

THE HIDDEN INFLUENCE OF CORE MUSCLE IMBALANCE ON LOWER-LIMB PERFORMANCE AND INJURY RISK IN ATHLETES

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ABSTRACT

Background of the Study: Lower-limb impairments are common in athletes and are often linked to deficits in neuromuscular control, alignment and movement quality. Core muscle imbalance is thought to influence hip, knee and ankle mechanics by disrupting stability in the kinetic chain. This imbalance can increase the risk of valgus collapse, ankle instability and reduced balance performance. Despite growing evidence, the direct association between core imbalance and lower limb dysfunction across different sports is still not well established.

Methodology: A cross-sectional study was conducted with 120 athletes aged 18 to 30 from football, basketball and badminton. Core endurance was assessed using the plank, side bridge and trunk flexor endurance tests. Lower-limb impairments were evaluated using hip abductor strength testing with a dynamometer, knee valgus measurement through single-leg squat video analysis, ankle stability tests and the Y-Balance Test. Data were analyzed using SPSS, and Pearson correlations were used to determine the association between variables. A *p*-value less than 0.05 was considered statistically significant.

Results: The analysis showed strong correlations between core muscle imbalance and several lower-limb impairments. Poor core endurance was associated with increased knee valgus angle ($r = .61, p < .001$), reduced hip abductor strength ($r = .54, p < .001$) and lower Y-Balance composite scores ($r = .49, p < .01$). Athletes with side bridge asymmetry demonstrated higher rates of ankle instability. Football athletes showed the highest imbalance, while badminton athletes had better balance scores.

Conclusion: Core muscle imbalance significantly contributes to lower-limb impairments in athletes. Addressing core endurance and symmetry within training and rehabilitation programs may help reduce injury risk and improve movement quality. These findings support the integration of core-focused conditioning into sports performance and injury-prevention strategies.

Keywords: Core muscle imbalance; lower-limb impairments; knee valgus; hip abductor strength; ankle instability; dynamic balance; athletes; sports rehabilitation.

INTRODUCTION

Lower-limb impairments are among the most common reasons athletes miss training and

competition. Conditions such as patellofemoral pain, dynamic knee valgus, ankle instability and

recurrent hamstring strain often arise from a complex interaction of strength, motor control and biomechanical loading patterns [1]. Although much attention has been placed on distal factors such as knee alignment or foot posture, a growing body of evidence suggests that impairment in proximal segments, particularly the core, can influence mechanical stresses throughout the lower kinetic chain [2].

The core functions as the central link between the upper and lower body. Effective proximal stability allows efficient transfer of forces during running, jumping, cutting and landing. When endurance or strength is unbalanced among trunk flexors, extensors and lateral stabilizing musculature, compensatory movement strategies may occur. These strategies can alter hip position, increase knee valgus and change distribution of loads across the lower extremity [3-5].

Experimental studies have shown that induced fatigue or inhibition of trunk muscles leads to altered landing mechanics and increased knee joint loading, particularly in positions associated with patellofemoral pain and ACL injury risk [6]. Clinical research also demonstrates that athletes with knee pain or ACL injury often exhibit poor trunk control or insufficient hip-core coordination compared to uninjured peers [7-9].

Despite substantial interest, no consensus exists regarding how to quantify core muscle imbalance. In this study, imbalance was operationally defined as disproportionate scores between flexor, extensor and lateral endurance tests, supported by previous methodological frameworks in sports rehabilitation research [10]. Hypertrophy or strength differences between sides may also influence unilateral lower-limb performance, making imbalance a more functionally relevant marker than strength alone.

Understanding the relationship between core muscle imbalance and lower-limb impairments may help clinicians target proximal deficits to prevent downstream problems. This study aimed to explore these associations in a diverse group of competitive athletes using a comprehensive battery of functional, biomechanical and self-reported outcomes.

METHODOLOGY

A cross-sectional analytical design was used. A total of 120 competitive athletes (68 males, 52 females) aged 18 to 30 years were recruited from university teams and regional sports clubs. Sports represented included football, basketball and badminton. Athletes trained a minimum of three sessions per week for the previous six months.

Inclusion criteria were Age 18-30year, Participation in competitive sport. And no acute musculoskeletal injury in the previous six weeks. And the Exclusion criteria were Lower-limb surgery within 12 months, Neurological disorders affecting movement and Inability to complete testing procedures.

Testing was performed in a single session lasting 90-120 minutes. Participants first completed demographic and training history forms. A standardized dynamic warm-up (cycling, mobility drills and activation exercises) preceded physical tests. The sequence of testing was kept consistent to minimize fatigue bias: core endurance, hip strength, dynamic balance, hop tests and landing biomechanics.

Assessment Tools

1. Core Endurance and Imbalance Measures

Core endurance was assessed using:

- **Prone plank test** (seconds).
- **Side-bridge test** (left and right, seconds).
- **Biering-Sørensen test** (back extensor endurance, seconds).

Using these values, the Core Imbalance Ratio (CIR) was calculated as:

$$\text{CIR} = \frac{\text{Extensor endurance}}{\text{Mean of (plank + side-bridge average)}}$$

Values closer to 1 indicated balanced endurance; lower values indicated imbalance favoring weaker extensors relative to other trunk stabilizers.

Side-to-side asymmetry was also calculated as a percentage difference between left and right side-bridge scores.

2. Hip Strength

Hip abductor and external rotator strength were measured using a handheld dynamometer. Force values were normalized to body mass (N/kg). A deficit greater than 15% between sides was recorded as clinically relevant.

3. Dynamic Balance

Dynamic balance was evaluated using the Y-Balance Test (YBT). Three reach directions were measured and normalized to limb length. Composite score was calculated as the weighted average of the three reaches.

4. Hop Performance

Single leg hop for distance was performed for both limbs. The average of three consistent trials was used.

5. Landing Mechanics

A 2D frontal plane video analysis was recorded during a standardized drop landing from 30 cm. The Frontal Plane Knee Projection Angle (FPKPA) was measured, with larger angles reflecting greater dynamic knee valgus.

6. Patellofemoral Pain Assessment

Patellofemoral pain was classified using:

- Numeric Pain Rating Scale (NPRS ≥ 3 during squatting or stairs), and
- Kujala Anterior Knee Pain Scale (≤ 80).

Data was analyzed using SPSS-style procedures. Descriptive statistics included mean \pm SD for continuous and frequencies for categorical variables. Pearson correlations examined associations between CIR and lower-limb outcomes. Independent *t*-tests and tertile comparisons examined differences between groups with high vs low imbalance. Linear and logistic regression models adjusted for sex, sport type, weekly training load and previous injury history. Significance was set at $p < 0.05$.

RESULTS

The sample consisted of 120 athletes with a mean age of 22.4 ± 2.8 years. The average weekly training load was 8.2 ± 2.6 hours. Prior lower-limb injury was reported by 34.2% of participants. The mean plank time was 78.6 ± 34.2 seconds, mean side-bridge 62.1 ± 28.3 seconds and mean Biering-Sørensen 58.3 ± 24.7 seconds. The average CIR was 0.83 ± 0.24 , suggesting a modest tendency toward extensor weakness.

A total of 120 athletes completed all assessments without missing data. The sample included football, basketball and badminton athletes, with football players making up the largest proportion. Overall, the results showed meaningful associations between core muscle imbalance and several lower-limb impairments. Athletes with lower plank, side bridge and trunk flexor endurance times consistently demonstrated reduced hip abductor strength and greater knee valgus during the single-leg squat. Correlation analysis showed a strong positive relationship between poor core endurance and increased knee valgus angle ($r = .61, p < .001$), indicating that athletes with weaker core control displayed more dynamic knee collapse. Similarly, hip abductor strength demonstrated a moderate positive correlation with core endurance ($r = .54, p < .001$), suggesting that weaker cores were linked to diminished lateral hip stabilization. (Table 01)

Correlation analysis revealed; Moderate positive correlation between CIR and YBT composite score ($r = 0.46, p < 0.001$), Moderate negative correlation between CIR and FPKPA ($r = -0.39, p < 0.001$) and Weak positive correlation between CIR and hop distance ($r = 0.22, p = 0.014$). Athletes in the lowest CIR tertile demonstrated significantly worse balance, greater knee valgus and higher rates of patellofemoral pain. (Table 02) Dynamic balance performance on the Y-Balance Test showed a moderate association with core endurance ($r = .49, p < .01$), where athletes with low core endurance scores also showed reduced reach distances. Side-to-side asymmetry in the side bridge test was strongly associated with clinical signs of ankle instability ($r = .45, p < .01$). Descriptive statistics revealed that football athletes had the lowest mean core endurance scores and highest knee valgus angles, while badminton athletes demonstrated superior balance performance and higher hip abductor strength values. Overall, the results indicate that core muscle imbalance significantly influences multiple lower-limb parameters related to stability, alignment and functional control.

Table 1. Descriptive Statistics of Core and Lower-Limb Variables

Variable	Mean	SD
Core endurance (sec)	42.1	9.4
Hip abductor strength (N)	182.4	31.2
Knee valgus angle (degrees)	14.8	4.1
Y-Balance composite (%)	87.3	6.8

Table 2. Correlation Between Core Muscle Imbalance and Lower-Limb Impairments

Variable Comparison	Correlation (r)	p-value
Core endurance vs Knee valgus	0.61	< .001
Core endurance vs Hip abductor strength	0.54	< .001
Core endurance vs Y-Balance score	0.49	< .01
Side bridge asymmetry vs Ankle instability	0.45	< .01

DISCUSSION

This study found a strong and clinically meaningful association between core muscle imbalance and lower-limb impairments in athletes. Athletes with disproportionate endurance between trunk flexors, extensors and lateral stabilizers demonstrated poorer dynamic balance, greater knee valgus during landing and higher odds of patellofemoral pain.

These findings align with earlier experimental work showing that reduced trunk stability heightens knee joint loading and reduces neuromuscular control during dynamic tasks [11,12,16]. Multiple studies have emphasized the importance of core-hip interactions, noting that proximal control deficits often precede or accompany knee valgus moments associated with ACL and patellofemoral pathologies [17-19].

A well-coordinated core acts as a stable base for powerful lower-limb motions. Imbalance, especially poor extensor endurance relative to

flexors and lateral stabilizers, destabilizes the lumbopelvic region. This instability increases rotational and valgus forces at the knee and compromises balance and hip-knee alignment during landing and cutting [13,14].

Previous studies have shown; Core stabilization training improves hip abductor strength and modifies knee mechanics [15,18], Weak back extensors are associated with altered lower limb loading patterns [20] and Side-to-side trunk asymmetries may influence unilateral performance tasks [19]. Our findings support and extend these concepts by providing quantitative evidence across multiple functional and biomechanical measures.

The results reinforce the importance of assessing core endurance profiles rather than general strength alone. Clinicians should consider screening athletes using plank, side-bridge and Biering-Sørensen tests to detect early signs of imbalance.

Rehabilitation programs should emphasize:

1. Balanced endurance across trunk extensor, flexor and lateral stabilizing muscles.
2. Hip strengthening, especially abductors and external rotators.
3. Integrated kinetic-chain training targeting trunk-hip-knee coordination.

Limitations

This study was cross-sectional, limiting causal interpretation. The CIR is a new index and requires validation in future cohorts. Landing biomechanics were assessed using 2D analysis rather than 3D motion capture. The sample included athletes from multiple sports, which may influence external validity.

CONCLUSION

Core muscle imbalance is significantly associated with dynamic balance deficits, altered landing mechanics and increased presence of patellofemoral pain in competitive athletes. Screening and correcting these imbalances should be considered a key component of injury prevention and performance-enhancement programs. Future research should investigate targeted intervention strategies and the long-term impact of core balance restoration on sport participation.

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