ISSN: 2469-5718

Lin and Guan. Int J Sports Exerc Med 2024, 10:270
DOI: 10.23937/2469-5718/1510270
Volume 10 | Issue 1
Open Access

International Journal of
Sports and Exercise Medicine

ORIGINAL RESEARCH

Injury Prediction Study Using Functional Movement Screen (FMS) in Adolescent Racket Sports Enthusiasts

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Abstract

This study utilized the Functional Movement Screen (FMS) to assess the athletic ability of adolescent racket sport athletes and explored its association with injury risk. The results indicate that shoulder mobility (2.58 ± 0.57) and active straight leg raise (2.38 ± 0.74) scored the highest, while deep squat (2.08 ± 0.83), in-line lunge (1.98 ± 0.75), and rotary stability (1.62 ± 0.49) were comparatively lower. The ROC curve analysis yielded an AUC of 0.779 (95% CI: 0.639-0.919, P < 0.001), suggesting a significant predictive value for injury risk. Athletes scoring ≤ 15 points on the FMS exhibited a higher risk of injury, with a relative risk (RR) of 1.58. The findings emphasize the importance of core strength and lower limb stability training, along with optimized warm-ups and technical guidance, to reduce injury risks among young athletes. These insights offer theoretical support for future training and rehabilitation strategies.

Keywords

Functional Movement Screen (FMS), Injury prediction, Adolescent, Racket sport, Physical fitness

Introduction

Research background

In recent years, the Functional Movement Screen (FMS) has become an essential tool for assessing the injury risk of athletes, particularly in adolescent athletic populations. FMS evaluates seven key movements to detect individuals' functional abilities, movement patterns, and asymmetries, helping to identify potential injury risks. In the fields of sports medicine and exercise science, FMS scores have been widely used to predict the occurrence of non-contact sports injuries, especially among adolescent athletes with poor movement patterns or functional deficiencies [1,2].

Research questions and objectives

Some studies have shown a significant association between FMS scores below 14 and a higher risk of sports injuries. Among adolescent athletes, individuals with lower FMS scores are more prone to overuse injuries in areas such as the knees and ankles [3]. Additionally, FMS scores are correlated with athletic performance, with higher-scoring athletes typically demonstrating better flexibility, balance, and strength control [4]. The objective of this study is to validate the application of FMS among adolescent racket sports enthusiasts, explore its relationship with injury risk, and provide theoretical support for training and injury prevention strategies for this group.

Significance of the study

Systematic reviews and meta-analyses have found that FMS not only effectively predicts sports injuries but also serves as a tool for evaluating the outcomes of training interventions, aiding in the design of more targeted training and rehabilitation programs for adolescents [5]. Although FMS has shown promise in predicting sports injuries, there are ongoing debates regarding its sensitivity and specificity across different genders, age groups, and sports types. Some studies suggest that the predictive ability of FMS may differ between male and female athletes, and its applicability

Citation: Lin Y, Guan S (2024) Injury Prediction Study Using Functional Movement Screen (FMS) in Adolescent Racket Sports Enthusiasts. Int J Sports Exerc Med 10:270. doi.org/10.23937/2469-5718/1510270

Accepted: December 04, 2024; **Published:** December 06, 2024

Table 1: Basic information of participants.

Basic Indicators	Minimum	Maximum	$\overline{\chi} \pm S$	P value
Height (M)	1.50	1.78	1.67 ± 0.59	0.241
Weight (KG)	43.70	69.40	57.48 ± 6.36	0.347
BMI	17.15	23.19	20.58 ± 1.48	0.061
Years of Sports Experience	1	4	2.60 ± 0.84	-

to different types of athletes requires further validation [2,3]. However, there is limited research focusing on adolescents with regular exercise habits. Compared to professional athletes, adolescent sports enthusiasts represent a larger population. Therefore, further research is needed to provide theoretical support for preventing injuries in this group and to confirm the general applicability of FMS.

Research Subjects and Methods

Research subjects

The subjects of this study are adolescents who are racket sports enthusiasts, and the objective is to predict injury risks using FMS. A total of 53 middle school students from a city were randomly selected, all of whom had more than one year of experience in racket sports. Participants were required to have no history of major surgery or prolonged rehabilitation in the past year, and all subjects consented to participate in interviews and signed informed consent forms. Their baseline information is shown in Table 1, and no significant statistical differences were found among the measured indicators prior to the tests.

Research methods

Literature review method: This study used databases including CNKI, Web of Science, PubMed, and Elsevier to search for literature with keywords such as “Functional Movement Screen,” “sports injuries,” “badminton,” “table tennis,” “tennis,” and “racket sports.” Relevant books and articles were also reviewed to understand FMS assessment methods and scoring systems, as well as factors related to sports injuries, providing a theoretical foundation for this research.

Testing method: In strict accordance with the FMS standards, 53 adolescent racket sports enthusiasts were evaluated using the Functional Movement Screen [6-8]. Before the tests, the content, procedures, and precautions were explained to participants in detail, with demonstrations provided as well.

FMS consists of seven movements: shoulder mobility, active straight leg raise, rotary stability, trunk stability push-up, in-line lunge, hurdle step, and deep squat. The deep squat and trunk stability push-up are symmetrical movements, while the others are asymmetrical, requiring separate assessments for both sides of the body. Additional exclusion tests were conducted for shoulder mobility, rotary stability, and trunk stability push-up to identify specific limitations.

For scoring, each movement was evaluated on a scale from 0 to 3 points:

- 3 points: The participant performed the movement correctly.
- 2 points: Compensatory movements occurred.
- 1 point: The movement was not completed.
- 0 points: Pain occurred during the movement.

Each movement was tested three times, with a maximum score of 21 points. To ensure data consistency, all tests and records were conducted and documented by the same researcher. The testing equipment included the FMS kit (approximately 1.2m long rods, short rods, a 0.6m × 1.8m testing board, and elastic cords) and a Nikon D7500 camera.

Statistical analysis method: SPSS 29.0 was used to analyze baseline information and FMS scores. Normally distributed data were expressed as X ± S, while non-normally distributed data were expressed as quartiles (Q1/Q2/Q3). The critical value for injury risk was determined using the Receiver Operating Characteristic (ROC) curve and the Youden index. Chi-square tests were used to compare the injury risks between athletes scoring above and below the FMS threshold, with relative risk (RR) and 95% confidence intervals (CI) calculated. Logistic regression analysis determined the influence of FMS scores on injury risk, with odds ratios (OR) used to assess injury risk in adolescent racket sports training.

Interview method: In this study, injuries were defined as any physical damage caused by racket sports, excluding those resulting from traveling, falls, or other accidents. Semi-structured interviews were conducted to collect participants’ injury history, affected areas, and causes. The participants were adolescents who regularly engaged in badminton, table tennis, or tennis.

The interview questions were designed based on relevant literature and research objectives, aiming to gain a deeper understanding of participants’ injury experiences and contributing factors. Core questions were asked to all participants, with additional questions tailored to each individual’s circumstances.

The interview questions included the following:

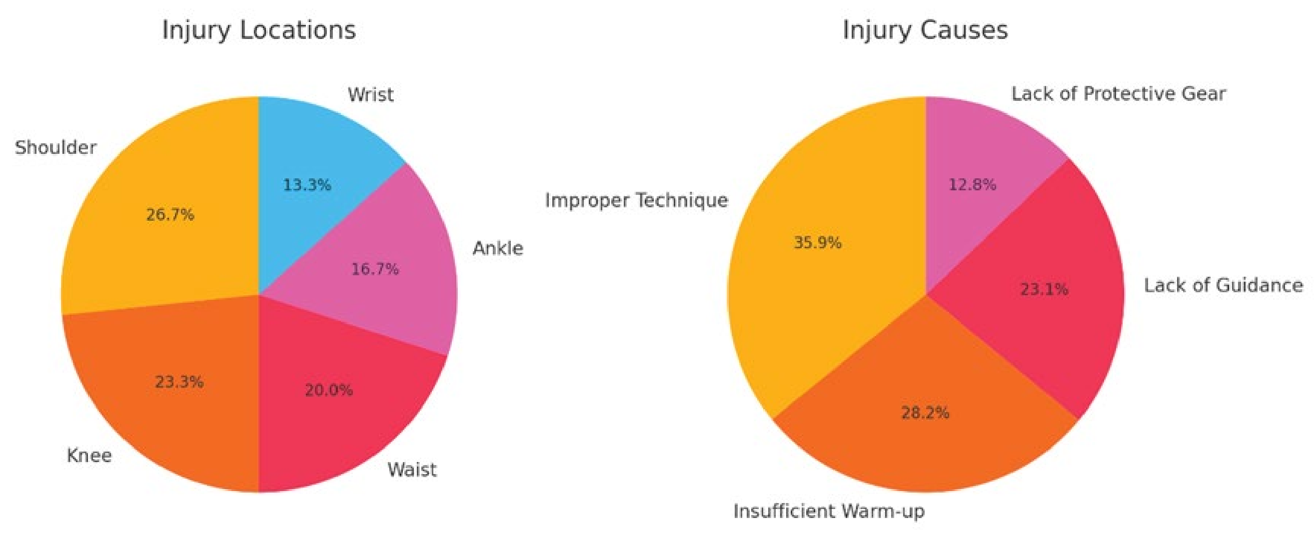

Figure 1: Distribution of injury sites and causes among adolescents.

Table 2: Distribution of total FMS scores among 53 adolescents.

FMS score	n	Percentage/%
More than 18 points	1	1.9%
18 points	1	1.9%
17 points	2	3.8%
16 points	11	20.8%
15 points	11	20.8%
14 points	12	22.6%
13 points	9	17.0%
12 points	3	5.7%
Less than 12 points	3	5.7%

1. In which sports have you sustained injuries? Please describe the injured areas (e.g., shoulder, knee, ankle).
2. What do you think were the primary causes of these injuries (e.g. overtraining, improper technique, environmental factors)?

The interviews were conducted in small groups, with each session lasting 10 minutes. The researcher interviewed participants individually in a quiet, private setting, ensuring they could express themselves comfortably. All interviews were recorded and transcribed for subsequent data analysis.

Research Results

Interview results of adolescents

Distribution of injury sites among adolescents: The interview results showed that the most frequently reported injury sites were the shoulders and knees. Specifically, shoulder injuries were reported by 21 participants (40%). Since the shoulder is heavily utilized in racket sports such as badminton and tennis, excessive use and improper techniques place significant strain on the joint. Knee injuries were reported by 19 participants (35%). During rapid starts and stops in sports like badminton and tennis, the knees endure considerable twisting forces, increasing the risk of injury. Lower back injuries were reported by 16 participants (30%). As the core is involved in frequent rotations and bending, this region is prone to strain. Ankle injuries were reported by 13 participants (25%). Ankle injuries often result from instability or insufficient preparation during sudden directional changes or jumps. Wrist injuries were reported by 11 participants (20%). Improper technique or lack of guidance can lead to overuse injuries in the wrist, given the torque it endures during racket swings (Figure 1).

Causes of injuries from interviews: Interviews with 53 adolescents identified key factors contributing to sports injuries. Improper technique was mentioned by 28 participants (52.8%) as the main cause of injury, especially during swings, sudden stops, and turns. These improper movements increased the risk of shoulder, knee, and back injuries. Insufficient warm-up was cited by 22 participants (41.5%). Inadequate preparation left joints and muscles unready for high-intensity sports loads, especially contributing to knee and ankle injuries. Lack of professional guidance was mentioned by 18 participants (34%). Beginners, in particular, found it challenging to master proper techniques without professional training, leading to injuries. Absence of protective gear was reported by 10 participants (18.9%). The lack of protective gear, such as knee pads, ankle supports, or wrist braces, increased the risk of acute injuries, especially during high-intensity sports activities.

Basic results of FMS testing

Distribution of total FMS scores among adolescents: The FMS scores of 53 participants are summarized in Table 2. The most common score was 14 points, with 12 participants (22.6%). The next most frequent scores were 15 points and 16 points, each with 11 participants

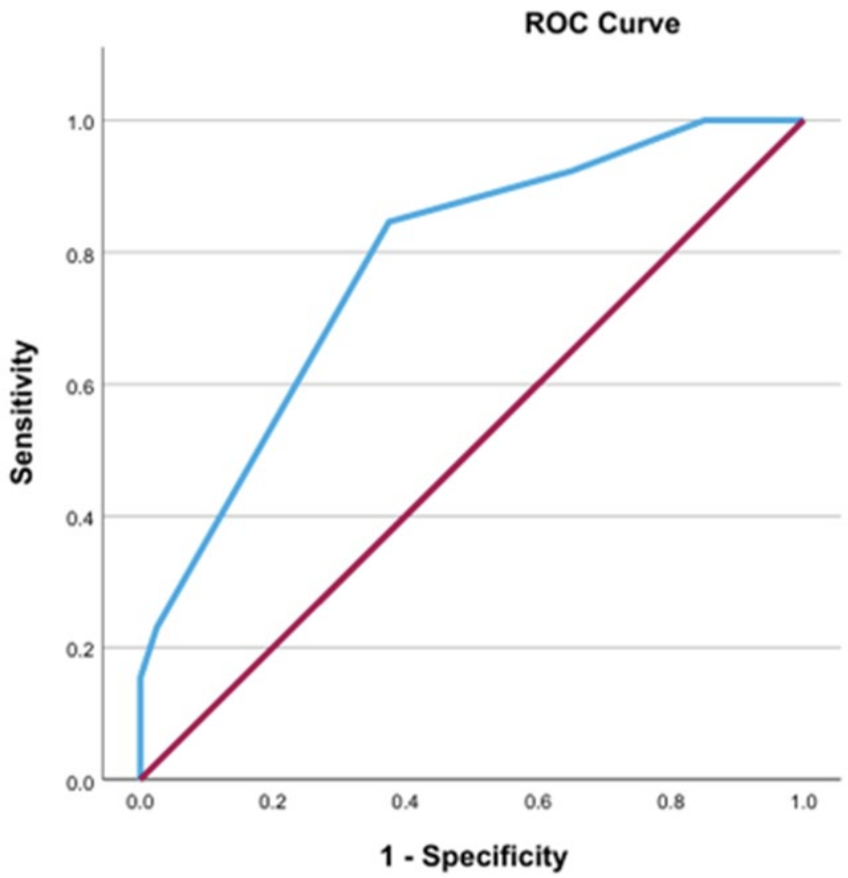

Figure 2: ROC curve diagram.

Table 3: Distribution of individual FMS scores among 53 adolescents.

Action pattern	**Action score/ (Q1/Q2/Q3)**	**Score proportion/%**			$\overline{\chi} \pm S$
		3	**2**	**1**	
Deep squat	1/2/3	37.7	32.1	30.2	2.08 ± 0.83
Hurdle step	2/2/3	28.3	49.1	22.6	2.06 ± 0.72
In-line lunge	1/2/3	26.4	45.3	28.3	1.98 ± 0.75
Shoulder mobility	2/3/3	62.3	34	3.8	2.58 ± 0.57
Active straight leg raise	2/3/3	52.8	32.1	15.1	2.38 ± 0.74
Trunk stability push-up	1/2/2	3.8	67.9	28.3	1.75 ± 0.52
Rotary stability	1/2/2	0	62.3	37.7	1.62 ± 0.49

Table 4: Area of the ROC curve.

AUC	**SE**	**P value**	**95%CI**	
			Lower	**Upper**
0.779	0.072	P < 0.001	0.639	0.919

(20.8%). The average score was 14.45 ± 1.70 with quartiles (Q1/Q2/Q3) of 13/14/16. The highest score was 19 points, achieved by only one participant, while three participants scored as low as 11 points. No participants achieved a perfect score, and the distribution suggests that fewer participants reached the higher score range.

Distribution of scores in individual FMS components: The individual FMS scores of 53 participants, as shown in Table 3, revealed variability in functional abilities. Shoulder mobility (2.58 ± 0.57) and active straight leg raise (2.38 ± 0.74) showed relatively good performance. Specifically, 62.3% of participants scored 3 points in shoulder mobility, and 52.8% achieved 3 points in the straight leg raise. Lower scores were observed in rotary stability (1.62 ± 0.49) and trunk stability push-ups (1.75 ± 0.52). Notably, 37.7% of participants scored only 1 point in rotary stability. Tests related to lower limb stability, such as in-line lunge (1.98 ± 0.75), hurdle step (2.06 ± 0.72), and deep squat (2.08 ± 0.83), also showed significant variability. For example, 49.1% of participants scored 2 points in the hurdle step, while 30.2% scored only 1 point in the deep squat.

These results highlight that participants performed better in flexibility tests but displayed notable weaknesses in core stability and lower limb control. These findings underscore the importance of improving core strength and lower limb stability to reduce the risk of injury.

ROC curve and injury threshold results

ROC curve analysis: Data analysis using SPSS 29.0 produced the ROC curve results shown in Table 4 and Figure 2. With an area under the curve (AUC) between 0.7 and 0.9, the model demonstrated good predictive value. The AUC value for adolescents was 0.779 (SE = 0.072, 95% CI: 0.639-0.919, P < 0.001), indicating that the model has statistically significant predictive ability for injury risk.

Injury threshold results: Based on ROC curve analysis, as shown in Table 5, the optimal threshold for predicting injury risk was determined to be an FMS total score of 14.5. At this threshold, the sensitivity was 0.846, specificity was 0.625, and the Youden index reached 0.471. Given the integer nature of FMS scoring, a score of 15 points was selected as the cutoff for distinguishing high-risk individuals. Adolescents scoring below 15 points should be considered at increased risk of injury.

Comparison of injury rates between two groups

Using 15 points as the threshold, participants were divided into two groups: Those scoring above 15 and those scoring 15 or below. The injury rate in the ≤ 15 group was 84.2%, while the rate in the > 15 group was 53.3%. These findings indicate that adolescents with lower FMS scores are more likely to experience injuries, with a calculated relative risk (RR) of 1.58, meaning that adolescents scoring ≤ 15 points are 1.58 times more likely to suffer injuries than those scoring above 15 points. The chi-square test results are shown in Table 6.

Evaluation of injury risk based on different movement patterns: Binary logistic regression analysis was used to determine the predictive value of the seven FMS movements for injury risk, as shown in Table 7. Key findings include: deep squat (OR = 0.246, P = 0.032), where each 1-point reduction in the deep squat score increases the likelihood of injury by 4.06 times; in-line lunge (OR = 0.124, P = 0.008), where each 1-point reduction in the lunge score raises the injury risk by 8.06 times; and rotary stability (OR = 0.118, P = 0.039), where a 1-point reduction increases the risk by 8.47 times.

These results suggest that deficits in core strength, lower limb stability, and whole-body coordination significantly raise the risk of injuries. Training programs for adolescents should prioritize improving these movement patterns to reduce injury risks effectively. Other movements, such as hurdle step and shoulder mobility, showed some trends but did not reach

Table 5: ROC curve coordinates and Youden index.

FMS total score	Sensitivity	1-Specificity	Specificity	Youden's Index
10.0000	1.000	1.000	0.000	0.000
11.5000	1.000	0.925	0.075	0.075
12.5000	1.000	0.850	0.150	0.150
13.5000	0.923	0.650	0.350	0.273
14.5000	0.846	0.375	0.625	0.471
15.5000	0.538	0.200	0.800	0.338
16.5000	0.231	0.025	0.975	0.206
17.5000	0.154	0.000	1.000	0.154
18.5000	0.077	0.000	1.000	0.077
20.0000	0.000	0.000	1.000	0.000

Table 6: Chi-square test results for FMS total score grouping.

Variable	Pearson Chi-Square (X^2)	df	P value
FMS Total Score (≤ 15 vs. > 15	5.539	1	0.019

Table 7: Logistic regression analysis of the impact of different movement patterns on sports injuries in adolescents.

Action pattern	OR	95% CI		P value
		Lower	Upper	
Deep squat	0.246	0.068	0.884	0.032
Hurdle step	0.357	0.093	1.372	0.134
In-line lunge	0.124	0.026	0.580	0.008
Shoulder mobility	1.231	0.268	5.644	0.789
Active straight leg raise	0.582	0.165	2.050	0.399
Trunk stability push-up	0.733	0.127	4.245	0.729
Rotary stability	0.118	0.015	0.901	0.039

statistical significance (P > 0.05), suggesting their predictive value is relatively limited.

Discussion

With the increasing popularity of sports programs in schools and the continuous improvement of facilities, students are actively engaging in various sports. However, the rate of sports injuries has also risen. This study used the Functional Movement Screen (FMS) as a tool to evaluate the athletic abilities and injury risks of adolescent racket sports enthusiasts. The results indicate that both total and individual FMS scores are closely related to the risk of sports injuries among adolescents, with a cutoff score of 15 points identified as the injury risk threshold.

Previous research reported varying injury thresholds based on different sports and athlete populations. For example, Linxian Fu [9] found a threshold of 17 points with a risk ratio (RR) of 13 in badminton athletes [9]. Meanwhile, Kangkang Zhou [10] identified 12 points as the injury threshold for elite table tennis athletes, with an RR of 28.5 [10]. For professional football players, two studies by Kiesel, et al. [11,12] found 14 points to be the injury threshold [11,12]. Similarly, Mokha, et al. [13] suggested a threshold of 14 points for collegiate athletes in sports like football, volleyball, and rugby [13] Studies on non-athlete populations, such as coast guard trainees and soldiers, found the same 14-point threshold [14,15]. In other research, firefighters were found to have an injury threshold of 15 points [16], while military recruits had a threshold of 13 points [17]. A meta-analysis also indicated that the effectiveness of FMS as a direct injury prediction tool may vary across populations and contexts due to study heterogeneity [18].

This study analyzed the FMS results and injury risks of 53 adolescent racket sports enthusiasts. Common injury sites included the shoulders, knees, ankles, and lower back, accounting for 26.7%, 23.3%, 16.7%, and 20.0% of reported injuries, respectively. The primary causes of injuries were identified as improper technique (35.9%), insufficient warm-up (28.2%), lack of guidance (23.1%), and insufficient use of protective gear (12.8%).

The results highlight that participants performed well in shoulder mobility (average score: 2.58 ± 0.57) and active straight leg raise (2.38 ± 0.74). These results are likely associated with the rapid growth phase of adolescents, during which joint and soft tissue development may be uneven. However, lower scores in deep squats (2.08 ± 0.83) and in-line lunges (1.98 ± 0.75) were strongly correlated with higher rates of knee and ankle injuries. This suggests that deficiencies in lower limb strength and control may increase the risk of injuries. The findings align with previous studies, which indicate that weak ankle mobility and improper lower limb mechanics are linked to ankle instability and knee injuries [19].

The occurrence of lower back injuries was associated with weak core stability, as reflected in the low average score for trunk stability push-ups (1.75 ± 0.52). Frequent rotational movements in sports like badminton and table tennis may exacerbate fatigue and strain in the lower back [20].

Conclusion

This study demonstrates that the FMS test effectively predicts the risk of sports injuries among adolescent racket sports enthusiasts and identifies key movement patterns linked to injury. Common injury sites included the shoulders, knees, ankles, and lower back. The primary causes were found to be improper technique, insufficient warm-up, and lack of guidance. The higher scores in shoulder mobility and straight leg raise reflect the participants' strengths in flexibility, but their weaknesses in lower limb stability and core strength significantly increased the risk of knee and lower back injuries.

Based on these findings, future research should focus on optimizing the use of FMS in racket sports, particularly by exploring the specific movement demands of different sports. Additionally, personalized training and rehabilitation programs should be developed to address the developmental characteristics of adolescents during growth spurts, with a focus on enhancing core strength and lower limb stability to prevent injuries. Longitudinal studies with larger sample sizes will further validate the predictive validity of the FMS and support the development of effective injury prevention strategies.

Given the low cost and ease of administration, the FMS test is recommended as a regular screening tool for coaches and teachers to monitor the athletic health of adolescent racket sports enthusiasts and prevent injuries. In this study, a total FMS score of 15 points was identified as the injury risk threshold, providing a valuable reference point for assessing the risk of sports injuries among young athletes.

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