Jumping-based Asymmetries are Negatively Associated with Jump, Change of Direction, and Repeated Sprint Performance, but not Linear Speed, in Adolescent Handball Athletes

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Conflicts of Interest Statement

The authors report no conflicts of interest with this study.

Abstract

The aim of the present study was to determine the association of multi-directional jumping asymmetries with measures of physical performance. Forty-two youth handball athletes (age: 16.0 ± 1.3 years; body height: 174.11 ± 7.3 cm; body mass: 70.49 ± 13.3 kg) performed a mid-season fitness test battery consisting of single leg countermovement, lateral and broad jump tests, two change of direction speed (CODS) tests, an 8 x 10 m repeated sprint test, and a 20 m sprint. The Kappa coefficient showed only 'slight' levels of agreement (K range = -0.05 to 0.15), indicating that asymmetries rarely favoured the same side during each of the jump tests. The single leg countermovement jump showed significantly ($p = 0.006$) larger asymmetries (11.2 ± 8.4) than the broad jump (6.4 ± 4.6) and significant correlations were present between jumping asymmetries and jump ($r = -0.32$ to -0.52), CODS ($r = 0.31$ to 0.32) and repeated sprint ($r = 0.35$ to 0.40) performance. The findings of the present study highlight the independent nature of jumping asymmetries and associations with measures of physical performance. Practitioners are encouraged to use multiple tests to detect existing side differences and consider appropriate training interventions for the reduction of inter-limb asymmetries.

Introduction

Inter-limb asymmetries refer to the performance or function of one limb in relation to the other (Bishop et al., 2018b) and have been a common line of investigation in recent years with numerous methods employed to detect their prevalence. For example, asymmetries in strength have been reported during the back squat (Sato and Heise, 2012), isometric squat and mid-thigh pull (Dos'Santos et al., 2018; Hart et al., 2014; Thomas et al., 2017), and isokinetic dynamometry (Costa et al., 2015; Ruas et al., 2015). Jump tests have also been commonly used to detect between-limb differences with the countermovement jump (CMJ), broad jump (BJ), and drop jump (DJ) frequently used in addition to their unilateral variations (Bishop et al., 2018c; Hoffman et al., 2015; Lockie et al., 2014; Maloney et al., 2017; Meylan et al., 2009). Further to this, between-limb asymmetries have also been measured in sprinting (Exell et al., 2012; Haugen et al., 2018), change of direction speed (CODS) tasks (Dos'Santos et al., 2018, Madruga-Parera et al., 2019a) and balance (Madruga-Parera et al., 2019b) and highlighting the versatility of physical performance tests that can be used to detect inter-limb asymmetries. Although useful, reporting their prevalence alone does little to further our understanding of whether their reduction is needed. For this, investigations into the effects of asymmetries on physical performance represent a useful starting point in understanding their importance (Bishop et al., 2018d; Bishop et al., 2019; Madruga-Parera et al., 2019a; Maloney, 2018).

When looking at the effects on performance, jump testing has been a common line of investigation, most likely because of its time-efficient nature and relatively easy test procedures (Bishop et al., 2017). Hoffman et al. (2007) reported jump height asymmetries from the single leg CMJ (SLCMJ) of 9.7% in 62 college soccer players; however, no significant relationships were reported with the L-run CODS test. These findings are supported in other studies (Dos'Santos et al., 2018; Lockie et al., 2014). Lockie et al. (2014) highlighted the test-specific nature of asymmetries by reporting asymmetries of 10.4% (jump height from the SLCMJ), 3.3% (jump distance from the single leg BJ [SLBJ]) and 5.1% (jump distance from the single leg lateral jump [SLLJ]). No meaningful correlations were found when compared to a 20 m sprint, the 505 or modified t-tests. Dos'Santos et al. (2017) reported jump distance asymmetries of 6.25 and 5.69% in the single leg and triple hop tests, respectively, and again, showed no associations with two CODS tests. Similarly, Dos'Santos et al. (2018) reported no

significant correlations between strength asymmetries during an isometric mid-thigh pull and performance during 180º and 90º cutting actions.

In contrast, Maloney et al. (2017) used the single leg DJ to assess side-to-side differences in jump performance and compare to CODS performance. Results highlighted that faster athletes during the CODS task showed asymmetries in jump height of only 2.4%, whereas slower athletes were significantly more asymmetrical (7.2%). In addition, jump height asymmetry was associated with slower CODS performance ($r = 0.60$). More recently, Bishop et al. (2018c) quantified asymmetries from the SLCMJ, single, triple and crossover hop tests for distance in elite youth female soccer players. Results showed that jump height asymmetries (from the single leg CMJ) were negatively associated with sprint performance ($r = 0.49$ to 0.59), noting that a positive correlation was indicative of slower times. Furthermore, asymmetries during the triple hop test were associated with reduced horizontal jump performance ($r = -0.47$ to -0.58) and jump height asymmetries were also negatively associated with jump height ($r = -0.47$ to -0.53).

Owing to the conflicting findings in the literature, further research is warranted to determine whether asymmetries are truly associated with decrements in physical performance. Therefore, the primary aim of the present study was to determine the effects of inter-limb asymmetries on measures of physical performance. In addition, previous literature has shown the task-specific nature of asymmetries; thus, the secondary aim was to assess the consistency of how frequently each asymmetry score favoured the same side (*i.e.,* left or right). This would provide a more in-depth picture of the task-specific nature of asymmetries, rather than just reporting different percentage values alone.

Methods

In the present study a mid-season fitness testing battery on a group of elite adolescent handball athletes over the course of two consecutive days was conducted. Handball is an intermittent, high intensity sport characterised by multiple accelerations, decelerations, changes of direction and ballistic jumping movements (Póvoas et al., 2017); thus, the selected tests represented ecologically valid criteria for the present sample.

Participants

Forty-two youth male handball players (age: 16.0 ± 1.3 years; body height: 174.1 ± 7.3 cm; body mass: 70.5 ± 13.3 kg), were recruited from a handball club in Barcelona. Players had a minimum of seven years of experience playing competitive handball (Catalan Handball Federation), consisting on average of three handball training sessions per week. Participants were excluded if they suffered any injury either at the time or during three months prior to testing. Written informed consent was obtained from each participants' parents or guardians, owing to their age. This study was approved by Catalan Sports Council Ethics Committee.

Design and Procedures

Testing was performed over two consecutive days. Day one consisted of three unilateral jump tests, two CODS tests and a 20 m sprint test. On day two, players performed the repeated sprint test which consisted of 8 x 10 m sprints. The 8 x 10 m repeated sprint was performed on the second day owing to the likelihood of it impacting the performance of other tests if conducted on the same day. Each participant completed a specific warm up procedure consisting of five minute light jogging at approximately 40-50% of the maximum perception of individual effort (indicated verbally) and 2 sets of 6 repetitions of dynamic stretches for the lower body, including multi-directional lunges, inchworms, bodyweight squats and spidermans. Upon completion, three practice trials were provided for each test where participants were instructed to perform them at 75, 90 and 100% of their perceived maximal effort. All tests were performed on an indoor handball court, and participants wore handball shoes through all assessments. Three minute rest intervals were given between the last practice trial and the start of the first test.

Single leg countermovement jump (SLCMJ). The SLCMJ was conducted on a contact mat (Chronojump, Boscosystem, Barcelona Spain) measuring jump height in centimetres (cm). Participants were required to step onto the centre of the contact mat with one leg and place their hands on their hips. When ready, participants performed a countermovement to a self-selected depth before accelerating as forcefully as possible into a unilateral vertical jump, following the instructions to 'jump as high as you can'. The non-jumping leg was slightly flexed at the knee with the foot hovering next to the ankle of the jumping leg. No additional swinging of the non-jumping leg was allowed

during the jump and hands were required to remain fixed at the hips. Any deviations from these criteria resulted in a void trial and subsequently retaken. Three trials were performed on each leg with 60-s rest intervals provided between each trial. The highest jump on each leg was then used for subsequent data analysis.

Single leg lateral jump (SLLJ). The SLLJ measured lateral jump distance (in cm) with a standard measuring tape that was fixed to the floor. Participants started just behind 0 cm with a selected test leg and performed a countermovement to a self-selected depth before jumping laterally as far as possible along the direction of the tape measure (without landing directly on it) with hands placed and held on the hips throughout. Owing to the increased difficulty of this test (by virtue of jumping in the frontal plane), the landing was performed on both limbs to increase the chance of a stable landing. Participants were required to stick the landing for 2 s with the distance measured from the outside edge of the landing foot (part of the foot closest to 0 cm). Three trials were performed on each leg with 60-s rest intervals provided between each trial. The trial with the furthest jump on each leg was then used for subsequent data analysis.

Single leg broad jump (SLBJ). The SLBJ measured horizontal jump distance (in cm) with a standard measuring tape that was fixed to the floor. Participants started with their toes just behind 0 cm with a selected test leg and performed a countermovement to a self-selected depth before jumping as far forward as possible along the direction of the tape measure (without landing directly on it) with hands placed on the hips throughout. Participants were required to land on the same leg and stick the landing for 2 s with the distance measured from the heel of the landing foot. The non-jumping leg was slightly flexed at the knee with the foot hovering next to the ankle of the jumping leg. No additional swinging of the non-jumping leg was allowed during the jump. Any deviations from these criteria resulted in a void trial and subsequently retaken. Three trials were performed on each leg with 60-s rest intervals provided between each trial. The furthest jump on each leg was then used for data analysis.

Change of direction speed test. This test was conducted in line with previous research by Meylan et al. (2009). Participants were instructed to conduct two 180º changes of direction with the same leg, for a total distance of 20 m. The first change of direction was performed after a distance of 7.5 m, whereby the participant then sprinted 5 m

before the second 180º change of direction, and subsequently sprinted another 7.5 m to finish the test. A trial was considered successful if the entire foot passed the marked line during the change of direction component. Total time was measured with photocell beams, placed on the starting line and 10 m from it, and connected to a computer (Chronojump, Boscosystem, Barcelona, Spain). Three trials were performed turning off both the dominant and non-dominant legs with 60-s rest intervals provided between each trial. The fastest trial was used for data analysis.

V-cut test. Participants performed a 25-m sprint with four 45° changes of direction, each after a distance of 5 m (Gonzalo-Skok et al., 2015). For the trial to be valid, athletes had to pass the line with each respective foot at every turn, which was clearly marked on the floor. Failure to adhere to these protocols resulted in a void trial, which was subsequently retaken after the appropriate rest interval of 60 s. The distance between each pair of cones was 0.7 m. A photocell beam sensor was connected to Chronojump software in order to acquire data (Chronojump, BoscoSystem, Barcelona, Spain). Three trials were performed with 60-s rest intervals provided in between and the fastest trial was subsequently used for further analysis.

8 x 10 m repeated sprint test. This test is related to an athlete's capacity to resist fatigue during a change of direction task. The test involved eight continuous repetitions of a 10 m sprint, with each 10 m sprint requiring a 180º change of direction at the half way point (5 m). A photocell beam sensor was connected to Chronojump software in order to acquire data (Chronojump BoscoSystem, Barcelona, Spain). With the intention of being able to observe the association between inter-limb asymmetries and performance when athletes are in an acute state of 'fatigue', we modified this previously validated CODS test (Castillo-Rodríguez et al., 2012) by carrying out eight consecutive sprints (no rest between any of them), instead of a single maximal effort. Owing to this test acutely inducing fatigue, it was only performed twice; each time ensuring that all turns were conducted off the same limb. A rest period of five minutes between trials was provided, with the outcome of total time for all eight sprints combined and used for further analysis.

20 m sprint test. Linear speed was assessed by means of a 20 m sprint from a staggered 2-point start position (front foot 0.5 m behind the start line). A photocell beam sensor

was connected to Chronojump software in order to acquire data (Chronojump BoscoSystem, Barcelona, Spain). Three trials were performed with 60-s rest intervals provided in between and the fastest trial was used for data analysis.

Statistical Analysis

All data were initially computed as means and standard deviations (SD) in Microsoft Excel and later transferred into SPSS (version 21.0; SPSS, Inc., Armonk, NY, USA) for additional analyses when required. Absolute and relative reliability was calculated via the coefficient of variation (CV) and intraclass correlation coefficient (ICC) with absolute agreement, respectively. CV values < 10% were considered acceptable (Cormack et al., 2008) and ICCs were interpreted in line with previous suggestions from Koo and Li (2016) where values > 0.9 = excellent, 0.75-0.9 = good, 0.5-0.74 = moderate, and < 0.5 = poor.

Noting that asymmetries may favour either side depending on which limb scores larger (Bishop et al., 2018a; Lake et al., 2018), a Kappa coefficient was calculated to determine how consistently asymmetries favoured the same side during jump tests. Kappa values were interpreted in line with suggestions from Viera and Garrett (2005), where ≤ 0 = poor, 0.01-0.20 = slight, 0.21-0.40 = fair, 0.41-0.60 = moderate, 0.61-0.80 = substantial, and 0.81-0.99 = almost perfect.

A one-way repeated measures ANOVA was conducted to determine whether significant differences in asymmetry scores were present between jump tests, with statistical significance (set at $p < 0.05$) identified via Bonferroni post-hoc analysis. Pearson's *r* correlations were conducted to determine the relationship between asymmetry scores and performance tests, with statistical significance set at $p < 0.05$. The following criteria were adopted for interpreting the magnitude of correlation between test measures: ≤ 0.1 = trivial; 0.1-0.3 = small; 0.3-0.5 = moderate; 0.5-0.7 = large; 0.7-0.9 = very large and 0.9-1.0 = almost perfect (Hopkins et al., 2009). Finally, inter-limb asymmetries were calculated using a percentage difference equation: 100/(max value)*(min value)*-1+100 (Bishop et al., 2018b, 2018c).

Results

Mean test scores, inter-limb asymmetries and reliability statistics are presented in Table 1. All tests reported acceptable variability with CV's < 10% and good to excellent reliability with ICC's ≥ 0.89. Kappa coefficients are presented in Table 2 and show that asymmetries rarely favoured the same side between jump tests (Kappa = -0.05 to 0.15), indicating that any existing side-to-side differences during jump tests were independent of each other.

Owing to the independent nature of these asymmetries, individual jump asymmetry data are presented in Figures 1-3. Remembering that any side-to-side differences should be reported in the context of the CV, the dotted lines show when an individual's asymmetry score is greater than the test variability. When considering how many participants showed asymmetries greater than the respective test CV score, 24 athletes (57%) reported larger values during the SLCMJ, 23 athletes (55%) showed larger values during the SLLJ, and 21 athletes (50%) showed larger values during the SLBJ test; this indicating that many participants had asymmetries greater than the test variability score, which likely suggests real imbalances (Bishop et al., 2018b; Exell et al., 2012). Results from the one-way ANOVA showed significantly greater asymmetries in the SLCMJ compared to the SLBJ ($p = 0.006$).

Pearson's *r* correlations between jumping asymmetries and performance test scores are presented in Table 3. Moderate correlations were found between jump height (SLCMJ) and large correlations were found between jump distance (SLLJ) asymmetries and jump performance. In addition, moderate correlations were found between jump height (SLCMJ) asymmetries and repeated sprint performance. Further to this, moderate correlations were found between jump distance (SLLJ) asymmetries and multidirectional CODS and sprint performance. No significant correlations were shown between asymmetries and 20 m sprint performance.

*** *Insert Tables 1-3 about here* ***
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Discussion

The aims of the present study were to determine the relationships between inter-limb asymmetries and measures of physical performance, and to quantify whether asymmetries consistently favoured the same side during three commonly used unilateral jump tests, in adolescent handball players. Results showed that jump height and distance-based asymmetries were associated with reduced performance during jumping, CODS and repeated sprint tests; but not linear speed. In addition, asymmetries rarely favoured the same side between jump tests.

Mean data for all test protocols, inclusive of test reliability and mean inter-limb asymmetry values (where appropriate), were calculated (Table 1). All tests reported good to excellent reliability (ICC range = 0.89-0.98) and acceptable variability (CV range = 1.3-8.9%), indicating that results can be interpreted with confidence. When mean asymmetry values are viewed, all jump tests reported larger between-limb differences than the CODS or repeated sprint tests, suggesting that they may be more sensitive at highlighting any existing imbalances than the outcome measure of CODS time alone. In addition, the SLCMJ showed significantly larger ($p = 0.006$) asymmetries than the SLBJ which is in agreement with previous research. Lockie et al. (2014) reported inter-limb differences of 10.4% for the SLCMJ, 5.4% for the SLLJ, and 3.3% for the SLBJ using 30 adult team sport athletes. Bishop et al. (2018c) reported significantly larger asymmetries for the SLCMJ (12.5%) compared to the SLBJ (6.8%) in elite youth female soccer players. As such, it would appear that the SLCMJ may be more sensitive at detecting inter-limb asymmetries than horizontal or lateral jump tests, which has been previously suggested (McCubbine et al., 2018), and is likely a useful test option for practitioners if they wish to quantify limb differences from jump tests.

The Kappa coefficient (Table 2) was calculated in order to know how frequently jumping asymmetries favor the same side among different measurements (i.e. right or left). This method of analysis was chosen because it describes the proportion of agreement between two methods after any agreement by chance has been removed (Cohen, 1960). Results show only 'slight' levels of agreement for the side consistency of asymmetry between jumps (-0.05 to 0.15). Previous research from Loturco et al. (2018) detected inter-limb asymmetries during isokinetic dynamometry, tensiomyography, and CMJ and squat jumps, and concluded that asymmetries from these three methods were not inter-related. This is further supported in recent research from Bishop et al. (2018a) who used the Kappa coefficient to report the side consistency

of peak force asymmetries between the SLCMJ and SLBJ. The Kappa coefficient was 0.05, again indicating very low levels of agreement in terms of which side favoured the imbalance. Consequently, this provides further support for the task-specific nature of asymmetries and arguably precludes the use of a single test as the sole screening method for the prevalence of existing side-to-side differences.

Although the correlations between jumping asymmetries and physical performance (Table 3) do not show an overall negative influence on the performance of the different tested capabilities, probably because of the task-dependent nature of asymmetries, some negative correlations should stand out. In this sense, negative correlations between jump height asymmetries and jump performance in the SLCMJ ND ($r = -0.47$) were found in the present study, and similar results have been recently shown at different ages (under-16, $r = -0.51, -0.54$; under 23, $r = -0.52, -0.77$ and under-18, $r = -0.58, -0.40$) in elite academy soccer players (Bishop et al., 2019). Related to jump distance asymmetries, no meaningful correlations were found between SLBJ and jump performance in our study, which is in agreement with previous research using this test in youth female soccer players (Bishop el al., 2018c) and youth tennis players (Madruga-Parera et al., 2019a). Furthermore, negative correlations were found between SLLJ asymmetries and SLBJ D ($r = -0.32$) and SLLJ ND ($r = -0.52$) performance, although no correlations in the same tests were found in Madruga-Parera et al. (2019a) and Fort-Vanmeerhaeghe et al. (2015) in youth tennis players and female basketball players, respectively. Thus, it seems a relationship between larger jumping asymmetries and jump performance exists in youth handball players, although it is not possible to establish a clear relationship. These results highlight the importance of test selection when aiming to detect between-limb differences.

Significant moderate correlations were shown for jump height asymmetries and time taken to complete the 8 x 10 repeated sprint protocol ($r = 0.35-0.40$). Noting that in this instance, a positive correlation is indicative of higher total time to complete the repeated sprint test; these results would suggest that larger asymmetries during the SLCMJ are associated with reduced repeated sprint performance. The same principle can also be said for jump distance asymmetries during the SLLJ, where significant correlations were found with the V-cut test ($r = 0.32$) and the CODS test ($r = 0.29-0.31$). In contrast, no significant relationships were previously found between jumping asymmetries and CODS performance in youth tennis players (Madruga-Parera et al., 2019a) and female basketball players (Fort-Vanmeerhaeghe et al., 2015). Considering

sprint capacity, no correlations with jumping asymmetries were found, as previously found in recreational team-sport athletes (Lockie et al., 2014). Furthermore, strength asymmetries have not been related to sprint performance as well (Lockie et al., 2017). These results contrast with others studies in female and male soccer players, where correlations between SLCMJ height asymmetry and reduced sprinting performance were found (Bishop et al., 2018c, 2019). The disparity of these data could be explained by the importance of correctly selecting tests to determine asymmetries based on age, gender, sport and positional differences where applicable.

Therefore, in our study, both jump height and distance asymmetries would appear to be associated with reduced performance during jumping, changing direction and repeated sprint-based tests. Intuitively, explaining these findings is somewhat challenging. However, the very nature of being asymmetrical during jumping would indicate the reduced capacity of one limb relative to another (Maloney et al., 2018). Thus, the associated force production often associated with CODS movements (Young et al., 2001) might then be detrimentally affected if one limb cannot produce as much force, which may in part explain the association between asymmetry and CODS performance. In addition, previous research has highlighted that strength may also be a decisive factor (rather than asymmetry) when affecting physical performance. Considering our sample, comprised of youth players, it is plausible to understand the high asymmetries found in the present study, as previously happen in less trained athletes (Bazyler et al., 2014; Maloney et al., 2018). This condition could explain the low performance level in the different tests carried out.

The asymmetry scores for each individual athlete are presented in Figures 1-3 and each test shows a dotted line which indicates the CV for each test, the relevance here being that when asymmetry scores surpass the CV, the imbalance is greater than test variability and can likely be considered real (Bishop et al., 2018b; Exell et al., 2012). When determining whether individual asymmetry scores were greater than the CV, the SLCMJ showed 24 athletes surpassed test variability, 23 for the SLLJ and 21 for the SLBJ. Therefore, it is evident that > 50% of these athletes were exhibiting real side-to-side differences during multi-directional jump testing. Furthermore, when viewing the asymmetry axis on each graph, it is apparent that the scale is much greater on the SLCMJ and SLLJ compared to the SLBJ. Thus, vertical and lateral jump testing may potentially detect larger inter-limb differences than horizontal jump tests. This is supported by Lockie et al. (2014) who reported asymmetry values of 10.4 and 5.1% for

the SLCMJ and SLLJ, compared to 3.3% for the SLBJ. Therefore, if asymmetry profiling is needed for team sport athletes, multi-directional jumping seems ecologically valid, and practitioners may find the vertical and lateral jumping is most effective when detecting existing between-limb differences.

Practical Implications

In conclusion, multi-directional jumping asymmetries appear to be independent of each other. Moreover, these asymmetries are detrimental to jumping, CODS and repeated sprint performance, but not linear speed. Given the negative association of jumping asymmetries and the reduction of performance tests, it is suggested to apply training interventions with the intention to reduce inter-limb asymmetries. Previous research has highlighted unilateral training such as rear foot elevated split squats and unilateral CMJ as effective methods to reduce imbalances (Gonzalo-Skok et al., 2017), as well as unilateral coordinative training with an iso-inertial device (Gonzalo-Skok et al., 2019). These suggestions could be useful when programming for youth handball players given the prevalence of unilateral movement patterns in the sport.

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Table 1. Mean data for jump testing, inter-limb asymmetries and reliability statistics.

Fitness Test	Mean ± SD	Asymmetry %	CV (%)	ICC (95% CI)
SLCMJ-D (cm)	15.7 ± 3.6	11.2 ± 8.4*	8.9	0.96 (0.93-0.98)
SLCMJ-ND (cm)	13.9 ± 3.6		7.7	0.95 (0.92-0.97)
SLLJ-D (cm)	140.7 ± 20.5	8.3 ± 7.5	5.5	0.95 (0.91-0.97)
SLLJ-ND (cm)	129.2 ± 21.5		5.8	0.96 (0.92-0.98)
SLBJ-D (cm)	143.2 ± 25.3	6.4 ± 4.6	6.1	0.92 (0.86-0.95)
SLBJ-ND (cm)	134.0 ± 24.3		6.5	0.94 (0.88-0.97)
CODS-D (s)	5.3 ± 0.5	2.6 ± 2.3	1.9	0.96 (0.93-0.98)
CODS-ND (s)	5.4 ± 0.5		2.2	0.96 (0.93-0.98)
8x10-D (s)	14.9 ± 2.0	5.8 ± 5.7	4.4[a]	0.89 (0.79-0.94)[a]
8x10-ND (s)	15.8 ± 2.2			
V-cut (s)	7.3 ± 0.6	-	1.6	0.97 (0.95-0.99)
20m (s)	3.1 ± 0.3	-	1.3	0.98 (0.97-0.99)

* significantly different from SLBJ % ($p = 0.006$)

[a] pooled data from both limbs, note that only 1 trial was performed with turns off each limb (due to it being a repeated sprint test)

CV = coefficient of variation; ICC = intraclass correlation coefficient; CI = confidence intervals; D = dominant; ND = non-dominant; SLCMJ = single leg countermovement jump; SLLJ = single leg lateral jump; SLBJ = single leg broad jump; CODS = change of direction speed; s = seconds

Table 2. Kappa coefficients comparing asymmetry side consistency between jump height and distance in the single leg countermovement, lateral, and broad jump tests.

Test Comparison	Kappa Coefficient	Descriptor
SLCMJ – SLLJ	0.15	Slight
SLCMJ – SLBJ	-0.05	Poor
SLBJ – SLLJ	0.00	Poor

SLCMJ = single leg countermovement jump; SLLJ = single leg lateral jump; SLBJ = single leg broad jump

Table 3. Pearson's r correlations between asymmetry scores and physical performance tests.

Asym %	SLCMJ D	SLCMJ ND	SLLJ D	SLLJ ND	SLBJ D	SLBJ ND	20m	V-cut	CODS D	CODS ND	8x10 D	8x10 ND
SLCMJ	-0.13	-0.47**	-0.06	-0.09	-0.24	-0.26	0.18	0.07	0.09	0.11	0.40**	0.35*
SLLJ	-0.04	-0.06	-0.06	-0.52**	-0.32*	-0.30	0.13	0.32*	0.31*	0.29	0.01	0.03
SLBJ	-0.19	-0.20	-0.05	-0.02	-0.03	-0.25	0.11	< 0.01	0.03	-0.01	0.20	0.30

** significant at $p < 0.01$; * significant at $p < 0.05$

Asym = asymmetry; SLCMJ = single leg countermovement jump; SLLJ = single leg lateral jump; SLBJ = single leg broad jump; D = dominant; ND = non-dominant; CODS = change of direction speed
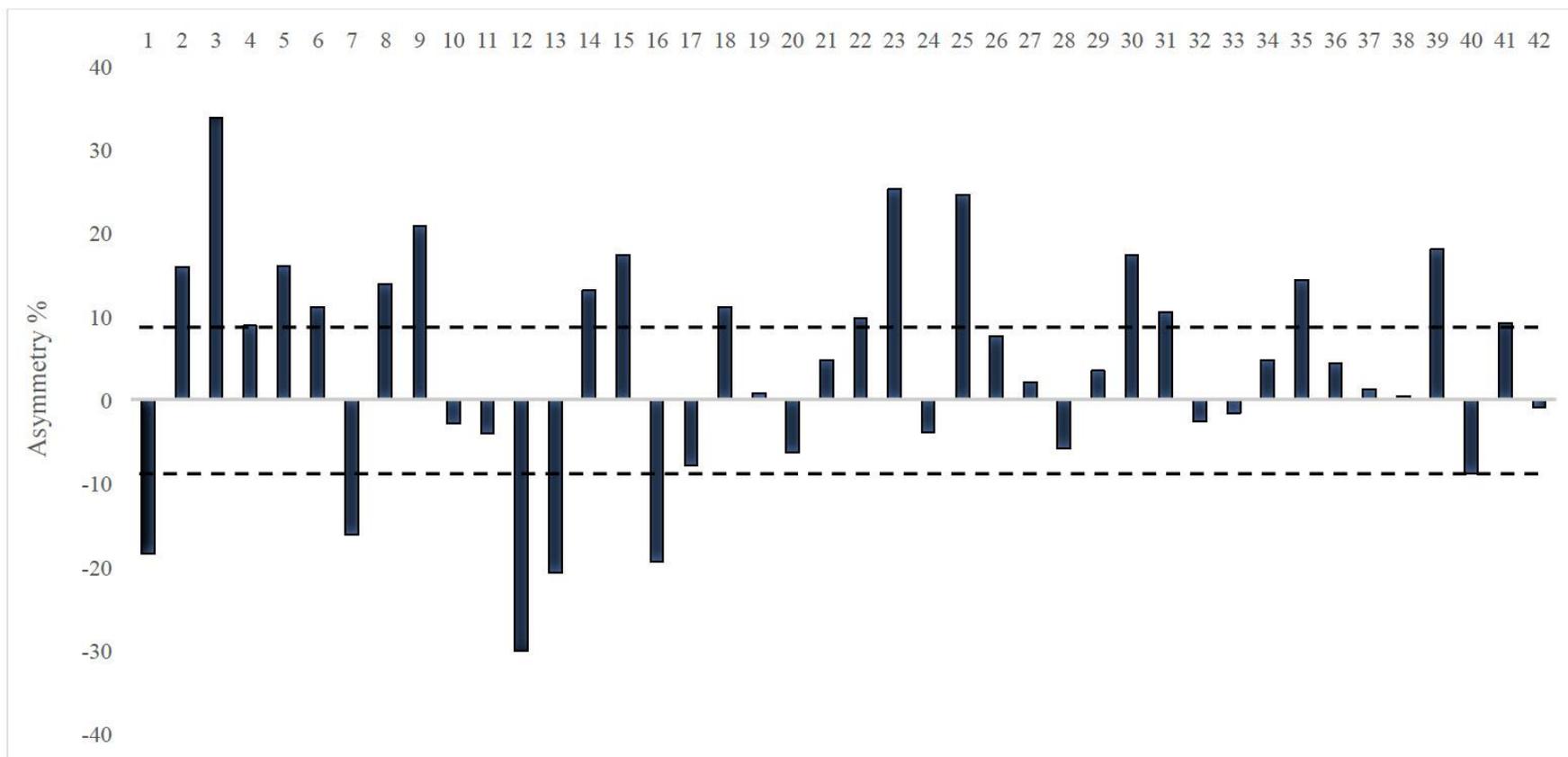
Figure 1. Individual single leg countermovement jump (SLCMJ) asymmetry scores (*n* = 42). N.B1: above 0 indicates that asymmetry is favoured on the right leg and below 0 indicates asymmetry favours the left leg. N.B2: dotted line indicates the average CV value for SLCMJ test (8.27%).
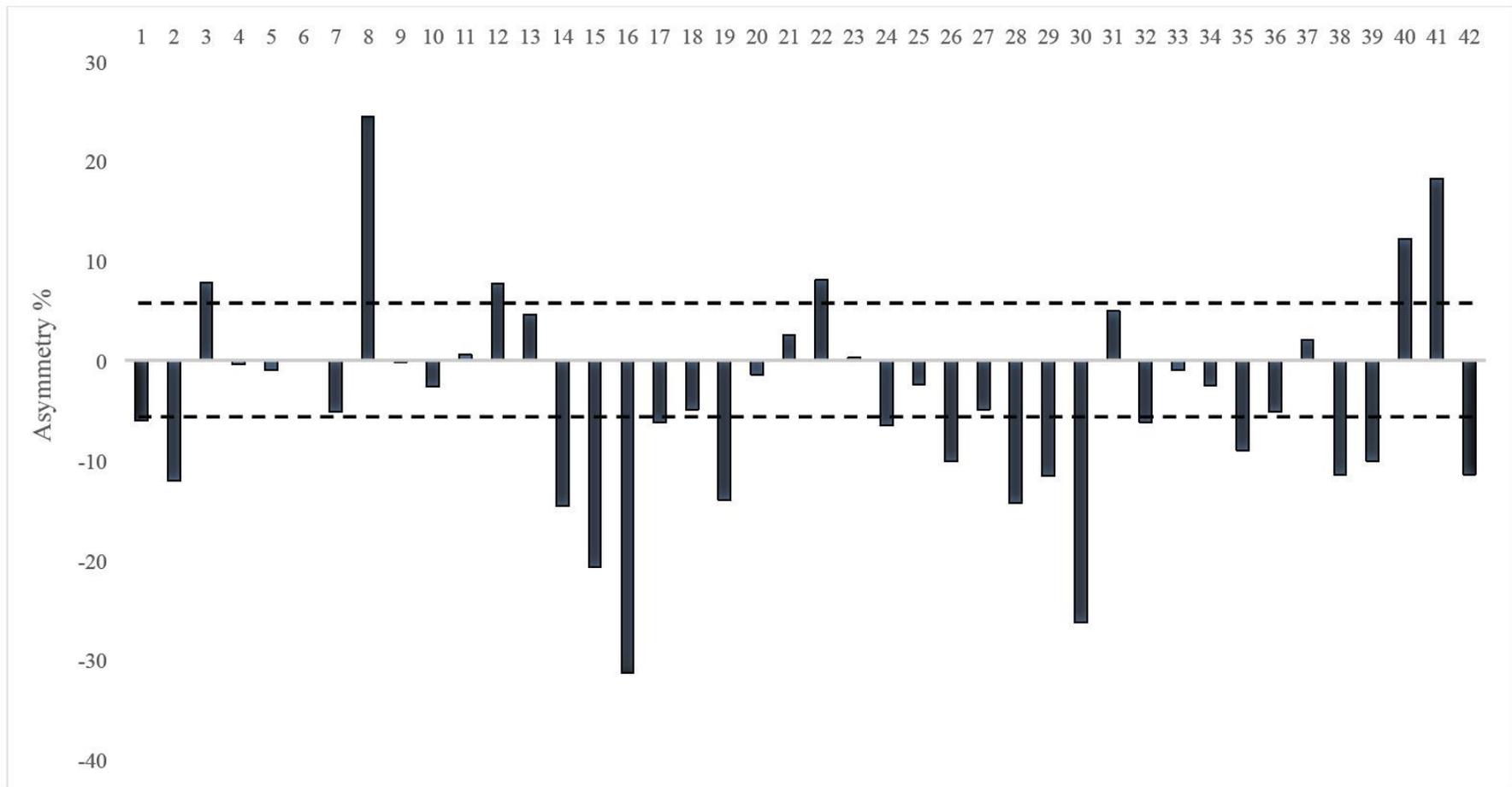
Figure 2. Individual single leg lateral jump (SLLJ) asymmetry scores (n = 42). N.B1: above 0 indicates that asymmetry is favoured on the right leg and below 0 indicates asymmetry favours the left leg. N.B2: dotted line indicates the average CV value for SLLJ test (5.65%).
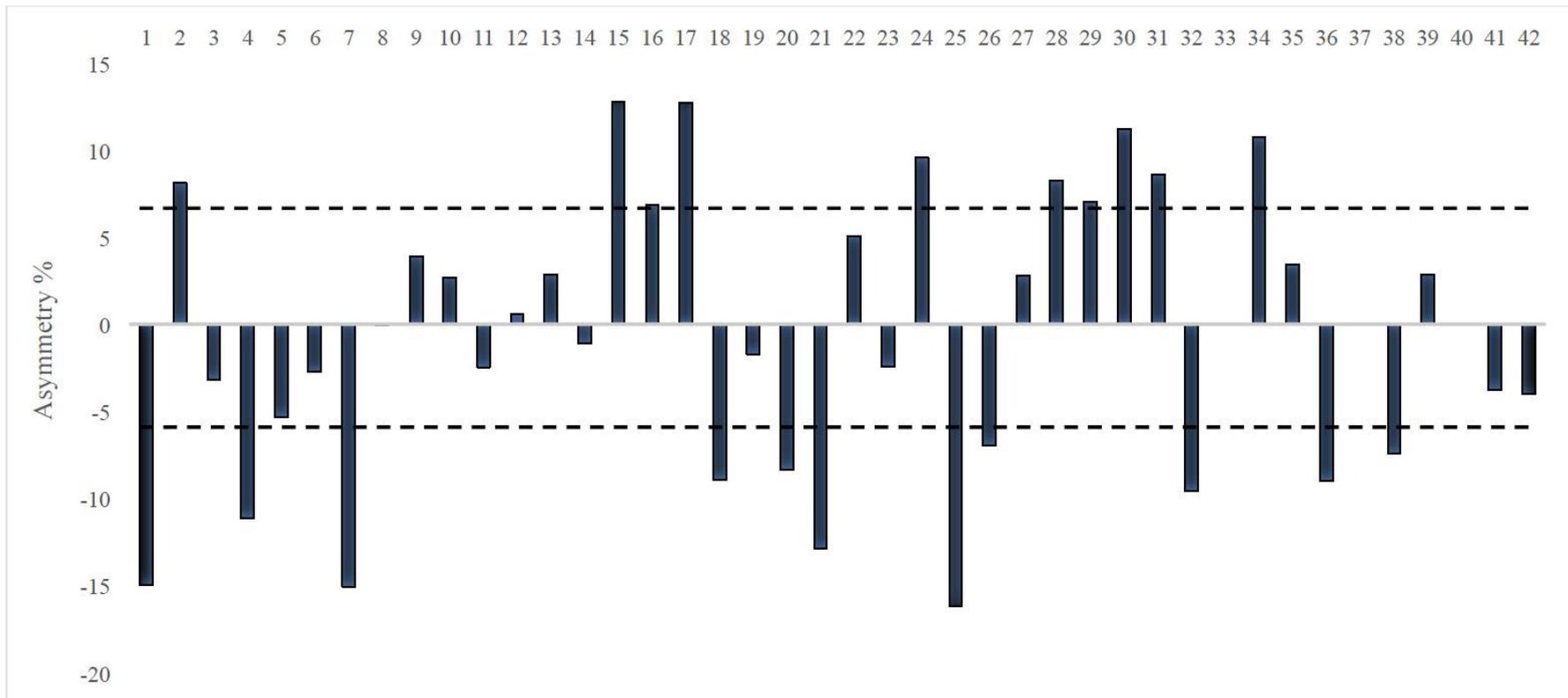
Figure 3. Individual single leg broad jump (SLBJ) asymmetry scores (*n* = 42). N.B1: above 0 indicates that asymmetry is favoured on the right

leg and below 0 indicates asymmetry favours the left leg. N.B2: dotted line indicates the average CV value for SLBJ test (6.28%).