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Inter-Limb Asymmetry in Female Sepak Takraw Players: An Observational Study

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Abstract: This study investigated the magnitude and direction of inter-limb asymmetry in 21 professional female sepak takraw players across several task-specific tests. Five inter-limb asymmetry assessments were employed: unilateral countermovement jump (Uni-CMJ), bilateral countermovement jump (Bi-CMJ), single-leg hop (SLH), triple hop test (THOP), and isokinetic concentric peak torque of the knee flexors and extensors at 60 deg/s^{-1}, 120 deg/s^{-1}, and 180 deg/s^{-1} angular velocities. A "true" inter-limb asymmetry was only observed for Uni-CMJ jump height (16.62%) and THOP distance (6.09%). Kappa coefficients demonstrated fair agreement in the direction of asymmetry between the Uni-CMJ and Bi-CMJ tests for jump height (Kappa = 26.67), but only slight agreement for peak force (Kappa = 0.11), propulsive impulse (Kappa = −0.12), and eccentric impulse (Kappa = −0.14). Fair agreement was observed between the SLH and THOP (Kappa = 0.32). Slight to moderate agreement was found for concentric peak torque across angular velocities for the knee extensors (Kappa = 0.08 to 0.48), while fair to nearly perfect agreement was noted for the knee flexors (Kappa = 0.31 to 1). The Uni-CMJ and THOP are most sensitive to detect between-limb asymmetries in female sepak takraw players. Given the inconsistencies in asymmetry direction across tests, monitoring asymmetry direction is important for strength and conditioning.

Keywords: between-limb differences; limb dominance; jump landing; Kappa coefficient

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1. Introduction

Sepak takraw (or kick volleyball) is a sport originating out of Southeast Asia, which incorporates acrobatic gymnastic type movements to return a small woven ball (rattan ball) over a 1.52 m high net into an area approximately the size (13.4 m × 6.1 m) of a badminton doubles court [1]. The sport requires three players on each team who may only use their head, chest, feet, or thighs to return the ball and score points [1]. The gymnastic nature of sepak takraw, incorporating explosive jumping movements such as the sun back spike and roll back spike (see Figure 1), typically requires landings onto a single leg while retaining balance. Similar to other sports that utilize repeated jump landings during match play and training (e.g., basketball, volleyball, and soccer), and independent of sustaining a lower limb injury, exposure to repetitive musculoskeletal and joint load forces placed on the same leg may result in marked between-limb (inter-limb) asymmetry [2–5]. Ultimately, a decrement in functional performance and injury may occur [6]. Therefore, assessing inter-limb asymmetry in sepak takraw players is justified as part of a periodic monitoring system to guide strength and conditioning programs and potentially prevent injury [7,8].

Currently, considerable attention has been focused on documenting the magnitude of lower-limb asymmetries in repetitive kicking and jump-related sports. Bishop et al. [9] reported jump height asymmetries for the unilateral countermovement jump (Uni-CMJ) to range between 5.8% to 9.0% across different age groups in male academy soccer players. Comparable inter-limb asymmetries for jump height have also been noted in adult female soccer players in both Uni-CMJ (8.7%) and unilateral drop jump tests (9.2%) [10]. In volleyball and basketball players, Fort-Vanmeerhaeghe et al. [4] found that 27–34% of all players exhibited lower-limb asymmetry values > 15% for jump height. While these studies have shown asymmetries to be present in various jump test metrics across different sports, there is also evidence that limb asymmetries can be detected using other assessments. A study by Schons et al. [11] revealed that inter-limb asymmetry in knee extensor isokinetic strength varied with contraction velocity in male volleyball players. At a slower contraction speed of 60 deg/s^{-1}, the mean inter-limb asymmetry index was relatively high at 11.24%. However, at the faster contraction speed of 180 deg/s^{-1}, the mean inter-limb asymmetry index decreased significantly to 5.28%. These findings, along with similar observations by Cheung et al. [12], suggest that observing inter-limb asymmetries might depend on the velocity of muscle contraction. This parallels findings from jumping tasks on a force plate, which have identified limb asymmetries to be specific to the metric under investigation [13].

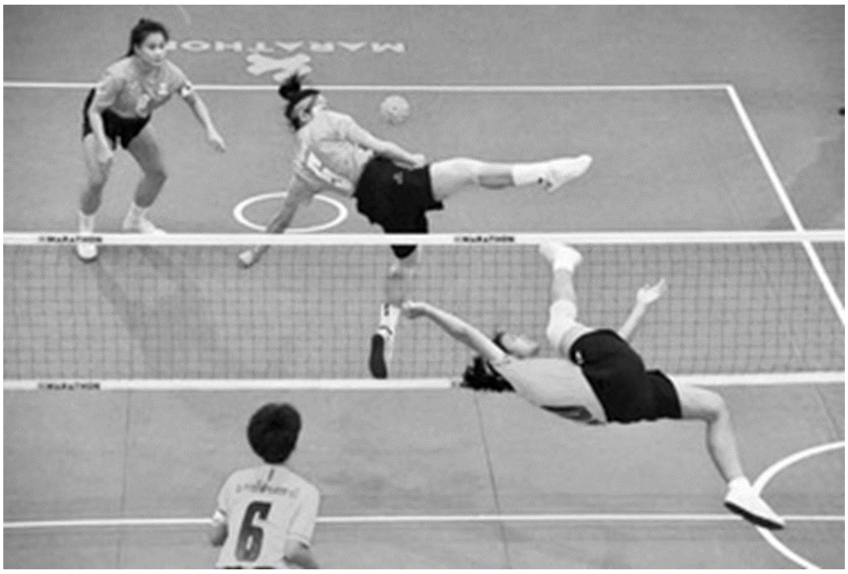

Figure 1. Sepak takraw players performing a roll back spike (permission was obtained for the use of these images).

Training programs, which focus on reducing inter-limb asymmetry to improve functional performance capacity, remain controversial due to mixed outcomes or small reductions in asymmetry [14]. Irrespective, documenting asymmetry can act as a return-to-play threshold after sustaining a lower limb injury where a greater magnitude of asymmetry may be apparent [15,16]. Previous studies have often cited a >10% inter-limb asymmetry as having the potential to negatively impact physical performance and expose an athlete to an increased risk of injury [15,17–19]. However, inter-limb asymmetry is sport specific and can vary depending on the testing procedure [17,20]. For example, the direction of inter-limb asymmetry may not favor the same limb across different tests, making limb dominance more complex to ascertain. Indeed, the direction of asymmetry between unilateral and bilateral jumping tests has been shown to have poor levels of agreement in soccer players [13]. This has led to the Kappa coefficient being employed [21] to assess the proportion of selected tests in which asymmetry favors the same limb between tests, beyond any test agreement occurring solely by chance [22,23]. While upon face validity, sepak takraw players may be susceptible to possessing limb dominance due to kicking, jumping, and landing [24] repeatedly onto the same leg; females in particular may exhibit greater limb-asymmetries compared to male counterparts [13,25]. Therefore, females may be more prone to experiencing greater decrements in performance and/or injury risk. Nevertheless, to our knowledge, there are no studies that have investigated the presence of inter-limb asymmetry in sepak takraw players (and in females), with a general lack of empirical literature conducted across the sport.

Accordingly, the aim of this study was to investigate the magnitude and direction of asymmetry across several task-specific tests to determine if limb dominance and inter-limb asymmetry is present in a cohort of female sepak takraw players. Based on previous observations in female soccer players [13], we hypothesized that both the magnitude and direction of asymmetry would be inconsistent across different task-specific assessments.

2. Materials and Methods

2.1. The Experimental Approach to the Problem

This study utilized a within-subject cross-sectional research design, consistent with a previously documented descriptive observational approach for assessing asymmetry [13]. A cohort of female sepak takraw players competing in the Thailand professional league were recruited and assessed using a variety of task-specific assessments. All participants were required to attend the laboratory on a single occasion after refraining from strenuous activity for 48 h preceding their arrival for experimental testing and 3 h post-prandial [23]. The laboratory visit included a warm-up and familiarization of all test procedures before commencing the experimental test protocol. A total of five inter-limb asymmetry assessments were conducted with the players: unilateral countermovement jump (Uni-CMJ), bilateral countermovement jump (Bi-CMJ), single-leg hop (SLH), triple hop test (THOP), and isokinetic peak torque of the leg extensors.

2.2. Participants

Twenty-one females (age, 20.9 ± 2.3 years; height, 1.63.1 ± 4.9 cm; body mass, 55.9 ± 6.7 kg; body mass index (BMI), 21.0 ± 1.9 kg·m^2) from two professional sepak takraw clubs were recruited to participate in this study. The participants completed a brief health and activity questionnaire to ensure their eligibility. Participants were excluded from the study if they reported a serious injury/surgery in the past 6 months. Each participant's dominant leg (DL) was identified via questionnaire as the limb that was frequently used to jump, land, and kick a ball. Given (1) the exploratory nature of our study, (2) the lack of previous studies attempting to assess lower limb asymmetry in sepak takraw players, (3) the sport-specific nature of asymmetry magnitude, and (4) ongoing debate about whether an asymmetry threshold can identify potential injuries, we justified our sample size (n = 21) using a heuristics approach. This approach replicated sample sizes reported in previous studies across different sports [6,26–28] Our sample size estimation encompasses a 10% asymmetry difference between limbs, an "arbitrary measure" often cited as increasing the likelihood of sustaining an injury [15,17,29] (i.e., the smallest effect size of interest). Using a conservative standard deviation (SD) of 15% [13], 80% power, and an alpha of 0.05 for a paired-sample t-test design (left v right leg), a sample of 20 participants is required. All participants voluntarily provided their written informed consent to participate in the study after being informed of the potential benefits and risks of the investigation. The institutional research ethics committee of Mahidol University approved the study (MU-CIRB 2020/111/2108), which conformed with the latest amendment of the Declaration of Helsinki.

2.3. Procedures

A standardized warm-up was performed, consisting of 5 min of low-intensity jogging, followed by a single set of 10× bodyweight squats, 10× forward and lateral lunges, and 10× leg swings in the frontal plane [20]. Immediately prior to each task-specific jump and hop assessment, participants were allowed 3 practice trials to control for learning effects [6,30], with verbal feedback provided to assist participants to attain technical proficiency. Participants were given a 5-min break after completing the familiarization/practice trials before completing the task-specific assessments. A 10-min recovery period was provided before moving to the next task.

Unilateral Countermovement Jump (Uni-CMJ) and Bilateral Countermovement Jump (Bi-CMJ): The participants performed the Uni-CMJ and Bi-CMJ on a force plate (Kistler Type

9286BA, Winterthur, Switzerland), which was connected to SMART tracker software (BTS SMART DX 5000, BTS Bioengineering, Milan, Italy) capable of collecting vertical ground reaction forces at a sample rate of 1600 Hz. The SMART tracker software was used to calculate both the concentric (propulsive) impulse force, representing the net force output during the upwards phase of jumping, and the eccentric impulse force, representing the net force output during the landing phase [20,31]. Peak force was determined as the maximum net force output during the propulsive phase of the jumps. For the Uni-CMJ, participants were instructed to step onto the force plate with their dominant leg and to maintain their hands on hips throughout the test. The jump began with a countermovement to a self-selected depth, followed by an explosive vertical acceleration to jump as high as possible. During the flight phase of the jump, the test limb was required to reach full extension before landing on the force plate [6]. The non-test leg was flexed at the hip to approximately 90° during each trial. The same procedure was repeated for the non-dominant leg. For Bi-CMJ testing, the participants stood upright with the feet positioned on two adjacent force plates. The participants squatted to a self-selected depth of approximately 90° knee flexion before jumping as high as possible without pausing while keeping hands on their hips [29]. Each of the Uni-CMJ and Bi-CMJ trials was separated by a 1-min rest period. All metrics were averaged over the three trials for further analysis. Uni-CMJ and Bi-CMJ heights (cm) were calculated from flight time using the following formula: Jump height = (flight time^2 $\times$ 9.81)/8 $\times$ 100 [32].

Single-Leg Hop (SLH) and Triple Hop (THOP) test: In the SLH and THOP, participants stood on one leg with their foot placed behind a marked line. In accordance with previous research [33], the SLH required participants to perform a countermovement before hopping horizontally forwards as far as possible and landing on the same leg. If not achieved, or if the participant removed their hands from their hips, the trial was repeated. A similar procedure was repeated for the THOP, but with participants performing three consecutive maximum hops on the same leg [33]. In both hop tasks, swinging of the non-landing leg was permitted and the contribution of the upper limbs to increase jump distance was limited by instructing participants to maintain hands on their hips [34]. Participants were instructed to land in a controlled manner and stick the landing of the final hop for at least 2 s [33]. The SLH and THOP distances were measured using a standard tape measure and recorded to the nearest 0.01 m from the start line to the heel of the foot at landing. Three trials were performed for each leg with a 1-min rest interval permitted between trials. The greatest distance recorded from the 3 trials was used for data analysis [33].

Isokinetic Peak Torque: Participants performed an isokinetic test (Biodex Medical Systems 4, Shirley, NY, USA) to determine concentric quadriceps and hamstrings peak torque at angular velocities of 60 deg/s^{-1}, 120 deg/s^{-1}, and 180 deg/s^{-1}. The dynamometer was calibrated following manufacturer guidelines, and a gravitational correction was applied. The participant was secured on the dynamometer chair via straps across the shoulders, waist, and thigh of the tested leg. The axis of rotation of the lever arm was aligned with the lateral condyle of the tested knee, and the cuff of the dynamometer lever attachment was attached to the proximal malleoli of the ankle. The leg range of motion (ROM) was set to a full range of motion: 0° (flexed) to 90° (full extension). The participants initially completed two submaximal efforts and one maximal effort of the quadriceps and hamstrings of the dominant leg. Then, participants performed 5 repetitions of maximum concentric contractions of the quadriceps and hamstrings at each selected angular velocity with a 5-s rest interval between each repetition. Each angular velocity was separated by a 1-min rest period. Then, the same test procedure was repeated on the non-dominant leg. Participants were advised to exert maximum effort throughout the range of motion, and verbal encouragement was provided by the researcher. The researcher provided external motivation to the participants who were also allowed visual feedback of their peak torque curves in real-time to help attain maximal peak torque values. The intra-limb hamstring/quadriceps (H:Q) ratio was calculated as follows: concentric peak torque of the knee flexors/concentric peak torque of the knee extensors $\times$ 100 [7,35].

2.4. Statistical Analyses

For the Uni-CMJ, Bi-CMJ, SLH, and THOP tests, within-session (trial) reliability measures were assessed using both the coefficient of variation (CV) and two-way (i.e., variability among subjects and trials) random intra-class correlation coefficients (ICC) with absolute agreement and 95% confidence intervals (95% CIs). ICC values were interpreted against the following benchmarks: >0.9 = excellent, 0.75–0.9 = good, 0.5–0.75 = moderate, and <0.5 = poor [36]. CV values were calculated as (SD/mean) × 100 and considered as good (<5%), moderate (5–10%), and poor (>10%) [13,37]. For the Uni-CMJ, SLH, THOP, and isokinetic peak torque tests, the percentage of inter-limb asymmetry was calculated using the bilateral strength asymmetry (BSA) formula [38,39]: BSA = (max value–min value/total value × 100). For Bi-CMJ, the symmetry index (SI) formula [38,40] was employed: SI = (high–low)/total × 100. The usage of an 'IF function' in Microsoft Excel was added to the end of the formulas: *IF (non-dominant leg < dominant leg, 1, −1) to illustrate the asymmetry direction without changing the magnitude [13].

Paired-sample *t*-tests were used to examine any differences in asymmetry metrics between the Uni-CMJ and Bi-CMJ tasks, SLH and THOP distance, and inter-limb H:Q ratio asymmetry (at each angular velocity). A one-way repeated measures analysis of variance (ANOVA) was employed to examine differences in asymmetry in both knee extensor and knee flexor concentric peak torque between angular velocities. To be deemed a "true" asymmetry, an inter-limb asymmetry had to exceed the CV of each leg [41,42]. The alpha level of statistical significance was set at $p < 0.05$. Hedges' g effect sizes were calculated for the magnitude of differences between limbs and interpreted using Hopkins' benchmarks [43]: <0.20 = trivial; 0.20–0.60 = small; 0.61–1.20 = moderate; 1.21–2.0 = large; 2.01–4.0 = very large. Kappa coefficients were also used to determine the levels of agreement in the direction of asymmetry between Bi-CMJ vs. Uni-CMJ metrics, SLH vs. THOP jump distance, and concentric peak torque of knee flexor and extensor measures. In accordance with Viera and Garrett's [21] recommendations, Kappa coefficient values were interpreted as follows: 0.01–0.20 = slight; 0.21–0.40 = fair; 0.41–0.60 = moderate; 0.61–0.80 = substantial; 0.81–0.99 = nearly perfect. Jamovi computer software (Version 2.3) [https://www.jamovi.org (accessed on 14 February 2024)] was used for statistical analysis. All data are presented as mean ± SD, unless otherwise stated.

3. Results

3.1. Reliability of Jump Tests

The within-subject reliability measures for the jump tests are presented in Table 1. In the Uni-CMJ, peak force exhibited moderate reliability across both legs, while jump height was only reliable in the right leg. Conversely, jump height in the left leg, propulsive impulse, and eccentric impulse had poor reliability. The Bi-CMJ demonstrated moderate reliability for jump height and peak force across both legs, with propulsive impulse reliable only in the left leg. Propulsive impulse in the right leg and eccentric impulse across both legs had poor reliability. CV values for the SLH showed moderate reliability, whereas THOP had good reliability across both legs (see Supplementary data). The variation in CVs led to only "true" asymmetries exhibited in Uni-CMJ jump height and THOP distance.

Table 1. Within-session reliability of jump tests (n = 21). Mean and [95% CI].

	Uni-CMJ		Bi-CMJ	
Test Reliability	***Left***	***Right***	***Left***	***Right***
CV (%):				
Jump Height (cm)	12.06 [9.05, 15.06]	9.41 [2.77, 16.06]	5.58 [2.67, 8.50]	7.89 [5.57, 10.21]
Prop Impulse (N.s)	15.44 [10.23, 20.65]	19.16 [12.75, 25.57]	8.24 [5.57, 10.92]	11.36 [8.73, 13.99]

Table 1. *Cont.*

Test Reliability	Uni-CMJ		Bi-CMJ	
	Left	*Right*	*Left*	*Right*
CV (%):				
Ecc Impulse (N.s)	19.68 [12.80, 26.56]	20.70 [16.00, 25.41]	20.86 [15.42, 26.31]	24.83 [19.45, 30.22]
Peak Force (N)	8.04 [4.62, 11.45]	8.91 [5.62, 12.19]	8.74 [5.98, 11.49]	7.37 [5.30, 9.43]
ICC:				
Jump Height (cm)	0.77 [0.63, 0.88]	0.82 [0.70, 0.91]	0.81 [0.69, 0.90]	0.81 [0.68, 0.90]
Prop Impulse (N.s)	0.62 [0.42, 0.78]	0.68 [0.51, 0.82]	0.87 0.78, 0.93]	0.79 [0.63, 0.89]
Ecc Impulse (N.s)	0.59 [0.39, 0.76]	0.68 [0.50, 0.82]	0.67 [0.49, 0.81]	0.47 [0.25, 0.67]
Peak Force (N)	0.65 [0.46, 0.80]	0.63 [0.44, 0.79]	0.71 [0.54, 0.84]	0.69 [0.52, 0.83]

Uni-CMJ = Uni-lateral countermovement jump; Bi-CMJ = Bi-lateral countermovement jump; CV = Coefficient of variation; ICC = Intra-class correlation coefficient; Prop = Propulsive; Ecc = Eccentric.

3.2. Agreement between Measurements across Trials

When considering the agreement between measurements across trials (Table 1), ICC values indicated good agreement for jump height and propulsive impulse in Bi-CMJ across both legs, with peak force showing moderate agreement. The left leg exhibited moderate agreement for eccentric impulse, while the right leg demonstrated poor reliability. In the Uni-CMJ, jump height had good agreement, with moderate agreement observed for propulsive impulse and eccentric impulse across both legs (Table 1). ICC values for the THOP demonstrated good to excellent agreement across legs, with moderate to good agreement observed for the SLH (see Supplementary data).

3.3. Absolute Jump Metrics and Isokinetic Concentric Peak Torque

Absolute jump metric and isokinetic concentric peak torque data (for each leg) are displayed in Tables 2 and 3, respectively (see Supplementary data for hop tests). A paired *t*-test revealed significant differences in asymmetry values across the Uni-CMJ and BI-CMJ tests. A significantly greater mean asymmetry was noted in the Uni-CMJ test for jump height, propulsive impulse, and peak force (Table 3). However, there was no significant difference in mean asymmetry noted between SLH and THOP (n = 19; p = 0.400; see Supplementary data). Similarly, concentric peak torques of the knee extensors (n = 19; p = 0.859) and knee flexors (p = 0.240) were not significantly different when comparing asymmetry across the different angular velocities. In addition, the intra-limb H:Q ratio was not significantly different between legs at each angular velocity (all $p < 0.05$; Table 3).

Table 2. Absolute jump metric data (n = 21). Mean ± SD.

Metric	**Uni-CMJ**		**Bi-CMJ**	
	Left	**Right**	**Left**	**Right**
Jump Height (cm)	7.33 ± 1.86	8.59 ± 1.93	19.62 ± 3.88	19.15 ± 3.85
Prop Impulse (N.s)	81.43 ± 22.86	88.83 ± 31.40	73.55 ± 17.12	64.07 ± 16.54
Ecc Impulse (N.s)	347.40 ± 101.83	358.53 ± 131.71	320.30 ± 116.93	297.89 ± 89.76
Peak Force (N)	406.28 ± 66.96	407.88 ± 76.23	301.34 ± 53.57	342.45 ± 48.41

Uni-CMJ = Uni-lateral countermovement jump; Bi-CMJ = Bi-lateral countermovement jump; Prop = Propulsive; Ecc = Eccentric.

Table 3. Isokinetic concentric peak torque (N.m) of knee flexors and extensors with calculated intra-limb H:Q ratio and inter-limb (directional) asymmetry. Mean ± SD (unless otherwise stated).

Angular Velocity	Left	Right	Inter-Limb Asymmetry (%)	Hedges g [95% CI] *p*-Value
60 deg/s^{-1}				*n = 20*
Flexion	69.56 ± 12.77	75.97 ± 10.58	10.79 ± 8.04	
Extension	136.71 ± 25.59	147.53 ± 27.84	8.60 ± 5.32	
H:Q Ratio (%)	51.26 ± 6.95	52.32 ± 7.02		0.15 [−0.30, 0.62]; p = 0.513
120 deg/s^{-1}				*n = 19*
Flexion	59.79 ± 11.17	66.63 ± 9.22	12.31 ± 8.31	
Extension	111.13 ± 18.79	119.54 ± 19.32	8.23 ± 5.27	
H:Q Ratio (%)	54.13 ± 8.20	56.29 ± 6.93		0.28 [−0.12, 0.71]; p = 0.185
180 deg/s^{-1}				*n = 20*
Flexion	53.45 ± 11.40	57.75 ± 11.08	10.30 ± 8.46	
Extension	91.98 ± 14.43	98.84 ± 15.03	8.58 ± 5.56	
H:Q Ratio (%)	58.62 ± 12.09	58.85 ± 9.78		0.02 [−0.34, 0.38]; p = 0.908

3.4. Direction of Inter-Limb Asymmetry

In comparing the direction of asymmetry between the Uni-CMJ and Bi-CMJ tests, Kappa coefficients revealed fair agreement for jump height, but only slight agreement for peak force, propulsive impulse, and eccentric impulse (Table 4). In contrast, fair agreement (Kappa = 0.32) was observed for jump distance between the SLH and THOP tests. In comparing the direction of asymmetry of concentric knee extensor peak torque between the different angular velocities, moderate agreement (n = 19, Kappa = 0.48) was found between 60 deg/s^{-1} and 180 deg/s^{-1} and between 60 deg/s^{-1} and 120 deg/s^{-1} (n = 19, Kappa = 0.48) angular velocities, respectively. Only slight agreement (Kappa = 0.08) was found between 120 deg/s^{-1} and 180 deg/s^{-1}. For concentric peak torque of the knee flexors, nearly perfect agreement (n = 19, Kappa = 1) was observed between 60 deg/s^{-1} and 120 deg/s^{-1} angular velocities. Fair agreement (n = 19, Kappa = 0.34) was found between 60 deg/s^{-1} and 180 deg/s^{-1} and between 120 deg/s^{-1} and 180 deg/s^{-1} (n = 19, Kappa = 0.31).

Table 4. Mean inter-limb asymmetry values and Kappa coefficients for comparable metrics between jump tests (n = 21). Mean ± SD (unless otherwise stated).

Asymmetry Metric	Uni-CMJ %	Bi-CMJ %	Uni-CMJ vs. Bi-CMJ Hedges g [95% CI]	Kappa Coefficient
Jump height	16.62 ± 11.25	4.41 ± 3.32	−1.44 [−2.17, −0.87]; p < 0.001	26.67 (*Fair*)
Prop Impulse	17.14 ± 13.04	6.16 ± 7.15	−1.02 [−1.76, −0.40]; p = 0.003	−0.12 (*Slight)*
Ecc Impulse	15.26 ± 12.04	10.55 ± 7.55	−0.46 [−0.98,0.01]; p = 0.072	−0.14 (*Slight*)
Peak Force	12.47 ± 9.00	7.21 ± 5.12	−0.70 [−1.34, −0.14]; p = 0.022	0.11 (*Slight*)

Uni-CMJ = Uni-lateral countermovement jump; Bi-CMJ = Bi-lateral countermovement jump; Prop = Propulsive; Ecc = Eccentric.

In line with recommendations [13], given the variability in the direction of asymmetry across assessments, we present individual inter-limb asymmetry differences for jump height (Figure 2), propulsive impulse (Figure 3), and eccentric impulse (Figure 4) (see Supplementary data for other metrics).

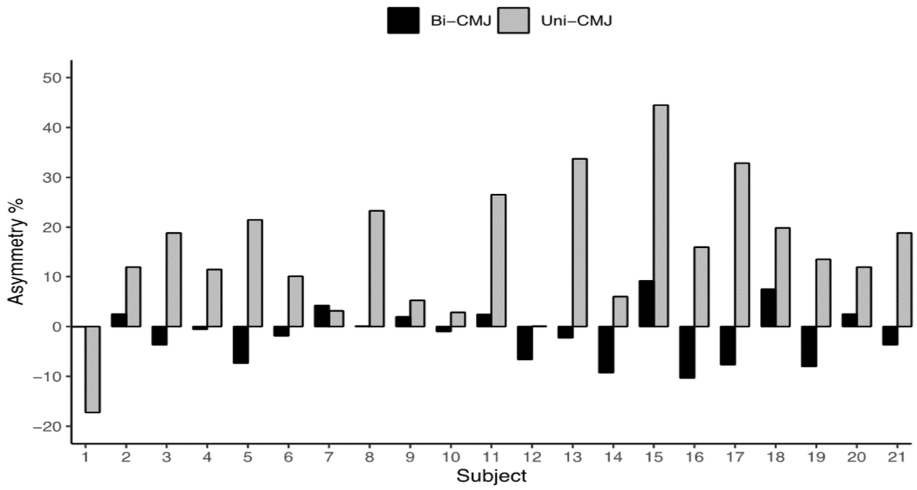

Figure 2. Individual jump height asymmetries (across jump tests). N.B: Above 0 indicates right leg dominance and below 0 indicates left leg dominance.

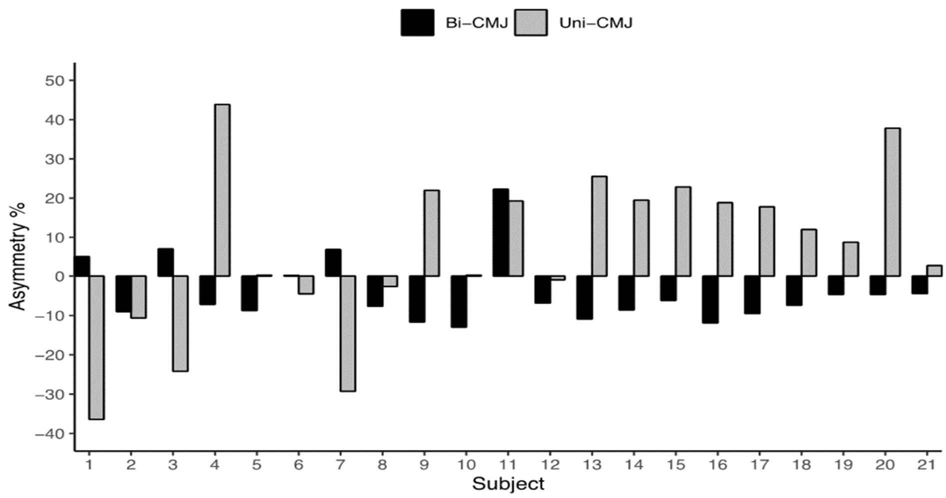

Figure 3. Individual asymmetries in propulsive impulse (across jump tests). N.B: Above 0 indicates right leg dominance and below 0 indicates left leg dominance.

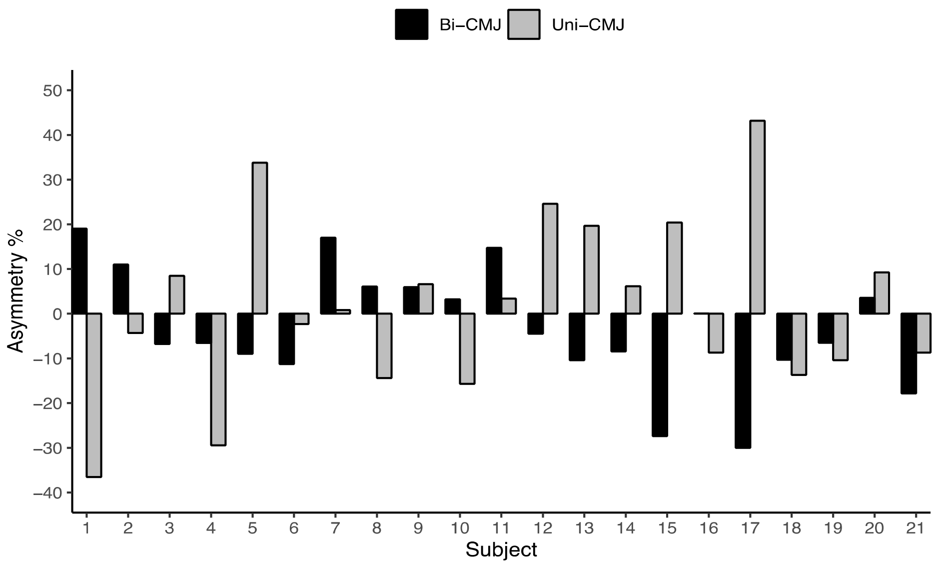

Figure 4. Individual asymmetries in eccentric impulse (across jump tests). N.B: Above 0 indicates right leg dominance and below 0 indicates left leg dominance.

4. Discussion

The main aim of this study was to quantify both the magnitude and direction of asymmetry across various task-specific tests among a cohort of professional female sepak takraw players. Our findings demonstrated that "true" asymmetry was only exhibited for Uni-CMJ jump height and THOP distance. When comparing similar metrics across assessments, significant differences in the magnitude of asymmetry values between the Uni-CMJ and Bi-CMJ tests were found. Specifically, significantly greater asymmetries for jump height, propulsive force, and peak force were revealed in the Uni-CMJ compared to the Bi-CMJ. However, Kappa coefficients indicated a general inconsistency in the direction of asymmetry across the different task-specific assessments and metrics. Taken together, our findings suggest that prioritizing the measurement of Uni-CMJ jump height and THOP distance is important in the monitoring of female sepak takraw players to identify between-limb imbalances.

The assessment of within-trial reliability revealed varying levels of consistency across different intra-limb task-specific metrics (Table 1 and Supplementary data). The observation of variation across trials is well documented [6,13,20,26,27], with Uni-CMJ reliability in our study being more inconsistent than previously reported in youth soccer players [6,20]. Conversely, while the Uni-CMJ and Bi-CMJ within-trial reliability was more in alignment with values previously reported for basketball players [27], participants generally performed the SLH and THOP with greater reliability compared to the jump tests (see Supplementary data). The inherent variation across CMJ trials can likely be attributed to participant unfamiliarity with the specific assessments and testing protocols. To ensure the identification of "true" asymmetry, consideration of the variation between trials is important [41,42]. This entails evaluating whether the discrepancy between limbs (magnitude of asymmetry) exceeds the discrepancy within limbs (i.e., intra-limb CVs), thereby signifying significance in the asymmetry assessment. We found that only jump height in the Uni-CMJ and THOP assessments were able to distinguish true asymmetry between limbs, with the other assessments (Bi-CMJ and SLH) possessing relatively poor reliability.

In attempting to make comparisons with past research across different sports and participant cohorts, the magnitudes of asymmetry for the Uni-CMJ height (16.62%), SLH (7.43%), and THOP (6.09%) are comparable to previous values recorded in elite youth female soccer players (12.54, 6.79%, and 6.81%, respectively; [19]). The inter-limb asymmetries recorded in the SLH and THOP are also in line with previous observations in multisport athletes (6.25% and 5.69%, respectively) [33]. In contrast to our findings, Bishop et al. [13] reported lower asymmetry values for jump height (8.88%) and peak force (6.21%) but similar asymmetry values for propulsive (concentric) impulse (16.84%) in elite youth female soccer players. Further comparisons with Bishop et al.'s [13] study revealed similar Bi-CMJ asymmetries for propulsive impulse (7.51%) and peak force (6.62%), but a greater asymmetry in jump height (11.50%). For strength indices, isokinetic knee extensor and flexor asymmetries of the female sepak takraw players (~8–13%) were within the range previously documented in English Premier League players (5.9–12.7%); [26]). However, while Nicholson et al. [26] reported similar H:Q intra-limb asymmetry ratios at a slow contraction velocity (51.22%) compared with the sepak takraw players in our study, the authors noted a higher H:Q ratio (69.99%) at higher contraction speeds (240 deg/s^{-1}). Taken together, our data support the notion that limb asymmetry is both sport and metric specific [13,17,20].

In comparing similar metrics across tests, the magnitudes of asymmetry were greater for jump height, propulsive impulse, and peak force in the Uni-CMJ compared to the Bi-CMJ (effect size = moderate to large; Table 4). However, we did not observe any difference in the magnitude of asymmetry in concentric peak torque for knee flexor or extensor angular velocities, intra-limb H:Q asymmetry, or hop distance in the SLH and THOP (see Supplementary data). It is widely understood that the magnitude of asymmetry varies depending on the task and the sport [2,14,20], making direct comparisons with past findings somewhat difficult. Nevertheless, in contrast to our observation of greater asymmetry across Uni-CMJ metrics, Bishop et al. [20] reported lower magnitudes of asymmetry (across various jump metrics) in both the unilateral and bilateral versions of the CMJ in elite academy male soccer players (leading to non-significant differences between jump tests). Similarly, lower asymmetry values for Uni-CMJ metrics have also previously been reported in elite youth female soccer players [13]. While difficult to ascertain, in our study, the greater asymmetry values for the Uni-CMJ may be partly explained by disparities in the sport and the age of the participants. Alternatively, it is perhaps more likely that the greater asymmetry is related to the sepak takraw players being less familiar with performing unilateral jumps as part of training or weekly monitoring. In the Uni-CMJ (and hop tests), the neuromuscular system must coordinate asymmetrical force production and balance on a single leg, demanding enhanced stability and proprioceptive control [44]. This likely contributes to variations in asymmetry metrics compared to the Bi-CMJ, emphasizing the importance of considering task-specific demands in lower-limb function assessment and adequate familiarization with test movement patterns. For instance, in sports such as sepak takraw that require repeated single-leg stabilization while kicking (with the ball not touching the floor), Uni-CMJ asymmetry may differentiate between different player abilities. Therefore, future cross-sectional studies comparing asymmetry across different player levels (i.e., recreational, national, international) may be further explored. Extrapolating our findings, sepak takraw players should include unilateral plyometric exercises into regular training routines to help mitigate the magnitude of asymmetries across selected jump metrics over time. In contrast to previous studies in volleyball players [11,12], we did not observe asymmetries to be greater at slower concentric knee or hamstring isokinetic angular velocities (Table 3). In the absence of other measures, such as surface electromyography (sEMG) data, an in-depth analysis to explain the disparity between our findings is not possible. However, it may be speculated that the participants were able to equally recruit the quadriceps and hamstrings musculature across each leg at each of the different angular velocities. Alternatively, the differences between our findings may simply be related to the differences in the training regimes and movement requirements of each sport. In addition, players were found to possess a H:Q ratio of ~51–59% across each leg for the tested angular velocities (Table 3). Similar to our data, a comparable H:Q ratio has previously been reported in intercollegiate soccer and volleyball players across legs [45]. The magnitude of the H:Q ratio in the sepak takraw players is considered in the normal range of 50 to 80%, with higher values reported to provide greater stability to the knee [45,46].

The direction of the asymmetry can help in understanding which limb performed better when determining the magnitude of inter-limb asymmetry [17]. Kappa coefficients indicate that the Uni-CMJ and Bi-CMJ showed only slight levels of agreement in the direction of asymmetry for propulsive impulse, eccentric impulse, and peak force metrics, but fair agreement for jump height (Table 3). Similarly, fair agreement was found for hop distance between the SLH and THOP (see Supplementary data), with fair to nearly perfect agreement calculated for the knee flexors when comparing concentric peak torque across the different angular velocities. In contrast, only slight to moderate agreement was observed for knee extensor peak torque across angular velocities. Our findings indicate that inter-limb differences were not consistent across comparable metrics between the different assessments, suggesting that individual asymmetry values should also be interpreted [13]. For jump assessments, only 8 of 21 players exhibited asymmetry on the same limb for jump height, 12 out of 21 for peak force, 4 out of 21 players for propulsive impulse, and 9 out of 21 for eccentric impulse (Figures 2–4 and Supplementary data). However, the direction of asymmetry appeared slightly more consistent across hop tests (14 out of 21 players) and isokinetic knee flexor and extensor peak torque measures (knee flexor = 16 out of 19 players; knee extension = 14 out of 19 players). Our present findings support past research by Bishop et al. [20], who reported an inconsistency in the direction of asymmetry between unilateral and bilateral countermovement jumps metrics in elite academy soccer players. A possible explanation for the lack of agreement between assessments is that the stance limb may potentially be stronger than the kicking limb when performing a unilateral task [19].

Sepak takraw players frequently utilize their non-dominant leg to maintain balance while additionally having to participate in the propulsive action of jumping to precisely spike the ball. Therefore, it is plausible to assume that the non-dominant leg can perform better during a unilateral task in one-legged dominant sports. Accordingly, practitioners should employ assessments that replicate the movements of sepak takraw when determining asymmetries [20].

When evaluating the current findings, practitioners should be aware of the study limitations. While the players were familiarized with test procedures, anecdotally, a number of players did not perform the task-specific assessments as part of their routine (weekly) training monitoring. Moreover, as our observations are specific to female sepak takraw players, it is recommended that future research be conducted to contrast the magnitude and direction of inter-limb asymmetries with male counterparts. Future research may also be conducted to associate the impact of lower-limb asymmetries on performance measures, such as change of direction speed and linear speed. While we assessed the within-session (trial) reliability of various test metrics, there is also a need to undertake between-session reliability measures, to be able to confidently track longitudinal asymmetry changes that may occur over the course of training or post-injury rehabilitation. Similarly, as the purpose of the present study was to describe the magnitude and direction of inter-limb asymmetry at a singular time point, there is a need to conduct longitudinal studies to assess season-long changes in inter-limb asymmetry across task-specific assessments. This is important, as limb dominance may be confounded due to heightened volumes of training and competitive scheduling throughout a season.

5. Conclusions

Determining the magnitude and direction of inter-limb asymmetry is specific to each sport, making its documentation valuable in defining the characteristics of the sport. "True" asymmetry differences were only noted for unilateral countermovement jump height and triple hop distance, suggesting that these two assessments should be prioritized in the monitoring of sepak takraw players to identify between-limb imbalances. Practitioners should be aware that players should be well-familiarized with task-specific assessments to identify true inter-limb asymmetry differences (i.e., increase within-session reliability). Furthermore, due to inconsistencies in the direction of asymmetry (i.e., favoring the same limb), practitioners should select assessments based on the movement patterns typical to sepak takraw.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/sym16070902/s1,: Table S1: Within-session reliability of hop tests; Table S2: Abolute hop data; Table S3: Mean-inter-limb asymmetry values and Kappa coefficient for hop tests; Figure S1: Individual asymmetry across hop tests; Figure S2: Individual asymmetry across knee extensor angular velocities; Figure S3: Individual asymmetry across knee flexor angular velocities; Figure S4: Individual peak force asymmetry (across jump tests).

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Data Availability Statement: The data and statistical analyses that support the findings of this study are available on Open Science Framework: https://osf.io/uskpz/?view_only=afb13db665b44bdcb29f1d6730bd77ba (accessed 29 March 2024).

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