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# Directional Agreement of Inter-Limb Asymmetry Between Isometric Knee Strength and Unilateral Jump Tests in Elite Female Football Players: A Cross-Sectional Study

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## ABSTRACT

**Background & objective:** Screening batteries in women's football commonly infer limb-specific weakness from a single test, which presumes that inter-limb asymmetry is a property of the athlete rather than of the task. To determine the level of agreement in the direction of inter-limb asymmetry across isometric knee extension, isometric knee flexion, unilateral squat jump and unilateral countermovement jump in elite female football players.

**Materials & Methods:** Cross-sectional study of the complete senior squad of the reigning Bulgarian women's national champion club (N = 19; 14 with complete strength data, 17 with complete jump data). Isometric knee strength was assessed with a Kineo dynamometer and jump height with an Optojump Next optical system. Directional agreement was quantified with Cohen's kappa and associations with Spearman's rho, with 95% confidence intervals and Holm adjustment for multiple testing.

**Results:** Complete data were available for 14 players in strength, 17 in jumping and 12 in both. Directional agreement did not exceed the fair level for any task pair (κ = −0.09 to 0.31): isometric knee extension against both jump tasks κ = −0.09, knee flexion against both κ = 0.31, and the two jump tasks κ = 0.06, with every confidence interval crossing zero. Only 3 of 12 players favoured the same limb across all four tasks. Mean asymmetry ranged from 5.2 ± 6.0% (knee extension) to 9.7 ± 5.8% (unilateral squat jump), and the proportion exceeding 10% varied from 21.4% to 52.9% by task. None of the 24 correlations remained statistically significant after Holm adjustment.

**Conclusions:** The findings were consistent with both pre-specified hypotheses. Under the testing conditions examined, the limb favoured in one task did not reliably indicate the limb favoured in another, so asymmetry identified with a single test should not be assumed to generalise to other neuromuscular qualities. Replication with larger samples and repeated measurements is required.

**Keywords**
women's football; inter-limb asymmetry; direction of asymmetry; isometric strength; vertical jump; athlete screening.

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## INTRODUCTION

### Global and Theoretical Context
### Critical Review of Existing Evidence
### Research Gap, Novelty, and International Contribution
### Objective and Hypothesis

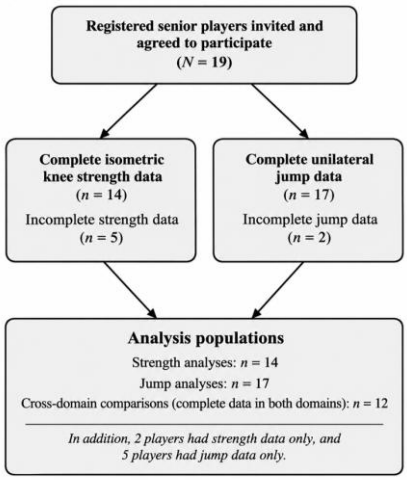
The primary objective was to determine the level of agreement in the direction of inter-limb asymmetry across four tasks: isometric knee extension, isometric knee flexion, unilateral squat jump and unilateral countermovement jump. Secondary objectives were to quantify the magnitude of asymmetry in each task, and to examine the association between isometric knee strength and bilateral jump performance and between asymmetry magnitude and bilateral jump performance. Two directional hypotheses were specified before analysis. First, agreement in the direction of asymmetry between strength tasks and jump tasks would be no better than fair, consistent with the task dependence reported by (Bishop et al., 2018, 2019). Second, asymmetry magnitude would show no meaningful association with bilateral jump height, consistent with the meta-analytic estimate of (Fox et al., 2023, p. 7).

## MATERIALS AND METHODS

### Study Design and Reporting Guideline
### Setting and Participants
### Sample Size and Rigor Justification
### Measures and Instruments
### Statistical or Analytical Procedures
### Ethical Approval and Informed Consent
### Data, Materials, and Code Availability

## RESULTS

### Participant Flow and Baseline Characteristics




Note. All 19 players agreed to participate. Complete strength data were available for 14 players and complete jump data for 17 players; 12 players had complete data in both domains.

Figure 1. Participant Flow and Availability of Complete Measurement Data.

## Primary Outcome

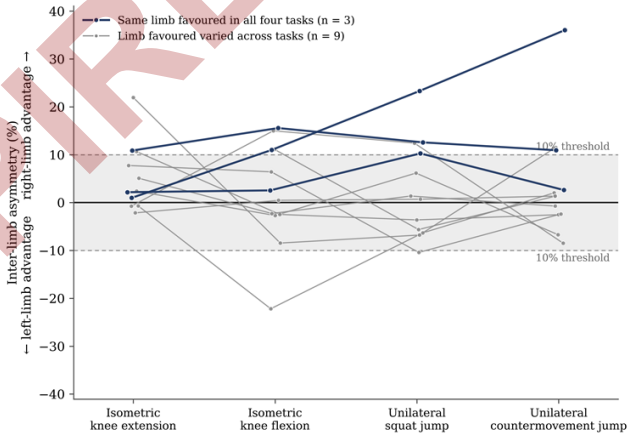
The primary outcome was agreement in the direction of inter-limb asymmetry between isometric knee extension, isometric knee flexion, unilateral squat jump (SJ), and unilateral countermovement jump (CMJ). Across the six pairwise comparisons, Cohen's kappa coefficients ranged from −0.09 to 0.31, and percentage agreement ranged from 50.0% to 66.7%. All six 95% confidence intervals included zero. Fisher's exact p-values ranged from 0.558 to 1.000, and all Holm-adjusted p-values were 1.000 (Table 2).

Table 2. Agreement in the Direction of Inter-Limb Asymmetry Between Assessment Tasks.

| Task pair | n | Agreement (%) | Cohen's κ | 95% CI | Fisher's exact *p* | Holm-adjusted *p* |
|---|---|---|---|---|---|---|
| Isometric knee extension vs isometric knee flexion | 14 | 50.0 | −0.09 | −0.46 to 0.43 | 1.000 | 1.000 |
| Isometric knee extension vs unilateral SJ | 12 | 50.0 | −0.09 | −0.50 to 0.47 | 1.000 | 1.000 |
| Isometric knee extension vs unilateral CMJ | 12 | 50.0 | −0.09 | −0.50 to 0.50 | 1.000 | 1.000 |
| Isometric knee flexion vs unilateral SJ | 12 | 66.7 | 0.31 | −0.33 to 0.80 | 0.558 | 1.000 |
| Isometric knee flexion vs unilateral CMJ | 12 | 66.7 | 0.31 | −0.33 to 0.80 | 0.558 | 1.000 |
| Unilateral SJ vs unilateral CMJ | 17 | 58.8 | 0.06 | −0.35 to 0.55 | 1.000 | 1.000 |

Note. Confidence intervals were obtained using bias-corrected and accelerated bootstrapping with 5,000 resamples. Fisher's exact p-values are two-sided; Holm adjustment was applied to the family of six comparisons. SJ = squat jump; CMJ = countermovement jump.

Among the 12 players with complete data across all four tasks, three favoured the same limb in all four assessments, whereas nine showed variation in the favoured limb. Specifically, two players favoured the right limb in one task, five in two tasks, two in three tasks, and three in all four tasks. The individual signed asymmetry values across the four tasks are shown in Figure 2.




Note. Each line represents one player. Positive values indicate right-limb advantage and negative values indicate left-limb advantage. The three dark lines identify players who favoured the right limb in all four tasks; the nine grey lines identify players whose favoured limb varied across tasks. The shaded band represents ±10% asymmetry.

Figure 2. Individual Signed Inter-Limb Asymmetry Across Four Assessment Tasks in Elite Female Football Players (n = 12).

## Secondary Outcomes

### Magnitude and Direction of Inter-Limb Asymmetry

Mean asymmetry ranged from 5.2 ± 6.0% for isometric knee extension to 9.7 ± 5.8% for unilateral SJ. Mean values for isometric knee flexion and unilateral CMJ were both 8.5%. The proportion of players exceeding the 10% asymmetry threshold ranged from 21.4% to 52.9% across the four tasks. The right limb produced the higher value more frequently than the left limb in all four assessments, with right-limb preference ranging from 57.1% to 78.6% (Table 3).

Table 3. Magnitude and Direction of Inter-Limb Asymmetry by Assessment Task.

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| Assessment task | n | ASI mean ± SD (%) | Median (IQR) (%) | Range (%) | ASI >10%, n (%) | Right limb favoured, n (%) [95% CI] |
|---|---|---|---|---|---|---|
| Isometric knee extension | 14 | 5.2 ± 6.0 | 2.3 (1.0–7.2) | 0.7–22.0 | 3 (21.4%) | 11 (78.6%) [52.4–92.4] |
| Isometric knee flexion | 14 | 8.5 ± 6.5 | 7.4 (2.6–13.1) | 0.5–22.2 | 6 (42.9%) | 8 (57.1%) [32.6–78.6] |
| Unilateral SJ | 17 | 9.7 ± 5.8 | 10.3 (6.2–12.6) | 0.7–23.3 | 9 (52.9%) | 12 (70.6%) [46.9–86.7] |
| Unilateral CMJ | 17 | 8.5 ± 9.0 | 6.7 (2.4–10.9) | 0.7–36.0 | 6 (35.3%) | 11 (64.7%) [41.3–82.7] |

Note. ASI was calculated as [(higher limb − lower limb)/higher limb] × 100. Proportion confidence intervals were calculated using the Wilson score method. ASI = asymmetry index; IQR = interquartile range; SD = standard deviation; SJ = squat jump; CMJ = countermovement jump.

### Associations Between Strength, Asymmetry, and Bilateral Jump Performance

A total of 24 Spearman rank-order correlations were calculated to examine associations between isometric strength, asymmetry magnitude, and bilateral jump height. None of the 24 coefficients remained statistically significant after Holm adjustment; adjusted p-values ranged from 0.086 to 1.000. The largest correlation was observed between unilateral SJ and unilateral CMJ asymmetry (n = 17; ρ = 0.68, 95% CI 0.24 to 0.89; permutation p = 0.004; Holm-adjusted p = 0.086). Knee flexion asymmetry was positively correlated with bilateral SJ height (n = 12; ρ = 0.67, 95% CI 0.09 to 0.91; permutation p = 0.020; Holm-adjusted p = 0.468). Relative knee extension strength was correlated with bilateral CMJ height at ρ = 0.56 (n = 12; 95% CI −0.07 to 0.87; permutation p = 0.063; Holm-adjusted p = 1.000), while the H:Q ratio and bilateral CMJ height showed a correlation of ρ = −0.58 (n = 12; 95% CI −0.88 to 0.04; permutation p = 0.051; Holm-adjusted p = 1.000). All 24 estimates are presented in Table 4.

Table 4. Spearman Correlations Between Strength, Asymmetry Magnitude, and Bilateral Jump Performance.

| Association | n | Spearman's ρ | 95% CI | Permutation *p* | Holm-adjusted *p* |
|---|---|---|---|---|---|
| Absolute knee extension vs bilateral SJ | 12 | 0.24 | −0.40 to 0.72 | 0.460 | 1.000 |
| Relative knee extension vs bilateral SJ | 12 | 0.28 | −0.36 to 0.74 | 0.382 | 1.000 |
| Absolute knee flexion vs bilateral SJ | 12 | −0.15 | −0.67 to 0.47 | 0.650 | 1.000 |
| Relative knee flexion vs bilateral SJ | 12 | −0.04 | −0.60 to 0.55 | 0.904 | 1.000 |
| H:Q ratio vs bilateral SJ | 12 | −0.20 | −0.70 to 0.43 | 0.547 | 1.000 |
| Absolute knee extension vs bilateral CMJ | 12 | −0.05 | −0.61 to 0.54 | 0.885 | 1.000 |
| Relative knee extension vs bilateral CMJ | 12 | 0.56 | −0.07 to 0.87 | 0.063 | 1.000 |
| Absolute knee flexion vs bilateral CMJ | 12 | −0.42 | −0.81 to 0.23 | 0.178 | 1.000 |
| Relative knee flexion vs bilateral CMJ | 12 | −0.15 | −0.67 to 0.47 | 0.652 | 1.000 |
| H:Q ratio vs bilateral CMJ | 12 | −0.58 | −0.88 to 0.04 | 0.051 | 1.000 |
| Knee extension ASI vs bilateral SJ | 12 | −0.08 | −0.63 to 0.52 | 0.802 | 1.000 |
| Knee flexion ASI vs bilateral SJ | 12 | 0.67 | 0.09 to 0.91 | 0.020 | 0.468 |
| Unilateral SJ ASI vs bilateral SJ | 17 | 0.06 | −0.43 to 0.53 | 0.808 | 1.000 |
| Unilateral CMJ ASI vs bilateral SJ | 17 | 0.26 | −0.26 to 0.66 | 0.310 | 1.000 |
| Knee extension ASI vs bilateral CMJ | 12 | 0.29 | −0.36 to 0.74 | 0.368 | 1.000 |
| Knee flexion ASI vs bilateral CMJ | 12 | 0.01 | −0.56 to 0.58 | 0.974 | 1.000 |
| Unilateral SJ ASI vs bilateral CMJ | 17 | 0.13 | −0.38 to 0.58 | 0.622 | 1.000 |
| Unilateral CMJ ASI vs bilateral CMJ | 17 | 0.46 | −0.06 to 0.78 | 0.068 | 1.000 |
| Knee extension ASI vs knee flexion ASI | 14 | −0.22 | −0.67 to 0.36 | 0.457 | 1.000 |
| Knee extension ASI vs unilateral SJ ASI | 12 | −0.06 | −0.62 to 0.53 | 0.851 | 1.000 |
| Knee extension ASI vs unilateral CMJ ASI | 12 | 0.19 | −0.44 to 0.69 | 0.560 | 1.000 |
| Knee flexion ASI vs unilateral SJ ASI | 12 | 0.64 | 0.05 to 0.90 | 0.027 | 0.603 |
| Knee flexion ASI vs unilateral CMJ ASI | 12 | 0.40 | −0.25 to 0.80 | 0.197 | 1.000 |
| Unilateral SJ ASI vs unilateral CMJ ASI | 17 | 0.68 | 0.24 to 0.89 | 0.004 | 0.086 |

Note. Strength variables represent the mean of the two limbs. Confidence intervals were calculated using the Fisher z transformation with the Bonett–Wright standard error. Two-sided p-values were obtained using 100,000 random permutations. Holm adjustment was applied to the family of 24 correlations. ASI = asymmetry index; H:Q = hamstring-to-quadriceps ratio; SJ = squat jump; CMJ = countermovement jump.

### Additional, Subgroup, Sensitivity, and Distributional Assessment

A sensitivity analysis was conducted by restricting pairwise agreement comparisons to players who exceeded 10% asymmetry in at least one of the two tasks being compared. The resulting sample sizes ranged from four to eleven participants. Cohen's kappa values ranged from −0.29 to 0.36, and percentage agreement ranged from 42.9% to 75.0%. The restricted estimates are presented in Supplementary Table S1. Confidence intervals and p-values were not reported for this analysis.

Table 5. Sensitivity Analysis of Directional Agreement Restricted to Players Exceeding 10% Asymmetry in at Least One Task of Each Pair.

| Task pair | n | Agreement (%) | Cohen's κ | Interpretation |
|---|---|---|---|---|
| Knee extension vs knee flexion | 8 | 50.0 | 0.00 | Slight |
| Knee extension vs unilateral SJ | 7 | 42.9 | −0.27 | Poor |
| Knee extension vs unilateral CMJ | 4 | 75.0 | 0.00 | Slight |
| Knee flexion vs unilateral SJ | 7 | 71.4 | 0.36 | Fair |
| Knee flexion vs unilateral CMJ | 6 | 50.0 | −0.29 | Poor |
| Unilateral SJ vs unilateral CMJ | 11 | 72.7 | 0.23 | Fair |

Note. The analysis was restricted to participants exceeding 10% asymmetry in at least one task of the relevant pair. Confidence intervals and p-values were not reported for these estimates. SJ = squat jump; CMJ = countermovement jump.

### Distributional Assessment

Shapiro–Wilk tests indicated departures from normality for isometric knee extension asymmetry (W = 0.76, p = 0.002) and unilateral CMJ asymmetry (W = 0.77, p < 0.001). No significant departures from normality were observed for isometric knee flexion asymmetry (W = 0.92, p = 0.234) or unilateral SJ asymmetry (W = 0.97, p = 0.798). Bilateral jump heights were normally distributed for both SJ (W = 0.97, p = 0.771) and CMJ (W = 0.97, p = 0.727).

## DISCUSSION

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### Principal Findings
### Comparison with International Evidence
### Theoretical, Methodological, and Practical Implications
### Strengths and Limitations
### Future Research

Three lines follow directly. The first is longitudinal: whether the direction of asymmetry in a given task is stable within a player across a season, which a single-session design cannot address and which determines whether directional information has any monitoring value at all. The second is replication at adequate scale. Kappa is unstable in samples of this size, and a multi-club design with sufficient players to estimate agreement precisely would establish whether the near-chance values observed here are the true state of affairs or an artefact of imprecision. The third concerns measurement mode: whether asymmetry direction derived from isometric dynamometry corresponds to that derived from isokinetic or eccentric assessment in the same players. Field-deployable eccentric protocols with acceptable test–retest reliability in youth football have been described, making this question tractable outside laboratory settings. A fourth line is more demanding but more consequential. If directional agreement between tasks is genuinely poor, the prospective question becomes which task, if any, produces a direction that carries injury-relevant information. Answering it requires injury surveillance alongside multi-task assessment in a cohort large enough to sustain the comparison.

## CONCLUSION

In the complete senior squad of a national champion women's football club, the direction of inter-limb asymmetry showed no better than fair agreement between any pair of four tasks assessed in a single session, and agreement between isometric knee extension and unilateral jumping fell marginally below chance. Only three of twelve players favoured the same limb across all four tasks. No association between asymmetry magnitude and bilateral jump height remained significant after correction for multiple testing, although a sample of this size cannot exclude such associations. The findings are therefore consistent with both pre-specified hypotheses. The finding of international relevance is that, under the testing conditions examined, the limb favoured by one routine asymmetry test showed limited agreement with the limb favoured by another. This matters most where resources are scarcest. Screening batteries in domestic clubs are commonly reduced to a single test on the implicit assumption that the asymmetry it reveals generalises across the lower limb; in this squad that assumption was not supported, which suggests that asymmetry identified with one test should not be used to direct limb-specific intervention aimed at a different quality without confirmation. This does not imply that a single test is invalid for the quality it measures. The practical response is closer correspondence between what is measured and what is trained. These conclusions describe association and agreement within one squad at one time point. The design does not support causal inference, and no injury surveillance was conducted, so no claim is made about injury risk or its prediction. Larger multi-club samples, repeated measurements of asymmetry direction and prospective designs including injury and performance outcomes are required before these findings are generalised.

## DECLARATIONS

### Ethical Approval
### Consent to Participate
### Consent for Publication
### Author Contributions (CRediT)
### Funding
### Conflict of Interest
### Data Availability
### Acknowledgements
### Generative AI Disclosure

A generative AI tool (Claude, Anthropic) was used to assist with structuring and language editing of the manuscript, with preparation of the statistical analysis code, and with the revision in response to peer review. The source data file, which contained player names, was processed within the tool during the revision; names were removed at the first processing step of the analysis code, and no identifiable information appears in any analysis output or in this article. The authors independently verified all scientific claims, calculations, citations and wording, and remain fully responsible for the content of this article.

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