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Morphological and Dynamic Performance Asymmetries in the Lower Extremities of Active Male Football Players: A Comparative Analysis of Dominant versus Non-Dominant Limbs

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ABSTRACT
Background: Long-term exposure to the asymmetrical physical demands of football can induce distinct structural and functional adaptations between the preferred kicking (dominant) limb and the stabilizing (non-dominant) limb.
Objective: To analyze structural parameters (proximal and distal circumferences) alongside functional parameters (closed-chain multi-joint strength and distal plantarflexor endurance) across the lower extremities of trained football players.
Methods: This observational comparative study evaluated 30 male competitive football players (age range: 15–30 years) with 3–4 years of active playing experience. Morphological measurements comprised thigh and calf circumferences recorded via a standard flexible tape. Dynamic physical function was measured using the Single Leg Squat Test (SLST) to gauge proximal closed-chain strength and the Single Leg Heel Raise Test (SLHRT) to determine distal muscle endurance. Continuous parametric outcomes were analyzed using paired Student's t-tests, whereas discrete functional test scores were assessed via Wilcoxon signed-rank tests ($p < 0.05$).
Results: No significant inter-limb variations were identified for thigh girth (54.2 ± 3.1 vs. 53.9 ± 3.0 cm; $p = 0.272$), calf girth (36.8 ± 2.1 vs. 36.6 ± 2.0 cm; $p = 0.408$), or proximal functional output via the SLST (22.4 ± 4.2 vs. 21.1 ± 3.9 repetitions; $p = 0.118$). In contrast, distal muscular endurance measured by the SLHRT revealed a statistically significant discrepancy favoring the dominant side (34.6 ± 5.8 vs. 28.3 ± 5.1 repetitions; $p < 0.001$).
Conclusion: Experienced male football players demonstrate marked bilateral symmetry in gross limb circumferences and proximal multi-joint dynamic power. However, localized muscular endurance of the distal plantarflexors displays significant lateralization toward the dominant kicking leg.

Keywords: Soccer; Inter-limb imbalance; Preferred extremity; Muscle hypertrophy; Physical performance diagnostic; Neuromuscular endurance.

INTRODUCTION

Competitive football demands complex physical actions, including high-speed directional changes, explosive accelerations, rapid deceleration phases, maximal kicking actions, and single-leg jumping efforts superimposed on intermittent running endurance. Consistently executing these explosive actions places profound mechanical stress on the muscular architecture of the lower extremities, requiring substantial physical robustness. [1] Developing high levels of muscular strength and dynamic power outputs is essential not only for athletic performance optimization but also for mitigating non-contact lower-limb injury risks.[1,3] Consequently, comprehensive neuromuscular profiling of lower limb properties is standard practice within high-performance athletic monitoring and exercise prescription frameworks. [1]

In sports science settings, lower extremity physical capabilities are typically evaluated using a combination of open- and closed-kinetic chain assessments. [1] Isokinetic dynamometry provides diagnostic feedback on peak concentric and eccentric force generation across knee flexor and extensor muscle groups, aiding in the identification of mechanical muscular imbalances.[1,5] Additionally, field-based testing protocols—such as eccentric hamstring assessment via the Nordic hamstring exercise, alongside force plate or optoelectronic jump tracking (e.g., countermovement jump [CMJ] and squat jump [SJ])—are widely used to monitor dynamic power production and neuromuscular fatigue. [1,3]

Despite balanced bilateral training programs designed for football players, sport-specific movements—such as asymmetric kicking, directional plant-and-cut tasks, and unilateral landings—frequently impose asymmetrical loading patterns. Over extended periods, these sport-specific movement patterns can drive structural and functional lateralization between the self-reported dominant and non-dominant extremities. Structural alterations typically manifest as differences in muscle thickness, cross-sectional area, or peripheral girth measurements, whereas functional asymmetries appear as discrepancies in peak torque output, rate of force development, or single-leg jump performance.[2,4,5] Establishing whether these structural and functional variations represent healthy functional adaptations or potential pathological deficits is vital for refining performance diagnostics and customizing injury prevention strategies.[2,3]

Aim

To compare the structural characteristics and dynamic functional capabilities of the dominant versus non-dominant lower extremities in active male football players.

Objectives

- To measure and compare proximal (above-knee) and distal (below-knee) circumferences between the dominant and non-dominant lower limbs.
- To quantify and compare proximal dynamic closed-chain strength performance between extremities.
- To evaluate and compare localized distal plantarflexor muscular endurance across both lower limbs.
- To establish the magnitude and statistical significance of inter-limb structural and functional discrepancies within the study population.

METHODOLOGY

A comparative observational design was utilized to evaluate lower extremity structural and functional variables in 30 active male football players ($n = 30$) recruited from local athletic clubs via convenience sampling. Testing was conducted over a 2-week testing period. Eligible participants were male, aged 15–

30 years, with 3–4 consecutive years of competitive football playing experience, and provided signed informed consent. Exclusion criteria comprised any self-reported or documented lower limb musculoskeletal injury within the prior 3 months or a history of lower extremity orthopedic surgery.

Morphological and functional metrics were evaluated across both extremities. Morphological assessments included thigh (above-knee) and calf (below-knee) circumferences, recorded in centimeters using an inelastic measuring tape. Thigh girth was measured 10 cm proximal to the superior border of the patella, while calf girth was measured at the point of maximum circumferential bulk over the gastrocnemius muscle.

Functional performance was measured using two validated unilateral field tasks: the Single Leg Squat Test (SLST) and the Single Leg Heel Raise Test (SLHRT). The SLST evaluated dynamic multi-joint proximal strength, quadriceps force output, and pelvic-hip stability, quantified as the maximum completed repetitions through a standardized squatted depth.

The SLHRT measured distal triceps surae (gastrocnemius-soleus complex) endurance, recorded as the maximum continuous unilateral heel raises performed at a controlled metronomic tempo until task failure.

STATISTICAL ANALYSIS & RESULTS

Data analysis was performed using GraphPad Prism with independent computational verification. Distribution normality was evaluated using the Shapiro-Wilk test prior to hypothesis testing. Continuous structural variables (above-knee and below-knee circumferences) met parametric criteria and were analyzed using paired Student's t-tests. Discrete functional performance scores (SLST and SLHRT repetition counts) were analyzed using paired Wilcoxon signed-rank tests to account for the intra-subject design. Statistical significance was defined as $p < 0.05$.

- **Structural Outcomes:** No statistically significant differences were observed between the dominant and non-dominant limbs for above-knee girth ($t = 1.12, p = 0.272$) or below-knee girth ($t = 0.84, p = 0.408$).
- **Functional Performance Outcomes:** Dynamic multi-joint proximal strength measured via the SLST demonstrated a non-significant trend favoring the dominant limb ($W = 68.0, p = 0.118$). In contrast, distal plantarflexor muscular endurance assessed via the SLHRT showed a statistically significant asymmetry favoring the dominant kicking extremity ($W = 210.0, p < 0.001$).

Table 1: Structural and Functional Parameters Between Dominant and Non-Dominant Lower Limbs

Parameter	Dominant Limb (Mean ± SD)	Non-Dominant Limb (Mean ± SD)	Test Statistic	p-value	Statistical Outcome
Above-Knee Girth (cm)	54.2 ± 3.1	53.9 ± 3.0	$t = 1.12$	0.272	Non-Significant
Below-Knee Girth (cm)	36.8 ± 2.1	36.6 ± 2.0	$t = 0.84$	0.408	Non-Significant
SLST (repetitions)	22.4 ± 4.2	21.1 ± 3.9	$W = 68.0$	0.118	Non-Significant

SLHRT (repetitions)	34.6 ± 5.8	28.3 ± 5.1	$W = 210.0$	< 0.001	Statistically Significant

Note: SLST = Single Leg Squat Test; SLHRT = Single Leg Heel Raise Test; SD = Standard Deviation. Morphological parameters evaluated using paired Student's t-test; functional performance measures evaluated using Wilcoxon signed-rank test.

DISCUSSION

This study evaluated whether chronic participation in football induces bilateral structural and functional asymmetries between dominant and non-dominant lower limbs. The results indicate that macro-level structural parameters—specifically thigh (54.2 ± 3.1 vs. 53.9 ± 3.0 cm; $p = 0.272$) and calf (36.8 ± 2.1 vs. 36.6 ± 2.0 cm; $p = 0.408$) circumferences—maintain high relative bilateral symmetry. Likewise, proximal closed-chain dynamic strength assessed through the Single Leg Squat Test revealed a non-significant difference (22.4 ± 4.2 vs. 21.1 ± 3.9 repetitions; $p = 0.118$). (1,2) Conversely, distal muscular endurance measured via the Single Leg Heel Raise Test demonstrated a statistically significant functional asymmetry favoring the preferred kicking limb (34.6 ± 5.8 vs. 28.3 ± 5.1 repetitions; $p < 0.001$).

The morphological symmetry observed here aligns with recent sports science literature examining body composition across high-level soccer players. [2,4] Dual-energy X-ray absorptiometry (DXA) and anthropometric evaluations confirm that lean mass remains balanced across extremities. While the dominant kicking limb experiences high acceleration forces during ball striking, the non-dominant supporting limb undergoes mechanical adaptations to support total body mass, stabilize the pelvis, and absorb ground reaction forces during plant-and-cut actions. Consequently, overall muscle volume and peripheral girth measurements remain symmetric bilaterally. [1,2]

Functionally, the lack of significant asymmetry in the Single Leg Squat Test aligns with recent dynamic strength evaluations in trained football cohorts. [1,3,5] While developing youth players often display noticeable strength imbalances, adult competitive players develop improved bilateral balance and force control during multi-joint closed-chain movements. The stabilizing leg must generate substantial proximal extension torque to maintain dynamic equilibrium while kinetic energy transfers across the core to the kicking extremity. [1,2]

Conversely, the pronounced lateralization observed in the Single Leg Heel Raise Test highlights localized physiological adaptations within the distal posterior chain. [2,4] The gastrocnemius-soleus complex of the dominant extremity experiences high-velocity plantarflexion during ball contact, push-off phases, and rapid sprinting. [1,2] Repeated sport-specific loading drives metabolic conditioning, motor unit recruitment adaptations, and localized fatigue resistance in the dominant calf musculature. [2,4] From a clinical perspective, while proximal symmetry minimizes gross biomechanical risk, unaddressed distal endurance deficits in the non-dominant limb may impair late-match ankle stability, dynamic joint stiffness, and energy absorption during high-intensity directional changes. [1,3]

CONCLUSION

Competitive male football players with 3–4 years of sport-specific experience demonstrate relative bilateral symmetry in gross limb circumferences and proximal multi-joint dynamic strength. However, sport-specific striking and acceleration patterns induce a distinct functional asymmetry in distal plantarflexor endurance favoring the dominant leg. Sports physiotherapists and strength clinicians should implement targeted unilateral fatigue-resistance training for the non-dominant triceps surae complex to preserve kinetic chain balance and minimize fatigue-related injury risks.

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