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Research Article

Correlations between functional movement screening, hop distance, flexibility, and pain in collegiate badminton players during an indoor sports event

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ABSTRACT

Badminton is a unilateral, high-speed sport requiring efficient neuromuscular control, lower-limb power, and flexibility. These physical demands predispose players to functional asymmetries and musculoskeletal pain. While Functional Movement Screening (FMS), hop performance, flexibility, and pain have been studied individually in athletic populations, their interrelationship remains underexplored in collegiate badminton players.

To investigate the correlations between selected FMS scores, hop distance, hamstring flexibility, and pain levels in collegiate badminton players during an indoor sports event.

A prospective observational study was conducted among collegiate badminton players. Movement quality was assessed using Deep Squat and Rotary Stability subtests from the Functional Movement Screen. Hop performance was evaluated through single-leg hop for distance on both dominant and non-dominant limbs. Flexibility was assessed using the Sit and Reach test at three intervals: pre-participation, post-participation, and 15 days post-event. Pain was recorded using the Verbal Rating Scale (VRS) at the same intervals. Pearson correlation and descriptive statistics were computed.

Moderate positive correlations were observed between Deep Squat and Rotary Stability scores with hop distance on the dominant limb ($r = 0.36–0.39$, $p < 0.05$), whereas weaker positive relationships were found on the non-dominant side. Sit and Reach scores showed significant inverse correlations with pain post-event ($r = –0.31$, $p < 0.05$) and at 15-day follow-up ($r = –0.48$, $p < 0.05$). Flexibility improved significantly from pre-event to post-event ($p < 0.05$) but showed no further change by 15 days ($p > 0.05$). VRS pain scores decreased significantly across all time points, with the greatest reduction observed at 15 days ($p < 0.001$).

Higher functional movement quality and flexibility are associated with better hop performance and reduced pain in collegiate badminton players. FMS subtests and sit-and-reach testing serve as valuable, low-cost screening tools for functional readiness and pain risk during high-intensity competition. Incorporating these assessments into regular athlete monitoring protocols may enhance performance outcomes and support injury prevention strategies

Keywords: Functional movement screening (FMS), Flexibility, Hop distance, Sit and reach, Verbal rating scale (VRS).

INTRODUCTION

Badminton is a fast-paced, asymmetrical sport characterized by rapid accelerations, decelerations, overhead strokes, and unilateral lower limb loading through lunges and jumps. The dynamic nature of the sport requires athletes to maintain high levels of neuromuscular coordination, balance, flexibility, and lower limb power. These biomechanical and physiological demands often place collegiate badminton players at heightened risk for musculoskeletal injuries, particularly in the knee, ankle, and lower back regions. Previous studies have documented a high prevalence of musculoskeletal complaints among adolescent and collegiate badminton athletes, frequently involving the lower extremities, and these have been closely associated with repetitive overuse, suboptimal movement quality, and muscular imbalances [1].

The Functional Movement Screen™ (FMS) has emerged as a standardized tool to evaluate movement efficiency, detect dysfunctional patterns, and identify athletes at risk of injury. It consists of seven fundamental movement tasks—deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability—each scored from 0 to 3, with a maximum composite score of 21. A score of zero is assigned if the athlete reports pain during a movement, which may indicate an underlying pathology or dysfunction [2]. In collegiate athletic populations, lower FMS scores have been associated with a greater incidence of injury [3]. Notably, Butler et al. demonstrated that in Division I collegiate football players, FMS scores were significantly correlated with single-leg hop distance, triple hop, and crossover hop tests, suggesting that higher quality of movement, as captured by the FMS, may contribute to better functional performance. Interestingly, they found that FMS scores correlated more strongly with hop distance than with isolated strength of the hip or knee, indicating the screen's sensitivity to integrated movement capacity rather than isolated muscle performance [4].

Hop distance testing is a widely accepted method for assessing lower limb functional power and return-to-sport readiness. Tests such as the single-leg hop for distance provide insight into limb symmetry, neuromuscular control, and joint stability. These qualities are critical in a sport like badminton, where explosive single-leg actions dominate movement patterns. While hop performance is often considered a reflection of strength, studies have increasingly highlighted the role of movement quality and flexibility in determining hop outcomes[4]. Moreover, limb asymmetries identified through hop testing can signal risk for future injury, particularly in athletes recovering from lower limb pathology [5].

Flexibility, particularly in the hamstrings and hip flexors, plays an essential role in athletic performance and injury prevention. Limited flexibility can disrupt normal biomechanics, reduce shock absorption capacity, and lead to compensatory movement patterns. In a recent study by Kimura et al., adolescent badminton players with reduced hamstring flexibility and impaired static balance reported significantly higher levels of knee and ankle pain, suggesting that flexibility may be a predictive factor in the development of lower limb symptoms. Similarly, tight posterior chain musculature has been shown to compromise lunge mechanics and increase lumbar spine loading, both of which are critical in badminton due to the frequency of forward lunges and overhead strokes [6].

Pain in badminton athletes frequently manifests during high-intensity training and tournament play, often related to repetitive landing mechanics, poor movement control, or accumulated fatigue. In competitive settings, even subclinical levels of pain may impair performance and increase injury risk. The presence of pain during FMS testing is particularly notable, as any painful movement warrants a zero score and serves as a red flag for deeper clinical assessment[2]. The strong relationship between functional movement quality and pain has been reinforced in studies across various sports, though research specific to badminton remains limited.

Although the individual roles of movement quality, functional strength, flexibility, and pain have been explored to varying extents in different athletic populations, their interrelationships have not been comprehensively studied in the context of collegiate badminton. Given the unique physical demands of the sport, it is essential to understand how these variables interact. Specifically, there is a need to determine whether athletes with poorer movement quality (as assessed by FMS), lower hop performance, or limited flexibility are more likely to report pain during competition. Identifying such correlations could provide valuable insights for targeted screening, injury prevention, and performance enhancement in this population.

Therefore, the present study aims to examine the relationships among Functional Movement Screening scores, single-leg hop distance, hamstring flexibility, and self-reported pain in collegiate badminton players during an indoor sports event. By understanding how these variables interact, this research seeks to inform athlete monitoring protocols and contribute to the development of more individualised, evidence-based intervention strategies for performance optimisation and injury risk reduction.

METHOD AND METHODOLOGY

This prospective observational study was conducted on 105 collegiate badminton players of Dr. Vithalrao Vikhe Patil COPT participating in an indoor sports event. The aim was to explore the correlations between functional movement quality, lower limb power, flexibility, and pain perception during and following athletic participation.

Participants

Eligible participants were collegiate-level badminton players aged between 18 and 25 years, actively competing at the collegiate level. Inclusion criteria required players to be injury-free at the time of testing, with a minimum of two years of competitive experience. Athletes with any acute musculoskeletal injury, history of lower limb surgery, or neurological deficits were excluded from the study. Participants were recruited using convenience sampling. Written informed consent was obtained before data collection. Ethical approval was secured from the Institutional Ethics Committee.

Study design

A prospective observational design was implemented over a period of 15 days, capturing data at three distinct time points:

Pre-Participation (Baseline)

Participation (Immediately after the event)

Post-15 Days of Participation (Follow-up)

Outcome measures

Functional movement screening (FMS)

FMS was used to assess the quality of fundamental movement patterns. Specifically, the Deep Squat and Rotary Stability sub-tests were selected, as they represent symmetrical and asymmetrical movement strategies, respectively. Each test was scored on the standard 0–3 FMS scale by trained assessors certified in FMS Level 1.

Hop distance test

The Single-Leg Hop for Distance test was employed to assess functional lower limb power. Participants performed maximal effort hops on both the dominant and non-dominant limbs following standardized instructions and practice trials. The best of three valid attempts was recorded in centimeters. Methodology was adapted based on Mojtaba Asgari et al. (2024), emphasising controlled landing and balance maintenance to ensure valid trial scoring.

Flexibility

Flexibility was assessed using the Sit and Reach Test, a validated measure of posterior chain (hamstring and lower back) flexibility. Participants performed the test barefoot using a standard sit-and-reach box. Three measurements were recorded at each testing session (Pre-, Post-, and Post-15 Days), and the highest value in centimetres was retained for analysis.

Pain assessment

Pain intensity was recorded using the Verbal Rating Scale (VRS), a reliable ordinal scale for subjective pain reporting. Participants verbally indicated their level of pain at rest and during play on a 10-point scale: 0 = No Pain, and 10 = Worst Possible Pain. Pain was recorded at the same three intervals: Pre-Participation, Post-Participation, and Post-15 Days.


Deep squat


Rotatory stability


Single leg hop distance


Sit and reach

Data collection procedure

All data were collected in a controlled indoor badminton facility. FMS and flexibility assessments were administered first to minimize fatigue effects. Hop tests were conducted with adequate rest between attempts. Pain scores were recorded before & after each session and again at 15-day follow-up via direct contact or digital form submission. All measurements were performed by the same assessor to ensure inter-rater consistency.

Statistical analysis

Data were analysed using IBM SPSS Statistics version 25. Descriptive statistics (mean ± SD) were calculated for all continuous variables. Normality of the data was calculated using Kolmogorov-smirnov test, which showed not normal distribution of data. Hence, Spearman's correlation coefficients were used to determine relationships between FMS scores, hop distances, flexibility measures, and pain scores. A significance level of $p < 0.05$ was considered statistically significant.

RESULTS

The study included 105 collegiate badminton players (mean age = 21.32 ± 2.91 years). Participants had an average playing history of 12.60 ± 1.64 years. Functional Movement Screen (FMS) scores were modest, with mean Deep Squat (1.92 ± 0.76) and Rotary Stability (1.78 ± 0.74). Hop distances were relatively symmetrical, though slightly higher on the dominant side (146.55 ± 19.51 cm vs. 145.69 ± 20.60 cm).

Hamstring flexibility (Sit-and-Reach Test, SRT) demonstrated gradual improvement from baseline (Pre = 16.22 ± 14.30 cm; Post = 16.93 ± 14.05 cm; post-15 days = 16.94 ± 14.09 cm). Pain scores (Visual Rating Scale, VRS) declined across the timeline, from Pre (3.26 ± 2.11) to Post (3.06 ± 2.14), with a marked reduction at 15 days (1.82 ± 1.81).

Normality indicators (skewness and kurtosis) suggested data distribution was within acceptable limits for parametric testing.

Flexibility (SRT)

Significant increases were found between Pre vs Post ($p = 0.027$) and Pre vs post-15 days ($p = 0.026$).

No significant difference was found between Post vs post-15 days ($p = 0.975$), indicating that flexibility improvements were sustained but plateaued after initial gains.

Pain (VRS)

Significant reductions occurred between Pre vs Post ($p = 0.027$), Pre vs post-15 days ($p < 0.001$), and Post vs post-15 days ($p < 0.001$).

This demonstrates that pain decreased progressively across all time points, with the largest decline observed after 15 days.

Table 1: Descriptive statistics for study variables (n = 105)

Variable	Mean ± SD	Skewness	Kurtosis
Age (years)	21.32 ± 2.907	1.285	1.656
Gender (M=1, F=2)	1.49 ± 0.652	1.008	-0.992
Playing Since (years)	12.60 ± 1.639	0.147	-0.236
Deep Squat	1.92 ± 0.755	-0.408	-0.811
Rotary Stability	1.78 ± 0.741	-0.442	-0.631
Dominant Hop Distance (cm)	146.55 ± 19.507	-0.178	-0.671
Non-Dominant Hop Distance (cm)	145.69 ± 20.601	-0.179	-0.698
Pre SRT (cm)	16.22 ± 14.302	-0.455	-1.316
Post SRT (cm)	16.93 ± 14.051	-0.439	-1.367
Post 15 days SRT (cm)	16.94 ± 14.091	-0.438	-1.367
Pre VRS (score)	3.26 ± 2.105	0.593	-0.868
Post VRS (score)	3.06 ± 2.135	0.585	-0.870
Post 15 days VRS (score)	1.82 ± 1.812	0.599	3.165

Table 2: Paired samples t-test results

Comparison	Mean Difference	t	df	p-value	Significance
Pre SRT vs Post SRT	-0.714	-2.251	104	0.027	Yes
Pre SRT vs Post 15 days SRT	-0.724	-2.263	104	0.026	Yes
Post SRT vs Post 15 days SRT	-0.010	-0.032	104	0.975	No
Pre VRS vs Post VRS	0.200	2.243	104	0.027	Yes
Pre VRS vs Post 15 days VRS	1.438	8.048	104	<0.001	Yes
Post VRS vs Post 15 days VRS	1.238	7.206	104	<0.001	Yes

Paired comparisons revealed significant improvements in flexibility and pain outcomes:

Correlation matrix & significance

Variables Compared	Pearson r	p-value	Significance	Interpretation
Deep Squat ↔ Dominant Hop Distance	0.385	0.001	Yes	Moderate Positive
Deep Squat ↔ Non-Dominant Hop Distance	0.282	0.004	Yes	Weak Positive
Rotary Stability ↔ Dominant Hop Distance	0.365	0.001	Yes	Moderate Positive
Rotary Stability ↔ Non-Dominant Hop Distance	0.340	0.001	Yes	Moderate Positive
Pre SRT ↔ Pain Pre	-0.470	0.001	Yes	Moderate Negative
Pre SRT ↔ Pain Post	-0.307	0.001	Yes	Weak Negative
Pre SRT ↔ Pain Post 15 Days	-0.517	0.001	Yes	Moderate Negative
Post SRT ↔ Pain Pre	-0.300	0.001	Yes	Weak Negative
Post SRT ↔ Pain Post	-0.307	0.001	Yes	Weak Negative
Post SRT ↔ Pain Post 15 Days	-0.487	0.001	Yes	Moderate Negative
Post 15 Days SRT ↔ Pain Pre	-0.307	0.001	Yes	Weak Negative
Post 15 Days SRT ↔ Pain Post	-0.487	0.001	Yes	Moderate Negative
Post 15 Days SRT ↔ Pain Post 15 Days	-0.484	0.001	Yes	Moderate Negative
Pain Pre ↔ Pain Post	0.843	0.001	Yes	Strong Positive
Pain Pre ↔ Pain Post 15 Days	0.345	0.001	Yes	Moderate Positive
Pain Post ↔ Pain Post 15 Days	0.237	0.001	Yes	Weak Positive

Pearson correlation coefficients revealed several key associations:

FMS ↔ Hop performance

Deep Squat correlated positively with both **dominant hop distance** (r = 0.385, p = 0.001; moderate) and **non-dominant hop distance** (r = 0.282, p = 0.004; weak).

Rotary Stability showed moderate positive correlations with **dominant hop** (r = 0.365, p = 0.001) and **non-dominant hop** (r = 0.340, p = 0.001).

These findings highlight that better movement quality was linked with greater hop performance.

Flexibility (SRT) ↔ Pain (VRS)

Strong inverse relationships were observed:

Pre SRT vs Pre Pain: r = -0.470 (moderate negative, p = 0.001).

Pre SRT vs post-15 days Pain: r = -0.517 (moderate negative, p = 0.001).

Similar consistent negative associations across post and 15-day follow-up suggest that greater hamstring flexibility predicted lower pain scores.

Pain intercorrelations

Pain measures across time points were strongly related, with Pre vs Post Pain showing the highest correlation (r = 0.843, p = 0.001), indicating consistency in pain perception trends across the recovery timeline.

Key interpretations

Players with better movement quality (Deep Squat, Rotary Stability) performed significantly better in hop tests, especially on the dominant side.

Flexibility improvements were small but statistically significant, with changes stabilizing after the immediate post-competition phase.

Pain levels decreased steadily, with the largest decline after 15 days, suggesting natural recovery enhanced by flexibility gains.

Flexibility and pain were consistently inversely related, confirming that athletes with greater hamstring extensibility experienced less discomfort.

Hop asymmetry favored the dominant leg, supporting sport-specific adaptations in badminton.

DISCUSSION

The present study explored the interrelationships between movement quality, hop performance, hamstring flexibility, and pain outcomes in collegiate badminton players during an indoor competition setting. The findings highlight the multifaceted nature of sports performance, where movement efficiency, neuromuscular control, and tissue flexibility converge to influence both performance outcomes and musculoskeletal health. By investigating these associations in a badminton-specific population, this study contributes to the existing literature on injury prevention and performance optimisation in racket sports.

Movement quality and HOP performance

One of the primary findings was the moderate positive correlation between Functional Movement Screen (FMS) subtest scores—specifically the Deep Squat and Rotary Stability—and single-leg hop distance on the dominant limb. Previous investigations have demonstrated similar associations, where higher FMS scores were predictive of superior hop performance among collegiate athletes across different sports [7]. These results suggest that FMS can capture aspects of functional readiness that are directly transferable to explosive lower-limb performance tasks such as hopping. The Deep Squat test is particularly relevant in this context, as it evaluates bilateral mobility of the hips, knees, and ankles in addition to trunk stability and symmetrical weight distribution. Successful performance in this subtest indicates the athlete's ability to maintain neuromuscular control across multiple joints simultaneously, which mirrors the biomechanical demands of hop propulsion and landing. Rotary Stability, on the other hand, measures trunk and core control during asymmetrical and contralateral movements. Given that badminton is a unilateral and rotational sport, superior performance in this subtest is likely to enhance dynamic control during movements such as lunges, smashes, and changes of direction[7].The underlying explanation for these findings lies in the principle of kinetic chain integration. In dynamic sporting actions, efficient force transfer from the distal to proximal segments depends on optimal mobility, alignment, and stability at each joint along the kinetic chain. Deficits in one link of the chain—such as limited ankle dorsiflexion or poor lumbopelvic control—can disrupt this sequence, leading to compensatory mechanics that reduce hop efficiency and predispose athletes to injury^8. Thus, the ability of FMS to capture such inefficiencies through functional patterns makes it a more holistic predictor of performance than isolated strength or endurance tests [8].

Limb asymmetry in hop performance

Another noteworthy finding was the consistent dominance of the leading leg in hop performance. This asymmetry is unsurprising given that badminton is inherently unilateral, involving repeated lunges, push-offs, and landing patterns predominantly on the dominant side. Similar trends have been documented in both elite and sub-elite badminton players, where asymmetrical training load fosters side-to-side performance discrepancies. While functional dominance may confer short-term performance benefits, long-term asymmetry is a recognised risk factor for overuse injuries, particularly in the lower extremities. Repeated preferential loading of one limb may result in neuromuscular imbalances, altered proprioceptive feedback, and compensatory strategies on the non-dominant side. This explains why FMS correlations with hop distance were significant only on the dominant limb in this study. The weaker association on the non-dominant side may reflect less refined motor control and stability, emphasising the need for asymmetry-targeted interventions such as unilateral balance training and contralateral strengthening programs [9].

Flexibility and pain

A second key outcome was the inverse correlation between hamstring flexibility and pain scores, both immediately post-competition and after 15 days. Players demonstrating greater posterior chain flexibility consistently reported lower pain levels across time points. This finding is consistent with prior research linking limited hamstring flexibility to increased musculoskeletal strain, particularly through altered lumbopelvic mechanics and restricted hip extension.

In sports like badminton, which demand frequent lunging, deceleration, and rapid directional changes, inadequate hamstring extensibility compromises landing mechanics and reduces shock absorption capacity. Physiologically, muscle stiffness elevates tissue loading during eccentric actions and limits joint range of motion. As a result, athletes with poor flexibility may compensate via excessive lumbar flexion or knee valgus collapse—mechanical patterns strongly associated with pain development and musculoskeletal injury.[10] Furthermore, previous systematic reviews have demonstrated that interventions targeting hamstring flexibility led to reductions in pain intensity and improvements in functional capacity, both in clinical populations and athletic cohorts. The present findings align with this evidence, underscoring the protective role of posterior chain flexibility in reducing musculoskeletal discomfort during competition [10].

Pain reduction and recovery trends

The decline in self-reported pain 15 days after the tournament likely reflects the body's natural recovery processes, including the resolution of inflammation and tissue microtrauma. However, the concurrent improvement in flexibility during this period suggests that recovery was not purely passive. It is plausible that athletes engaged in post-event stretching or light activity, both of which may have accelerated symptom reduction. Evidence supports that structured flexibility and balance training programs contribute to faster recovery, reduced delayed onset muscle soreness (DOMS), and enhanced return to sport readiness.[11] These observations reinforce the notion that flexibility is not merely a static measure of tissue extensibility but a dynamic factor influencing recovery trajectories and long-term musculoskeletal health.

Interconnected role of flexibility, movement quality, and pain

Although no direct correlation was observed between FMS scores and hamstring flexibility in this study, both independently predicted functional performance and pain outcomes. This lack of association may be due to the partial administration of the FMS tool, which does not fully account for posterior chain extensibility. Nonetheless, the independent predictive value of both variables highlights the necessity of a multidimensional approach to performance assessment. A single assessment tool is insufficient for capturing the complexity of sport-specific demands. Instead, combining movement quality screening (FMS), flexibility assessment, and pain monitoring provides a more comprehensive overview of athlete readiness and injury risk. This approach is supported by recent findings that advocate for integrated evaluation protocols in sports medicine and performance sciences [11, 12, 13].

Practical applications

The findings of this study hold several practical implications for sports physiotherapists, strength and conditioning professionals, and coaches.

Functional movement screening (FMS)

Subtests such as Deep Squat and Rotary Stability should be integrated into pre-season or pre-participation assessments to identify neuromuscular control deficits that may compromise explosive tasks like hopping and landing.

Flexibility assessments

The Sit-and-Reach test, despite its simplicity, remains a valuable tool for identifying athletes with limited hamstring extensibility who may be at greater risk of pain and overuse injuries.

Asymmetry monitoring

Given the dominance-related differences in hop performance, regular assessments of bilateral performance should be conducted. Corrective training strategies targeting the non-dominant side may reduce asymmetry and subsequent injury risk.

Integrated screening battery

A cost-effective, field-based screening protocol that combines FMS, flexibility tests, and pain self-reporting can offer holistic insight into athlete readiness, guide individualized interventions, and reduce injury burden in racket sports.

CONCLUSION

This study provides important insights into the functional relationships between movement quality, lower-limb performance, flexibility, and pain among collegiate badminton players. The findings demonstrate that higher scores in functional movement patterns—specifically Deep Squat and Rotary Stability—are associated with greater hop distance on the dominant limb, reflecting the value of neuromuscular coordination and postural control in explosive movements. Additionally, increased hamstring and posterior chain flexibility, as assessed by the Sit & Reach test, showed a consistent inverse relationship with pain scores, suggesting a protective role of mobility in managing post-competition musculoskeletal symptoms.

These results emphasize the need for integrated assessment protocols in badminton, combining tools like the Functional Movement Screen with flexibility tests and subjective pain scales. By identifying athletes with suboptimal movement quality or flexibility deficits, early interventions can be applied to reduce injury risk and enhance performance. This approach is especially relevant during competitive events, where cumulative fatigue and repetitive strain may predispose athletes to pain and dysfunction.

In summary, this study supports the clinical and practical utility of functional and flexibility screening in the proactive management of collegiate badminton athletes. Coaches and clinicians should consider including these low-cost, time-efficient tools as part of regular pre-participation and post-competition evaluations.

Limitations

Several limitations should be acknowledged. First, only two subtests from the Functional Movement Screen (Deep Squat and Rotary Stability) were assessed, which may not capture the full spectrum of movement dysfunction present in athletes. The inclusion of the complete seven-test FMS battery could offer more detailed insights into totalbody coordination and asymmetry. Second, the study was conducted on a relatively small convenience sample, which limits generalizability. A larger cohort would increase statistical power and allow for subgroup analysis by gender, training age, or injury history.

Third, the observational nature of the study prevents causal inference between variables such as flexibility and pain. Although associations were statistically significant, longitudinal follow-up is needed to determine whether improvements in movement quality or flexibility directly led to reductions in pain or injury incidence. Lastly, while pain was captured using the Verbal Rating Scale, this method is inherently subjective and may vary based on individual tolerance or reporting tendencies. Incorporating more specific clinical diagnostic tools or biomechanical assessments would strengthen the findings.

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Conflict of interest

The authors declare no conflict of interest.

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