-test at various intervals.

Conclusion: The main findings of this study indicate that the FMS is not a predictor of in-season injuries in female adolescent volleyball players and that FMS scores can improve during the season, along with other physical performance measures. The FMS may be used to measure quality of movement over time, but not as a method to predict injury.

KEYWORDS: Adolescent, Female, Volleyball, Functional Movement Screen, Physical performance

INTRODUCTION

Volleyball is a dynamic sport that has become increasingly popular among adolescent girls throughout the world. Presently, more than 400,000 girls in the United States alone play high school volleyball, however, this statistic does not include the number of adolescent girls playing at an earlier age, in the intermediate school years.[1] Unfortunately, the number of injuries that female adolescent volleyball athletes experience over the course of a season is considerable, with reported incidence of injuries as high as nearly 67%.[2] Thus, methods for identifying female adolescent volleyball players who are at risk of an in-season injury are important.

The Functional Movement Screen (FMS) is a physical performance test used to measure movement patterns, with the purposes of identifying body asymmetries, assess mobility and stability, and detect poor-quality movement patterns.[3,4] In practical application, the FMS is utilized as a screen to identify athletes in various sports who are at risk of sustaining an injury. The FMS is also used to measure changes in movement patterns as a result of physical performance training.[3,4]

Data from previous research have suggested that the FMS has the ability to identify athletes in various sports, as well as candidates in training academies, who are at risk for injury, where differences in FMS scores were found between injured and uninjured individuals.[5-11] In contrast, the findings of a meta-analysis did not support the use of the FMS to predict injury.[12] Analysis of extracted data from prior studies indicated that the FMS was more specific (0.85) than sensitive (0.24).[12] Specificity was interpreted as the ability of the FMS to classify individuals who scored over the cut score and did not experience an injury. Sensitivity was interpreted as the ability of the test to categorize people who scored on or below the FMS cut score and sustained an injury. The higher specificity means that the FMS was more accurate in classifying uninjured athletes who were at low risk of injury, but the lower sensitivity means that the FMS was less accurate for categorizing injured individuals who were at high risk of injury. Therefore, additional investigations are needed to determine if the FMS can be used to predict injury in adolescent female volleyball players.

A problem exists in that the predictive validity of the FMS in identifying adolescent female volleyball players who are at risk of sustaining an injury during a season is lacking. If the FMS is a predictor variable, a clinical rationale can be made to use the FMS as a pre-season screening tool and subsequently implement injury prevention strategies in at-risk athletes. The primary aim of this study was to investigate the FMS as a predictor of in-season injuries in national adolescent female volleyball players. A secondary purpose was to evaluate changes in FMS scores, as well as other physical performance measures, over the course of a tournament season.

METHODS

Setting and Participants

Adolescent female volleyball players, ages 13-18 years old, were recruited from the National competition teams of a club volleyball program in the United States of America, through the use of formal verbal announcements, word of mouth, and electronic announcements. Data were collected at team practice sights. Participants were excluded from the study if any of the following criteria were met: 1) a physical impairment that prevents participation in the study, or 2) a medical history of a systemic musculoskeletal condition. Each parent and participant signed a written, informed consent prior to the athlete's participation in the study. Additionally, due to the age of the subjects, each participant signed an assent form, written in plain language. Following informed consent, participants completed a brief medical history and the following were assessed: height and weight. This study was approved by the Harding University Institutional Review Board.

Study Design

This investigation was a multi-site prospective observational study. Subjects participated in a tournament season of volleyball games over a period of 20 weeks. Data were collected by research personnel trained on the study protocol. Administration of the FMS and other physical performance measures by the investigators was scripted. Participants completed three performance measures: (1) the FMS, (2) T-test, and (3) Vertical Jump, measured with the VERT Basic. Block randomization determined the order in which the performance measures were administered. Rotation between performance measure stations provided participants sufficient rest. To investigate the FMS as a predictor of injury, the FMS was administered prior to the beginning of the season (pre-season) and injury data were collected using a questionnaire. To examine changes in FMS scores over the course of the season, the FMS and the other physical performance tests were administered pre-season, mid-season, and post-season.

Functional Movement Screen (FMS)

The Functional Movement Screen (FMS) is a tool developed to address the disconnect between traditional performance testing and fundamental movement as it relates to function. The purpose of administering the FMS is to determine if an individual possesses the necessary movement competencies to safely participate or return to sports, employment, or other activities.[2,3,13,14] The FMS is often utilized as a pre-season, pre-employment or pre-placement screen.[2,3,13,14] The functional movements in the screen include three complex tasks (In-line Lunge, Hurdle Step, and Deep Squat) and four component tasks (active straight leg raise, shoulder mobility, rotary stability, and trunk stability). The seven tasks are scored on a 0 to 3 scale for a maximum comprehensive final score of 21.[2,3,13,14] The FMS has been found to be reliable with good content and translational validity.[15-22]

T-test

The T-test is a measurement of speed and agility that has been found to be reliable and valid in numerous populations, including volleyball players.[23-25] The T-test requires individuals to change directions quickly incorporating forward, lateral and retro movement in 5 and 10 yard increments, executing a "T" shape.[23,26] Evidence supports the use of the T-test in assessing volleyball players.[25] T-test scores were recorded in seconds for this study.

Vertical Jump

Vertical jump is often implemented as a functional measurement of power in volleyball players and is correlated with performance on the court.[24,27,28] Two types of vertical jump, the block and approach jump, are considered fundamental to success in higher level volleyball players and have been found to be reliable and valid.[24,29,30] The VERT (VERT; version VTS Basic, Mayfonk, Athletic, Ft. Lauderale, FL, USA) is a quick and feasible instrument to measure block and approach jump height in participants in their normal practice environment. The VERT has been found to be reliable and valid with a narrow margin of error for measuring jump height in athletic and non-athletic populations.[31-34] Both block and approach jump height were measured in inches for this study.

Injury Data

Injury data were collected through administration of a questionnaire that was completed by the participants at the end of the study. Only practice- and competition-related injuries were included. *Injury* was defined as a musculoskeletal trauma that occurred during practice or competition and caused localized symptoms in the area of injury such as pain, swelling, redness, warmth, or loss of function.

Data Analysis

An *a priori* power analysis was conducted to estimate the total number of study participants. One of the purposes of this study was to examine changes in FMS scores. Chimera et al[35] reported that the minimal clinically important difference (MCID) for the FMS was 1.25 with a standard deviation (SD) of 2.4. The *a priori* power analysis found that 26 participants would be required to detect an effect of 1.25 for the FMS (SD = 2.4) with a statistical power of at least 0.90 at an alpha level of 0.05.

Means and standard deviations were calculated for all variables, except injuries. Injuries were recorded as counts. Sensitivity, specificity, ROC curve, and AUC were used to explore the value of the FMS composite score as a predictor of injury risk. The Shapiro-Wilk test was conducted to examine normal distribution of data. All data were normally distributed ($p > 0.05$), except FMS data. Thus, changes in FMS scores were analyzed using the Wilcoxon signed-ranks test. For all other data, repeated measures analysis of variance (ANOVA) was used to evaluate within-group changes. Mean differences and 95% confidence intervals (95% CIs) were also calculated for all variables. For all analyses, an alpha level of 0.05 was used. Data analyses were performed using IBM SPSS Statistics for Windows version 25.0 (IBM Corp, Armonk, NY).

RESULTS

A total of 40 female participants (age range = 13 – 18 years) were enrolled in this study. For all analyses, a per protocol method was used, where only data from participants with complete data were evaluated and participants with missing data were not included in the analyses. The per protocol method resulted in a different sample size for each variable. The sample size for each variable has been inserted into Table 1.

Means and SDs for body weight and height were 78.9 kilograms (SD = 2.7) and 173.7 centimeters (SD = 6.1), respectively. The ROC curve analysis (n = 38) identified a FMS cut-off score of 15.5 that resulted in the best balance between sensitivity and specificity. The SPSS outputs for sensitivity and specificity were calculated in 0.5 increments and indicated that 15.5 (sensitivity = 0.462, specificity = 0.440) was the score that resulted in the best balance. However, the AUC (0.480, 95% confidence interval = 0.282, 0.678) for the ROC curve analysis was not statistically significant ($p = 0.84$).

Table 1: FMS Composite, Functional Movement Motor Screen, T Test, and Vertical Jump Results

Variable	Pre-season	Mid-season	Post-season
FMS Composite (n = 36)	15.9 (2.0)	16.3 (2.1)	17.1 (2.0)
Functional Movement Motor Screen – Left Upper Extremity (n = 36)	60.5 (10.1)	64.9 (9.8)	68.1 (9.9)
Functional Movement Motor Screen – Right Upper Extremity (n = 36)	60.4 (9.9)	63.5 (9.6)	66.9 (9.0)
Functional Movement Motor Screen – Left Lower Extremity (n = 36)	64.2 (6.5)	64.5 (5.9)	66.0 (7.1)
Functional Movement Motor Screen – Right Lower Extremity (n = 36)	63.4 (5.4)	64.1 (5.9)	64.8 (5.9)
T Test (n = 35)	12.4 (0.9)	11.7 (0.9)	11.6 (0.8)
Vertical Jump Block Test (n = 34)	16.8 (1.8)	16.7 (2.0)	17.7 (2.2)
Vertical Jump – Approach Method (n = 34)	20.7 (2.4)	20.5 (2.6)	21.2 (2.5)

Data are reported as mean (standard deviation).

Statistically significant improvements in FMS composite scores were observed when comparing: 1) pre-season versus post-season ($p = 0.001$) and 2) mid-season versus post-season ($p = 0.01$). No statistically significant changes in FMS composite scores were found when comparing pre-season versus mid-season ($p = 0.19$).

For T-test data, repeated measures ANOVA detected a statistically significant effect ($p < 0.001$). Pairwise comparisons indicated statistically significant improvements in T-test scores when comparing: 1) pre-season versus post-season and 2) pre-season versus mid-season, but no statistically significant changes between mid-season versus post-season.

When evaluating vertical jump data from the vertical jump block test, repeated measures ANOVA found a statistically significant effect ($p = 0.001$). Pairwise comparisons indicated statistically significant improvements in vertical jump block test scores when comparing: 1) pre-season versus post-season and 2) mid-season versus post-season, but no statistically significant changes between pre-season versus mid-season. Repeated measures ANOVA did not indicate a statistically significant change in vertical jump using the approach method ($p = 0.08$). Refer to Table 1 and Table 2 for additional findings of this study.

Table 2: Differences between Pre-season, Mid-season, and Post-season

Variable	Difference (Mid-season Minus Pre-season)	Difference (Post-season Minus Mid-season)	Difference (Post-season Minus Pre-season)
FMS Composite	0.4 (-0.1, 1.0); p = 0.19	0.7 (0.1, 1.3); p = 0.01	1.2 (0.5, 1.8); p = 0.001
Functional Movement Motor Screen – Left Upper Extremity	4.4 (1.8, 7.0); p = 0.001	3.1 (1.5, 4.8); p < 0.001	7.6 (4.8, 10.3); p < 0.001
Functional Movement Motor Screen – Right Upper Extremity	3.1 (0.3, 5.9); p = 0.02	3.3 (1.4, 5.2); p = 0.001	6.5 (4.2, 8.7); p < 0.001
Functional Movement Motor Screen – Left Lower Extremity	0.3 (-1.7, 2.4); p = 0.75	1.4 (-0.7, 3.7); p = 0.19	1.8 (-0.7, 4.3); p = 0.15
Functional Movement Motor Screen – Right Lower Extremity	0.6 (-1.2, 2.6); p = 0.48	0.6 (-0.5, 1.9); p = 0.26	1.3 (-0.8, 3.5); p = 0.21
T Test	-0.6 (-0.9, -0.4); p < 0.001	-0.1 (-0.2, 0.03); p = 0.11)	-0.8 (-1.0, -0.5); p < 0.001
Vertical Jump Block Test	-0.08 (-0.7, 0.5); p = 0.79	0.9 (0.4, 1.5); p = 0.002	0.9 (0.3. 1.4); p = 0.002
Vertical Jump – Approach Method	-0.2 (-0.9, 0.4); p = 0.41	0.7 (0.1, 1.3); p = 0.02	0.4 (-0.2, 1.0); p = 0.17

Data are reported as mean difference based on estimated marginal means (95% confidence interval).

DISCUSSION

Based on an extensive literature review, this study is the first investigation of the FMS as a predictor of in-season injury exclusively in adolescent female volleyball players where changes in FMS scores, along with other physical performance measures, were analyzed at pre, mid, and post-season intervals. The findings indicate that FMS composite score was not a predictor of in-season injury. Statistically significant improvements were observed at various time points for all outcome measures, except vertical jump using the approach method.

The results of our study were similar to the findings of previous research, with some differences. Dorrel et al[36] examined the ability of the FMS to predict injury in National Collegiate Athletic Association athletes and reported an AUC for musculoskeletal injury of 0.544 (95% confidence interval = 0.47, 0.61). In our study, the AUC for musculoskeletal injury was 0.480 (95% confidence interval = 0.282, 0.678). The ROC curve analyses by Dorrel et al[36] found that the optimal cut-off score for the FMS to predict musculoskeletal injury was 15, with a sensitivity of 0.62 and specificity of 0.49. Similarly, we identified a FMS cut-off score of 15.5 for predicting musculoskeletal injury (sensitivity = 0.462, specificity = 0.440). A considerable difference between our study and Dorrel et al[36] was the characteristics of the study participants.

When evaluating vertical jump changes, statistically significant improvements in vertical jump block test scores were found ($p = 0.001$), but no statistically significant changes were observed in vertical jump using the approach method ($p = 0.08$). Sattler et al[30] investigated the reliability of these two vertical jump tests and reported coefficients of variation (CV) for the block test and approach method as 2.1% and 2.8%, respectively. Although both tests have demonstrated acceptable reliability, the small degree of measurement error may explain why changes in vertical jump using the approach method approached statistical significance, but did not reach the alpha level threshold of 0.05. Also, one could infer that the mean differences and 95% confidence intervals are comparable between the two tests, from a clinical interpretation standpoint (see Table 2).

The clinical importance of the findings of this investigation was considered. Statistical methods such as the ROC curve, AUC, sensitivity, and specificity can be used to examine the accuracy of a test to diagnose a condition or predict an outcome. In our study, the AUC represented the probability of the FMS to differentiate between individuals who were at risk of sustaining a musculoskeletal injury. The AUC of 0.480 suggested that the FMS would correctly identify at-risk athletes 48% of the time (slightly less than random chance). One could also infer that the sensitivity (0.462) and specificity (0.440) of the FMS was not clinically acceptable. Based on these data, we suggest that the FMS should not be used as a tool to identify national adolescent female volleyball players who are at risk of a musculoskeletal injury. Regarding changes in FMS scores, Chimera et al[35] reported that the MCID for the FMS composite score was 1.25 for decreasing risk of injury. In our study, we found a mean difference in FMS composite scores between post-season and pre-season of 1.2 with a 95% confidence interval of 0.5 - 1.8. Based on the mean difference and 95% confidence interval, group gains in FMS composite scores may or may not have been clinically important. Of the 37 study participants with complete pre-season and post-season FMS composite score data, 18 participants (approximately 48.6%) experienced an improvement of greater than 1.25. These data indicate that approximately half of the study participants experienced a clinically important gain in FMS composite scores. Future studies are warranted to identify sub-groups of adolescent female volleyball players who are most likely to experience an improvement in composite scores of the FMS over the course of a season.

The limitations of this study were also given consideration. One possible limitation of this investigation was that injury data were collected using a questionnaire as opposed to a more objective means, such as diagnostic imaging. A detailed questionnaire was administered to the athletes, which served as a self-report of injuries that occurred during matches and practices across the entire volleyball season. Questionnaire items included clear information such as when the injury occurred (for example, during practice), the mechanism of the injury, the body region of injury (for example, shoulder), and the result of the injury (for example, localized pain or loss of function). The study investigators (physical therapists) reviewed the questionnaires at the conclusion of the study to accurately classify injuries and to exclude injuries that were not musculoskeletal (for example, concussion) or injuries that were not volleyball-related. Future research may include methods for addressing these limitations, such as the use of x-ray or magnetic resonance imaging to confirm musculoskeletal trauma.

CONCLUSION

In conclusion, the main findings of this study indicate that the FMS is not a predictor of in-season injuries in female adolescent volleyball players. A secondary finding was that FMS scores can improve over the course of a season, along with other performance measures. Thus, the FMS may be used to measure quality of movement over time, but not as an assessment to predict injury.

ACKNOWLEDGMENTS

None.

FUNDING

The authors declare that no funding was received for this study.

CONFLICTS OF INTEREST

All authors declare that they have no conflicts of interest.

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