Do asymmetry scores influence speed and power performance in elite female soccer players?

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ABSTRACT: This study examined the relationships between vertical jump asymmetries and speed and power performance in elite female soccer athletes. Sixteen professional female soccer players (age: 23.0 ± 3.8 years; body mass: 60.2 ± 7.3 kg; height: 165.1 ± 5.5 cm) from the same professional club participated in this study. Athletes performed unilateral and bilateral squat jumps (SJ) and countermovement jumps (CMJ) on a portable force plate; 30-m sprinting test; Zigzag change-of-direction (COD) test; and muscle power testing using the jump squat (JS) exercise. Asymmetry scores were obtained from the results of the unilateral SJ and CMJ by the percentage difference between the dominant and non-dominant legs. The Pearson product-moment coefficient of correlation was used to analyse the correlations between the bilateral and unilateral vertical jump variables and the physical tests. The bilateral vertical jump performance (in both SJ and CMJ) was closely related to sprinting and JS power performances (r values ranging from 0.50 to 0.73; P< 0.05). In contrast, no significant associations were found between jump asymmetries and performance measures. Our data suggest that asymmetry scores derived from unilateral vertical jumps are not capable of influencing the speed-power performance of professional female soccer players.

INTRODUCTION

In elite sports, different monitoring tools have been proposed to help practitioners reduce the risk of injury and improve athletes' performance [1-3]. In this context, recently, great attention has been paid to the study of asymmetry, which can be defined as an unevenness or mechanical imbalance in corresponding body parts (i.e., contralateral upper or lower limbs) [4-7]. Numerous methods exist to quantify between-limb differences, such as via isokinetic dynamometry [8,9], unilateral isometric squats or mid-thigh pulls [10,11], and jumping-based tasks [12-15]. Theoretically, larger asymmetry scores could induce poor physical performance, thus increasing the potential risk of non-traumatic injuries and compromising technical efficiency [14,16,17]. As a consequence, better understanding of the influence of asymmetries on the functional performance of elite athletes is required.

Several studies have been developed to analyse the relationships between different measures of asymmetry and sport-specific performance [5,13,18,19]. After analysing lower limb symmetries in 73 elite male and female Jamaican track and field athletes (age:

23.0 ± 3.2 years; events ranging from the 100 to the 800 m), Trivers et al. [19] observed that higher symmetry scores (in knee and ankle traits) were positively associated with sprinting speed. Another study demonstrated that higher asymmetries in pedal force were related to better 4-km time-trial performance in cyclists and triathletes [18]. Lockie et al. [13] did not find differences in 20-m sprint and change of direction (COD) ability after comparing recreational team sport athletes with higher and lower levels of asymmetries. Together, these data reveal a lack of consistency regarding the actual impact of asymmetry on distinct measures of athletic performance. This is even more important for team sport athletes, where technical proficiency during match tasks is required of both limbs, and previous literature has suggested that the prevalence of asymmetry is somewhat a by-product of performing the same repeated actions over time [20].

More specifically, Loturco et al. [14] reported that lower-limb asymmetry determined by three different functional screening assessments (i.e., isokinetic strength testing, unilateral vertical jumps,

and tensiomyography) was not related to impaired jump performance in professional male soccer players. In contrast, Bishop et al. [12] observed that higher asymmetry scores obtained from unilateral vertical jump tests were significantly associated with slower sprint times and lower unilateral vertical jump height in youth female soccer players. However, to date, it is not clear whether the differences in outcomes between these two investigations are related to the level (i.e., youth versus elite), sex of the players (i.e., male versus female), or motor activities performed (i.e., unilateral versus bilateral jumps, straight running versus cutting manoeuvres). Therefore, it would be relevant and of interest to investigate these relationships in a more specialised sample of female soccer athletes, using a comprehensive testing battery.

Hence, the purpose of this study was to examine the correlations between multiple asymmetry scores (assessed via unilateral vertical jump tests) and speed- and power-related measures in professional female soccer players. We hypothesised that higher jumping asymmetries would not necessarily be associated with reduced levels of performance in both speed and power measurements.

MATERIALS AND METHODS
Study Design
On the same day, all soccer players performed, in the same order: unilateral squat (SJ) and countermovement jumps (CMJ); bilateral SJ and CMJ (SJbi and CMJbi); sprint velocity in 5, 10, and 20 m; Zigzag COD test; relative maximum bar-power outputs and bar-velocity with a load corresponding to 40% of the players' body mass (BM) in the jump squat (JS) exercise. Athletes arrived at the sports laboratory prior to the first training session of the week in a fasting state for at least 2 h, avoiding alcohol and caffeine consumption for at

least 24 h before the tests. All athletes were previously familiarized with the testing procedures due to their constant physical assessments conducted throughout the soccer season. A 5-minute rest interval was provided between tests and between bilateral and unilateral vertical jumps. A standardised warm-up was performed before the vertical jump tests comprising moderate to light self-selected runs for 5 min and sub-maximal attempts at each test. For all asymmetry analysis, the dominant leg (dom) was determined as the leg that presented the higher score for a given variable [10].

Participants
Sixteen elite female soccer players (age: 23.0 ± 3.8 years; body mass: 60.2 ± 7.3 kg; height: 165.1 ± 5.5 cm) from the same professional team participated in this study. The players were at the beginning of the preseason prior to their participation in the São Paulo State Championship. In the season before the study, the soccer players won the *Libertadores da America* Championship, and 8 players had already participated in the National Brazilian soccer team, thus competing at the highest level of soccer in Brazil. Prior to participation in the study, the soccer players signed an informed consent form. The study was approved by the Anhanguera-Bandeirante University Ethics Committee.

Vertical jump assessments
Vertical jump height was assessed using bilateral and unilateral SJ and CMJ. In the SJ, athletes remained in a static position with a 90° knee flexion angle for ~2 s before jumping, without any preparatory movement. In the CMJ, athletes were instructed to execute a downward movement followed by complete extension of the legs and were free to determine the countermovement amplitude to avoid changes in jumping coordination. Both SJ and CMJ were executed with the hands on the hips. The jumps were performed on a portable force platform (AccuPower, AMTI, Graz, Austria) sampling data at 400 Hz. A total of five attempts were allowed for each jump, interspersed by 15-s intervals [14]. The following variables were automatically obtained from the custom designed software of the force plate, from both types of jumps: jump height, peak force (PF), peak power (PP), and landing force (LF), which were all normalised to the athlete's BM. The best SJ and CMJ attempts were retained for analyses.

Zigzag change of direction test
The Zigzag COD test was performed on an indoor court and consisted of four 5-m sections (total 20-m linear distance) marked with cones (50-cm height) set at 100° angles (Figure 1), requiring the athletes to decelerate and accelerate as fast as possible around each cone. Two maximal attempts were performed with a 5-min rest interval between attempts. Starting from a standing position with the front foot placed 0.3 m behind the first pair of timing gates (Smart Speed, Fusion Equipment, Brisbane, Australia) (i.e., the starting line), the athletes were instructed to complete the test as quickly as possible, before crossing the second pair of timing gates, placed 20 m from
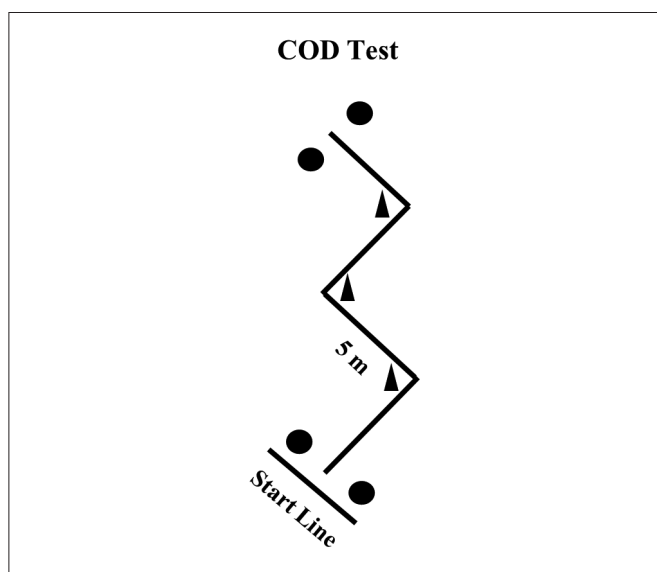

COD Test

5 m

Start Line

FIG. 1. A schematic presentation of the Zigzag test. Circles represent the position of the timing gates.

the starting line [21]. The fastest time from the two attempts was retained for further analysis.

Sprinting speed and calculation of COD deficit

For assessment of sprint velocity, four pairs of timing gates (Smart Speed, Fusion Equipment, Brisbane, Australia) were positioned at distances of 0, 5, 10, and 20 m on an indoor running track. Each athlete started from a staggered stance standing position 0.3 m behind the start line. A 5-min rest interval was allowed between the two attempts and the fastest time was used for further analysis. To evaluate the efficacy of the individual's ability to utilise their sprint speed during a COD task, a modified COD deficit was calculated based on prior research [22]. The current study presented the COD deficit as a velocity measure calculated as follows: *20-m velocity – Zigzag test velocity*; providing a measure of how much of the individual's maximal sprint velocity could be used or maintained despite the changes of direction required during the Zigzag test which was also 20 m in length.

Bar-power and bar-velocity outputs in the jump squat exercise

Maximum bar-power outputs in the JS exercise were assessed on a Smith machine (Hammer Strength, Rosemont, IL, USA). Players were instructed to execute two repetitions at maximal velocity for each load starting at 40% of their BM, as described elsewhere [23]. Athletes executed a knee flexion until the thigh was parallel to the ground (~100° knee angle) and, after a command, jumped as fast and high as possible without losing contact between their shoulder and the barbell. A load of 10% BM was gradually added until a decrease in mean power (MP), mean propulsive power (MPP), and/or peak power (PP) was observed. A 5-minute interval between sets was provided. To determine power output, a linear position transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was attached to the Smith-machine barbell. Due to its close relationship with actual sport performance [24,25], the mean velocity (MV), mean propulsive velocity (MPV), and peak velocity (PV) associated with 40% of the players' BM was retained. In addition, the maximum MP, MPP, and PP values normalised by the players' BM (i.e., relative values) were considered for data analysis.

Statistical Analyses

Data are presented as means ± standard deviation (SD). The statistical analysis was performed using the SPSS software package version 22.0. (SPSS, Inc., Chicago, IL, USA). The normality of data was tested using the Shapiro-Wilk test. Asymmetry scores were obtained from the results of the unilateral SJ and CMJ examining the percentage difference between the dom and non-dominant (ndom) legs [26]. An asymmetry score for a given jump variable was considered as "real" if it was higher than the within-subject coefficient of variation (CV) of the same variable [12,26,27]. In addition, it was calculated the effect sizes (ES) between the dom and ndom legs for the unilateral jump variables. The magnitude of the ES was interpreted using the following thresholds: <0.2, 0.2-0.6, 0.6-1.2, 1.2-2.0, 2.0-4.0, and >4.0 for trivial, small, moderate, large, very large, and near perfect, respectively [28]. The Pearson product-moment coefficient of correlation was used to analyse the relationships between the bilateral and unilateral vertical jump derived variables with sprint velocities, Zigzag speed, COD deficit, and bar-power and bar-velocity outputs in the JS exercise. Correlations were also tested between the asymmetry scores of unilateral vertical jumps and sprint velocities, Zigzag speed, COD deficit, and bar-power and bar-velocity outputs in the JS exercise, and finally among the asymmetry scores obtained from each unilateral vertical jump variable. The threshold used to qualitatively assess the correlations was based on the following criteria: <0.1, trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, very large; >0.9 nearly perfect [28]. The significance level was set as $P < 0.05$. Intraclass correlation coefficients were calculated for every test performed in this study and were all > 0.90.

RESULTS

Table 1 shows the descriptive data of the different bilateral and unilateral vertical jump variables. Table 2 demonstrates mean ± SD values for bar-power and bar-velocity outputs in the JS exercise, sprint velocity in the different distances tested, Zigzag COD test, and COD deficit. Table 3 presents the correlations between physical performance tests and bilateral and unilateral vertical jump variables. Large and significant correlations were observed between SJbi and CMJbi height, and PP with sprint velocity in 10, 20, and 30 m, and bar-power and

TABLE 1. Mean ± standard deviation of the bilateral and unilateral vertical jump derived variables.

	Height (cm)	Peak Force (N·kg⁻¹)	Peak Power (W·kg⁻¹)	Landing Force (N·kg⁻¹)
SJbi	29.0 ± 3.6	22.1 ± 2.0	42.3 ± 4.1	22.4 ± 1.6
SJdom	15.7 ± 1.9	18.6 ± 1.6	25.9 ± 2.1	23.9 ± 1.9
SJndom	14.2 ± 2.1	17.6 ± 1.1	24.0 ± 2.4	22.6 ± 1.7
CMJbi	28.9 ± 3.6	28.1 ± 2.6	39.5 ± 3.8	26.2 ± 3.1
CMJdom	17.5 ± 2.0	18.2 ± 0.9	27.4 ± 2.6	24.0 ± 1.7
CMJndom	15.6 ± 1.8	17.4 ± 0.9	25.2 ± 2.8	22.6 ± 1.9

SJ: squat jump; CMJ: countermovement jump; bi: bilateral jump; dom: dominant leg; ndom: non-dominant leg.

TABLE 2. Mean ± standard deviation (SD) of the bar-power and bar-velocity outputs in the jump squat (JS) exercise, sprint velocity (VEL) in the different distances, Zigzag change of direction (COD) speed test, and COD deficit.

	Mean ± SD
JS MV (m·s⁻¹)	0.95 ± 0.05
JS MPV (m·s⁻¹)	1.07 ± 0.11
JS PV (m·s⁻¹)	2.10 ± 0.24
JS MP (W·kg⁻¹)	4.31 ± 0.81
JS MPP (W·kg⁻¹)	6.17 ± 1.09
JS PP (W·kg⁻¹)	13.71 ± 2.24
VEL 5 m (m·s⁻¹)	4.59 ± 0.16
VEL 10 m (m·s⁻¹)	5.30 ± 0.14
VEL 20 m (m·s⁻¹)	6.09 ± 0.19
VEL 30 m (m·s⁻¹)	6.50 ± 0.23
ZIGZAG (m·s⁻¹)	3.25 ± 0.12
COD deficit (m·s⁻¹)	2.84 ± 0.15

MV: mean velocity; MPV: mean propulsive velocity; PV: peak velocity; MP: mean power; MPP: mean propulsive power; PP: peak power.

bar-velocity outputs in the JS exercise. Table 4 demonstrates the mean asymmetry percentages (and their respective CVs and ES) for each jump variable. Based on the previously established criteria, all vertical jump variables presented significant asymmetry scores.

The correlations between the asymmetries in vertical jump tests and physical performance tests are presented in Table 5. The SJbi PF was strongly and significantly correlated with the asymmetry in the SJ height and in the SJ PF. Finally, Table 6 presents the correlations between the different asymmetry scores in vertical jump tests.

DISCUSSION

This is the first study to examine the relationships between multiple asymmetry scores and athletic performance in elite female soccer players. The main findings reported here are that: (1) as hypothesised, higher levels of asymmetries in vertical jump seem to have no impact on speed, COD, and jump qualities; (2) the bilateral vertical jump ability is strongly associated with the performance obtained in a series of speed and power tests; (3) there are some positive correlations between some bilateral jump measures (namely PF and PP) and

TABLE 3. Correlation coefficients between physical performance tests and bilateral and unilateral vertical jump variables.

	VEL 5m	VEL 10m	VEL 20m	VEL 30m	ZIGZAG (velocity)	COD deficit	JS MV	JS MPV	JS PV	JS MP	JS MPP	JS PP
SJbi height	0.01	0.56*	0.54*	0.50*	0.67*	0.17	0.50*	0.50*	0.49*	0.65*	0.65*	0.58*
SJbi PF	0.07	-0.10	-0.17	-0.18	-0.29	0.01	-0.14	-0.19	-0.11	-0.32	-0.38	-0.27
SJbi PP	0.08	0.67*	0.72*	0.69*	0.70*	0.37	0.53*	0.51*	0.47*	0.51*	0.59*	0.55*
SJbi LF	-0.18	-0.25	-0.31	-0.36	-0.43	-0.06	0.25	0.25	0.14	0.06	0.06	0.08
CMJbi height	0.04	0.65*	0.69*	0.68*	0.63*	0.39	0.56*	0.59*	0.51*	0.64*	0.67*	0.63*
CMJbi PF	-0.05	-0.33	-0.39	-0.42	-0.39	-0.19	-0.21	-0.19	-0.13	-0.26	-0.20	-0.17
CMJbi PP	-0.02	0.62*	0.70*	0.73*	0.64*	0.40	0.62*	0.63*	0.58*	0.68*	0.68*	0.63*
CMJbi LF	0.04	0.02	-0.08	-0.08	-0.33	0.15	0.26	0.28	0.21	-0.01	-0.04	-0.08
SJdom height	-0.31	0.15	0.28	0.30	0.39	0.05	0.48	0.47	0.42	0.60*	0.61*	0.58*
SJndom height	-0.21	0.21	0.36	0.37	0.35	0.19	0.52*	0.53*	0.50*	0.68*	0.68*	0.59*
SJdom PF	0.17	-0.11	-0.24	-0.27	-0.30	-0.07	-0.33	-0.34	-0.29	-0.50*	-0.51*	-0.49*
SJndom PF	0.19	-0.20	-0.30	-0.32	-0.50*	0.00	-0.38	-0.40	-0.35	-0.53*	-0.54*	-0.50*
SJdom PP	-0.13	0.30	0.38	0.41	0.53*	0.07	0.42	0.40	0.38	0.47	0.45	0.41
SJndom PP	-0.07	0.36	0.52*	0.53*	0.44	0.32	0.39	0.40	0.35	0.54*	0.56*	0.50*
SJdom LF	-0.22	-0.26	-0.32	-0.37	-0.35	-0.13	0.19	0.16	0.12	0.07	0.04	0.02
SJndom LF	-0.13	-0.30	-0.36	-0.41	-0.48	-0.08	0.04	0.06	0.09	-0.05	-0.07	-0.08
CMJdom height	0.20	0.47	0.41	0.37	0.44	0.18	0.26	0.24	0.22	0.28	0.26	0.23
CMJndom height	0.15	0.38	0.45	0.46	0.41	0.25	0.32	0.31	0.30	0.34	0.32	0.29
CMJdom PF	0.22	-0.16	-0.31	-0.37	-0.47	-0.04	-0.22	-0.25	-0.29	-0.33	-0.36	-0.38
CMJndom PF	0.28	-0.12	-0.28	-0.32	-0.45	-0.01	-0.25	-0.28	-0.26	-0.41	-0.42	-0.40
CMJdom PP	0.26	0.44	0.38	0.36	0.40	0.18	0.13	0.16	0.19	0.14	0.15	0.17
CMJndom PP	0.27	0.40	0.41	0.42	0.37	0.24	0.18	0.15	0.16	0.15	0.12	0.13
CMJdom LF	0.02	-0.23	-0.35	-0.41	-0.51*	-0.06	-0.05	-0.09	-0.06	-0.24	-0.27	-0.25
CMJndom LF	-0.04	-0.24	-0.36	-0.42	-0.44	-0.12	-0.01	-0.01	-0.07	-0.22	-0.22	-0.25

VEL: sprint velocity; SJ: squat jump; CMJ: countermovement jump; JS: jump squat; MV: mean velocity; MPV: mean propulsive velocity; PV: peak velocity; MP: mean power; MPP: mean propulsive power; PP: peak power; bi: bilateral jump; dom: dominant leg; ndom: non-dominant leg; PF: peak force; LF: landing force; *$P < 0.05$.

TABLE 4. Mean asymmetry percentages (coefficient of variation) and between legs effect sizes (ES) for each jump variable.

	Jump Height	Peak Power	Peak Force	Landing Force
SJ	9.8 (6.5)	7.1 (4.7)	5.3 (3.3)	5.4 (4.1)
ES	0.77	0.81	0.75	0.73
CMJ	10.6 (5.5)	7.8 (4.6)	3.9 (2.9)	5.9 (5.5)
ES	1.02	0.79	0.79	0.77

SJ: squat jump; CMJ: countermovement jump.

TABLE 5. Correlation coefficients between the asymmetries in vertical jump tests and physical performance tests.

	Asymmetry							
	SJ h	SJ PF	SJ PP	SJ LF	CMJ h	CMJ PF	CMJ PP	CMJ LF
VEL 5m	-0.10	-0.02	-0.08	-0.29	0.05	-0.20	-0.09	0.27
VEL 10m	-0.13	0.17	-0.20	0.11	0.10	-0.20	-0.06	0.12
VEL 20m	-0.22	0.07	-0.35	0.11	-0.07	-0.18	-0.19	0.12
VEL 30m	-0.19	0.03	-0.33	0.14	-0.14	-0.23	-0.25	0.14
ZIGZAG (velocity)	-0.03	0.40	-0.03	0.36	0.05	-0.10	-0.05	-0.14
COD deficit	-0.25	-0.20	-0.41	-0.13	-0.13	-0.15	-0.19	0.26
JS MV	-0.20	0.02	-0.14	0.34	-0.08	0.05	-0.08	-0.18
JS MPV	-0.19	0.05	-0.12	0.36	-0.11	0.10	-0.05	-0.27
JS PV	-0.17	0.08	-0.18	0.32	-0.06	0.03	-0.04	-0.20
JS MP	-0.27	-0.04	-0.31	0.35	-0.09	0.22	-0.06	-0.09
JS MPP	-0.25	-0.06	-0.29	0.37	-0.10	0.24	-0.02	-0.14
JS PP	-0.23	-0.09	-0.32	0.33	-0.07	0.17	-0.03	-0.11
SJbi height	-0.10	0.21	-0.17	0.43	0.35	0.29	0.31	-0.01
SJbi PF	0.54*	0.43	0.55*	0.34	0.41	0.00	0.39	-0.06
SJbi PP	-0.14	0.41	-0.24	0.50	0.11	0.09	0.02	-0.13
SJbi LF	0.16	0.34	0.20	0.23	0.38	0.14	0.42	-0.09
CMJbi height	-0.16	0.12	-0.17	0.40	0.22	0.21	0.20	0.02
CMJbi PF	0.18	-0.04	0.26	0.12	0.33	0.45	0.51*	0.34
CMJbi PP	-0.05	0.26	-0.14	0.59*	0.02	0.07	0.01	-0.07
CMJbi LF	0.40	0.39	0.45	0.37	0.27	-0.09	0.31	-0.13

VEL: sprint velocity; SJ: squat jump; CMJ: countermovement jump; JS: jump squat; MV: mean velocity; MPV: mean propulsive velocity; PV: peak velocity; MP: mean power; MPP: mean propulsive power; PP: peak power; bi: bilateral jump; h: jump height; PF: peak force; LF: landing force; *$P < 0.05$.

TABLE 6. Correlation coefficients between the different asymmetry scores in vertical jump tests.

	Asymmetry						
	SJ PF	SJ PP	SJ LF	CMJ h	CMJ PF	CMJ PP	CMJ LF
Asymmetry SJ h	0.42	0.76*	0.57*	0.43	0.01	0.34	-0.32
Asymmetry SJ PF		0.50*	0.58*	0.28	-0.11	0.13	-0.64*
Asymmetry SJ PP			0.41	0.38	0.10	0.33	-0.45
Asymmetry SJ LF				0.24	0.15	0.35	-0.24
Asymmetry CMJ h					0.42	0.87*	-0.07
Asymmetry CMJ PF						0.61*	0.23
Asymmetry CMJ PP							0.18

SJ: squat jump; CMJ: countermovement jump; h: jump height; PF: peak force; PP: peak power; LF: landing force; *$P < 0.05$.

certain asymmetry scores (jump height, PF, PP, and LF); and (4) several asymmetries are closely interrelated. Together, these data support the concept that the relationship between asymmetry scores and speed-power performance is highly variable. Studies that follow athletes during a competitive season are still needed to identify whether the levels of asymmetry may vary according to the training phases. Nevertheless, the outcomes of our study could help in the design of more efficient and tailored training strategies and serve as a basis for developing future investigations involving elite female soccer players.

The fact that athletes with larger asymmetries (assessed by unilateral jumps) can also produce greater mechanical outputs during bilateral SJ and CMJ has previously been reported in a similar study executed with professional male soccer players [14]. To some extent, this contrasts with the data obtained by Bishop et al. [12], who reported that jump asymmetries are significantly associated with reduced sprint and jump performance in youth female players. From these results, it may be inferred that, at the elite level, the neuromechanical performance of male and female soccer athletes is not necessarily influenced or predicted by higher or lower levels of asymmetry. This is even clearer when analysing the complete absence of correlations between sprinting speed at different distances and the multiple asymmetry metrics (Table 5). Thus, despite the influence of asymmetry scores on athletic performance of recreationally active adults [15] and the apparent effectiveness of unilateral plyometrics at increasing both single and double-leg jumping abilities in moderately trained subjects [29], additional studies are warranted to confirm or refute this hypothesis in top-level team sport athletes.

The significant inter-relationships among asymmetry scores within the same tests (and the lack of associations between different measurements) appear to be commonplace in investigations examining this question [14,30]. As reported here (Table 6), even tests with relatively similar movement patterns (i.e., SJ and CMJ) can present limited relationships between them, which evidences the necessity to use comprehensive testing approaches to properly determine asymmetries in top-level athletes [14,31,32]. In this context, among all tested asymmetry measures, only CMJ LF was shown to be negatively correlated with SJ PF. However, due to the unique aspect of this outcome, it is not possible to draw solid conclusions about this phenomenon. From a general perspective, our findings corroborate and extend previous results, suggesting that professional female soccer players also need to be assessed by more than one type of exercise or technique to adequately detect potential imbalances and bilateral differences between contralateral limbs [14,32]. Although it is not clear whether these mechanical metrics necessarily affect speed and power performance, their possible effects on the risk of injuries in athletic populations justify the adoption of more complex and multifaceted testing approaches [17,31,33].

Speed is a key element in modern soccer; therefore, coaches and technical staff should make every effort to maximise this physical capacity in their players [34,35]. Several studies have tried to iden-

tify effective approaches to increase sprint performance in soccer athletes, despite the inherent difficulties imposed by the interference phenomenon (i.e., concurrent effects of the predominantly aerobic soccer-training sessions) [36-38]. Due to the congested schedule of professional soccer, practitioners are encouraged to implement efficient training methods, able to concomitantly maximize strength, power, and speed qualities in their players [36,37]. Our data suggest that bilateral jump ability is much more closely related to performance than its metrics of asymmetry, partially confirming the effectiveness of traditional training practices (e.g., strength training and plyometrics) to improve some specific physical capacities at elite level [37,39,40]. Although it is not possible to infer causality from our results, professional female soccer athletes, as well as their male counterparts, may substantially benefit from the inclusion of bilateral strength- and power exercises in their daily training routines [36,37,39].

Our research is limited by its cross-sectional design, small sample size, and the selected characteristics of the subjects (i.e., professional female soccer players), which might compromise the extrapolation of our findings to other populations, especially when considering athletes with functional performance deficits and lower extremity injury. Nonetheless, according to the previously established criteria [12,26,27], the asymmetry scores presented herein may be considered real and consistent, which certainly strengthens and supports our assumptions. In summary, it seems that speed and power performance of elite female soccer players is closely related to the bilateral jumping capacity, being minimally influenced by higher or lower levels of jump asymmetries measured in more traditional vertical jump tests (SJ and CMJ).

CONCLUSIONS

Practitioners are constantly seeking more effective approaches to improve performance and reduce the risk of injury in team sport athletes. Based on our results, higher levels of asymmetry scores derived from unilateral vertical jump tests are not capable of impairing the speed and power performances of professional female soccer players. As such, at least when the goal is to increase speed-power-related capabilities, elite female soccer players should focus their efforts on maximizing bilateral vertical jump capacity. While it is not possible to establish causality or even identify associations between different metrics of asymmetry and performance in team sports, the use of unilateral training strategies should primarily be based on preventive interventions aiming to reduce the potential risk of injury [17,41]. Future studies are warranted to examine the relationships between different asymmetry measurements (e.g., tensiomyography, isokinetic testing) and sport-specific performance in female soccer players and to confirm these results through longitudinal observations of this cohort.

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