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Review

The Effects of Inter-Limb Asymmetry on Change of Direction Performance: A Systematic Review

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Abstract: Objectives: This review aimed to clarify the associations between COD performance and asymmetries on horizontal jumping, vertical jumping, and strength. Methods: Three databases, including PubMed, Web of Science, and MEDLINE(EBSCOhost) were used to perform a systematic literature search. The search was up to 13 March 2022 and was limited to the literature in the English language and on the human species. Studies included reported exact measurement tools and correlation coefficients and studies in which participants aged >14 years were included. Moreover, studies that were not peer-reviewed and those that did not report an asymmetry index were excluded, as were studies for which the full text was not available. The modified Downs and Black Quality Index tool was used to evaluate the quality of the studies. Results: The systematic literature identified 1151 studies, but only 12 studies were included in this review. A total of 354 participants, ranging from 15 to 23 years of age, were recruited for these studies. The methodological quality score ranged from 6 to 8, with an average of 7.25. The associations between COD performance and vertical jump height, horizontal jump distance, and lower-limb strength asymmetries were examined in 11, 5, and 2 studies, respectively. Six studies reported that vertical jump height asymmetries scores can significantly reduce COD performance, while significant associations between COD performance and horizontal jump distance asymmetries and strength asymmetries were only observed in one study each. Specifically, four studies explored the relationships between CMJ height asymmetries scores and COD performance, and all reported significant associations between them. The main limitations of this review were that it did not consider the sports in which the participants were involved. Conclusions: This study suggests that drop jump height and eccentric knee strength asymmetries can reduce COD performance. Moreover, low horizontal jump asymmetries may not influence COD performance. Further research needs to determine whether the minimal threshold of horizontal jump asymmetries would not affect COD performance.

Keywords: horizontal jump; vertical jump; lateral jump; agility; imbalance

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1. Introduction

A lack of balance between limbs or muscle groups is referred to as inter-limb asymmetry [1,2]. In various sports, inter-limb asymmetry is prevalent because many movements must be executed unilaterally. Football players, for example, preferred to do hard and intensive motions such as kicking, cutting, and jumping with their dominant lower limb [3–7]. A previous study has proved that inter-limb asymmetries are the results of competing in a single sport over time [8]. Lower-limb strength asymmetries can be assessed using the back squat [9], isometric squat [10,11], and isokinetic knee extension [12,13]. Jumping tests, including the single-leg countermovement jump (CMJ) and drop jump (DJ) can be used to assess functional asymmetries [14]. Given the prevalence of inter-limb asymmetry, the threshold of asymmetry must be established. Massive studies have suggested that 10–15%

asymmetry is utilized to identify abnormal differences between limbs [8,15–18]. Moreover, a 10% asymmetry has been suggested as a goal for athletes returning to sport [17,18].

Change of direction (COD) is an action for which no immediate response to a stimulus is necessary, and thus the direction change is preplanned [19,20]. COD speed forms the physical foundation for agility as it incorporates the mechanics associated with agility performance (i.e., the deceleration, directional change, and acceleration) [21,22] while allowing for progression from lower joint loading received in the preplanned movements before training the higher joint loadings that must be handled during agility. The capability of COD is critical to the success of multidirectional sports [21,22]. The COD performance was commonly measured using the COD time and COD-Deficit (COD-D), and both are valid and reliable. For elite male soccer athletes, they need to perform <90°, 90°–180°, >180° COD up to 600, 90, and 20 times, respectively, during a single game [19]. Recently, considerable attention has been put on inter-limb asymmetry and its associations with athletic performance. High lower-limb asymmetry can result in reductions in athletic performance, such as sprint [23] and COD [23]. Bishop et al. [23] reported no significant differences in CMJ height asymmetry in three varied age groups, but the authors concluded that there are significant associations between CMJ height asymmetries and 505 performance. This finding was in line with the study conducted by Madruga-Parera et al. [24], the authors reported that lateral jump (LJ) distance asymmetry scores significantly associate with reduced dominant-leg COD performance and V-cut performance. Similarly, for the national level youth basketball athletes, there were significant associations between DJ height asymmetries and COD speed [25]. These findings proved that greater inter-limb asymmetries may be detrimental to COD performance.

However, there are conflicting findings regarding the associations between asymmetry scores and COD performance. Dos' Santos et al. [26] have reported that force-time characteristics of isometric mid-thigh pull (IMTP) cannot influence modified 505 (mod 505) performance in collegiate athletes. In the study conducted by Dos' Santos et al. [26] the measurement tool involved the isometric strength test, which can impact its associations with interlimb asymmetries. Bishop et al. [27] explored how inter-limb asymmetries affected COD performance in soccer and cricket players and found that inter-limb asymmetries were not significantly associated with reductions in football players' COD performance, whereas the opposite result was observed in elite cricketers. The factors of movement patterns in the asymmetry tests can partly explain these findings as the authors reported [27]. Similarly, massive studies also reported no significant associations between COD performance and inter-limb asymmetries scores [28,29].

Several factors can be used to explain these conflicting findings, and the movement nature of the measurement tools may be the major reason. Specifically, the measurement tools for assessing interlimb asymmetry can be classified into jumping tests and muscle strength tests. According to the direction, jumping tests included horizontal jumping and vertical jumping tests, which reflected horizontal power and vertical power abilities, respectively. For example, DJ height asymmetry revealed the differences in vertical power output asymmetry, while standing long jump (SLJ) distance asymmetry demonstrated horizontal power output asymmetry. However, a larger horizontal power output asymmetry does not mean that there would be a larger vertical power output asymmetry because there are differences between them, such as force direction, technique, and so on. Moreover, there are notable differences between maximal strength and power output. Therefore, these conflicting findings need to be further analysis and more clearly understanding the exact correlations between strength/power (horizontal and vertical power) asymmetries scores and COD performance can provide useful information to practitioners.

All in all, it is necessary to systematically synthesize the existing evidence regarding the associations between lower-limb asymmetry and COD performance. Thus, this review aimed to clarify the associations between COD performance and horizontal jumping asymmetries, vertical jumping asymmetries, and strength asymmetries. We hypothesized that COD performance would be significantly associated with horizontal jump distance and vertical jump height asymmetry scores but not with lower-limb strength asymmetries.

2. Methods

In this systematic review, the authors implemented the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement guidelines [30].

2.1. Systematic Literature Search

We conducted systematic literature in PubMed, Web of Science, and Medline (EBSCO-host) up to 13 March 2022. We searched terms as follows: ("asymmetry" OR "imbalance" OR "dissymmetry" OR "side-to-side difference" OR "side difference" OR "lateral difference") AND ("agility" OR "agility performance" OR "agility time" OR "change of direction" OR "COD") AND ("association" OR "correlation" OR "relationship"). Moreover, the literature search was limited to studies in the English language and on the human species. The reference lists of included relevant articles were screened for additional compatible studies.

2.2. Selection Criteria/Study Eligibility

Studies included in this systematic review should meet the following criteria: (1) data for correlation coefficients between lower-limb asymmetry and COD performance were reported; (2) lower-limb asymmetries were assessed using strength (isometric and isokinetic tests) and jump tests (vertical jump tests and horizontal jump tests); (3) data and tools of COD performance (e.g., 5-0-5) were reported; (4) subjects were at least 14 years old. Studies were excluded if they were (1) non-peer-reviewed studies or (2) the calculation formula of the asymmetry index was not reported.

The titles and abstracts of identified studies were screened by two authors (L and S) independently, and the irrelevant studies were removed. Ultimately, the full text of potential studies was screened to choose eligible studies. When there were disagreements on the inclusion of a study, Z was contacted.

2.3. Data Extraction

The characteristics of studies were extracted into an Excel sheet. The variables of studies included: (a) sample size; (b) subject characteristics: age, gender, and training status; (c) measurement tools, calculation formula, and asymmetry scores of inter-limb asymmetry; (d) test methods and data of COD; (e) correlation coefficients. Data from included studies were extracted by L and checked by S. Any disagreement regarding study eligibility was resolved in a discussion. Any full-text articles were excluded, with reasons, and recorded. All records were stored in the datasheet.

2.4. Quality Assessment

The methodological quality in this systematic review was evaluated using a modified version of the Downs and Black Quality Index tool, which was created to assess the major core methodological characteristics of research [31–33]. The 10 items of the assessment checklist were selected in this study, and the remaining 3 items were removed since they were not relevant and applicable to this study. Each item is rated using a 1 or 0, with a total score out of 10,with higher scores reflecting a better quality.

3. Results

3.1. Study Identification and Selection

Our initial search identified 1151 studies. After the removal of 103 duplications, the remaining 1048 studies were excluded based on titles and abstracts. The full-text evaluation was conducted on 45 studies, and 10 studies met the inclusion criteria. Moreover, 2 additional studies were selected via the reference lists. A total of 12 studies were included in this review. The process of studies identification is provided in Figure 1.

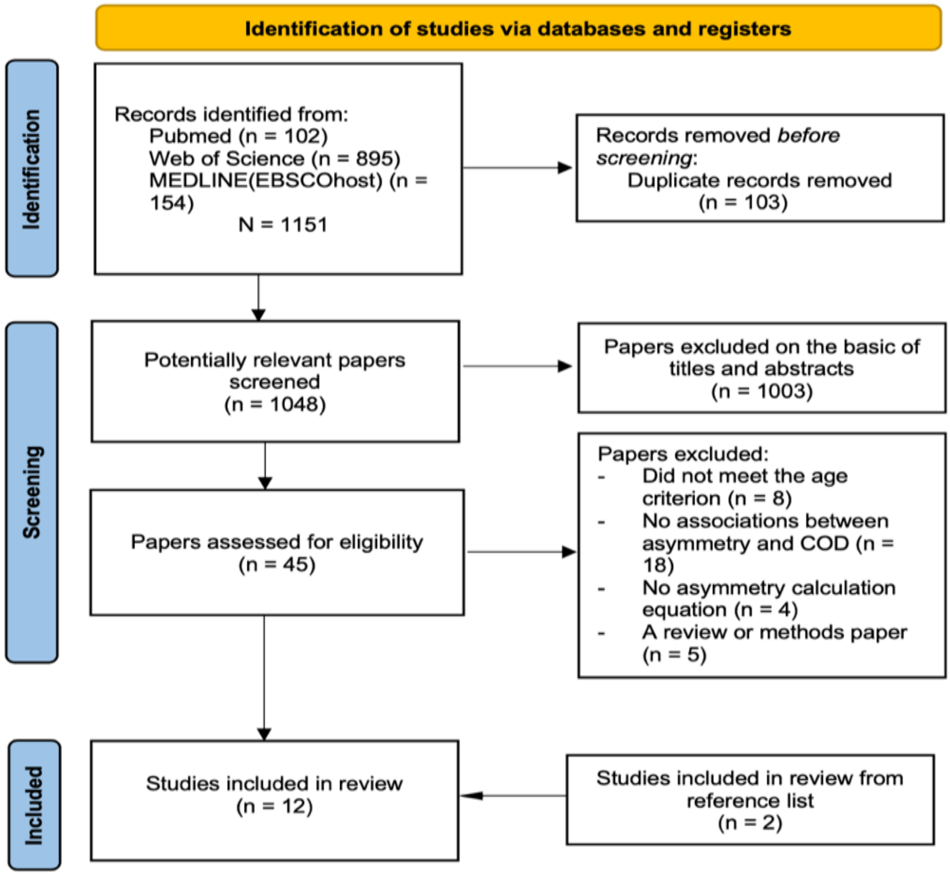

Figure 1. Flowchart.

3.2. Study Quality

The methodological quality of the studies included in this review is presented in Table 1. The quality scores ranged from 6 to 8, with an average of 7.25. This indicates that there is no internal validity bias. All studies included in this review exceeded the pre-determined cut-off value; thus, no studies were removed due to quality.

Table 1. Quality assessment of studies.

Study	1	2	3	4	5	6	7	8	9	10	Total Score
Dos' Santos. [26]	1	1	1	1	0	0	?	1	1	1	7
Bishop et al. [23]	1	1	1	1	0	0	?	1	1	1	7
Coratella et al. [34]	1	1	1	1	0	1	?	1	1	1	8
Maloney et al. [28]	1	1	1	1	0	1	?	1	1	1	8
Bishop et al. [27]	1	1	1	1	1	0	?	1	1	1	8
Madruga-Parera et al. [35]	1	1	1	1	0	0	?	1	1	1	7
Madruga-Parera et al. [24]	1	1	1	1	0	0	?	1	1	1	7
Fort-Vanmeerhaeghe. [29]	1	1	1	1	0	0	?	1	1	1	7
Madruga-Parera et al. [36]	1	1	1	1	0	0	?	1	1	1	7
Lockie et al. [37]	1	1	1	1	0	1	?	1	1	1	8
Bishop et al. [38]	1	1	1	0	0	0	?	1	1	1	6
Bishop et al. [25]	1	1	1	1	0	0	?	1	1	1	7

1. The objectives of the study were clearly reported; 2.The main outcomes to be assessed were clearly reported; 3. The characteristics of the participants were clearly reported; 4. The main findings were clearly reported; 5. The estimates of the random variability in the data for the main outcomes were clearly reported; 6. The actual probability values were clearly reported; 7. The participants represent the entire population; 8. Clarity regarding any of the results of the study based on 'data dredging,'; 9. The statistical tests were appropriate; 10. The main outcome measure was accurate. 1—The item was clearly reported, 0—the item was not clearly reported, ?—unable to determine.

3.3. Study Characteristics

A total of 354 participants were recruited for these studies, with an average sample size of 29.5. The age of participants ranged from 15 to 23. The participants were soccer players [23,26,27,34,38], handball players [36], basketball players [24,25,29], cricket players [26,27], rugby players [26], tennis players [35], and healthy males [28]. The details of the study characteristics are presented in Table 2.

3.4. Inter-Limb Asymmetries and COD Tests

The evaluation tools of inter-limb asymmetries were limited to jumping and strength tests in this review. Of the 12 studies included in this review, vertical jump, horizontal jump, and strength asymmetries were assessed in 10 [23–25,27–29,35–38], 5 [24,29,35–37], and 2 studies [26,34], respectively. The vertical jump measurement tools in these studies involved single-leg CMJ [23–25,27,29,35–38] and DJ [25,27,28,38]. Horizontal jump tests involved SLJ [24,29,35–37] and single-leg LJ [24,29,35–37]. Strength tests included isometric [26] and isokinetic assessments [34].

The COD performance was assessed using the total time of the COD tasks and COD-D. All studies included in this review reported COD time, while only one study reported COD-D [38]. Moreover, the change of direction of a 180° turn was performed in 11 studies [23–27,29,34–38], the task of 90° turn was completed in 2 studies [28,36], and one study assessed V-cut [24].

3.5. Associations between Asymmetry and COD

Regarding strength asymmetry, it is hard for us to draw an accurate result due to conflict results. Dos' Santos et al. [26] examined the associations between force-time characteristics asymmetries from isometric mid-thigh pull (IMTP) and COD performance and found that greater strength asymmetries cannot reduce the COD performance. However, moderate and large relationships between asymmetry scores from both quadriceps and hamstrings eccentric fast-velocity peak force and COD performance were observed in the study conducted by Coratella et al. [34].

Out of the ten studies included in this review examined the jump asymmetries [23–25,27–29,35–38], six demonstrated that jump asymmetries were significantly correlated with COD time [23–25,27,28,38].

Specifically, regarding vertical jump height asymmetries, there was strong evidence that drop jump height asymmetry scores were significantly correlated with reduced COD performance. Out of the four studies assessed DJ height asymmetries, all reported that they were significantly correlated with COD performance [25,27,28,38]. However, the study conducted by Bishop et al. [27] found that DJ height asymmetries were significantly correlated with 505 scores in cricket players, not in soccer players. Moreover, only one of nine studies found significant relationships between COD performance and CMJ height asymmetry scores [23]. Other studies also found that vertical jump height asymmetries cannot reduce dominant and non-dominant 505 performance [23,25,27,37], 90° COD [36], 180° COD [29,35,36], and COD-D [38].

Regarding horizontal jump distance asymmetries, there were no significant associations between COD performance and SLJ distance asymmetries [24,29,35,36]. For LJ asymmetry, the asymmetry scores did not associate with COD performance. A study conducted by Madruga-Parera et al. [24] demonstrated significant relationships between asymmetries on LJ distance and V-cut performance, but there was no significant relationship between LJ distance asymmetries and non-dominant side COD performance. Moreover, the other four studies reported that its asymmetries cannot affect COD performance [29,35–37].

Table 2. The characteristics of included studies.

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
Dos' Santos. [26]	N = 20 Male, Teamsport players (soccer, rugby and cricket) Age: yr 21 ± 1.9 Height: m 1.77 ± 0.04 Mass: kg 78.7 ± 8.9	Isometric mid-thigh pull test: Relative peak force: N/kg D: 35.3 ± 4.6 ND: 33.2 ± 4.25 Impulse during 200 ms: N×s D: 279.8 ± 34.2 ND: 251.3 ± 4.9 Impulse during 300 ms: N×s D: 497.7 ± 60.7 ND: 431.6 ± 79.4	ASI = (D-ND)/D × 100 Relative peak force ASI: 6.6 Impulse during 200 ms ASI: 12.2 Impulse during 300 ms ASI: 12.9	Modified 505 test: s D: 2.69 ± 0.14 ND: 2.79 ± 0.14 ASI: −4.46	Modified 505 ASI VS relative peak force ASI: r = −0.03, p = 1.000 VS Impulse during 200 ms ASI: r = −0.11, p = 1.000 VS Impulse during 300 ms ASI: r = −0.25, p = 0.380
Bishop et al. [23]	N = 51 Male, Soccer players Under 23, N = 21, Height: cm 180.2 ± 6.5, Mass: kg 76.9 ± 8.5 Under 18, N = 14, Height: cm 181.6 ± 8.6, Mass: kg 76.4 ± 7.4 Under 16, N =16, Height: cm 174.8 ± 11.1, Mass: kg 66.1 ± 11.0	CMJ:cm Under 23: Left: 24.88 ± 3.18 Right: 24.31 ± 2.83 Under 18 Left: 24.08 ± 3.25 Right: 24.07 ± 2.54 Under-16 Left: cm 22.30 ± 3.71 Right: cm 21.80 ± 3.97	ASI = 100/(maximum value) × (minimum value) × −1 +100	505: s Under 23 Left: 2.46 ± 0.06 Right: 2.46 ± 0.08 Under 18 Left: 2.50 ± 0.07 Right: s 2.49 ± 0.08 Under 16: Left: 2.48 ± 0.08 Right: 2.51 ± 0.07	Under 23 CMJ ASI VS 505 Left: r = 0.61, $p < 0.01$ CMJ ASI VS 505 Right: r = 0.71, $p < 0.01$ Under 18 CMJ ASI VS 505 Left: r = 0.13, $p > 0.05$ CMJ ASI VS 505 Right: r = 0.15, $p > 0.05$ Under 16 CMJ ASI VS 505 Left: r = 0.63, $p < 0.01$ CMJ ASI VS 505 Right: r = 0.85, $p < 0.01$

Table 2. *Cont.*

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
Coratella et al. [34]	N = 27 Male, Elite soccer players Age: yr 18–21 Height: m 1.81 ± 0.05 Mass: kg 73.7 ± 7.0	Isokinetic peak force: N×m/kg Strong side: low-velocity quadriceps: con: 3.46 ± 0.38 ecc: 4.12 ± 0.63 low-velocity hamstring: con: 1.95 ± 0.25 ecc: 2.42 ± 0.43 high-velocity quadriceps: con: 1.77 ± 0.18 ecc: 3.59 ± 0.57 high-velocity hamstring: con: 1.06 ± 0.22 ecc: 2.26 ± 0.44 Weak side: low-velocity quadriceps: con: 3.14 ± 0.35 ecc: 3.71 ± 0.73 low-velocity hamstring: con: 1.75 ± 0.23 ecc: 2.17 ± 0.49 high-velocity quadriceps: con: 1.63 ± 0.16 ecc: 3.46 ± 0.64 high-velocity hamstring: con: 1.05 ± 0.22 ecc: 2.19 ± 0.46	ASI = (strong side − eak side)/strong side × 100 quadriceps con peak force ASI: low-velocity: 9.0 ± 6.5 high-velocity: 7.8 ± 5.0 quadriceps ecc peak force ASI: low-velocity: 9.7 ± 7.5 high-velocity: 9.0 ± 7.3 hamstring con peak force ASI: low-velocity: 9.6 ± 6.6 high-velocity: 10.7 ± 6.0 hamstring ecc peak force ASI: low-velocity: 10.5 ± 8.2 high-velocity: 11.7 ± 9.4	20 m shuttle: s 7.56 ± 0.29 *T*-test: s 8.73 ± 0.49	20 m shuttle VS quadriceps con peak force ASI: low-velocity: r = 0.123, p = 0.371 high-velocity: r = 0.120, p = 0.317 20 m shuttle VS quadriceps ecc peak force ASI: low-velocity: r = 0.426, p = 0.038 high-velocity: r = 0.404, p = 0.041 *T*-test VS quadriceps con peak force ASI: low-velocity: r = 0.284, p = 0.178 high-velocity: r = 0.301, p = 0.105 *T*-test VS quadriceps ecc peak force ASI: low-velocity: r = 0.259, p = 0.311 high-velocity: r = 0.433, p = 0.031 20 m shuttle VS hamstrings con peak force ASI: low-velocity: r = 0.126, p = 0.325 high-velocity: r = 0.066, p = 0.603

Table 2. *Cont.*

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
					20 m shuttle VS hamstrings ecc peak force: low-velocity: r = 0.251, $p = 0.299$ high-velocity: r = 0.416, $p = 0.037$ *T*-test VS quadriceps con peak force ASI: low-velocity: r = 0.190, $p = 0.354$ high-velocity: r = 0.614, $p < 0.001$ *T*-test VS quadriceps ecc peak force: low-velocity: r = 0.394, $p = 0.041$ high-velocity: r = 0.397, $p = 0.040$
Maloney et al. [28]	N = 18 Male, Healthy men Age: yr 22 ± 4 Height: m 1.80 ± 0.08 Mass: kg 81.7 ± 14.9	DJ: m Fast group: 0.12 ± 0.05 Slow group: 0.11 ± 0.03	ASI = (Left-Right)/average (Left-Right) × 100 DJ ASI: fast group: 2.4 ± 3.9 slow group: 7.2 ± 3.8	Double 90° cuts: s Fast group: 5.18 ± 0.18 Slow group: 5.64 ± 0.14	Double 90° cuts VS DJ ASI r = 0.598, $p = 0.009$

Table 2. *Cont.*

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
Bishop et al. [27]	N = 41 Soccer players, N = 18 Age: yr 23.00 ± 4.27 Height: m 1.82 ± 0.06 Mass: kg 78.72 ± 7.76 Cricket players, N = 23 Age: yr 20.57 ± 1.73 Height: m 1.83 ± 0.08 Mass: kg 80.23 ± 9.91	CMJ: m Soccer players: Left: 0.18 ± 0.04 Right: 0.18 ± 0.04 Cricket players: Left: 0.19 ± 0.03 Right: 0.18 ± 0.03 DJ: cm Soccer players: Left: 22.39 ± 4.02 Right: 22.82 ± 3.83 Cricket players: Left: 18.47 ± 4.45 Right: 18.48 ± 4.06	ASI = 100/(maximum value) × (minimum value) × −1 +100 CMJ ASI: Soccer players: 11.14 Cricket players: 9.57 DJ ASI: Soccer players: 6.51 Cricket players: 11.49	505: s Soccer players: Left: 2.27 ± 0.07 Right: 2.26 ± 0.06 Cricket players: Left: 2.21 ± 0.10 Right: 2.22 ± 0.12	Soccer players: CMJ ASI VS 505 Left: r = −0.23, $p > 0.05$ Right: r = 0.14, $p > 0.05$ DJ ASI VS 505 Left: r = 0.39, $p > 0.05$ Right: r = 0.29, $p > 0.05$ Cricket players: CMJ ASI VS 505 Left: r = 0.03, $p > 0.05$ Right: r = 0.07, $p > 0.05$ DJ ASI VS 505 Left: r = 0.56, $p < 0.05$ Right: r = 0.59, $p < 0.05$

Table 2. *Cont.*

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
Madruga-Parera et al. [35]	N = 22; Boys: N = 10, Girls: N = 12, Elite tennis players Age: yr 16.3 ± 1.4 Height: m 1.73 ± 0.1 Mass: kg 62.6 ± 9.7	CMJ: cm D: 14.66 ± 3.48 ND: 12.43 ± 3.06 SLJ: cm D: 160.83 ± 25.84 ND: 153.92 ± 23.38 LJ: cm D: 150.16 ± 22.98 ND: 140.09 ± 21.99	ASI = (D-ND)/D × 100 CMJ ASI: 15.03 ± 6.91 SLJ ASI: 4.14 ± 3.72 LJ ASI: 6.63 ± 5.30	2-time 180° COD: s D: 5.19 ± 0.22 ND: 5.29 ± 0.27	CMJ ASI VS 2-time 180° COD D: r = 0.01, $p > 0.05$ ND: r = 0.05, $p > 0.05$ SLJ ASI VS 2-time 180° COD D: r = 0.02, $p > 0.05$ ND: r = 0.02, $p > 0.05$ LJ ASI VS 2-time 180° COD: D: r = 0.07, $p > 0.05$ ND: r = 0.06, $p > 0.05$
Madruga-Parera et al. [24]	N = 42 Male, Handball players Age: yr 16.0 ± 1.3 Height: cm 174.1 ± 7.3 Mass: kg 70.5 ± 13.3	CMJ: cm D: 15.7 ± 3.6 Nd: 13.9 ± 3.6 LJ: cm D: 140.7 ± 20.5 ND: 129.2 ± 21.5 SLJ: cm D: 143.2 ± 25.3 ND: 134.0 ± 24.3	ASI = 100/(maximum value) × (minimum value) × −1 +100 CMJ ASI: 11.2 ± 8.4 LJ ASI: 8.3 ± 7.5 SLJ ASI: 6.4 ± 4.6	COD speed: s D: 5.3 ± 0.5 ND: 5.4 ± 0.5 V-cut test: s 7.3 ± 0.6	COD speed: D VS CMJ ASI: r = 0.09, $p > 0.05$ D VS LJ ASI: r = 0.31, $p < 0.05$ D VS SLJ ASI: r = 0.03, $p > 0.05$ ND VS CMJ ASI: r = 0.11, $p > 0.05$ ND VS LJ ASI: r = 0.29, $p > 0.05$ ND VS SLJ ASI: r = 0.01, $p > 0.05$ V-cut test: VS CMJ ASI: r = 0.07, $p > 0.05$ VS LJ ASI: r = 0.32, $p < 0.05$ VS SLJ ASI: r < 0.01, $p > 0.05$

Table 2. *Cont.*

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
Fort-Vanmeerhaeghe. [29]	N = 29 Female, Elite basketball players Age: yr 15.66 ± 1.34 Height: m 1.82 ± 0.07 Mass: kg 69.69 ± 10.18	CMJ: m D: 0.16 ± 0.03 ND: 0.13 ± 0.02 SLJ: m D: 1.61 ± 0.11 ND: 1.55 ± 0.11 LJ: m D: 1.50 ± 0.09 ND: 1.45 ± 0.09	ASI = (D − ND) / ND ×100 CMJ ASI: 14.11 ± 8.62 SLJ ASI: 3.86 ± 2.49 LJ ASI: 3.33 ± 2.49	180° COD: s D: 2.81 ± 0.16 ND: 2.85 ± 0.16 s	180° COD VS CMJ ASI: r = 0.036, $p > 0.05$ 180° COD VS SLJ ASI: r = 0.194, $p > 0.05$ 180° COD VS LJ ASI: r = −0.096, $p > 0.05$
Madruga-Parera et al. [36]	N = 26 Male, Handball players, Age: yr 16.2 ± 0.9 Height: m 1.76 ± 0.60 Mass: kg 78.2 ± 12.4	CMJ: cm D: 19.05 ± 6 3.78 ND: 17.39 ± 3.65 SLJ: cm D:168.77 ± 24.12 ND:162.58 ± 23.5 LJ: cm D: 150.32 ± 22.86 ND:141.10 ± 20.76	ASI= 100 / (maximum value) × (minimum value) × −1 +100 CMJ ASI: 8.76 ± 4.80 SLJ ASI: 3.66 ± 2.55 LJ ASI: 5.97 ± 5.05	90° COD speed: s D: 4.41 ± 0.29 ND: 4.57 ± 0.28 90° COD-D: s D: 1.28 ± 0.18 ND:1.44 ± 0.20 180° COD speed: s D: 4.91 ± 0.27 ND: 5.02 ± 0.31 180° COD-D: s D: 1.78 ± 0.14 ND: 1.88 ± 0.18	CMJ ASI VS 90° COD speed D: r = −0.06, $p > 0.05$ ND:r = −0.16, $p > 0.05$ LJ ASI VS 90° COD speed D: r = 0.21, $p > 0.05$ ND: r = 0.29, $p > 0.05$ SLJ ASI VS 90° COD speed D: r = 0.16, $p > 0.05$ ND: r = 0.21, $p > 0.05$ CMJ ASI VS 180° COD speed D: r = 0.18, $p > 0.05$ ND: r = 0.21, $p > 0.05$ LJ ASI VS 180° COD speed D: r = 0.28, $p > 0.05$ ND: r = 0.39, $p > 0.05$ SLJ ASI VS 180° COD speed D: r = 0.28, $p > 0.05$ ND: r = 0.17, $p > 0.05$

Table 2. *Cont.*

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
Lockie et al. [37]	N = 30 Male, Team-sport athletes Age: yr 22.60 ± 3.86 Height: m 1.80 ± 0.07 Mass: kg 79.03 ± 12.26	CMJ: m Left: 0.39 ± 0.08 Right: 0.40 ± 0.07 SLJ: m Left: 2.05 ± 0.19 Right: 2.03 ± 0.17 LJ: m Left: 1.86 ± 0.19 Right: 1.82 ± 0.21	ASI: CMJ ASI: 10.4 ± 10.8 SLJ ASI: 3.3 ± 3.0 LJ ASI: 5.1 ± 3.9	505: s Left: 2.398 ± 0.093 Right: 2.397 ± 0.110 *T*-test: s Left: 6.281 ± 0.082 Right: 6.285 ± 0.368	CMJ ASI vs 505: Left: r = 0.073, p = 0.701 Right: r = 0.083, p = 0.664 CMJ ASI VS *T*-test Left: r = 0.124, p = 0.514 Right: r = 0.061, p = 0.747 SLJ ASI VS 505 Left: r = 0.027, p = 0.889 Right: r = 0.036, p = 0.849 SLJ ASI VS *T*-test Left: r = 0.060, p = 0.755 Right: r = 0.000, p = 0.999 LJ ASI VS 505 Left: r = 0.189, p = 0.316 Right: r = 0.176, p = 0.352 LJ ASI VS *T*-test Left: r = 0.029, p = 0.878 Right: r = −0.081, p = 0.672

Table 2. *Cont.*

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
Bishop et al. [38]	N = 18 Male, Elite academy soccer players Age: yr 19.0 ± 2.2 Height: m 1.80 ± 0.07 Mass: kg 73.3 ± 9.0	CMJ: m Left: Preseason: 0.17 ± 0.04 Midseason: 0.15 ± 0.03 Endseason: 0.17 ± 0.03 Right: Preseason: 0.17 ± 0.03 Midseason: 0.15 ± 0.02 Endseason: 0.17 ± 0.02 DJ: cm Left: Preseason: 21.0 ± 4.0 Midseason: 20.5 ± 5.0 Endseason: 21.5 ± 5.3 Right: Preseason: 21.0 ± 4.4 Midseason: 20.6 ± 4.3 Endseason: 21.4 ± 3.8	ASI = 100 / (maximum value) × (minimum value) × −1+100 CMJ ASI: High group: Preseason: 17.97 ± 9.06 Midseason: 12.88 ± 7.72 Endseason: 14.64 ± 4.80 Low group: Preseason: 4.40 ± 3.03 Midseason: 4.33 ± 1.79 Endseason: 3.22 ± 1.62 DJ ASI: High group: Preseason: 13.20 ± 6.31 Midseason: 16.24 ± 8.91 Endseason: 16.22 ± 8.54 Low group: Preseason: 3.65 ± 1.34 Midseason: 4.02 ± 3.80 Endseason: 3.77 ± 2.49	505: s Left: Preseason: 2.34 ± 0.12 Midseason: 2.30 ± 0.11 Endseason: 2.23 ± 0.08 Right: Preseason: 2.32 ± 0.12 Midseason: 2.30 ± 0.12 Endseason: 2.23 ± 0.10 COD-D: s Left: Preseason: 0.57 ± 0.12 Midseason: 0.53 ± 0.12 Endseason: 0.45 ± 0.14 Right: Preseason: 0.56 ± 0.11 Midseason: 0.53 ± 0.12 Endseason: 0.45 ± 0.11	DJ ASI vs 505 Right: r = 0.65, p = 0.003

Table 2. *Cont.*

Study	Participants	Asymmetry Tests	ASI	COD Tests	Correlations
Bishop et al. [25]	N = 30 National level youth basketball athletes Age: yr 17.67 ± 1.32 Height: m 1.81 ± 0.10 Mass: kg 73.33 ± 13.34	CMJ: cm Session 1 Left: 13.67 ± 5.40 Right: 14.15 ± 5.30 Session 2 Left: 13.72 ± 5.87 Right: 13.34 ± 4.74 DJ: cm Session 1 Left: 11.61 ± 6.02 Right: 12.10 ± 5.86 Session 2: Left: 10.98 ± 5.69 Right: 11.34 ± 5.66	ASI = 100/(maximum value) × (minimum value) × −1+100 CMJ ASI: Session 1: 10.64 ± 8.56 Session 2: 10.93 ± 9.17 DJ ASI: Session 1: 14.28 ± 10.28 Session 2: 11.07 ± 9.44	505: s Session1 Left: 2.85 ± 0.24 Right: 2.80 ± 0.23 505 test ASI: 3.27 ± 2.66 Session 2 Left: 2.86 ± 0.25 Right: 2.84 ± 0.25 505 ASI: 2.60 ± 1.79	CMJ ASI VS 505 Left: r = 0.25, $p > 0.05$ Right: r = 0.34, $p > 0.05$ DJ ASI VS 505 Left: r = 0.45, $p < 0.05$ Right: r = 0.48, $p < 0.05$

N: number; yr: year; D: dominant leg; ND: non-dominant leg; con: concentric; ecc: eccentric; CMJ: countermovement jump; DJ: drop jump; SLJ: standing long jump; LJ: lateral jump; ASI: symmetries index; COD: change-of-direction; COD-D: change of direction-deficit; m: meter; kg: kilogram; cm: centimeter; N: Newton; s: second; ms: millisecond; VS: associated with; r: correlation coefficients; *p*: *p*-value.

4. Discussion

In this systematic review, we investigated the associations between inter-limb asymmetries and change of direction performance. Twelve studies and a total of 354 participants were included in this study. This study found that COD performance was significantly correlated with DJ height asymmetry scores, not with CMJ height asymmetry scores. In other words, larger DJ height asymmetry can significantly reduce COD performance. However, no significant relationships were observed between COD performance and horizontal jump distance asymmetries. Moreover, there was weak evidence that eccentric knee strength asymmetries may reduce COD performance.

Vertical jump asymmetry reflected vertical power asymmetry. Specifically, DJ height asymmetry can be used to assess reactive strength asymmetry. The primary finding of this review was that COD performance was significantly correlated with DJ height asymmetry scores, but not with CMJ height asymmetries. This result can be explained by several reasons. First, the small CMJ height asymmetries may compromise the magnitude of associations with COD performance. The study conducted by Bishop et al. [25] found that DJ asymmetry scores (11.07 ± 9.44 to 14.28 ± 10.28) were larger than CMJ asymmetry scores (10.64 ± 8.56 to 10.93 ± 9.17) in youth basketball players. The authors also reported that 505 performance was significant correlated with DJ asymmetry scores (r: 0.45 and 0.48, $p < 0.05$), but not with CMJ height asymmetry scores [25]. Moreover, the DJ task has more similar mechanisms to the COD task than the CMJ. In other words, most of the factors that determine the success of COD and DJ performance are the same. Both tasks involve braking phase and propulsive phase [39,40], and this specific phase is called the stretch and shortening cycle (SSC), which requires stronger eccentric strength and reactive strength [41–43]. A meta-analysis explored the associations between reactive strength and athletic performance, the authors reported that the reactive strength index significantly correlated with COD speed [33]. Notable, when performing CMJ tasks, the impact force of eccentric phase was smaller than that in the DJ and COD tasks, which means that COD and DJ tasks require greater demand of eccentric strength than CMJ. Therefore, it is plausible to assume that COD performance would be comprised when one side is hard to highly apply reactive and eccentric strength during a DJ or COD task.

Horizontal jump distance asymmetry mainly reflected horizontal power asymmetry. No significant associations were observed between horizontal jump distance asymmetry scores and COD performance in this review. This finding demonstrated that horizontal power asymmetries cannot affect COD performance. Previous studies supported this finding [28], the study conducted by Maloney et al. [28] reported that jump distance asymmetry did not negatively influence COD performance during single- and triple-hop tests. This result can be partially explained by the small magnitude of horizontal jump distance asymmetries score. Massive studies reported that vertical jump height asymmetry scores are greater than horizontal jump distance asymmetries scores [24,37]. For male recreational team-sport athletes, the greatest asymmetries score was observed in CMJ height, followed by horizontal jump distance (SLJ and LJ) [37]. It is worth noting that the degree of inter-limb asymmetries may influence the magnitude of associations between inter-limb asymmetries and COD performance. This may compromise the real level of horizontal power ability. Therefore, the jumping distance may not be the optimal and effective strategy to determine two-side differences, and the vertical jump tests can be chosen by practitioners.

According to the nature of the measurement tools, lower strength asymmetries can be divided into concentric, eccentric, isometric strength asymmetries, and so on. Although only two studies included in this study assessed the associations between COD performance and maximal strength asymmetry, and it is thus hard for us to draw a confirmed conclusion due to conflicting results. Dos' Santos et al. [26] reported small and no significant differences between inter-limb isometric relative peak force (6.6%, p = 0.08), impulse during 200 (12.2%, p = 0.31), and impulse during 300 (12.9%, p = 0.12) in 20 male collegiate athletes. No significant associations between isometric peak force and COD performance were observed in this study [26]. These results demonstrated that male athletes who showed small asymmetries in isometric actions may not reduce their COD performance. Similarly, the study conducted by Lockie et al. [37] also indicated that low asymmetry indexes of 3.3%–10.4% did not correlate with the reduction in COD performance. Coratella et al. [34] reported that asymmetries scores of quadriceps and hamstrings ranged from 7.9% to 9.8% and 9.7% to 11.8%, respectively, in U21 elite soccer players. It was noting that although small inter-limb asymmetries scores were observed, there were moderate associations between quadriceps and hamstrings eccentric peak force asymmetries and *T*-test and 20 m shuttle-test performance. Eccentric strength plays a critical role in limiting joint displacements during the eccentric phase in the movements involving SSC, such as COD and vertical jump [44], and forwarding the body through stabilizing both knee and hips during the propulsion phase [45]. The eccentric strength asymmetries detriments COD performance when one side is used to move primarily in side-stepping [45]. Therefore, there was weak evidence that eccentric knee strength asymmetries can influence the COD performance.

Moreover, out of five studies assessing associations between lateral jump symmetries and COD performance, significant correlations between both variables were only observed in one study [24]. Better lateral jump performance indicated better performance on dominant-side 505 and V-cut in handball athletes [24]. This may be due to muscles recruited required for COD tasks and for lateral jump seeming similar, for example, the important role of hamstrings, gluteal, and quadriceps played in both movements [46,47]. Moreover, the capability of explosive action laterally also enhanced COD performance [22,48]. However, there were no significant associations between lateral jump distance and COD performance [29,35–37]. Again, this finding may be explained by the low asymmetries score. Lateral jump distance asymmetries scores in these studies ranged from 3.3% to 6.6%, with an average of 5.9%. It is therefore necessary to consider whether greater asymmetries are detrimental to COD performance.

This study has several limitations. First, this study did not consider the sports in which the participants were involved. The degree of performance differences between inter-limb is certainly influenced by the magnitude of the inter-limb asymmetries. The larger inter-limb asymmetries scores may be observed in participants who take part in team sports such as baseball and basketball, while players who take part in individual sports may display low asymmetries. Second, only three databases were searched in this study, more specifically only English peer-journal were considered in this study.

5. Conclusions

This study suggests that drop jump height and eccentric knee strength asymmetries can reduce COD performance. Moreover, the low horizontal jump may not influence COD performance. Further research needs to determine that the minimal threshold of horizontal jump asymmetries would not affect COD performance.

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References

1. Bishop, C.; Read, P.; Lake, J.; Chavda, S.; Turner, A. Interlimb Asymmetries: Understanding How to Calculate Differences From Bilateral and Unilateral Tests. *Strength Cond. J.* **2018**, *40*, 1–6. [CrossRef]
2. Keeley, D.W.; Plummer, H.A.; Oliver, G.D. Predicting asymmetrical lower extremity strength deficits in college-aged men and women using common horizontal and vertical power field tests: A possible screening mechanism. *J. Strength Cond. Res.* **2011**, *25*, 1632–1637. [CrossRef] [PubMed]
3. Ball, K. Loading and performance of the support leg in kicking. *J. Sci. Med. Sport* **2013**, *16*, 455–459. [CrossRef] [PubMed]
4. Ball, K.A. Kinematic comparison of the preferred and non-preferred foot punt kick. *J. Sport Sci.* **2011**, *29*, 1545–1552. [CrossRef] [PubMed]
5. Hart, N.H.; Nimphius, S.; Cochrane, J.L.; Newton, R.U. Leg mass characteristics of accurate and inaccurate kickers–an Australian football perspective. *J. Sport Sci.* **2013**, *31*, 1647–1655. [CrossRef] [PubMed]
6. Hart, N.H.; Nimphius, S.; Spiteri, T.; Newton, R.U. Leg strength and lean mass symmetry influences kicking performance in Australian football. *J. Sport Sci. Med.* **2014**, *13*, 157–165.
7. Hart, N.H.; Spiteri, T.; Lockie, R.G.; Nimphius, S.; Newton, R.U. Detecting deficits in change of direction performance using the preplanned multidirectional Australian football league agility test. *J. Strength Cond. Res.* **2014**, *28*, 3552–3556. [CrossRef]
8. Hart, N.H.; Nimphius, S.; Weber, J.; Spiteri, T.; Rantalainen, T.; Dobbin, M.; Newton, R.U. Musculoskeletal Asymmetry in Football Athletes: A Product of Limb Function over Time. *Med. Sci. Sport Exerc.* **2016**, *48*, 1379–1387. [CrossRef]
9. Flanagan, S.P.; Salem, G.J. Bilateral differences in the net joint torques during the squat exercise. *J. Strength Cond. Res.* **2007**, *21*, 1220–1226. [CrossRef] [PubMed]
10. Bailey, C.; Sato, K.; Alexander, R.; Chiang, C.-Y.; Stone, M.H. Isometric force production symmetry and jumping performance in collegiate athletes. *J. Trainol.* **2013**, *2*, 1–5. [CrossRef]
11. Hart, N.; Nimphius, S.; Wilkie, J.; Newton, R. Reliability and Validity of Unilateral and Bilateral Isometric Strength Measures Using a Customised, Portable Apparatus. 2012. Available online: https://ro.ecu.edu.au/cgi/viewcontent.cgi?article=1235&context=ecuworks2012 (accessed on 2 September 2022).
12. Silva, J.R.L.C.; Detanico, D.; Pupo, J.D.; Freitas, C.d.l.R. Bilateral asymmetry of knee and ankle isokinetic torque in soccer players u20 category. *Rev. Bras. De Cineantropometria Desempenho Hum.* **2015**, *17*, 195–204.
13. Dickin, C.D.; Too, D. Effects of movement velocity and maximal concentric and eccentric actions on the bilateral deficit. *Res. Q. Exerc. Sport* **2006**, *77*, 296–303. [CrossRef] [PubMed]
14. Bishop, C.; Turner, A.; Jarvis, P.; Chavda, S.; Read, P. Considerations for Selecting Field-Based Strength and Power Fitness Tests to Measure Asymmetries. *J. Strength Cond. Res.* **2017**, *31*, 2635–2644. [CrossRef] [PubMed]
15. Impellizzeri, F.M.; Rampinini, E.; Maffiuletti, N.; Marcora, S.M. A vertical jump force test for assessing bilateral strength asymmetry in athletes. *Med. Sci. Sport Exerc.* **2007**, *39*, 2044–2050. [CrossRef] [PubMed]
16. Barber, S.D.; Noyes, F.R.; Mangine, R.E.; McCloskey, J.W.; Hartman, W. Quantitative assessment of functional limitations in normal and anterior cruciate ligament-deficient knees. *Clin. Orthop. Relat. Res.* **1990**, *255*, 204–214. [CrossRef]
17. Rohman, E.; Steubs, J.T.; Tompkins, M. Changes in involved and uninvolved limb function during rehabilitation after anterior cruciate ligament reconstruction: Implications for Limb Symmetry Index measures. *Am. J. Sport Med.* **2015**, *43*, 1391–1398. [CrossRef]
18. Kyritsis, P.; Bahr, R.; Landreau, P.; Miladi, R.; Witvrouw, E. Likelihood of ACL graft rupture: Not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture. *Br. J. Sport Med.* **2016**, *50*, 946–951. [CrossRef]
19. Bloomfield, J.; Polman, R.; O'Donoghue, P. Physical demands of different positions in FA Premier League soccer. *J. Sport Sci. Med.* **2007**, *6*, 63–70.
20. Yap, C.W.; Brown, L.E. Development of Speed, Agility, and Quickness for the Female Soccer Athlete. *Strength Cond. J.* **2000**, *22*, 9. [CrossRef]
21. Nimphius, S.; Callaghan, S.J.; Spiteri, T.; Lockie, R.G. Change of Direction Deficit: A More Isolated Measure of Change of Direction Performance Than Total 505 Time. *J. Strength Cond. Res.* **2016**, *30*, 3024–3032. [CrossRef] [PubMed]
22. Sheppard, J.M.; Young, W.B. Agility literature review: Classifications, training and testing. *J. Sport Sci.* **2006**, *24*, 919–932. [CrossRef] [PubMed]
23. Bishop, C.; Brashill, C.; Abbott, W.; Read, P.; Lake, J.; Turner, A. Jumping Asymmetries Are Associated With Speed, Change of Direction Speed, and Jump Performance in Elite Academy Soccer Players. *J. Strength Cond. Res.* **2021**, *35*, 1841–1847. [CrossRef] [PubMed]
24. Madruga-Parera, M.; Bishop, C.; Read, P.; Lake, J.; Brazier, J.; Romero-Rodriguez, D. Jumping-based Asymmetries are Negatively Associated with Jump, Change of Direction, and Repeated Sprint Performance, but not Linear Speed, in Adolescent Handball Athletes. *J. Hum. Kinet.* **2020**, *71*, 47–58. [CrossRef] [PubMed]
25. Bishop, C.; Perez-Higueras Rubio, M.; Gullon, I.L.; Maloney, S.; Balsalobre-Fernandez, C. Jump and Change of Direction Speed Asymmetry Using Smartphone Apps: Between-Session Consistency and Associations With Physical Performance. *J. Strength Cond. Res.* **2020**, *36*, 927–934. [CrossRef]
26. Dos'Santos, T.; Thomas, C.; Jones, P.A.; Comfort, P. Asymmetries in Isometric Force-Time Characteristics Are Not Detrimental to Change of Direction Speed. *J. Strength Cond. Res.* **2018**, *32*, 520–527. [CrossRef]

27. Bishop, C.; Read, P.; Brazier, J.; Jarvis, P.; Chavda, S.; Bromley, T.; Turner, A. Effects of Interlimb Asymmetries on Acceleration and Change of Direction Speed: A Between-Sport Comparison of Professional Soccer and Cricket Athletes. *J. Strength Cond. Res.* **2021**, *35*, 2095–2101. [CrossRef]
28. Maloney, S.J.; Richards, J.; Nixon, D.G.; Harvey, L.J.; Fletcher, I.M. Do stiffness and asymmetries predict change of direction performance? *J. Sport Sci.* **2017**, *35*, 547–556. [CrossRef]
29. Fort-Vanmeerhaeghe, A.; Montalvo, A.M.; Sitjà-Rabert, M.; Kiefer, A.W.; Myer, G.D. Neuromuscular asymmetries in the lower limbs of elite female youth basketball players and the application of the skillful limb model of comparison. *Phys. Sport* **2015**, *16*, 317–323. [CrossRef]
30. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Bmj* **2021**, *372*, n71. [CrossRef]
31. Bujalance-Moreno, P.; Latorre-Román, P.; García-Pinillos, F. A systematic review on small-sided games in football players: Acute and chronic adaptations. *J. Sport Sci.* **2019**, *37*, 921–949. [CrossRef]
32. Fox, J.L.; Stanton, R.; Sargent, C.; Wintour, S.A.; Scanlan, A.T. The Association Between Training Load and Performance in Team Sports: A Systematic Review. *Sport Med.* **2018**, *48*, 2743–2774. [CrossRef] [PubMed]
33. Jarvis, P.; Turner, A.; Read, P.; Bishop, C. Reactive Strength Index and its Associations with Measures of Physical and Sports Performance: A Systematic Review with Meta-Analysis. *Sport. Med.* **2022**, *52*, 301–330. [CrossRef] [PubMed]
34. Coratella, G.; Beato, M.; Schena, F. Correlation between quadriceps and hamstrings inter-limb strength asymmetry with change of direction and sprint in U21 elite soccer-players. *Hum. Mov. Sci.* **2018**, *59*, 81–87. [CrossRef] [PubMed]
35. Madruga-Parera, M.; Bishop, C.; Fort-Vanmeerhaeghe, A.; Beltran-Valls, M.R.; Skok, O.G.; Romero-Rodríguez, D. Interlimb Asymmetries in Youth Tennis Players: Relationships With Performance. *J. Strength Cond. Res.* **2020**, *34*, 2815–2823. [CrossRef] [PubMed]
36. Madruga-Parera, M.; Bishop, C.; Beato, M.; Fort-Vanmeerhaeghe, A.; Gonzalo-Skok, O.; Romero-Rodríguez, D. Relationship Between Interlimb Asymmetries and Speed and Change of Direction Speed in Youth Handball Players. *J. Strength Cond. Res.* **2021**, *35*, 3482–3490. [CrossRef] [PubMed]
37. Lockie, R.G.; Callaghan, S.J.; Berry, S.P.; Cooke, E.R.; Jordan, C.A.; Luczo, T.M.; Jeffriess, M.D. Relationship between unilateral jumping ability and asymmetry on multidirectional speed in team-sport athletes. *J. Strength Cond. Res.* **2014**, *28*, 3557–3566. [CrossRef] [PubMed]
38. Bishop, C.; Read, P.; Bromley, T.; Brazier, J.; Jarvis, P.; Chavda, S.; Turner, A. The Association Between Interlimb Asymmetry and Athletic Performance Tasks: A Season-Long Study in Elite Academy Soccer Players. *J. Strength Cond. Res.* **2022**, *36*, 787–795. [CrossRef]
39. Kipp, K.; Kiely, M.T.; Giordanelli, M.D.; Malloy, P.J.; Geiser, C.F. Biomechanical Determinants of the Reactive Strength Index During Drop Jumps. *Int. J. Sport Physiol. Perform.* **2018**, *13*, 44–49. [CrossRef] [PubMed]
40. Dos'Santos, T.; Thomas, C.; Comfort, P.; Jones, P.A. The Effect of Angle and Velocity on Change of Direction Biomechanics: An Angle-Velocity Trade-Off. *Sport Med.* **2018**, *48*, 2235–2253. [CrossRef]
41. Komi, P.V. Stretch-shortening cycle: A powerful model to study normal and fatigued muscle. *J. Biomech.* **2000**, *33*, 1197–1206. [CrossRef]
42. Nicol, C.; Avela, J.; Komi, P.V. The stretch-shortening cycle: A model to study naturally occurring neuromuscular fatigue. *Sport Med.* **2006**, *36*, 977–999. [CrossRef] [PubMed]
43. Wilson, J.M.; Flanagan, E.P. The role of elastic energy in activities with high force and power requirements: A brief review. *J. Strength Cond. Res.* **2008**, *22*, 1705–1715. [CrossRef] [PubMed]
44. Cormie, P.; McGuigan, M.R.; Newton, R.U. Changes in the eccentric phase contribute to improved stretch-shorten cycle performance after training. *Med. Sci. Sport Exerc.* **2010**, *42*, 1731–1744. [CrossRef]
45. Rouissi, M.; Chtara, M.; Owen, A.; Chaalali, A.; Chaouachi, A.; Gabbett, T.; Chamari, K. Effect of leg dominance on change of direction ability amongst young elite soccer players. *J. Sport Sci.* **2016**, *34*, 542–548. [CrossRef] [PubMed]
46. Hart, J.M.; Garrison, J.C.; Kerrigan, D.C.; Palmieri-Smith, R.; Ingersoll, C.D. Gender differences in gluteus medius muscle activity exist in soccer players performing a forward jump. *Res. Sport Med.* **2007**, *15*, 147–155. [CrossRef] [PubMed]
47. Kyröläinen, H.; Avela, J.; Komi, P.V. Changes in muscle activity with increasing running speed. *J. Sport* **2005**, *23*, 1101–1109. [CrossRef] [PubMed]
48. Young, W.; Farrow, D. A Review of Agility: Practical Applications for Strength and Conditioning. *Strength Cond. J.* **2006**, *28*, 24. [CrossRef]