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Predictive Value of Functional Movement Screening Combined with Physical Performance Measures for Musculoskeletal Injury Prevention in College Students: A 12-Month Prospective Cohort Study

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Abstract

Background: Musculoskeletal Injuries (MSKIs) significantly impact the functional independence and academic consistency of college students. While the Functional Movement Screen (FMS) is widely deployed to identify movement dysfunctions, its isolated prognostic utility remains highly controversial.

Objective: To determine whether combining the FMS with targeted physical performance measures improves the predictive accuracy for non-contact MSKIs in college students over a 12-month prospective timeline.

Methods: A prospective cohort study evaluated 384 healthy, physically active college students (aged 18-25 years). Baseline assessments included the FMS, Lower Extremity Y-Balance Test (YBT), core endurance tests (flexor, extensor, side planks), isometric hip abductor strength via hand-held dynamometry, ankle dorsiflexion Range Of Motion (ROM) using the weight-bearing lunge test, and single-leg hop test distance. Non-contact MSKIs tracking occurred weekly across 12 months. Multivariable logistic regression and Receiver Operating Characteristic (ROC) curve analysis evaluated predictive models.

Results: Over the 12-month tracking period, 98 participants (25.5%) sustained a verified noncontact MSKI. An isolated baseline composite FMS score ≤14 demonstrated poor discriminative capacity (AUC=0.58, Sensitivity=54.1%, Specificity=61.2%). The integrated multivariable prediction model-comprising the FMS deep squat component (aOR=2.14), YBT anterior asymmetry (aOR=1.88), reduced core extensor endurance (aOR=1.05), and restricted ankle dorsiflexion (aOR=1.42) adjusted for prior injury history-demonstrated excellent discriminative performance (AUC=0.83, Sensitivity=81.6%, Specificity=78.3%).

Conclusion: Standalone FMS scores are insufficient for identifying musculoskeletal injury vulnerability in college students. Incorporating specific localized metrics of dynamic balance, joint mobility, and core endurance within a multi-factorial screening matrix yields a highly sensitive and clinically predictive injury-risk algorithm.

Keywords: Biomechanics; Injury Risk Stratification; Physical Therapy; Prehabilitation; Surface Electromyography

Introduction

Musculoskeletal Injuries (MSKIs) represent a major public health challenge within higher education environments, leading to significant functional deficits, financial strain, and academic disruption. While existing sports medicine literature thoroughly examines tracking paradigms in elite, collegiate, or tactical athletes, the general college student population remains significantly understudied.

Modern college students represent a unique demographic marked by an abrupt lifestyle shift. This transition is frequently characterized by prolonged sitting during study blocks, poor ergonomic postures, and variable participation in unconditioned recreational sports or high intensity fitness trends. This combination of structural deconditioning and sudden physical stress creates a biomechanical environment highly susceptible to overuse and acute musculoskeletal trauma.

To identify movement dysfunctions before they manifest as clinical conditions, clinicians frequently use screening protocols like the Functional Movement Screen (FMS). The FMS evaluates fundamental movement quality across seven patterns to identify mobility deficits, asymmetry, and motor control limitations. However, its isolated predictive accuracy remains a subject of debate in physical therapy literature. Some studies support using a total composite score of ≤14 as a definitive threshold for injury risk, while other robust prospective trials demonstrate negligible predictive value.

This inconsistency stems from the multi-factorial nature of musculoskeletal injuries. Movement quality, while important, represents only one aspect of physical capacity. An individual may demonstrate clean movement patterns during a low-velocity, unweighted test like the FMS, yet exhibit inadequate core endurance, compromised hip abductor torque, restricted ankle mobility, or dynamic balance deficits under high-velocity physical loading. Evaluating the FMS in isolation ignores these interconnected physiological subsystems, resulting in poor screening sensitivity and high false-negative rates.

While existing literature relies heavily on cross-sectional designs, brief follow-up windows, and homogeneous athletic cohorts, there is a clear need for high-quality prospective cohort data detailing the unique musculoskeletal risk profiles of college students. This study addresses these limitations by establishing a comprehensive, multi-dimensional screening matrix. By shifting away from the traditional, reductive binary analysis of the total FMS score, this research uses advanced multivariable modeling to evaluate the independent and collective predictive weight of individual FMS components alongside specific physical performance metrics. The goal is to develop a validated, clinically actionable risk stratification algorithm for physiotherapy settings.

Materials and Methods

Study design and setting

This prospective cohort study was conducted over a continuous 12-month tracking window at an urban institutional health and physical therapy research center. Baseline testing and structural screening protocols occurred between April and June 2025, followed by longitudinal tracking extending through June 2026. The study layout strictly followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort investigations.

Participants and selection criteria

Participants were recruited through institutional networks, digital message boards, and academic wellness platforms.

Inclusion criteria: Full-time undergraduate or postgraduate college students aged 18 to 25 years; self-reported engagement in structured or unstructured physical activity, recreational sports, or fitness training at least three times per week (minimum of 150 minutes of moderate-intensity exercise per week); and asymptomatic status with no physical restrictions limiting daily living or exercise capacity.

Exclusion criteria: History of major orthopaedic surgical interventions to the spine or lower extremities within the preceding 12 months; acute or chronic musculoskeletal pain syndromes; confirmed neurological or vestibular disorders compromising postural stability; systemic metabolic conditions affecting soft tissue healing; and current pregnancy.

A total of 420 students volunteered for initial screening. After applying selection criteria and accounting for baseline dropouts, 384 participants were formally enrolled and completed the full baseline profiling sequence. All participants provided written informed consent prior to data collection.

Operational protocols for predictor metrics

The baseline assessment utilized a standardized battery of six objective physical screening modalities, administered by three physical therapists blinded to each other's measurements.

Functional Movement Screen (FMS)

The FMS protocol was executed using the standard scoring framework described by Cook *et al.,* Participants performed seven movement patterns: Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability Push-Up, and Rotary Stability. Each pattern was scored from 0 to 3 based on established performance criteria.

A score of 0 indicated pain during the movement; 1 indicated an inability to complete the pattern; 2 indicated performance with compensatory adjustments; and 3 indicated flawless execution. The total composite score ranged from 0 to 21. For asymmetrical tests, the lower performing side score was utilized for composite calculation, though individual side metrics were preserved for asymmetry calculations.

Lower extremity Y-Balance Test (YBT)

Dynamic postural stability was quantified using the standardized Y-Balance Test platform. Standing barefoot on the central stance box, participants extended their contralateral limb as far as possible in the Anterior (ANT), Posteromedial (PM), and Posterolateral (PL) directions. Three successful trials were recorded for each direction on both limbs, with the maximum reach distance measured to the nearest 0.5 cm.

Absolute reach distances were normalized to the participant's true limb length (measured from the anterior superior iliac spine to the medial malleolus). The comprehensive YBT Composite Score was calculated using the standard formula:

$YBT\ Composite\ Score$ (%) = $(ANT+PM+PL/3 \times Limb\ Length)$ × 100

Limb asymmetry was calculated as the absolute difference in reach distance (cm) between the left and right lower extremities across the three directions.

Core Muscular Endurance Testing

Core muscular endurance was evaluated using three static holding tests, timed to the nearest 0.01 seconds:

- Trunk Flexor Endurance Test: The participant maintained a static 60° back support tilt angle against a mechanical wedge until failure.
- Prone Plank Test: The participant sustained a rigid prone plank position supported on the forearms and toes. The test was terminated immediately if the pelvic alignment dropped or deviated for more than two consecutive seconds.
- Side Plank Test: The participant elevated the hips into lateral alignment, supported by one forearm and the stacked edges of the feet, performed bilaterally.

Hand-Held Dynamometry (Hip Abductor Strength)

Isometric hip abductor force production was quantified using a calibrated digital Hand-Held Dynamometer (HHD). The participant was positioned in side-lying with the lower limb stabilized, and the HHD was secured via an inelastic strap 5 cm proximal to the lateral malleolus.

Participants performed three Maximal Voluntary Isometric Contractions (MVIC) against the device, pushing upward into abduction for a continuous 5-second window, separated by 60second rest intervals. Peak force values (Newtons) were converted to torque using the individual's measured lever arm length and normalized to total body mass (Nm/kg).

Weight-Bearing Lunge Test (Ankle Dorsiflexion)

Ankle dorsiflexion range of motion was evaluated using the Weight-Bearing Lunge Test (WBLT). The participant positioned their toe away from a wall and performed a forward lunge until the knee made structural contact with the wall, keeping the heel flat on the floor.

The distance between the toe and the wall was advanced progressively until the maximum distance was reached where knee contact was maintained without heel elevation, recorded to the nearest 0.1 cm. Concurrently, a digital inclinometer placed along the anterior border of the tibia captured the maximum angle of ankle dorsiflexion in degrees.

Single-Leg Hop Test for Distance

Functional lower extremity power and unilateral dynamic control were evaluated using the Single-Leg Hop Test for Distance. Participants stood on one leg and performed a maximal forward hop, landing cleanly on the same index limb without losing balance or making compensatory ground contact with the opposite foot. The absolute distance hopped from the starting line to the posterior aspect of the heel was recorded in centimetres. Three successful trials were measured bilaterally, and the Limb Symmetry Index (LSI) was computed:

$$LSI\ (\%) = (Hop\ Distance\ of\ Non-Dominant\ Limb /\ Hop\ Distance\ of\ Dominant\ Limb) \times 100$$

Demographic Data and Covariates

Baseline age, biological sex, body mass index (BMI=kg/m^2), and self-reported physical activity levels via the International Physical Activity Questionnaire Short Form (IPAQ-SF, quantified as MET-min/week) were recorded. Previous musculoskeletal injury history within the past 12 months was captured via a structured intake interview and coded as a binary covariate (Yes/No).

Injury surveillance protocol

The primary dependent variable was the prospective incidence of a new, non-contact musculoskeletal injury sustained during the 12-month observation window. A reportable injury event was defined as any physical complaint involving the muscles, tendons, ligaments, joints, or bone structures sustained during physical activity or daily routines that met the following criteria:

1. Occurred via a non-contact, insidious, or overuse mechanism.

2. Forced the student to modify or completely miss structured physical activity, recreational sports, or routine academic obligations for a minimum of 48 consecutive hours.

3. Required clinical evaluation and verification by the university's sports physical therapy clinic.

Weekly digital surveillance forms were distributed to all participants via an institutional tracking interface. If an injury event was flagged, the participant underwent a standardized clinical assessment within 48 hours by an independent physical therapist blinded to the participant's baseline screening metrics. Clinicians documented the injury localization, structural diagnosis, mechanical onset, and severity based on total time lost from activity:

Mild (2-7 days), Moderate (8-28 days), or Severe (>28 days).

Statistical analysis plan

Statistical processing was performed using SPSS Version 28.0 and R Studio (Version 4.2.1). Continuous variables were analyzed for normality using the Shapiro-Wilk test. Normally distributed metric data were expressed as Means±Standard Deviations (SD), while nonnormal data were presented as medians and interquartile ranges (IQR).

Bivariate differences between the injured and uninjured groups were analyzed using independent-samples t-tests or Mann-Whitney U tests for continuous metrics, and Pearson Chi-Square (χ^2) analyses for categorical variables.

To identify independent predictors of injury, binary logistic regression models were constructed. Model 1 evaluated the standalone predictive capacity of the continuous composite FMS score. Model 2 integrated individual FMS component marks alongside continuous metrics from the YBT, core endurance tests, hip abductor torque, WBLT angles, and hop distance measures, adjusting for baseline covariates (Age, Sex, BMI, IPAQ-SF status, and Prior Injury History). Variable selection utilized a backward step-wise elimination protocol based on likelihood ratio tests (inclusion threshold $p<0.05$, exclusion threshold $p>0.10$). Multicollinearity was evaluated using Variance Inflation Factors (VIF), setting an exclusion threshold at VIF>2.5. Adjusted Odds Ratios (aOR) were reported alongside 95% Confidence Intervals (CI).

Discriminative capacity was evaluated using the Area Under the Receiver Operating Characteristic (ROC) curve (AUC). The optimal clinical cut-off value was calculated using Youden's Index (J=Sensitivity+Specificity-1). Model calibration was checked via the Hosmer-Lemeshow goodness-of-fit test. Internal validation of the final prediction model was performed using a bootstrapping technique with 1,000 resamples to generate bias-corrected estimates for performance metrics.

Results

Cohort characteristics and injury epidemiology

Out of the 384 enrolled participants, 352 (91.6%) successfully completed the entire 12-month prospective tracking cycle. Over the 12-month observation window, 98 participants sustained at least one confirmed non-contact musculoskeletal injury, representing a cumulative incidence rate of 25.5% within the tracked cohort.

Anatomical mapping of the recorded injuries showed a higher prevalence in the lower extremities, with ankle sprains (n=31, 31.6%), hamstring strains (n=24, 24.5%), patellofemoral pain syndrome (n=19, 19.4%), and lumbar muscle strains (n=14, 14.3%) accounting for the majority of events. In terms of clinical severity, 58 injuries (59.2%) were classified as mild, 29 (29.6%) as moderate, and 11

Table 1:

Baseline Assessment Parameter	Injured Group (n=98)	Uninjured Group (n=254)	Statistical Significance (*p*-value)
Age (Years)	21.2 ± 1.8	20.9 ± 1.7	0.16
Body Mass Index (kg/m^2)	24.2 ± 3.1	23.5 ± 2.8	0.04*
Prior Injury History [Yes, %]	42.8%	18.5%	<0.001*
Total FMS Composite Score	13.4 ± 1.6	14.8 ± 1.9	<0.001*
FMS Deep Squat Component Score	1.4 ± 0.5	2.1 ± 0.6	<0.001*
YBT Anterior Reach Asymmetry (cm)	4.8 ± 1.4	2.1 ± 0.9	<0.001*
YBT Composite Score (%)	91.4 ± 5.2	96.8 ± 4.7	<0.001*
Prone Plank Endurance (seconds)	62.4 ± 14.8	84.2 ± 19.3	<0.001*
Hip Abductor Torque (Nm/kg)	0.28 ± 0.06	0.35 ± 0.08	<0.001*
Ankle Dorsiflexion WBLT Angle (°)	34.2 ± 4.1	41.8 ± 4.6	<0.001*
Single-Leg Hop LSI (%)	92.1 ± 4.3	95.6 ± 3.8	0.002*

Statistically significant at the level of $p<0.05$

Table 2:

Retained Independent Predictor	Beta Coefficient (β)	Adjusted Odds Ratio (aOR)	95% Confidence Interval (CI)	Statistical Significance (*p*-value)
Prior Injury History (Yes *vs.* No)	0.982	2.67	1.64-4.35	<0.001
FMS Deep Squat Score (≤1 *vs.* ≥2)	0.761	2.14	1.32-3.47	0.002
YBT Anterior Reach	0.631	1.88	1.21-2.92	0.005
Asymmetry (≥4 cm)				
Ankle Dorsiflexion ROM (≤36°)	0.351	1.42	1.08-1.87	0.012
Prone Plank Endurance (Per 10-s decrease)	0.049	1.05	1.01-1.09	0.038

The Hosmer-Lemeshow test for this combined model yielded a non-significant result (χ^2 = 6.84, p=0.554), indicating acceptable model calibration and agreement between predicted and observed injuries.

(11.2%) as severe.

Bivariate comparison of baseline metrics

Bivariate analyses revealed statistically significant baseline differences between participants who subsequently sustained an injury and those who remained uninjured. The injured cohort demonstrated a lower average composite FMS score (13.4±1.6 *vs.* 14.8±1.9, $p<0.01$), greater asymmetry on the Y-Balance Test, reduced core extensor endurance, lower normalized hip abductor torque, and restricted ankle dorsiflexion range of motion (Table 1).

Multivariable logistic regression models

Binary logistic regression was used to isolate independent predictors and determine whether combining modalities improved injury risk assessment.

Model 1, which evaluated the continuous total FMS composite score in isolation, showed a statistically significant but modest association with injury risk (aOR=1.34, 95% CI=1.12–1.58, p=0.002).

Model 2 evaluated individual FMS component scores alongside localized performance metrics and baseline covariates. After step-wise backward elimination, the final model retained five independent risk predictors: FMS Deep Squat score, YBT Anterior Reach Asymmetry, Prone Plank Endurance, Ankle Dorsiflexion Angle, and Prior Injury History (Table 2).

The Hosmer-Lemeshow test for this combined model yielded a non-significant result (χ^2=6.84, p=0.554), indicating acceptable model calibration and agreement between predicted and observed injuries.

Predictive performance and ROC curve analysis

ROC curve analysis showed a substantial difference in discriminative capacity between the isolated FMS score and the combined screening matrix (Figure 1).

Model 1 (Isolated FMS Composite Score) achieved an Area Under the Curve (AUC) of 0.58 (95% CI=0.51–0.65). Applying the traditional clinical cut-off score of ≤14 yielded a sensitivity of 54.1% and a specificity of 61.2%, indicating limited isolated predictive capability in this cohort.

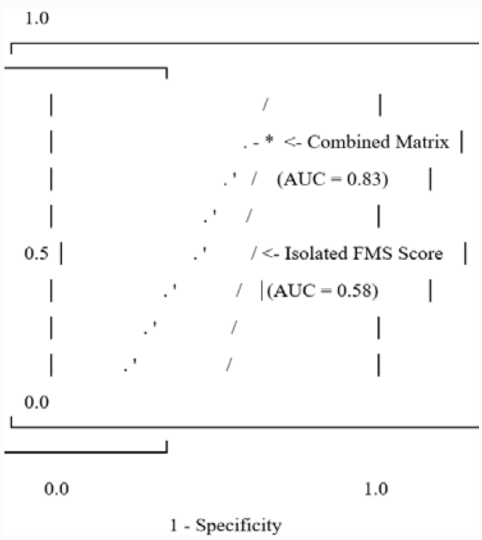

Figure 1: ROC curve discrimination summary.

Model 2 (Combined Screening Matrix) achieved an AUC of 0.83 (95% CI=0.77–0.89). DeLong's test confirmed that this increase in discriminative capacity was statistically significant (Z=4.62, p<0.001). Using Youden's Index, the optimal risk threshold for the combined model demonstrated a sensitivity of 81.6%, a specificity of 78.3%, a Positive Predictive Value (*PPV*) of 64.2%, and a Negative Predictive Value (NPV) of 89.1%. Internal validation *via* bootstrapping (1,000 resamples) demonstrated minimal optimism bias, with a corrected AUC value of 0.81.

Discussion

The primary objective of this prospective cohort study was to evaluate the predictive value of combining the Functional Movement Screen with objective physical performance measures for non-contact musculoskeletal injuries in college students. The results indicate that while the standalone composite FMS score has limited isolated predictive utility (AUC=0.58), integrating specific movement component scores with targeted physical performance measures-such as dynamic balance asymmetry, localized core endurance, and ankle range of motion-significantly improves risk stratification accuracy (AUC=0.83).

Our finding that the isolated composite FMS score possesses poor overall predictive capability is consistent with a growing body of sports medicine literature that questions the traditional cut-off threshold of ≤14. While early studies in elite athletic populations reported strong associations with injury risk, recent systematic reviews and meta-analyses suggest that aggregating seven distinct movement domains into a single composite score masks localized biomechanical vulnerabilities.

For instance, a participant could score poorly on the deep squat due to structural ankle mobility constraints, yet achieve a passing composite score of 15 by compensating with high marks in upper extremity domains. Bivariate analysis in this study supports this hypothesis: the individual FMS deep squat component emerged as a significant independent predictor of injury (aOR=2.14), whereas the total composite score demonstrated limited predictive accuracy.

The superior predictive performance of the combined matrix highlights the multi-factorial nature of musculoskeletal injury mechanisms. In our final regression model, lower extremity dynamic balance asymmetry (≥4 cm difference in the YBT anterior reach direction) significantly increased injury risk (aOR=1.88). Anterior reach asymmetry often reflects a failure of quadriceps neuromuscular control and altered patellofemoral tracking under stress. When this asymmetry is paired with restricted ankle dorsiflexion range of motion (≤36° *via* the WBLT), the kinetic chain undergoes compensatory adjustments. Specifically, limited ankle mobility forces increased knee valgus collapse and rapid subtalar pronation during dynamic activities, increasing mechanical stress on the medial knee structures and plantar fascia.

Additionally, our model identified core muscular endurance (measured via prone plank duration) as a significant independent predictor of injury. Core stability forms the foundation of the kinetic chain; insufficient endurance in the deep stabilizing musculature (such as the transversus abdominis and lumbar multifidus) can lead to uncontrolled pelvic tilting and altered force transmission during movement. This deficit increases shear stresses along the lumbar spine and modifies loading patterns down the lower extremities, elevating the risk of overuse injuries like hamstring strains and patellofemoral pain.

These findings have direct practical applications for institutional health settings and physical therapy clinics. Relying solely on standard FMS screening may lead to missed opportunities for early intervention due to high false-negative rates. Conversely, deploying a comprehensive testing battery allows clinicians to construct a detailed physical profile for each student. Identifying individual biomechanical deficits-such as combining an asymmetric YBT reach with restricted ankle mobility-enables the design of targeted prehabilitation programs to address specific vulnerabilities before structural injury occurs.

Study Limitations

While this study utilized a prospective design and met statistical power requirements, certain limitations should be noted. First, tracking relied partly on self-reported digital forms, which may introduce recall bias, though this was mitigated by requiring confirmation through clinical examinations within 48 hours. Second, while the model adjusted for key covariates like age, BMI, and physical activity volume, it did not account for psychological stress, nutritional variables, or sleep health, which are known to influence musculoskeletal vulnerability in college populations. Finally, because the cohort was drawn from active college students, caution should be exercised when generalizing these specific risk thresholds to elite competitive athletes or completely sedentary groups.

Future research should focus on external validation of this combined prediction model across diverse educational institutions and evaluate the clinical efficacy of targeted prehabilitation programs guided by this screening algorithm.

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