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Relationship between Active Flexibility and Hamstring-to-Quadriceps Peak Torque Ratio in Male Soccer Players: A Cross-Sectional Study

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A B S T R A C T

Objective: This cross-sectional study aimed to explore the relationship between hamstring flexibility and hamstring-to-quadriceps (H:Q) strength ratios in male professional soccer players.

Methods: The study included 47 male professional soccer players (mean age: 25.19 ± 3.67 years). Hamstring flexibility was assessed using the Askling H-test with 2D video analysis, while isokinetic dynamometry measured H:Q ratios. Correlation and regression analyses examined relationships between flexibility, strength ratios, and age.

Results: Age significantly predicted H:Q strength ratios in players aged ⩾25 years, explaining 25.1% of the variance. Hamstring flexibility did not significantly predict H:Q ratios across age groups. Older players exhibited lower H:Q ratios, suggesting a decline in muscle balance with aging.

Conclusion: Hamstring flexibility plays a role in performance assessment, while age predominantly affects H:Q strength ratios in older players. These findings emphasize the importance of integrating flexibility and age-specific strength training strategies to enhance performance and reduce injury risk in elite soccer players.

Keywords: Hamstring flexibility, Isokinetic strength, Soccer players, H:Q ratio, Return-to-sport strategies, Muscle imbalance, Injury prevention

1. Introduction

Lower limb injuries account for 92% of all sports-related injuries, with hamstring injuries being the most common (37%). Reinjury rates range from 13.9% to 63.3%, often due to inadequate rehabilitation and premature return-to-sport (RTS) decisions. This study investigates the relationship between hamstring flexibility and H:Q ratios to improve injury prevention and rehabilitation strategies(1) Hamstring injuries are more than just numbers on a medical report; they significantly disrupt performance and team dynamics, particularly in professional soccer. Athletes suffering hamstring strains often face frustrating absences from competition, with recovery times ranging from three to twenty-eight days or longer(2)

Standard clinical evaluations, such as flexibility and strength tests, fail to fully account for sport-specific demands or the psychological readiness of athletes to return to competition(3,4) To address this shortfall, the H-test was developed as a targeted RTS assessment tool for hamstring strain injuries (HSI). This well-established test assesses hamstring flexibility dynamically, capturing both maximum speed and range of motion (ROM) through ballistic movements. As a result, it allows for a more functional and objective (subjective) evaluation of an athlete's readiness for high-performance tasks(4)

The role of hamstring weakness as a risk factor for HSIs remains a subject of debate, largely due to inconsistencies in research methodologies and measurement timings(5) Meta-analyses have revealed no definitive link between hamstring injuries and reduced knee flexor strength as measured by isokinetic testing or Nordic Hamstring Exercises (6) Notably, the importance of muscle strength ratios, such as H:Q ratio, is often overlooked in RTS protocols. The H:Q ratio serves as a marker for muscle balance, calculated by dividing knee flexor torque by knee extensor torque(7) Maintaining an optimal H:Q ratio is essential, as targeted interventions to improve this ratio have been shown to reduce injury risks among soccer players(8,9)

Despite the wealth of research on hamstring injuries, gaps remained in understanding the relationship between hamstring flexibility, and the H:Q ratio. Bridging this gap was critical for developing evidence-based return-to-sport protocols that prioritized both performance and injury prevention. Pain often dictated rehabilitation decisions, with return-to-sport timelines historically driven by clinical evaluations and functional tests. However, these conventional criteria frequently fell short, offering only arbitrary benchmarks that failed to predict re-injury risk accurately. Emerging tools, such as the

Askling H-test and isokinetic dynamometry, showed promise as alternatives, linking their use to reduced reinjury rates, even though return-to-play (RTP) durations varied(10,11).

This study aimed to explore the relationship between 2D-video analysis of hamstring flexibility during the H-test, and the H:Q ratio in professional soccer players. By investigating these factors, the research sought to pave the way for safer and more effective return-to-sport protocols, enabling athletes to recover confidently and reduce the risk of recurrence.

2. Methodology

This observational cross-sectional study aimed to assess H:Q peak torque ratio, and hamstring flexibility during the H-test using 2D-video analysis in professional male soccer players. The study was conducted in the isokinetic laboratory at Alhayah University and Fizik Physical Therapy and Rehabilitation Center between August 13, 2024, and November 7, 2024. Ethical approval was obtained from the Faculty of Physical Therapy Research Ethics Committee (approval number: P.T.REC/012/005295), and the trial was prospectively registered on ClinicalTrials.gov (ID: NCT06818929).

Forty-seven male soccer players (mean age: 28 ± 7 years; BMI: 22.98 ± 1.16 kg/m²) were recruited. Inclusion criteria included a history of hamstring strain for more than three months. Participants were excluded if they had a recent hamstring injury in the last 3 months prior to the study, ACL injury within the past 12 months (hamstring graft), lumbar disc issues (L3-L4, L5-S1), or sacroiliac dysfunction. Sample size calculations were conducted using G*Power software (version 3.0.10) for a biserial correlation model with a power of 0.80, alpha level of 0.05, and effect size of 0.38 (12) Determined a minimum of 47 participants, with 10% added for potential dropouts, yielding a total sample size of 52.

2.1 Standardization Procedures

To reduce measurement variability, the principal investigator was responsible for all aspects of experimental preparation, including providing instructions, adjusting the isokinetic machine, attaching adaptors, placing braces, identifying bony landmarks, and collecting data. The chair, dynamometer, and adaptor settings were configured according to CSMI guidelines to enhance inter-rater reliability (13). Participants received standardized instructions on the warm-up process, isokinetic testing, and performing the H-test. Familiarization sessions for both the isokinetic and H-tests were conducted beforehand using submaximal effort to ensure participants were well-versed in the procedures.

2.2 H-test

The primary outcome measure, hamstring active flexibility, was assessed by measuring the ROM during hip flexion (4) In the H-test procedure, participants were positioned supine on a table with straps securing the contralateral leg, hip, and trunk to ensure stability and correct posture throughout the test. Two visual markers were placed on the greater trochanter and lateral malleolus of the tested limb. A knee support (Orthopedic Bracewear Air-X©) was applied to the tested limb to maintain knee extension and prevent flexion during the movement (14) The procedure began with a warm-up consisting of three slow hip flexions, followed by three maximum-velocity trials, each separated by 5 seconds of rest to avoid the Cavagna effect (15) Hip flexion was recorded using a smartphone (iPhone 12©, 30 Hz) mounted on a tripod positioned 3 meters from the participant and 1 meter in height. The setup was calibrated with a 10 cm scale placed on the table to ensure accurate measurement during the video recording(14).

Participants were then instructed to perform hip flexions at maximum speed and ROM while maintaining full knee extension. The angle between the visual markers, placed on the greater trochanter and lateral malleolus, was captured through 2D video recording during each trial. This process was repeated for three trials, with each performed at maximum velocity to ensure an accurate measurement of the participant's hip flexion ROM. The recorded video footage was then analyzed using Kinovea software (version 0.9.5), calibrated to 600% zoom, to calculate the hip flexion ROM by measuring the angle formed between the markers from the start to the end of the movement (14)

2.3 Peak torque ratios assessment

The Cybex Norm (Computer Sports Medicine Inc., Stoughton, MA, USA) isokinetic dynamometer was utilized for measurements of H:Q ratio. Prior to the test, participants began with a 5-minute warm-up on a stationary bike, followed by dynamic stretching exercises targeting both the hamstrings and quadriceps. This warm-up was crucial to minimize the risk of injury and to ensure the participant was prepared for the maximum-effort movements during the subsequent tests.

The participant was seated on the isokinetic dynamometer with the knee axis aligned with the dynamometer's axis of rotation (Appendix A). Familiarization sets consisting of submaximal-effort repetitions were performed to allow the participant to become accustomed to the testing procedure. After the familiarization phase, maximal-effort repetitions were conducted to assess the peak torque produced by both the hamstrings and quadriceps. The H:Q ratio was calculated by dividing the peak torque of the hamstrings by that of the quadriceps (16).

3. Data Processing and Statistical Analysis

Data were analysed using Python (version 3.10). Descriptive statistics summarized participant characteristics and outcomes. The normality of data was confirmed using the Shapiro-Wilk test. Pearson correlation was applied to examine relationships between H-test scores, and, H:Q ratio. Multiple regression analyses assessed the influence of H-test scores and age on torque ratios, including interaction terms for combined effects. Subgroup analyses stratified participants into age groups (≤25 years and >25 years) to explore age-related differences, with significance set at $p < 0.05$.

3.1 Results

This study included 47 male professional soccer players with a mean age of 25.19 ± 3.67 years, mean weight of 74.74 ± 7.66 kg, mean height of 1.80 ± 0.06 m, and mean BMI of 22.98 ± 1.16. These values highlight a lean and athletic physique suitable for professional soccer demands (Table 1).

3.2 Descriptive Statistics for Quantitative Variables

Table 1:

Variable	Description	Mean ± SD
Age (Years)	Age of the participants	25.19 ± 3.67
Weight (kg)	Body weight	74.74 ± 7.66
Height (m)	Height	1.80 ± 0.06
BMI	Body Mass Index	22.98 ± 1.16
H:Q Ratio (Right)	Hamstring-to-Quadriceps ratio (Right leg)	62.96 ± 7.03
H:Q Ratio (Left)	Hamstring-to-Quadriceps ratio (Left leg)	64.19 ± 8.53
Askling H-test Avg (Right)	Flexibility score (Right leg)	58.59 ± 11.97
Askling H-test Avg (Left)	Flexibility score (Left leg)	57.30 ± 12.31

3.3 Normality Testing

Shapiro-Wilk test results confirmed the normality of H:Q and Askling H-test variables, allowing for parametric analysis. Key distributions are visualized in Figures 1 and 2. For the H:Q ratios, the W-statistic values were 0.976 ($p = 0.433$) for the right leg and 0.983 ($p = 0.739$) for the left leg, indicating approximate normality in both cases as shown in figure (1). Similarly, H-test using 2D-video analysis averages exhibited normal distributions, with W-statistic values of 0.680 ($p = 0.594$) for the right leg and 0.721 ($p = 0.634$) for the left leg as shown in figure (2).

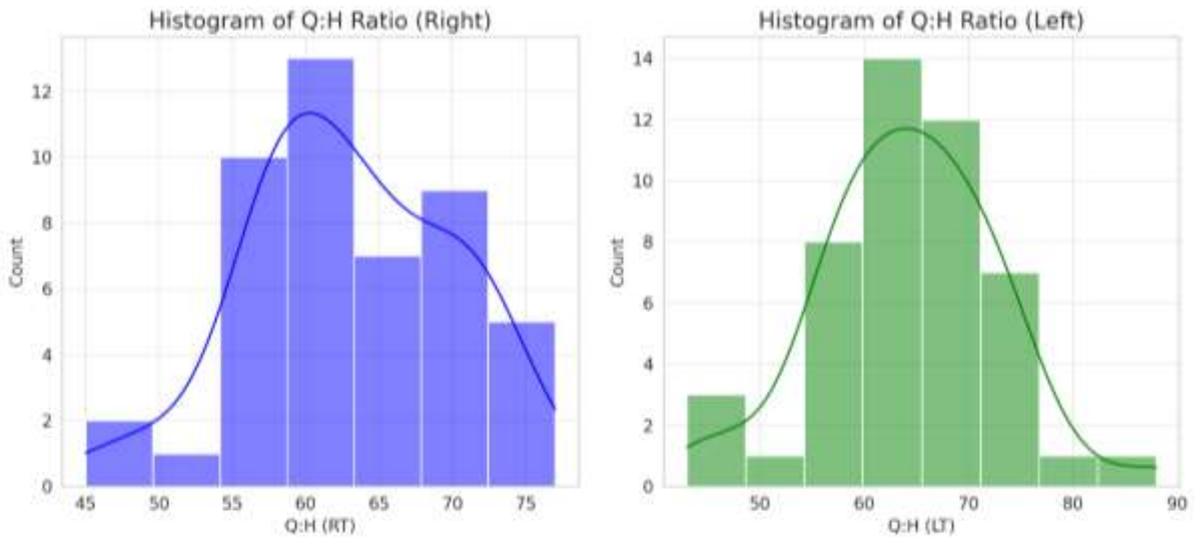

Figure 1: These histograms display the distribution of the hamstring-to-quadriceps peak torque ratios for both the right and left legs.

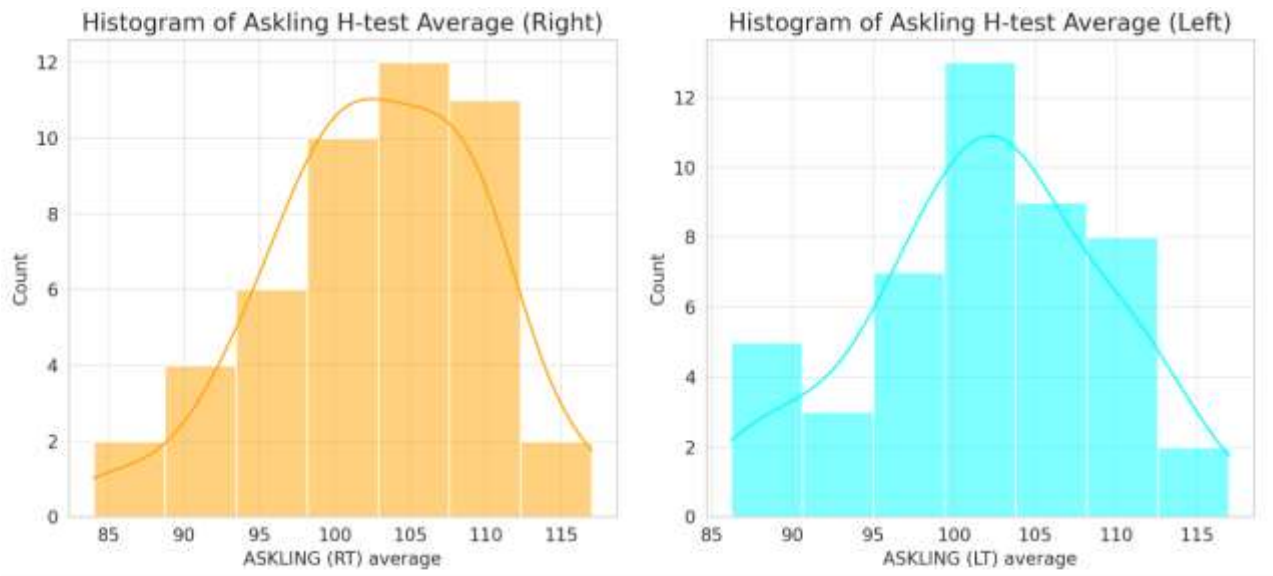

Figure 2: Histograms represent the distribution of Askling H-test averages, measuring active hamstring flexibility, for both the right (orange) and left (cyan) legs.

3.4 Correlation Analysis

Correlation coefficients between Askiling and H:Q ratio was weaker and not statistically significant as shown in table 3.

Table 3: Correlation Coefficients Between Askling H-test and H:Q Ratio

Correlation Pair	Coefficient (r)	p-value
Askling H-test (Right) vs H:Q Ratio (Right)	-0.24	0.104
Askling H-test (Left) vs H:Q Ratio (Left)	0.07	0.921

(*Statistically significant at p < 0.05)

3.5 Regression Analysis

Age significantly predicted H:Q ratios, accounting for 20.1% and 19.3% of the variance in the right and left legs, respectively. These findings are summarized in Table 4.

Table 4: Multiple Regression Analysis Results Table

Outcome Variable	R-squared (%)	Significant Predictor	Non-significant Predictors
H:Q Ratio (Right)	20.1	Age (p = 0.045)	Askling H-test (Right, p = 0.604), Askling H-test (Left, p = 0.076), Interaction Terms (p > 0.05)
H:Q Ratio (Left)	19.3	Age (p = 0.028)	Askling H-test (Right, p = 0.826), Askling H-test (Left, p = 0.245), Interaction Terms (p > 0.05)

3.6 Subgroup Analysis

Age-related differences were prominent in participants aged ≥25 years, where age significantly predicted H:Q ratios, explaining up to 25.1% of the variance. In contrast, for participants aged <25 years, none of the predictors demonstrated statistical significance.

Table 5: Subgroup Analysis of Predictors

Age Group	Outcome Variable	R-squared (%)	Significant Predictors	Non-significant Predictors
<25 years	H:Q Ratio (Right)	22.3	None	Askling H-test (Right &Left), Age
	H:Q Ratio (Left)	18.5	None	
≥25 years	H:Q Ratio (Right)	25.1	Age (p = 0.032)	Askling H-test (Right &Left), Interaction Terms
	H:Q Ratio (Left)	20.8	Age (p = 0.025)	

Footnote: R-squared values indicate the proportion of variance explained by the predictors. Significant predictors have p-values < 0.05.

Discussion

This study investigated associations between hamstring flexibility metrics derived from 2D video analysis of the Askling H-test and conventional H:Q strength ratios in elite male soccer athletes. The primary objective was to optimize RTS protocols by evaluating these parameters to balance injury prevention and athletic performance outcomes. Contrary to hypotheses, analyses revealed no significant associations between H:Q ratios and Askling H-test scores ($p > 0.05$), indicating that these parameters capture different facets of neuromuscular function. These results challenge the clinical utility of traditional H:Q ratios as standalone predictors of reinjury risk in high-performance athletes. Notably, prior evidence suggests functional H:Q assessments incorporating sport-specific dynamic loads may better stratify injury susceptibility (17,18).

Age emerged as a significant predictor of H:Q ratios, accounting for approximately 20% of the observed variance (right limb: $R^2=0.20$, $p=0.045$; left limb: $R^2=0.20$, $p=0.028$). This relationship was amplified in athletes aged >25 years, explaining 25.1% (right) and 20.8% (left) of variance. These findings corroborate existing literature identifying age as a non-modifiable risk factor for hamstring injuries (19,20), potentially mediated by age-related declines in neuromuscular coordination and alterations in musculotendinous compliance (21).

A key methodological strength lies in the employment of isokinetic dynamometry, the gold standard for quantifying strength ratios (22), ensuring high-precision data to inform rehabilitation decisions. Similarly, the Askling H-test demonstrated strong criterion validity and test-retest reliability (14), with practical advantages for clinical implementation due to its cost-effectiveness and minimal technical requirements.

Study limitations include the ecological validity constraints of isokinetic testing, executed under controlled laboratory conditions that may not replicate sport-specific demands. The inherent constraints of the cross-sectional design preclude causal interpretations, while seasonal training variations and potential sample size limitations in subgroup analyses may have influenced outcomes.

Clinically, rehabilitation protocols should account for limb dominance patterns, given potential asymmetries in neuromuscular adaptation. While active flexibility metrics offer valuable insights, augmenting active flexibility assessments with passive measures may enhance injury risk profiling.

Conclusion:

Integration of isokinetic dynamometry and 2D motion analysis into return-to-sport assessments may optimize rehabilitation efficacy by providing objective, multidimensional data. Future research should prioritize longitudinal investigation of individualized interventions targeting age-related neuromuscular decline and sport-specific functional capacity.

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Appendix A.

Knee Extension/Flexion (Seated) Test Setup

- **Parts Required:** Knee/Hip Adapter, Knee/Hip Pad, Contralateral Limb Stabilizer, Lumbar Cushion (optional)
- **Chair Setup:**

- Chair Rotation Scale: 40° (Right Limb: Teal; Left Limb: Black)
- Chair-Back Angle: 85°
- Chair-Seat Position: Up

- **Dynamometer Settings:**
  - Dyna Tilt Scale: 0°
  - Dyna Height Scale: 8
  - Dyna Rotation Scale: 40° (Right Limb: Teal; Left Limb: Black)
  - Monorail Scale: 38

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