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Research article

The functional movement screen predicts sports injuries in Chinese college students at different levels of physical activity and sports performance

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ABSTRACT

Background: Functional Movement Screen (FMS) is used to evaluate the movement quality of an individual. However, the FMS composite score used to predict sports injuries is currently ambiguous. Further refinement of the FMS scoring method may be required to more accurately predict sports injuries.
Objectives: To investigate whether FMS scores could accurately predict sports injuries in college students with different levels of physical activity (PA) and sports performance (SP).
Methods: One hundred eighty-seven college students aged 18 to 22 were prospectively screened by the FMS test and grouped by the levels of PA and SP. Sports injury occurrences were monitored and collected 12 months later. Spearman's rank coefficients and binary logistic regression were used to identify the risk factors for sports injuries. The receiver operating characteristic (ROC) curve and the total area under the curve (AUC) value were used to determine the optimal FMS cut-off point for sports injuries.
Results: The FMS composite score (sum of the seven FMS tests) exhibited a fair association with sports injuries ($r = -0.434$, $P < 0.001$). Those with an FMS cut-off point of 17.5 were more likely to acquire sports injuries. The AUC value of the ROC curves was 0.764 (95% CI: 0.618–0.909) in the low PA students, 0.781 (95% CI: 0.729–0.936) in the moderate PA students, and 0.721 (95% CI: 0.613–0.879) in the high PA students. Furthermore, students stratified by SP level showed an AUC value of 0.730 (95% CI 0.607–0.853) in the low SP group and 0.778 (95% CI 0.662–0.894) in the moderate SP group, while it declined to 0.705 (95% CI 0.511–0.800) in the high SP group. The FMS cut-off score successfully identified individuals who reported sports injuries at a higher rate in the low (PA, 84.62%; SP, 90.48%) and moderate (PA, 93.75%; SP, 77.78%) groups than in the high groups (PA, 65.52%; SP, 57.89%).
Conclusions: The FMS composite score could be used to predict sports injuries in college students with an FMS cut-off value of 17.5. Population stratification by the levels of PA and SP seems to influence the predictive accuracy of the FMS.

Abbreviations: FMS, functional movement screen; PA, physical activity; SP, sports performance; ROC, receiver operating characteristic; AUC, area under the curve; DS, deep squat; HS, hurdle step; ILL, in-line lunge; SM, shoulder mobility; ASLR, active straight leg raise; TSPp, trunk stability pushup; RS, rotary stability; body mass index, BMI; IPAQ-LF, the International Physical Activity Questionnaire Long Form; MET, metabolic equivalents of energy; AMPD1, adenosine monophosphate deaminase isoform 1; ACTN3, α-actinin-3; CKM, creatine kinase.

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1. Introduction

The Functional Movement Screen (FMS) is proposed by Gray Cook and Lee Burton to measure and analyze participants' movement deficits [1]. It includes seven functional movements: deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability pushup (TSPp), and rotary stability (RS). The FMS composite score (sum of seven tests) is intended to detect deficiencies in flexibility, balance, core stability, and bilateral strength asymmetries, all of which requires appropriate stability and mobility, and contributes to performance and sports injuries [2]. Because of its acceptable to exceptional inter-rater and intra-rater reliability, FMS is a reliable evaluation instrument [3,4]. Some evidence of its efficacy and reliability for injury prediction has been found in professional and collegiate sports teams, as well as the military [5–7].

Sports injury is generally known as the loss of bodily function or structural damage caused by exercise [8], with the greatest risk being in youth and young adults. In China, for example, 24.2% of ordinary university students suffered at least one sports injury that needed medical care in the preceding year [9]. The burden of sport-related injuries is significant, which may produce substantial pain and a loss in activity capability, resulting in poor sports performance (SP). Avoiding sports injuries is crucial for improving youth health and even potentially cutting medical expenses in communities [10]. Effective athletic injury prevention may imply excellent SP and winning competition rewards for young athletes.

Several studies have shown that an optimal FMS cut-off score of 14 or below in non-contacted and contacted sports such as professional football, rugby, and basketball is associated with an increased risk of injury [11–13]. The FMS cut-off score for Wushu young athletes is 16 [14], whereas for police officers it is 13.5 [15]. Unfortunately, FMS still has been controversial as an injury prediction tool. According to current research, the FMS composite score does not accurately predict sports injury in children or young athletes [16,17], but it does predict better in senior athletes [18]. Researchers propose that the FMS composite score can be replaced with asymmetry or individual FMS score, which may be more effective in predicting sports injuries in collegiate athletes [19]. In addition, an attempt has been made to improve the predicted accuracy of the FMS composite score by breaking down the conception of sports injuries into statistics in elite athletes [20]. Moreover, when the characteristics of adolescents including age, gender, and body mass index (BMI) had been statistically adjusted by machine learning, the FMS score may be more accurate in predicting injury [17]. Physical activity (PA) is one of the most important factors of sports injuries. Subjects with no sports participation had higher injury risk [21]. However, it is currently unclear whether PA and SP can influence the accuracy of FMS in predicting sports injuries.

The aim of this prospective study was to evaluate the prognostic accuracy of the FMS in predicting sports injuries among a sample of young students, who were classified according to their levels of physical activity, and further divided based on their performance levels on the FMS tasks for correlation analysis.

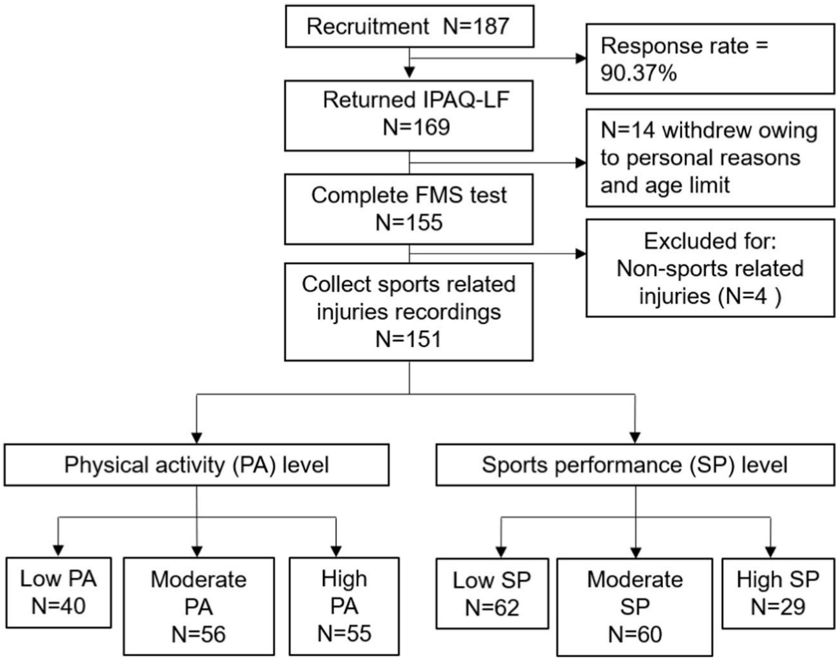

Fig. 1. Flowchart for recruitment in the study. IPAQ-LF indicates The Long Form International Physical Activity Questionnaire. Sports-related injuries generally involve muscle strain, sprain, tendon rupture and fracture, not including delayed muscle soreness and chronic injuries with more than one year in the investigation.

2. Methods

2.1. Participants

The college students and athlete-students from the same university volunteered to participate in this study. One hundred eighty-seven college students between the ages of 18 and 22 who had no acute injuries (such as bone fractures or muscle sprains and ruptures) were recruited. The International Physical Activity Questionnaire Long Form (IPAQ-LF) was distributed to the students, and 169 valid questionnaires were returned (90.37% response rate), despite the fact that 18 participants had blank or incorrect answers. Fourteen students withdrew out of the study due to personal reasons and the age limit (<18 years). A total of 155 students then completed FMS test. Four students were eliminated from the study based on 12-month sports injury records for sports-unrelated injuries. As a result, data from 151 students were included in the statistics, with three levels of SP: those who entered college without any physical training (Low SP; LSP, N = 62), those who had sports training experience for less than three years (Moderate SP; MSP, N = 60), and Wushu and tennis student-athletes who received awards in national competitions and had at least five years of sports training experience (High SP; HSP, N = 29). According to the results of IPAQ-LF, these students were further divided into low PA (LPA, N = 40), moderate PA (MPA, N = 56), and high PA (HPA, N = 55) groups (Fig. 1). The study was carried out according to the Declaration of Helsinki. All participants read and signed an informed consent form approved by the University Medical Ethics Committee (Ethics approval number: 2022048-0).

2.2. Procedures

2.2.1. Functional movement screen and pain screening

To ensure the accuracy of the test, the same expert evaluated the participants immediately after completing each action. The students performed three trials for each movement to obtain the best performance. The lower scores for the left and right limbs were measured and analyzed. The FMS performance is scored on a 0–3 point scale. A score of 3 indicates that the movement was completed correctly, with a maximum score of 21. Score 2 indicates compensatory actions, whereas score 1 indicates that participants are unable to finish the exercise. Any pain detected during the mobility or clearing tests results in an automatic score of 0. The FMS was conducted by two trained physical therapists and administered by the researchers.

2.2.2. Self-reported physical activity assessment

The PA level of the students was determined by the IPAQ-LF questionnaire, which included energy consumption of four types: occupation, transportation, household, and leisure on working days and weekends, as calculated by metabolic equivalents of energy (MET). IPAQ is used as a standardized measure to estimate the customary practice of physical activities among populations of different countries and socio-cultural contexts [22]. Participants reported the frequency (days/week), intensity, and duration (minutes/day) of their activities and rest time over the last seven days to calculate the energy consumption of PA.

The METs coefficient of IPAQ-LF questions was set at 8.0 for vigorous activity, 4.0 for moderate activity, and 3.3 for low activity [23]. According to the calculated energy consumption values, the participants were divided into different PA levels following guidelines of the American College of Sports Medicine:

1) Low physical activity (LPA, 0–599 METs·min/week);
2) Moderate physical activity (MPA, 600–3000 METs·min/week);
3) High physical activity (HPA, ≥3,000 METs·min/week).

2.2.3. Sports injuries recording

To explore the relationship between the FMS score and sports injury risk, physical therapists monitored and recorded sports injuries for 12 months after the FMS test. The definition of a sports injury must include sports-related injuries. It generally involves skeletal muscle strains, sprains, tendon ruptures, and fractures, not including delayed muscle soreness and chronic injuries lasting more than one year.

2.3. Statistical analysis

Microsoft Excel 2019 and IBM SPSS for Windows version 26.0 software were used for record storage and all data analyses. The Shapiro-Wilk test was used to perform normality analysis. The Mann-Whitney U test, a nonparametric approach, was used to compare differences of the FMS scores in the injured and non-injured. To differentiate between injured and non-injured students by exploring the optimal cut-off point for FMS scores, the receiver operator characteristic (ROC) curve and the area under the curve (AUC) was calculated with a 95% confidence interval (CI). The optimal cut-off value is captured by identifying the point with the highest Youden index (J). Correlations of composite score, sports injuries, PA, and SP were analyzed using Spearman's rank coefficients and Binary logistic regression. The predictive accuracy was calculated based on identifying the population with sports injuries. Correlations visualization was carried out based on Python 3.9 and R 4.2 language. The level of significance was set at $P < 0.05$ for all tests.

3. Results

3.1. Descriptive statistics for all variables

The demographic and anthropometric characteristics of the subjects are shown in Table 1, including sex, age, BMI, and FMS score. There was no significant difference in age and BMI. However, sports injuries were found to be occurred more frequently in the HPA group (52.73%) and in the HSP group (65.52%).

The distinctive distributions of the FMS scores in the PA and SP groups were shown in Figs. 2 and 3. Among the different PA groups, the FMS composite score with the largest number of students were on 18 and 19 in the low PA group, 18 in the moderate and high PA group (Fig. 2A). The FMS composite scores with the largest number of subjects in low, moderate, and high SP groups were 18, 18, and 19 respectively (Fig. 2B). The FMS composite score measured for all students was between 9 and 21 (Fig. 2C). The number of students who scored 3 points was low on the RS test in all levels of PA (Fig. 3A) and SP (Fig. 3B).

Fig. 4 showed composite score (Fig. 4A) and seven FMS items scores (Fig. 4B) in injured and non-injured groups. The scores of DS, ILL, SM, and RS were obviously higher in non-injured students ($P < 0.05$; $P < 0.01$; $P < 0.001$).

3.2. Correlation analysis of FMS with PA and SP levels

The correlations were analyzed between composite score, sports injury, SP and PA level in all students using Spearman rank coefficients. A significant correlation between injury and FMS composite score ($r = 0.434$, $P < 0.001$). However, the PA of all students was not related to sports injury and FMS score. Factors of BMI, age, gender and training years were not related to FMS scores and were not listed in the correlation heatmap (Fig. 5).

3.3. FMS predicts sports injury at different PA and SP levels

Once the cut-off score of FMS was established, we calculated the specificity and sensitivity for prediction of sports injury. Through the logistics regression analysis, the results showed that the composite score ($P < 0.001$) and MET ($P = 0.021$) had a specificity of 0.821 and a sensitivity of 0.354 for predicting injury. To further identify the best indicators in FMS, we calculated and found that the AUC values of FMS composite score was 0.743 higher than that of MET with 0.572. After stratifying students by PA level, the AUC value of ROC curve was 0.764 (95% CI 0.618–0.909) in the LPA group, 0.781 (95% CI 0.729–0.936) in the MPA group, and 0.721 (95% CI 0.613–0.879) in the HPA group (Fig. 6A). Furthermore, students stratified by SP level with the AUC value from 0.730 (95% CI 0.607–0.853) in the LSP group and 0.778 (95% CI 0.662–0.894) in the MSP group, while declined the AUC to 0.705 (95% CI 0.511–0.900) in the HSP group (Fig. 6B).

Interestingly, we found that using the ROC curve analysis, the optimal cut-off value of FMS in all college students' groups was 17.5. The prediction accuracy prediction was assessed by successfully identifying populations with sports injuries. The overall predictive rates were relatively higher in LPA, MPA, LSP and MSP groups, as compared with the HPA and HSP groups (Table 2). The FMS cut-off score successfully identified individuals who reported sports injuries at a greater rate in the low (PA, 84.62%; SP, 90.48%) and moderate (PA, 93.75%; SP, 77.78%) groups than in the high (PA, 65.62%; SP, 57.89%) groups.

4. Discussion

The FMS composite score and its predictive potential for sports injuries in college students were evaluated in this study, and it was discovered that the cut-off FMS score was 17.5, and its accuracy and specificity showed significant differences at different levels of PA and SP through logistic regression and the ROC analysis.

The individuals chosen for this research had a mean FMS of 16.87, which was greater than previous studies in college students or student-athletes with an FMS of 14 [24]. Scores 0–2 of FMS indicate a variety of functional movement impairments, including asymmetry, stability, and flexibility during movement, which might contribute to the sports injuries by movement deficiencies and asymmetries. Vehrs et al. categorized the FMS test's different components based on their action characteristics into three subcategories: movement score (DS, HS, and LL), mobility score (SM and ASLR), and stability score (TSPp and RS) [25]. The unusual

Table 1
The demographic and anthropometric characteristics of the students in different PA and SP groups (Mean ± SD).

Groups	LPA	MPA	HPA	LSP	MSP	HSP
N	40	56	55	62	60	29
Age (y)	20 ± 0.92	20 ± 0.78	20 ± 2.03	20 ± 0.76	20 ± 1.01	20 ± 1.00
Sex (man%)	21 (52.50)	25 (44.64)	25 (70.00)	21 (33.87)	43 (71.67)	21 (72.41)
BMI (kg/cm^2)	22 ± 4.30	22 ± 3.06	23 ± 2.97	22 ± 4.20	21 ± 2.00	23 ± 2.98
Injure (%)	13 (32.50)	16 (28.57)	29 (52.73)	21 (33.87)	18 (30.00)	19 (65.52)
FMS composite score	17 ± 2.73	17 ± 2.61	17 ± 2.13	16 ± 3.01	17 ± 1.91	17 ± 1.85

LPA: low physical activity (0–599 METs·min/week); MPA: moderate physical activity (600–3000 METs·min/week); HPA: high physical activity (≥3,000 METs·min/week); LSP: low sports performance; MSP: moderate sports performance; HSP: high sports performance; BMI: Body Mass Index; FMS: Functional Movement Screen.

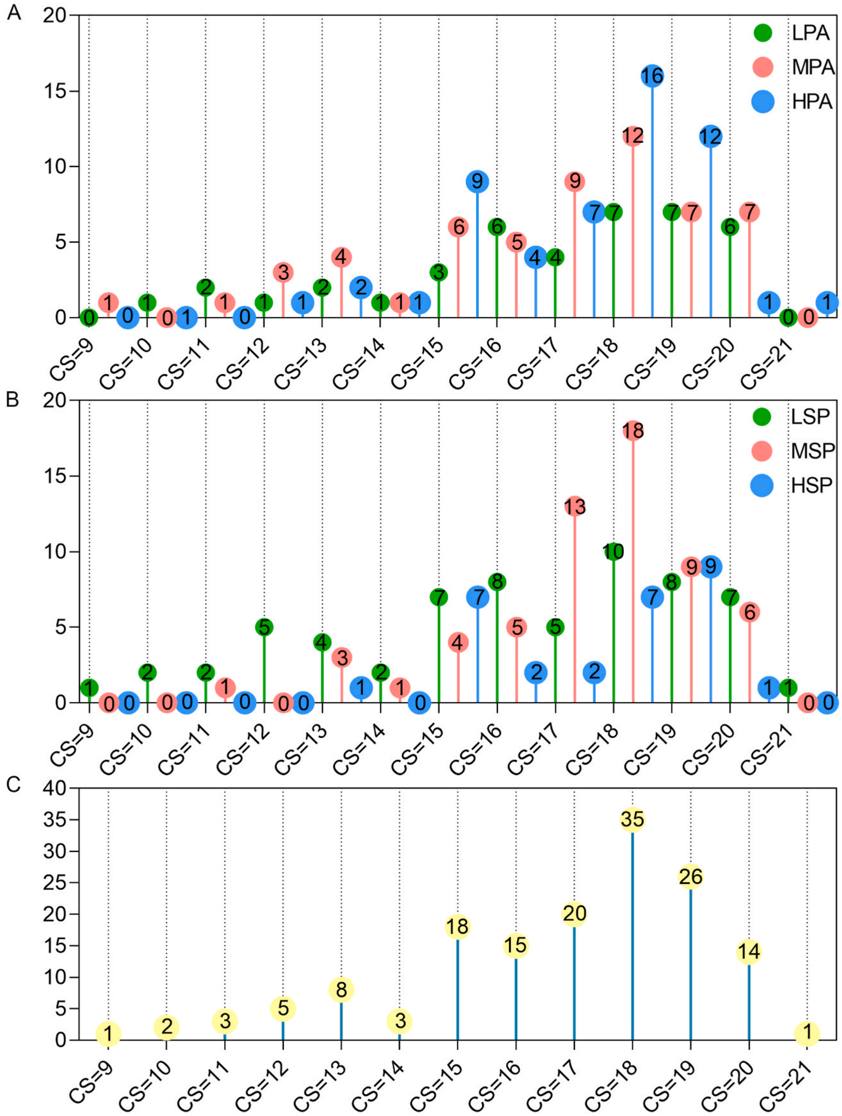

Fig. 2. Distribution of scores of FMS. (A) Distribution of the number of students on the FMS composite scores stratified by PA. CS: sum of the seven individual test movements in the FMS; (B) Distribution of the number of students on the FMS composite scores stratified by SP; (C) Distribution of the number on the FMS composite scores among all students.

distribution of the FMS composite score was associated with lower scores in the DS, ILL, SM, and RS tests, showing that young students should focus on shoulder mobility and stability training to avoid sports injuries. For example, core strengthening exercises [26] or yoga interventions [27].

Athletes with high SP and PA had a greater injury risk in this study (Table 1), which was consistent with previous research findings. The risk of sports injury rises as weekly physical activity time increases, which is a typical dose-response pattern [28]. Furthermore, increasing the amount of time spent performing low-intensity exercise does not substantially increase the risk of sports injuries [28]. Athletes who specialize in sports before the age of 14 and exercise for more than 28 h per week are more likely to report a higher number of total injuries [29]. SP and PA exhibited a weak relationship with sports injuries in this study ($r = 0.202$ & 0.176, $P < 0.05$). However, it is uncertain whether these are the variables that may affect the FMS scores.

The influencing factors of FMS scores were explored in this study. Obesity, age, and physical activity were all shown to have a significant impact on the FMS composite score in previous research. The FMS score in normal-weight children reached 13.9, which was considerably higher than the FMS score in overweight or obese children [30]. Since the in-line lunge, trunk stability push-up, and rotational stability tests were difficult for overweight and obese kids to accomplish [30]. The average FMS score in those over 50 was 12.2 [6], significantly lower than in young adults and adolescents [31–33]. Substantial evidence showed that FMS had no significant relationship with low PA but was highly connected with moderate or above PA in preschool-aged children [34], and in middle-aged healthy people, the greater the amount of exercise activity they did, the higher their FMS score [35]. However, in this study, FMS

Fig. 3. Distribution characteristics of 7 FMS items scores. (A) The number of FMS scores at different PA levels in the 7 items (0–3 points). The columns of each test from left to right were low, model, and high group; (B) The number of FMS scores at different SP levels in the 7 items (0–3 points).

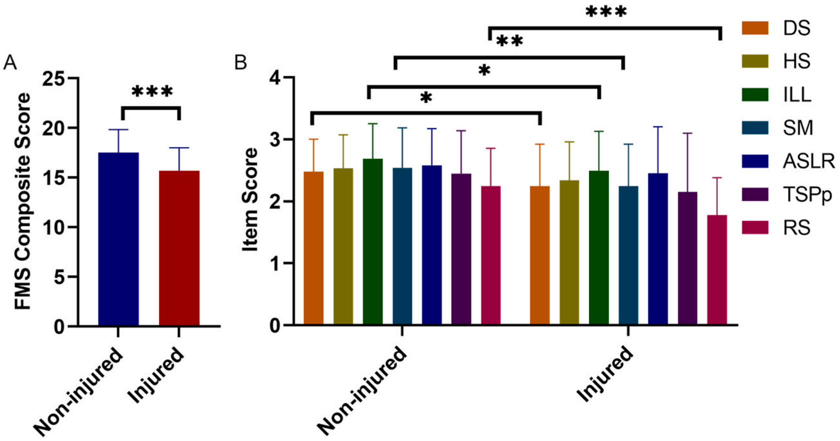

Fig. 4. The differences of FMS composite score and seven FMS items scores in injured and non-injured students. (A) FMS composite score; (B) seven FMS items scores. Data are expressed as mean ± SD. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$. DS: deep squat; HS: hurdle step; ILL: in-line lunge; SM: shoulder mobility; ASLR: active straight leg raise; TSPp: trunk stability pushup; RS: rotary stability.

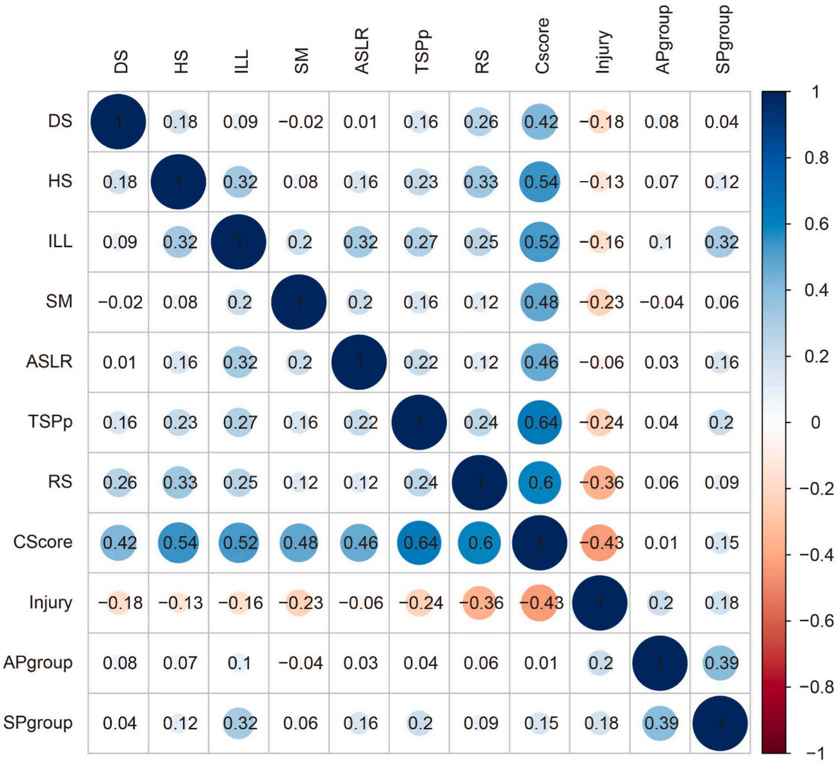

Fig. 5. Correlation heatmap of FMS with PA and SP levels. DS: deep squat; HS: hurdle step; ILL: in-line lunge; SM: shoulder mobility; ASLR: active straight leg raise; TSPp: trunk stability pushup; RS: rotary stability; Cscore: composite score; PA: physical activity; SP: sports performance.

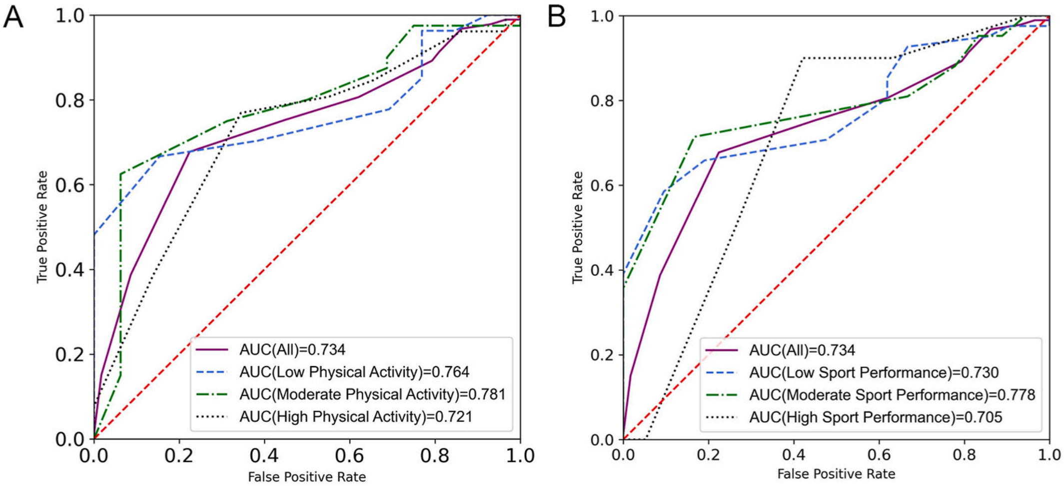

Fig. 6. Cut-off points of FMS at different PA and SP levels established by ROC curve method. (A) FMS cut-off points at PA level; (B) FMS cut-off points at SP level. PA: physical activity; SP: sports performance.

composite scores did not show strong correlations with BMI, age, PA, or SP in correlation analysis. The study found no gender differences in injury or FMS, similar to previous investigations [36].

Regression analysis was further used to show the association between the influencing variables, the FMS scores, and sports injuries. The composite FMS score and the MET value were shown to be more relevant predictors of sports injury than gender, BMI, and age. The FMS composite score was determined to be the best predictor of injury depending on the AUC values as well as the specificity and sensitivity, which is consistent with the findings of a previous study [20].

According to the ROC curve and AUC value in our research, the FMS cut-off score calculated for the prediction of sports injuries was

Table 2
Predictive rate and FMS cut-off value in different PA and SP groups.

Groups	Total number of injuries	Predictive rate %	AUC	Cut-off value of FMS
Low PA	13	84.62%	0.764	17.5
Moderate PA	16	93.75%	0.781	17.5
High PA	29	65.52%	0.721	17.5
Low SP	21	90.48%	0.730	17.5
Moderate SP	18	77.78%	0.778	17.5
High SP	19	57.89%	0.705	17.5
All	58	72.41%	0.734	17.5

PA: physical activity; SP: sport performance; AUC: the total area under the curve; FMS: the functional movement screen.

17.5. Our findings also showed that the FMS score had a moderate correlation with sports injury ($r = -0.434$), which was consistent with the previous study [37]. While the FMS is not a diagnostic tool, it is designed to identify mobility impairments that might lead to injury. As a consequence, poor movement performance during FMS tasks should be considered a risk factor for injury.

Several studies indicated that the FMS score was unlikely to predict sports injury risk in young or elite athletes [18,38]. This might be due to failing to examine the affecting aspects of the FMS score. The FMS score is not linked with low PA in preschool-aged children and adolescents [34], but it is associated with total PA and moderate-to-vigorous PA [39,40]. Although this study demonstrated no apparent association between PA and injury occurrence, when the prediction accuracy was evaluated, the AUC of FMS increased to 0.764 and 0.781 in the LPA and MPA groups, respectively, and decreased to 0.721 in the HPA group. In general, an AUC of 0.7 indicates that the prediction model is of good quality. In this study, the FMS composite score was shown to be an acceptable predictor of injury in groups with low to moderate PA among college students. Either the AUC value or the prediction rate in the current study imply that the FMS composite score may correctly identify people at risk of sports injury as belonging to the low and moderate levels of PA and SP groups.

There are several limitations to the current investigation. First, the number of high SP-level athletes is lower than in other groups. Second, there has been no additional investigation into the validity of FMS individual scores in predicting sports injuries using ROC methods. Several studies have combined FMS test items together or used sub-scores to better prediction of sports injuries. Researchers observe that the seven FMS tasks have poor internal consistency and are not indicative of a single component [31,41], hence individual FMS scores are increasingly being used to predict sports injuries. Individual scores of 1 or asymmetric scores of the FMS test, for example, have been shown to be more acceptable for athletes for sports injury prediction than the FMS composite score [19]. In future research, the individual FMS test for asymmetry and its accuracy in predicting sports injuries might be explored.

Interestingly, genotype is often associated with sports performance. More than 155 genes have been linked to the identity of competitive athletes [42], which may increase the risk of sports injuries. The regulator of skeletal muscle energy metabolism named adenosine monophosphate deaminase isoform 1 (AMPD1) [43], the "speed gene" α-actinin-3 (ACTN3) [44], and the muscle-specific creatine kinase (CKM) are all associated with the endurance and resistance phenotypes [45]. The distribution of allele frequency of these gene polymorphisms might be different between non-injured and injured elite endurance athletes [46]. Therefore, future research may focus on the relationship between FMS scores and genetic and sports injuries.

5. Conclusion

In summary, the current research discovers that an FMS cut-off score of 17.5 is likely to predict sports injuries in college students. Moreover, it seems to appropriately identify college students with low and moderate PA and SP who are at risk for sports injuries. However, this research did not evaluate the validity of FMS individual scores, which might be one of the future improvements to the FMS scoring systems for sports injuries. Further research should also look at the mechanisms of FMS in predicting sports injuries, such as the role of genotype.

Ethics approval and consent to participate

The study was carried out according to the Declaration of Helsinki. All participants and/or their legal guardians consented to participate in the present study and signed an informed consent form that was approved by the medical ethics committee of Wuhan Sports University (ethic approval number: 2022048-0).

Consent for publication

All authors have read and agreed to the publishing of this manuscript.

Availability of data and materials

The data used and/or analyzed during the current study are available from the corresponding author.

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Production notes

Author contribution statements

Hua Liu: Conceived and designed the experiments; Wrote the paper.
Huixian Ding & Junjie Xuan: Performed the experiments.
Xing Gao: Contributed reagents, materials, analysis tools or data.
Xuejuan Huang: Conceived and designed the experiments; Analyzed and interpreted the data.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e16454.

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