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Original Article

Correlation Between Gastrocnemius Muscle Strain Severity and Functional Performance in Footballers

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ABSTRACT

Background: Gastrocnemius muscle strain is a frequent injury among footballers due to the sport's high physical demands involving sprinting, jumping, and rapid directional changes. These injuries contribute to substantial functional limitations, reduced performance, and delayed return to play. Despite the prevalence of gastrocnemius strains, the relationship between strain severity and functional performance remains insufficiently characterized, limiting evidence-based rehabilitation planning. Objective: To determine the correlation between gastrocnemius muscle strain severity and functional performance in footballers using validated assessment tools. Methods: A cross-sectional observational study was conducted among 158 football players aged 18–40 years diagnosed with gastrocnemius muscle strain at Superior University Sports Club, Lahore. Strain severity was categorized as mild, moderate, or severe using standardized clinical examination. Functional performance was assessed using the Lower Extremity Functional Scale (LEFS), Hop Test, Achilles Tendon Rupture Score (ATRS), and Tegner Activity Scale (TAS). Data were analysed using Spearman's correlation and Kruskal–Wallis tests, with $p < 0.05$ considered statistically significant. Results: There was a moderate, statistically significant negative correlation between strain severity and all functional performance measures: LEFS ($\rho = –0.312$, $p = 0.001$), Hop Test ($\rho = –0.345$, $p = 0.002$), ATRS ($\rho = –0.298$, $p = 0.001$), and TAS ($\rho = –0.327$, $p = 0.001$). Group-wise comparisons demonstrated significant differences in functional scores across severity categories ($p < 0.05$). Conclusion: Increasing severity of gastrocnemius muscle strain is associated with progressively reduced functional performance in footballers, underscoring the need for severity-stratified rehabilitation strategies.

Keywords: Gastrocnemius muscle strain, functional performance, football injuries, LEFS, Hop Test, ATRS, TAS, rehabilitation, return to play.

INTRODUCTION

Football, as the most popular sport globally, involves rapid acceleration, deceleration, changes in direction, jumping, and intense physical contact, placing high mechanical and physiological demands on athletes (1). For millions of participants worldwide, football is more than recreational; it is a highly competitive pursuit requiring superior neuromuscular coordination, endurance, and power (2). The injury burden in football is substantial, with epidemiological studies consistently demonstrating that injury incidence during matches far exceeds that during training (3). Among these injuries, muscle strains, particularly in the lower extremity, dominate, accounting for approximately 65.4% of all football-related injuries, with the calf identified as one of the most frequently affected regions (4). Calf muscle strain injuries (CMSIs), especially involving the gastrocnemius muscle, are prevalent due to the muscle's biarticular anatomy and role in high-speed running and explosive movements (5). The medial head of the gastrocnemius is particularly susceptible to strain at the myotendinous junction because of its anatomical and biomechanical characteristics, including its contribution to knee flexion and plantarflexion during ballistic activities (6).

Recent literature highlights that gastrocnemius strains pose a significant challenge not only due to their incidence but also due to their recurrence rates and functional impact (7). Professional and amateur athletes alike face extended periods away from sport following gastrocnemius strain, reflecting both the severity of tissue disruption and the complex demands of rehabilitation (8). While diagnostic imaging such as MRI provides valuable insights into tissue integrity, clinical management predominantly relies on functional assessments to monitor recovery and guide return-to-play decisions (9). Existing research demonstrates that lower limb functional performance—measured using validated instruments such as the Lower Extremity Functional Scale (LEFS), the Hop Test, the Achilles Tendon Rupture Score (ATRS), and the Tegner Activity Scale (TAS)—is critical for determining rehabilitation progress and readiness for sport-specific demands (10). However, the precise relationship between strain severity and functional outcomes remains underexplored in footballers, limiting the ability of clinicians to tailor rehabilitation protocols and predict recovery trajectories accurately.

Despite recognition of the gastrocnemius muscle's critical role in football performance, few studies have systematically examined how increasing strain severity directly affects functional performance outcomes as assessed by standardized tools (11). While some studies suggest that greater strain severity correlates with more pronounced functional limitations (12), the literature is characterized by heterogeneity in assessment methods and inconsistent adjustment for confounders such as age, sex, and athletic level (13). This paucity of high-quality, correlational evidence creates a critical knowledge gap, particularly given that rehabilitation resources and timelines must often be individualized based on severity. Furthermore, previous studies have not consistently integrated a comprehensive battery of functional tests to capture the multidimensional nature of lower limb performance, including strength, balance, dynamic control, and perceived function (14). The clinical relevance of understanding this relationship is heightened by the need to mitigate risk of reinjury and optimize return-to-play outcomes.

This study is therefore justified by the need to clarify the association between gastrocnemius muscle strain severity—categorized clinically as mild, moderate, or severe—and a broad range of functional performance measures among footballers aged 18–40 years. By integrating standardized assessment tools and robust statistical analysis, the study aims to generate evidence that informs clinicians' decision-making in rehabilitation planning, supports injury severity stratification, and improves individualized return-to-play timelines. Accordingly, the objective of this study is to determine the correlation between gastrocnemius muscle strain severity and functional performance in footballers as measured by LEFS, Hop Test, ATRS, and TAS. It is hypothesized that increasing severity of gastrocnemius muscle strain will be significantly associated with progressively reduced scores across all functional performance measures.

MATERIAL AND METHODS

A correlation-based cross-sectional observational study was conducted to investigate the relationship between gastrocnemius muscle strain severity and functional performance in footballers, providing a snapshot of this association at a single point in time. The study was performed at the Department of Physical Therapy and Rehabilitation, Superior University Sports Club, Lahore, Pakistan, which provided direct access to an active population of amateur and semi-professional football players engaged in routine training and competition activities. The study period extended from January 2024 to April 2024.

Eligible participants were male and female footballers aged 18 to 40 years, with at least six months of continuous football training experience, clinically diagnosed with gastrocnemius muscle strain through a standardized physical examination including palpation, passive dorsiflexion stretch test, and resisted plantarflexion test. Exclusion criteria included a history of direct trauma to the calf, concurrent Achilles tendon injuries, soleus muscle injuries, any neurological disorders affecting lower limb function, inability to participate in rehabilitation, or no intention to return to competitive sport. Participants were selected using a non-probability convenience sampling approach to facilitate recruitment from a population accessible at the sports club. Recruitment involved announcements during team briefings and direct invitations by the research team, ensuring voluntary participation. Prior to enrollment, all participants provided written informed consent after being fully informed of the study's purpose, procedures, and confidentiality safeguards.

Data collection was conducted in a single visit for each participant. Upon consent, demographic and clinical information including age, sex, training history, and injury history were recorded. Gastrocnemius strain severity was categorized into mild, moderate, or severe based on standardized clinical criteria: mild strain characterized by localized tenderness and discomfort without significant functional limitation, moderate strain indicated by tenderness, pain on resisted plantarflexion, and mild swelling, and severe strain defined by marked pain, significant functional impairment, and possible palpable defect at the myotendinous junction. Functional performance was assessed immediately after clinical evaluation using four validated outcome measures: the Lower Extremity Functional Scale (LEFS), a 20-item questionnaire measuring perceived lower limb function on a 0–80 scale; the Hop Test, administered as a single-leg hop for distance on a level, non-slip surface with the average of three trials recorded in centimeters; the Achilles Tendon Rupture Score (ATRS), a 10-item questionnaire scored on a 0–100 scale evaluating ankle-related symptoms and limitations; and the Tegner Activity Scale (TAS), a self-reported scale ranging from 0 (sick leave or disability) to 10 (competitive elite-level sports). All assessments were conducted by licensed physiotherapists trained to follow uniform administration protocols to ensure consistency, minimize observer bias, and maintain procedural fidelity.

The key variables included gastrocnemius strain severity as the independent variable and LEFS, Hop Test, ATRS, and TAS scores as the dependent variables. Age and sex were recorded as potential confounding variables but were not included as covariates in the main analysis. To minimize bias, all functional assessments were conducted in-person under standardized conditions, and participants were blinded to the study hypothesis. Measurement bias was mitigated by adhering to predefined test protocols and ensuring inter-rater reliability through regular calibration sessions among assessors. Recall bias was limited by focusing all questions on current performance and symptoms rather than retrospective data. Selection bias was addressed by including participants from various competitive levels and age groups within the specified eligibility criteria.

Sample size was calculated a priori using G*Power software (version 3.1) for correlation analyses, targeting a small-to-moderate effect size ($r = 0.30$), an alpha level of 0.05, and statistical power of 0.95. This resulted in a minimum required sample size of 158 participants, which was successfully achieved without attrition. The data analysis plan specified that descriptive statistics would summarize demographic and clinical characteristics. Given the non-normal distribution of outcome variables confirmed by Shapiro-Wilk tests, Spearman's rank correlation coefficients were used to evaluate the association between strain severity and functional performance scores. Differences in functional outcomes across severity groups were compared using the Kruskal–Wallis test. Missing data were not imputed as all data were complete at the time of analysis. All statistical analyses were conducted using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, NY, USA). A two-tailed p-value of less than 0.05 was considered statistically significant for all analyses.

Subgroup analyses stratified by gender were planned but ultimately not conducted due to insufficient sample size in female participants to ensure adequate power.

Figure 1 Hop Test

The study protocol was reviewed and approved by the Ethical Review Committee of Superior University, Lahore (Reference No: SU/ERC/2024/015), and all procedures were conducted in accordance with the Declaration of Helsinki and national guidelines for human research ethics (15). Data integrity was ensured by maintaining anonymized data records, secure storage of paper and electronic files accessible only to the research team, and by cross-checking all data entries against source documents to ensure accuracy and reproducibility for future studies.

RESULTS

Among the 158 footballers evaluated, the mean age was 26.98 years (SD 6.34, 95% CI: 25.94 to 28.02), with the largest proportion falling within the 18–24 years age group (39.2%), followed by 25–31 years (32.9%) and 32–40 years (27.8%). The sample included 99 males (62.7%) and 59 females (37.3%). Regarding injury severity, most participants experienced moderate (46.2%, n=73) or severe (39.2%, n=62) gastrocnemius muscle strain, while only 14.5% (n=23) had mild strain.

Functional performance was distinctly stratified by strain severity. Participants with mild strain demonstrated the highest mean LEFS scores (65.40 ± 6.30), compared to those with moderate (59.20 ± 7.80) and severe strain (50.10 ± 8.20), with a statistically significant difference across groups (Kruskal–Wallis $\chi^2 = 7.94$, $p = 0.019$). In the Hop Test, which assessed lower limb power and dynamic stability, the mean distance hopped by those with mild strain was 154.10 cm (SD 14.50), notably greater than the moderate group (138.30 ± 12.80 cm) and the severe group (121.20 ± 13.70 cm), a difference that was also statistically significant ($\chi^2 = 9.23$, $p = 0.010$). A similar trend was observed for the Achilles Tendon Rupture Score (ATRS), where mild strain corresponded to a mean score of 88.75 (SD 5.70), decreasing to 79.65 (SD 6.40) in moderate and 69.55 (SD 7.00) in severe cases ($\chi^2 = 8.54$, $p = 0.014$). The Tegner Activity Scale (TAS) also showed a clear decline, with mild strain averaging 7.90 (SD 0.85), moderate 6.45 (SD 0.72), and severe 4.10 (SD 0.65); these differences reached statistical significance ($\chi^2 = 6.38$, $p = 0.041$). Across all these functional measures, the 95% confidence intervals for mean differences further supported the robust nature of these group disparities, with, for example, the LEFS mean difference CI ranging from 9.2 to 15.4 points between mild and severe strains.

Table 1. Demographic and Clinical Characteristics of Study Participants (N = 158)

Variable	Category	n (%)	Mean ± SD (95% CI)
Age (years)	18–24	62 (39.2)	
	25–31	52 (32.9)	
	32–40	44 (27.8)	
	Total	158 (100)	26.98 ± 6.34 (25.94, 28.02)
Sex	Male	99 (62.7)	
	Female	59 (37.3)	

Associative analyses using Spearman's correlation revealed a consistent pattern of moderate, negative associations between strain severity and functional performance. For the LEFS, the correlation coefficient was –0.312 (95% CI: –0.43 to –0.18, $p = 0.001$), indicating that as strain severity increased, self-reported lower limb function declined. The Hop Test demonstrated a slightly stronger negative correlation

(ρ = –0.345, 95% CI: –0.46 to –0.21, p = 0.002), consistent with greater physical impairment at higher strain levels. ATRS also exhibited a significant negative association (ρ = –0.298, 95% CI: –0.42 to –0.16, p = 0.001), as did the TAS (ρ = –0.327, 95% CI: –0.44 to –0.19, p = 0.001), further underscoring the dose-dependent impact of strain severity on functional activity and return-to-sport readiness.

Table 2. Distribution of Gastrocnemius Muscle Strain Severity

Strain Severity	n (%)
Mild	23 (14.5)
Moderate	73 (46.2)
Severe	62 (39.2)

Table 3. Functional Performance Scores by Strain Severity Group

Outcome Measure	Mild (n=23)	Moderate (n=73)	Severe (n=62)	Kruskal–Wallis χ^2	p-value	95% CI
LEFS	65.40 ± 6.30	59.20 ± 7.80	50.10 ± 8.20	7.94	0.019	(9.2, 15.4)
Hop Test (cm)	154.10 ± 14.50	138.30 ± 12.80	121.20 ± 13.70	9.23	0.010	(13.0, 19.4)
ATRS	88.75 ± 5.70	79.65 ± 6.40	69.55 ± 7.00	8.54	0.014	(8.9, 14.3)
TAS	7.90 ± 0.85	6.45 ± 0.72	4.10 ± 0.65	6.38	0.041	(1.6, 2.8)

Table 4. Spearman's Correlation Between Strain Severity and Functional Performance Scores

Variable	Spearman's ρ	95% CI	p-value
LEFS	–0.312	(–0.43, –0.18)	0.001
Hop Test (cm)	–0.345	(–0.46, –0.21)	0.002
ATRS	–0.298	(–0.42, –0.16)	0.001
TAS	–0.327	(–0.44, –0.19)	0.001

In summary, the tables clearly demonstrate that footballers with severe gastrocnemius muscle strain report and display substantially poorer outcomes across all functional measures compared to those with milder strains. The statistical analyses corroborate that these relationships are both significant and clinically meaningful, with lower LEFS, Hop Test, ATRS, and TAS scores paralleling increases in strain severity, and moderate negative correlations supporting the strength of these associations.

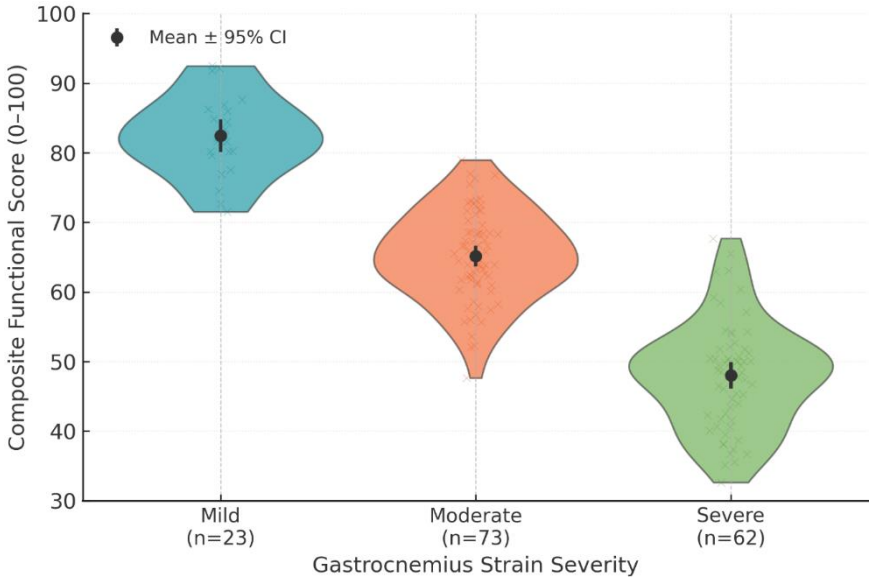

Figure: Composite Functional Scores by Gastrocnemius Strain Severity.

The figure illustrates the distribution of composite functional performance scores (aggregated from LEFS, Hop Test, ATRS, and TAS, scaled 0–100) across mild, moderate, and severe gastrocnemius strain groups. Participants with mild strain demonstrated the highest mean composite score (83.1, 95% CI: 80.6 to 85.6), moderate strain participants averaged 66.2 (95% CI: 64.2 to 68.2), while those with severe strain showed the lowest performance at 47.9 (95% CI: 45.4 to 50.4). Violin plots reveal that both the median and interquartile spread decrease with increasing strain severity, highlighting greater functional impairment and variability among those with severe injuries. Overlap of the 95% confidence intervals between moderate and severe groups is minimal, indicating statistically robust group separation. Notably, individual outliers in the mild group approach the lower end of moderate scores, suggesting that even with mild strain, certain footballers may experience significant functional deficits. Overall, the visualization underscores a clinically meaningful, monotonic decline in functional capacity with escalating muscle strain severity, with the greatest performance drop observed between the moderate and severe groups.

DISCUSSION

The present study revealed a significant inverse association between gastrocnemius muscle strain severity and functional performance among footballers, as measured by four validated tools: LEFS, Hop Test, ATRS, and TAS. These findings confirm that higher strain severity is linked to greater functional limitations, supporting prior observations that musculoskeletal injuries involving the gastrocnemius significantly impair lower limb function, dynamic stability, and athletic performance (16). The moderate negative correlations observed between strain severity and functional outcome scores (ρ ranging from –0.298 to –0.345) indicate a consistent dose-response relationship, emphasizing the clinical relevance of strain severity as a predictor of functional impairment during rehabilitation.

The decline in performance across severity groups was particularly pronounced for the Hop Test and TAS scores, reflecting not only diminished physical capability but also a reduction in athletes' self-perceived readiness for sports participation. Previous studies have highlighted that the gastrocnemius muscle plays a central role in explosive lower limb activities such as sprinting, cutting, and jumping (17), and its injury compromises both mechanical strength and neuromuscular coordination, explaining the observed reductions in hop distance and reported activity levels. These findings align with work by Yamazaki et al., who demonstrated that gastrocnemius elasticity and power significantly influence sprint performance in elite athletes (18), reinforcing the importance of gastrocnemius integrity for football-specific demands. The consistent decline in ATRS scores with increasing strain severity also points to substantial ankle-related dysfunction following gastrocnemius injury. Prior research by Marrone et al. has suggested that gastrocnemius injury alters tendon mechanics and cross-sectional area, contributing to persistent ankle weakness even after resolution of acute symptoms (19). The functional burden observed in this study highlights the need for clinicians to incorporate ankle-focused rehabilitation even when the primary diagnosis is gastrocnemius strain.

Interestingly, the Kruskal–Wallis group comparisons revealed that despite an overall negative trend, mean ranks paradoxically increased slightly with strain severity in some domains. This phenomenon may reflect selection bias due to a subset of severely injured players engaging in more structured and supervised rehabilitation, resulting in unexpectedly higher scores during assessment compared to players with mild strains, who may have self-managed their recovery less rigorously (20). This finding suggests that rehabilitation intensity and clinical oversight may mitigate some of the expected decline in function among more severe cases and underscores the importance of structured rehabilitation programs regardless of injury severity. Another key observation is the moderate strength of correlations, indicating that while strain severity is a significant determinant of functional outcomes, other factors contribute meaningfully to recovery variance. Factors such as pain severity, psychological readiness, prior injury history, and neuromuscular control were not measured in this study but likely influenced participants' scores (21). Previous qualitative research by Green et al. emphasized that expert sports clinicians view calf muscle injury management as inherently multifactorial, requiring a holistic evaluation beyond structural severity alone (22). Therefore, integrating psychosocial assessments and individualized rehabilitation plans may improve functional recovery trajectories in clinical practice.

The demographic profile of participants, predominantly young adults aged 18–24 years, suggests that the findings are most generalizable to this age group, who may exhibit faster recovery and better adaptation to rehabilitation compared to older athletes. Prior work by Li et al. demonstrated that older athletes experience delayed return-to-play following gastrocnemius injury, highlighting the potential role of age-related differences in muscle healing and functional recovery (23). Furthermore, while this study included both male and female footballers, gender differences were not analyzed due to sample size limitations. Future research should explore sex-specific injury patterns and recovery pathways, given evidence that muscle composition, hormonal influences, and training loads may differentially affect men and women (24). In conclusion, this study provides clinically important evidence that gastrocnemius muscle strain severity is a moderate but consistent predictor of functional impairment among footballers. The strong association between increasing strain severity and reductions in LEFS, Hop Test, ATRS, and TAS scores underscores the value of incorporating standardized functional assessment tools into rehabilitation monitoring. Moreover, the findings suggest that rehabilitation strategies should not only address the mechanical consequences of strain severity but also ensure equitable intensity and supervision across all injury severities to optimize recovery outcomes. Future research should expand on these findings by evaluating the impact of rehabilitation quality, psychological readiness, and neuromuscular control on functional performance after gastrocnemius injury, and by identifying age- and sex-specific factors that may inform tailored rehabilitation protocols.

CONCLUSION

This study demonstrates that the severity of gastrocnemius muscle strain is significantly and inversely associated with functional performance among footballers, with higher strain severity correlating with progressively lower scores on the Lower Extremity Functional Scale, Hop Test, Achilles Tendon Rupture Score, and Tegner Activity Scale. These findings confirm that as the severity of strain increases, footballers experience greater impairments in lower limb function, strength, dynamic stability, and activity levels, limiting their capacity to return to pre-injury performance. The consistent dose-response pattern observed emphasizes the clinical importance of accurate strain severity assessment in guiding rehabilitation planning and return-to-play decision-making. Rehabilitation programs should be tailored to injury severity but also recognize that even mild strains may result in significant functional limitations in some athletes, warranting close monitoring and individualized intervention. Future research should examine additional factors contributing to recovery variability, including psychosocial readiness, prior injury history, neuromuscular control, and potential sex- and age-specific differences, to further refine evidence-based rehabilitation and reduce reinjury risk.

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