Gender differences in bilateral and ipsilateral lower limb strength asymmetry among football players

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ABSTRACT

Background: Lower limb muscle strength asymmetry is a significant factor that can impact playing ability and increase the risk of injury in soccer players. Differences in leg use and the specific movement requirements of a sport can lead to strength imbalances, either on both sides of the body or on the same side. Lower limb muscle strength asymmetry, particularly bilateral and ipsilateral strength asymmetry, is a significant factor influencing performance and increasing injury risk in football players. Differences in limb dominance and sport-specific movement demands can lead to strength imbalances. An asymmetry level exceeding approximately 10–15% is considered above the ideal limit and may elevate injury risk.

Objectives: This study aimed to compare bilateral and ipsilateral lower limb strength asymmetry between male and female football players.

Methods: A cross-sectional study was conducted involving 50 amateur football players (26 males and 24 females; aged 18–21 years). Isokinetic strength testing of knee extensors and flexors was performed at 60°/s. Bilateral asymmetry was calculated based on peak torque differences between limbs, while ipsilateral asymmetry was assessed using the hamstring-to-quadriceps (H/Q) ratio. Statistical analyses included the Mann–Whitney U test and independent t-test ($p < 0.05$).

Results: Significant sex differences were found in bilateral strength asymmetry for both quadriceps (7.21 ± 4.04% vs 5.04 ± 3.13%, $p = 0.02$) and hamstrings (9.13 ± 5.15% vs 5.06 ± 4.04%, $p = 0.01$), with males showing greater asymmetry. Female athletes demonstrated values closer to the recommended asymmetry threshold (≤10–15%). No significant differences were observed in ipsilateral strength asymmetry (H/Q ratio) between groups ($p > 0.05$).

Conclusions: Bilateral strength asymmetry differs by sex, with male athletes exhibiting higher imbalance, while ipsilateral strength balance is comparable between groups. These findings highlight the importance of monitoring individual strength asymmetry to inform targeted training strategies, reduce injury risk, and optimize performance in football players.

Keywords: bilateral, football, ipsilateral, isokinetic, strength asymmetry.

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INTRODUCTION

Football is a sport that requires physical condition, strength, explosive power, and running ability, which are determining factors in achieving performance. Lower limb strength is the most important factor in supporting the ability to run, change direction, accelerate, and decelerate (Ruscello et al., 2018). During training and matches, football players use their lower body parts to kick the ball, run, and sometimes tackle opponents. This will undoubtedly affect the asymmetry in strength production and the biomechanical structure of the movement, as previous studies have reported.

Numerous studies have reported that most injuries in football players occur in the lower extremities, particularly the hamstrings, ACLs, and knees (Aiello et al., 2023; Alyami et al., 2023; Ferdinand et al., 2025; Huygaerts et al., 2020; Loose et al., 2019). Lower extremity strength imbalances increase the risk of injury (Benson et al., 2024; Hanief et al., 2025), particularly in female athletes. One of the best parameters for assessing injury risk is measuring differences in lower-extremity muscle strength. Valid measurements include an isokinetic dynamometer, which measures the strength of the knee extensor and flexor muscles during eccentric and concentric contractions (Kalata et al., 2020).

Strength asymmetry refers to the bilateral or ipsilateral ratio of the maximum strength values of both legs relative to a reference point. Bilateral muscle strength asymmetry in the range of 10-15% increases the risk of injury, while a hamstring/quadriceps (H/Q) strength ratio of less than 60% is associated with lower extremity injuries (Akarsu Taşman et al., 2025).

An imbalance in lower extremity strength can directly affect athletic performance and plays a significant role in preventing long-term injuries. Imbalance in strength can be influenced by ligament laxity in the knee joint, anatomical structures, and gender-related factors such as hormonal status and the menstrual cycle.

Physiological differences between male and female athletes, such as body weight, muscle mass, and body fat levels, can influence maximal quadriceps and hamstring strength, as well as interbody strength imbalances (Coto Martín et al., 2025; Kalata et al., 2020). While reports indicate that female athletes have lower force output than male athletes, further research is needed to determine whether gender influences lower-body strength imbalances.

Previous research has reported conflicting results on sex-related differences in strength asymmetry (Daneshjoo et al., 2013; Kalata et al., 2020). While some studies suggest greater asymmetry in female athletes, others report no significant differences, indicating a lack of consensus. Moreover, limited studies have simultaneously examined both bilateral and ipsilateral strength asymmetry using isokinetic assessment in male and female football players, particularly in amateur populations. Therefore, a clear research gap remains regarding the extent to which sex influences different types of lower limb strength asymmetry. Addressing this gap is important for developing evidence-based training and injury prevention strategies tailored to athlete characteristics.

This study provides a novel contribution by examining both bilateral and ipsilateral lower limb strength asymmetry in male and female football players using isokinetic assessment. Given the inconsistent findings in previous research and the limited evidence in amateur populations, this study is important to clarify sex-related differences in strength imbalance. The findings have practical implications for developing targeted training programs, improving performance, and reducing injury risk.

METHODS

Study Design and Participants

This study used a cross-sectional design to compare groups by evaluating participants' characteristics at a single point in time. Participants were selected through purposive sampling based on the study's eligibility requirements. The study received ethical approval from the relevant review board, ensuring adherence to ethical standards. All athletes were briefed on the study's goals and methods, in accordance with the Declaration of Helsinki. Participation was voluntary, and written informed consent was secured from each participant before data collection began.

Participants in this study included 50 amateur football players, comprising 26 male and 24 female athletes, aged 18-21 years, in Batangas Province, Philippines. All athletes involved had at least 3 years of football experience, had not suffered any injuries in the past 3 months, and were actively playing football.

Ethical approval statement

Following ethical standards helped protect everyone involved. Approval came through J.H. Cerilles State College's Institutional Ethics Review Board after a full review. Before anything else started, each person signed a form giving clear permission to take part.

Research Instruments

The researchers conducted body composition and isokinetic strength tests on the participants at Batangas State University's Department of Physical Education, within the Physical Profile, Performance, and Biomechanics Laboratory. To ensure the study's results were not influenced, the tests were carried out under controlled conditions, with the temperature maintained at 20-21°C and the humidity at 45-50%.

The body composition of the athletes involved in the study was assessed using Bioelectrical Impedance Analysis (Tanita BC418). Participants were briefed on the procedure prior to measurement. Measurements were taken while wearing sportswear (shorts and a tank top) and without shoes. Weight was recorded on a scale with an accuracy of ± 0.1 kg, and height was measured using a stadiometer with an accuracy of ± 1 mm, measuring the distance from the top of the head to the foot after a deep breath, with the head positioned in the Frankfort plane.

The participants' knee extensor and flexor isokinetic strength was measured using an isokinetic dynamometer. Before testing, they completed a standardized 10-minute warm-up involving treadmill running and dynamic exercises. The isokinetic assessment was conducted on both knees at an angular velocity of 60°/s, consisting of three sets of five repetitions with 30-second rest intervals, following familiarization trials performed at a higher speed. During the test, participants were securely positioned to limit unnecessary movement, and the range of motion was set to 90°. The device was calibrated and gravity-corrected according to the manufacturer's instructions, and verbal encouragement was given throughout. Bilateral strength asymmetry was calculated by comparing peak torque differences between limbs, while ipsilateral asymmetry was assessed using the hamstring-to-quadriceps peak torque ratio.

Data Analysis

Statistical analysis was performed using SPSS version 22. Descriptive statistics were used to summarize participant characteristics. Differences between male and female groups in bilateral and ipsilateral strength asymmetry were analyzed using the Mann–Whitney U test and independent samples t-test, as appropriate. Statistical significance was set at $p < 0.05$.

RESULTS

This study aims to examine the differences in strength imbalance between the left and right legs in the lower extremities of male and female football players. The results of the measurement and recording of participant characteristics are shown in Table 1.

Table 1. Participants Demographic Characteristics

Variable	Gender	Minimum	Maximum	Mean	Standard Deviation
Age (years)	Male	18	21	19.11	1.15
	Female	18	21	20.06	1.54
Height (cm)	Male	160	165	162.77	4.35
	Female	150	158	154.32	4.03
Weight (kg)	Male	61.75	74.41	68.08	7.59
	Female	56.20	66.60	61.40	7.02
BMI (kg/m2)	Male	18.08	25.75	21.92	2.32
	Female	18.98	26.66	22.82	2.48
REPT (Nm)	Male	102	179	131.77	20.47
	Female	143	277	218.50	28.85
RFPT (Nm)	Male	76	159	119.53	18.87
	Female	51	99	69.32	10.87
LEPT (Nm)	Male	151	254	207.54	24.66
	Female	95	170	128.97	17.87
LFPT (Nm)	Male	82	149	113.65	14.61
	Female	51	95	68.59	9.78
Bilateral Difference (%) (Q/Q)	Male	0.73	21.55	7.21	4.04
	Female	0	10.57	5.04	3.13
Bilateral Difference (%) (H/H)	Male	0	20.21	9.13	5.15
	Female	0	17.32	5.06	4.04
Ipsilateral (%) (H/Q Right)	Male	31.11	65.70	48.45	6.11
	Female	32.49	64.36	48.42	6.02
Ipsilateral (%) (H/Q Left)	Male	40.50	68.77	53.33	6.45
	Female	39.19	64.83	53.21	6.26

** REPT: Right Extension Peak Torque; RFPT: Right Flexion Peak Torque; LEPT: Left Extension Peak Torque; LFPT: Left Flexion Peak Torque; Nm: ewton meter; Q/Q: Quadriceps/Quadriceps; H/H: Hamstring/Hamstring; H/Q: Hamstring/Quadriceps.*

Table 2. Analysis of Sex Differences in Bilateral Lower Limb Strength Asymmetry

Variable	Gender	n	Mean	Standar Deviation	Z	p
Bilateral Difference (%) (Q/Q)	Male	26	7.21	4.04	-2.137	0.02*
	Female	24	5.04	3.13		
Bilateral Difference (%) (H/H)	Male	26	9.13	5.15	-3.321	0.01*
	Female	24	5.06	4.04		

**p<0.05; Q/Q: Quadriceps/Quadriceps; H/H: Hamstring/Hamstring*

Table 3. Analysis of Sex Differences in Ipsilateral Lower Limb Strength Asymmetry

Variable	Gender	n	Mean	Standar Deviation	Z	p
Ipsilateral (%) (H/Q Right)	Male	26	48.45	6.11	-0.675	0.78
	Female	24	48.42	6.02		
Ipsilateral (%) (H/Q Left)	Male	26	53.33	6.45	-0.673	0.71
	Female	24	53.21	6.26		

H/Q: Hamstring/Quadriceps

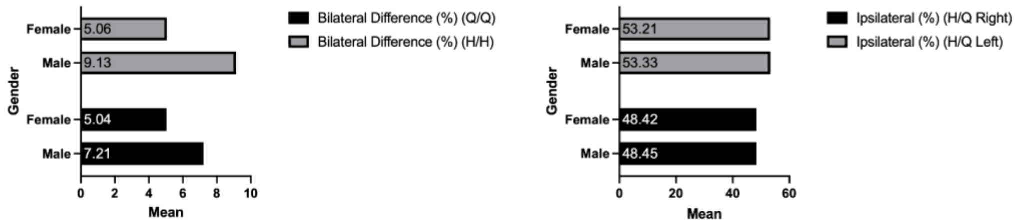

Figure 1. Analysis of Gender Differences in bilateral and Ipsilateral Strength Asymmetry

Referring to Table 2, it is known that there are significant differences between the two muscle groups, quadriceps ($p<0.02$) and hamstrings ($p<0.01$). The level of asymmetry in male amateur football players is higher than in female players. The fit statistics suggested that the model was a reasonable representation of the data however due to the low general fit index of 0.819 and the sample size the results should be treated with caution and viewed as exploratory rather than confirmatory.

Referring to Table 3, it is known that there is no difference in strength asymmetry between male and female, but the male group has a more ideal value than female

Figure 1 presents the comparison of bilateral and ipsilateral strength asymmetry between male and female participants. In terms of bilateral asymmetry, male participants demonstrated higher mean differences than females for both quadriceps (Q/Q) and hamstrings (H/H), indicating greater side-to-side strength variability. Specifically, males showed mean values of 7.21% (Q/Q) and 9.13% (H/H), compared to 5.04% and 5.06% in females, respectively. For ipsilateral strength ratios (hamstring-to-quadriceps, H/Q), both male and female participants exhibited relatively similar values between limbs. The right limb showed slightly higher H/Q ratios (approximately 53%) compared to the left limb (approximately 48%) in both groups. These findings suggest a consistent pattern of muscle balance within limbs, although minor asymmetries between sides are present. Overall, males tended to exhibit greater bilateral asymmetry, while ipsilateral strength ratios appeared relatively comparable across genders. However, these differences should be interpreted cautiously, as no statistical significance is indicated in the figure.

DISCUSSION

The findings revealed significant bilateral differences, defined as strength imbalances between the two limbs, with female athletes closer to ideal values. Furthermore, there were no gender differences in ipsilateral strength imbalances, with male athletes closer to ideal values.

This outcome highlights differences among individuals and reinforces the importance of assessing each athlete individually to identify their specific weaknesses. In football players, Iga et al. (2009) found that players seldom use both legs equally, as a tendency to favor one leg over the other is linked to the brain's hemispheric dominance on the opposite side. This fact can affect specific preferences, leading to varying degrees of morphological and pathophysiological maladaptation in athletes, with one side of the body favored over the other.

The observed differences in bilateral strength asymmetry between male and female athletes may be explained by several underlying mechanisms. One possible explanation relates to differences in neuromuscular control and limb dominance, as repeated unilateral actions in football (e.g., kicking and cutting) may lead to asymmetric muscle development (Bishop et al., 2018; Dos'Santos et al., 2021). Male athletes, who generally produce greater absolute force, may also be more susceptible to developing strength imbalances due to higher mechanical loading during training and competition (Maloney, 2019; Read et al., 2019).

Additionally, physiological differences such as muscle mass distribution, tendon stiffness, and hormonal influences may contribute to variations in strength asymmetry between sexes (Brownstein et al., 2021; Tøien et al., 2023). Female athletes, despite having lower absolute strength, may exhibit more balanced inter-limb coordination and movement control, which could explain why their asymmetry values are closer to the recommended threshold (Bishop et al., 2018; Dos'Santos et al., 2021).

The absence of significant differences in ipsilateral asymmetry suggests that the hamstring-to-quadriceps (H/Q) ratio is relatively consistent between sexes. This finding aligns with previous studies indicating that neuromuscular coordination between agonist and antagonist muscles tends to be preserved regardless of sex, particularly in trained populations (Baroni et al., 2020; Hanief et al., 2025; Tengku Kamalden et al., 2021). This may indicate that although inter-limb asymmetry differs, intra-limb muscle balance is maintained similarly across groups.

The results of this study also occurred in several other sports such as volleyball and tennis. In volleyball, players frequently perform multiple vertical jumps starting from the same leg during play. Landing occurs in a significantly unbalanced position, leading to a substantial and uneven engagement of the lower limb muscles (Taylor et al., 2019). Tennis involves a sequence of active movements, frequent changes in direction, and quick speeding up or slowing down. This can lead to differences in how the lower limbs function in both young and adult tennis players (Fernandez-Fernandez et al., 2010).

In 2015, Bailey and his team conducted a study on differences in isometric strength and countermovement jump performance between genders (Bailey et al., 2015). Their findings indicated that women exhibited greater asymmetry than men. Bell and others noted that female athletes showed greater strength imbalances than male athletes (Bell et al., 2014). Our research results show that the level of strength imbalance between the two sides of the body of female soccer players is closer to the figure considered ideal than that of male players.

The results of this study have significant implications across various areas, including training, injury prevention, and athlete performance. The findings on differences in power imbalances between the left and right arms in male and female athletes indicate that training programs should be tailored to each individual's gender and strength level. Female athletes who exhibit modest differences in leg strength still require ongoing monitoring to maintain muscle strength balance, whereas male athletes require additional attention to reduce leg imbalances.

The absence of differences in ipsilateral asymmetry between men and women indicates that the hamstring-to-quadriceps strength ratio is similar, suggesting that knee-strengthening and stabilization training methods can be applied equally to both male and female athletes. Furthermore, the results of this study emphasize the importance of individual assessment of strength imbalances, as specific leg dominance and sport-specific movement habits can lead to different nervous and muscular system adaptations among athletes.

Practically, these findings serve as a basis for developing training programs aimed at preventing injuries, restoring body function after injury, and improving athlete performance, particularly through isokinetic testing, particularly in sports that require repeated single movements such as soccer.

Limitations of the study

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design does not allow for causal inference, limiting the ability to determine whether strength asymmetry directly contributes to injury risk or performance outcomes. Second, the relatively small sample size and focus on amateur football players may restrict the generalizability of the results to elite athletes or different competitive levels.

Furthermore, the use of a single angular velocity (60°/s) in isokinetic testing may not fully represent sport-specific movement demands, potentially limiting the ecological validity of the findings. In addition, factors such as limb dominance, playing position, training load, and injury history were not controlled, which may have influenced the observed asymmetry patterns.

Therefore, future studies should include larger and more diverse samples, multiple testing velocities, and additional performance-related variables to provide a more comprehensive understanding of strength asymmetry in football players.

CONCLUSIONS

This study demonstrated differences in bilateral strength asymmetry between male and female football players, with female athletes tending to have values closer to the ideal range. However, no significant differences were found in ipsilateral strength asymmetry between the sexes. These findings suggest that inter-limb strength balance and hamstring-to-quadriceps ratios should be evaluated separately, as leg dominance and sport-specific demands may influence asymmetry patterns.

From a practical perspective, the results highlight the importance of isokinetic assessment in designing individualized training programs aimed at reducing injury risk and improving performance.

However, these findings should be interpreted with caution, as the relatively small sample size and focus on amateur athletes may limit the generalizability of the results to other populations. Future research should include larger and more diverse samples, as well as additional variables such as playing position, limb dominance, and training load, to provide a more comprehensive understanding of strength asymmetry in football players.

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AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the authors used Gemini (Gemini 3.1 Pro, Google) to check grammar, improve linguistic clarity, and refine the academic English phrasing of the text. All AI-generated outputs were critically reviewed and thoroughly edited by the authors to ensure factual accuracy, clarity of expression, and compliance with academic standards. The authors take full responsibility for the integrity and content of this manuscript.

DATA AVAILABILITY

The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available because they contain information that could compromise the privacy of research participants

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CONFLICT OF INTEREST

The author hereby declares that this research is free from conflicts of interest with any party.

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