The Association between Inter-limb Asymmetry and Athletic Performance Tasks: A Season Long Study in Elite Academy Soccer Players

Abstract

The aims of the present study were to determine the association between asymmetry and measures of speed and change of direction speed (CODS) performance throughout a competitive soccer season and, determine if any observed changes in asymmetry were associated with changes in speed and CODS performance. Eighteen elite male under-23 academy soccer players performed unilateral countermovement jumps (CMJ), unilateral drop jumps (DJ), 10, 30 m sprints, and 505 CODS tests at pre, mid and end of season. No significant relationships were evident during pre or mid-season between asymmetry and speed or CODS performance. Significant correlations were shown at the end of season between DJ height asymmetry and 10 m sprint time ($\rho = 0.62$; $p = 0.006$) and 505 time on the right limb ($\rho = 0.65$; $p = 0.003$). No significant correlations between changes in asymmetry and changes in speed or CODS were evident at any time point. Although numerous studies have reported associations between asymmetry and reduced athletic performance, it appears that these associations with speed and CODS do not track consistently over time. Thus, suggestions for the reduction of asymmetry which may indirectly enhance athletic performance cannot be made.

Key Words: Between-limb differences; jumping; change of direction speed; speed.

Introduction

Soccer is a high intensity, intermittent team sport that requires the development of multiple athletic qualities including sprinting, jumping and changing direction to optimise physical performance (33). Frequent repetitions of these movements that involve significant musculoskeletal forces and joint loads can result in between-limb asymmetry in functional performance where preferred lower limb dominance may be evident (2,5,7,26). This may be further confounded by heightened volumes of training and match play occurring at different points throughout a competitive soccer season. Thus, testing these physical qualities represent ecologically valid methods of assessment for soccer athletes.

There are a wide range of assessment methods which can be used to measure inter-limb asymmetry. Jump testing in particular, is a simple and time-efficient method commonly used in soccer and also has the advantage of providing information relating to the inter-limb asymmetry profiles. Selecting tests such as the countermovement jump (CMJ), drop jump (DJ) and their associated unilateral versions, enables practitioners to assess different athletic qualities (e.g., slow and fast stretch-shortening cycle characteristics), and determine how inter-limb differences vary between tasks. Whilst measuring asymmetry during sprint tasks is also possible (e.g., between-limb differences in ground reaction forces), this often requires expensive equipment which may not always be conducive to test protocols with elite level players in the field. Further to this, previous research has highlighted a distinct lack of associations between sprint asymmetry and sprint performance (19,29), but significant correlations between jump height asymmetry and reduced sprint and change of direction speed (CODS) in youth (5) and adult (7) soccer athletes. Thus, further reinforcing the use of jump tasks for measuring between-limb differences.

Research investigating the association between asymmetry and athletic performance has shown equivocal findings (2,5,7,13,21,23,24,25,28). For example, Lockie et al. (25) reported no significant correlations between speed or change of direction speed (CODS) tasks and jump height or distance asymmetry in male collegiate athletes. Similarly, Dos'Santos et al. (13) showed no association between single leg and triple hop for distance asymmetry and two CODS tasks. In contrast, Bishop et al. (5) showed moderate correlations (r = 0.49-0.59) between jump height asymmetry from the unilateral CMJ and slower 5, 10 and 20 m sprint performance in youth female soccer players. In addition, Bishop et al. (7) showed moderate relationships (r = 0.52-0.66) between unilateral drop jump (DJ) asymmetries and slower 10, 30 m and 505 CODS performance in adult female soccer players. Thus, given the conflicting findings in the literature to date, further research on the association between asymmetry and athletic performance is warranted.

When interpreting studies investigating the association between jump asymmetry and athletic performance, it should also be noted that all studies have been conducted at a single time point (2,5,7,13,21,23,24,25,28). Previous research has highlighted that longitudinal data pertaining to asymmetry and athletic performance is missing (6). Thus, our understanding of the long-term association between asymmetry and performance measures, is unknown. In addition, changes in jump performance are to be expected during a soccer season (8,9,19), and monitoring jump performance across a competitive soccer season provides opportunities to examine if changes in asymmetry are also associated with changes in athletic performance. These data would assist practitioners by determining if the common practice of measuring asymmetry during jump tests is a valid method to identify relationships with athletic performance tasks.

As such, jump testing serves as a useful method to monitor jump performance and measure inter-limb asymmetry, with longitudinal associations with athletic performance measures also needed to aid our understanding of the importance of asymmetry in team sport athletes. Thus, the aims of the present study were twofold: 1) to determine the association between jump asymmetry and measures of speed and CODS performance at different time points during a competitive soccer season and, 2) to determine if any observed changes in asymmetry were associated with changes in speed and CODS performance. To the authors' knowledge, no longitudinal data relating to asymmetry and performance is available; thus, developing a true hypothesis was challenging. However, it was postulated that significant associations between asymmetry and performance would be present throughout the season, but these may not be consistent at all time points.

Methods

Experimental Approach to the Problem

This study used a repeated measures design employing unilateral jump tests, linear speed and CODS tests during pre (July), mid (January) and end of season (May). When considering the players' weekly schedule, on average, each player undertook 4 on-pitch training sessions (consisting of technical and conditioning based activities such as sprinting and CODS drills), 2 resistance training sessions (focusing on the maintenance of lower body strength and power) and 1 game each weekend. All testing was conducted on two separate days with test sessions at each respective time-point, separated by 48 hours, in an attempt to minimize fatigue impacting any single test. Unilateral CMJ and unilateral DJ tests were performed on day 1, with the 30 m (inclusive of a 0-10 m split) and 505 tests conducted on day 2. All athletes were previously familiarized with testing protocols as these formed part of their regular testing battery.

Subjects

Eighteen elite male under-23 male academy soccer players (age: 19.0 ± 2.2 years; height: 1.80 ± 0.07 m; body mass: 73.3 ± 9.0 kg) from a professional soccer club volunteered to participate in the present study. A minimum of 21 subjects was determined from a priori power analysis using G*Power (Version 3.1, University of Dusseldorf, Germany) implementing statistical power of 0.8 and a type 1 alpha level of 0.05, which has been used in comparable literature (14). All players were contracted to the same club during the 2018-2019 English soccer season and had a minimum of six years' competitive soccer experience and a minimum of two years' structured strength and conditioning training experience. Players were required to be free from injury for at least four weeks prior to each testing session and deemed fit to participate fully in training and competition by the respective clubs' medical departments. This time frame was chosen to limit the impact of any compensatory movement patterns due to previous minor muscle injuries. Further to this, no major injuries (classified as > 28 days) (16) were reported for all players throughout the duration of this study. For subjects over the age of 18, written informed consent was provided and for subjects under 18, written parental consent was obtained in addition to subject ascent. This study was approved by the [*deleted for peer review*] research and ethics committee.

Procedures

All testing was conducted at the same time of day (12:00-14:00) to limit the impact of circadian rhythms (28). A standardized dynamic warm up was performed each time and consisted of a single set of 10 repetitions of multi-planar lunges, inchworms, Spiderman's and bodyweight squats, followed by three practice trials of each respective test. Athletes were asked to perform practice trials at 60, 80 and 100% of their perceived maximal effort, with jump and CODS tests practiced on both limbs. Three minutes of rest was provided between the last practice trial and the start of the first test and 60-seconds of rest was provided between trials during jump tests and 3-minutes between trials for the speed and CODS tests. For jump tests, athletes performed three trials on each leg with the average value taken from all trials on each side, and asymmetry subsequently computed thereafter. Given asymmetry has been shown to be a variable concept (1,3), averaging data was deemed appropriate in order to capture some of the variability that may have existed between trials.

Unilateral Countermovement Jump. Subjects were instructed to step onto the centre of a single uniaxial force platform (size: 0.42 x 0.42 m; PASPORT force plate, PASCO Scientific, California, USA) sampling at 1000 Hz, with their designated test leg. Hands were placed on hips and were required to remain in the same position throughout the duration of the test. Test instructions were the same at each time point with athletes asked to "jump as high as you can". The jump was initiated by performing a countermovement to a self-selected depth before accelerating vertically as fast as possible into the air. The test leg was required to remain fully extended throughout the flight phase of the jump before landing back onto the force plate as per the set up. The non-jumping leg was slightly flexed with the foot hovering at mid-shin level, and no additional swinging of this leg was allowed during trials. Recorded metrics included jump height and concentric impulse, with definitions for their quantification conducted in line with suggestions by Gathercole et al. (17) and Chavda et al. (10). Jump height was defined as the maximum height achieved calculated from velocity at take-off squared divided by 2*9.81 (where 9.81 equals gravitational force). Concentric impulse was defined as the net force (where net force was calculated by subtracting body weight from vertical force) multiplied by the time taken to produce it; i.e., the area under the net force-time curve. The first meaningful change in force was established when values surpassed ± five standard deviations (SD) of each participant's body weight, minus 30 milliseconds (32). The force plate was calibrated prior to each data collection and all force traces were extracted unfiltered, and subsequently copied into a custom-made spreadsheet previously suggested (10).

Unilateral Drop Jump. The unilateral DJ was performed using the OptoJump™ measurement system (Microgate, Bolzano, Italy), sampling at 1000 Hz with all athletes required to step off an 18 cm box. This height was chosen in line with previous research using this test (27,28). With hands fixed on hips, subjects were required to step off the box with their designated test leg which subsequently landed on the hard rubber flooring between the optimal measurement system below. Upon landing, subjects were instructed to "minimize ground contact time and jump as high as possible" thereafter in line with previous suggestions (27,28). Recorded metrics included jump height (calculated from the flight time method) and reactive strength index (RSI), quantified using the equation flight time/ground contact time (28).

30 m sprint test. Dual beam electronic timing gates (Brower Timing Systems, Utah, USA) were positioned at 0, 10 and 30 m, at a height of 1 m, enabling athlete's acceleration and top speed ability to be measured. Athletes started the test in a staggered 2-point stance with toes positioned 30 cm behind the start line so as to not break the beam of the timing gates prior to the initiation of the test. When ready, subjects sprinted through the timing gates as fast as they could allowing time to be recorded to the nearest hundredth of a second. Three trials were performed on a grass soccer pitch with an average of all trials used for further analysis. All players performed sprints and 505 tests in their own football boots.

505 change of direction speed test. A distance of 15 m was measured with electronic timing gates (Brower Timing Systems, Utah, USA) positioned at the 10 m mark and the 15 m point marked out by an existing white line on the pitch, to ensure that players could clearly see the turning point, as they approached. Players sprinted 15 m and then performed a 180° turn off both the right and left legs, with a total of two trials completed on each leg. The time started when players broke the electronic beam at the 10 m mark and after turning 180°, subsequently sprinted back through the timing gates to complete a recorded distance of 10 m. Trials were only deemed successful if the players' foot fully crossed the line during the turn. Both trials were averaged on each limb for subsequent data analysis. The change of direction deficit was also calculated for left and right sides, by subtracting the 10 m linear sprint time from the 505 times. In line with previous suggestions, this provided a better indication of each player's change of direction ability (31).

Statistical Analyses

All data were initially recorded as means and SD in Microsoft Excel and later transferred to SPSS (version 25.0; SPSS, Inc., Armonk, NY, USA). Normality was assessed using the Shapiro-Wilk test and showed asymmetry data to not be normally distributed ($p < 0.05$). All other data was normally distributed. Within-session reliability of test measures was computed at each time point using an average measures two-way random intraclass correlation coefficient (ICC) with absolute agreement and 95% confidence intervals, and the coefficient of variation (CV). Interpretation of ICC values was in accordance with previous research by Koo and Li (22) where values > 0.9 = excellent, 0.75-0.9 = good, 0.5-0.75 = moderate, and < 0.5 = poor. The CV was calculated via the formula: (SD[trials 1–3]/average[trials 1–3]*100) with values ≤ 10% suggested to be considered acceptable (12).

Mean inter-limb asymmetries were computed using a standard percentage difference equation for both jump tests: 100/(max value)*(min value)*-1+100, which has been suggested to be accurate for the quantification of asymmetries from unilateral tests (1,4). Interpretation of individual asymmetry scores was conducted in relation to the CV, noting that an asymmetry has been suggested to be 'real' if greater than the test variability (CV) score (15). Thus, on Figures 1 and 2, subjects with real asymmetries are represented by a square symbol, with circle symbols representing an asymmetry less than the CV value.

Spearman's rank order correlations (ρ) were conducted twice. Firstly, to establish the relationship between inter-limb asymmetries and fitness test scores at each time point and secondly, to establish the relationship between changes in asymmetry (as a percentage) and changes in athletic performance tasks (as raw scores) between time points. Bonferroni corrections were applied to all correlations to account for multiple comparisons and the familywise type I error rate, resulting in statistical significance being set at $p < 0.012$. Correlation values were interpreted in line with suggestions from Hopkins et al. (20) where 0-0.10 = trivial, 0.11-0.30 = small, 0.31-0.50 = moderate, 0.51-0.70 = large, 0.71-0.90 = very large and 0.91-1.0 = nearly perfect. Kappa coefficients were also used to determine levels of agreement between changes in asymmetry and changes in athletic performance (e.g., if asymmetry increased, did players get slower at speed and CODS tasks). Values were interpreted in line with suggestions from Viera and Garrett, (34) 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 = nearly perfect.

A median split analysis was performed at each time point creating high and low asymmetry groups for each jump metric, to determine whether players with larger between-limb differences performed slower during the speed and CODS tasks. Between group differences were examined using Mann-Whitney U tests, with statistical significance set at $p < 0.05$. Cohen's *d* effect sizes (ES: 95% confidence intervals) were also used to determine differences between high and low asymmetry groups. Values were interpreted in line with suggestions by Hopkins et al. (20) where < 0.2 = trivial, 0.2-0.6 = small, 0.6-1.2 = moderate, 1.2-2.0 = large, 2.0-4.0 = very large, and > 4.0 = near perfect. Finally, a repeated measures ANOVA was conducted to test for significant differences between time points for all test scores, with statistical significance set at $p < 0.05$. This was also complemented with the use of Cohen's *d* ES and 95% confidence intervals.

Results

Reliability data are presented for each time point in Table 1. All metrics showed acceptable CV values (< 10%) with the exception of jump height during the unilateral CMJ in pre-season, which showed a slightly elevated value of 10.96%. Relative reliability (ICC) ranged from moderate to excellent for all metrics at each time point.

Descriptive data showing fitness testing data at each time point, with accompanying effect sizes are presented in Table 2. For the unilateral CMJ, significant reductions in jump height and concentric impulse were evident at mid-season ($p < 0.05$; d for pre to mid = -0.57 to -1.08; d for pre to end = 0.67 to 1.52) and for the unilateral DJ, RSI showed improvements throughout the season with statistical significance reached at the end of the season ($p < 0.05$; d for pre to end = 0.69 to 0.86). No significant changes were evident for linear speed tests, with trivial to small changes evident throughout the season (d range = 0.10 to 0.38). Conversely, players displayed faster CODS as the season progressed, with significantly improved performance at the end of the season ($p < 0.05$) corresponding to moderate reductions in total time from pre to end of season (d range = -0.81 to -1.08) and mid to end of season (d range = -0.63 to -0.73). For the change of direction deficit, players showed a trend of reduced deficits as the season progressed with statistically significant changes observed at the end of the season ($p < 0.05$) compared to pre-season on the right (d = -0.92) and left (d = -1.00) sides, and compared to mid-season on the left side only (d = -0.69).

***** Insert Tables 1 and 2 about here *****

No significant relationships were present between asymmetry measured during jump tests and any of the athletic performance tasks at pre or mid-season testing (ρ = -0.32 to 0.37). However, at the end of season, significant large relationships were found between DJ height asymmetry and 10 m sprint (ρ = 0.62; p = 0.006) and 505 time on the right limb (ρ = 0.65; p = 0.003).

Longitudinal analysis did not identify any significant relationships between changes in jump asymmetry and changes in athletic performance tasks (ρ = -0.44 to 0.56). Supporting this, Kappa coefficients showed varying levels of agreement between changes in asymmetry and changes in performance tasks across the season (Table 3). For unilateral CMJ metrics, values ranged from poor to substantial (Kappa = -0.44 to 0.64), and the unilateral DJ ranged from poor to moderate (Kappa = -0.33 to 0.44).

***** Insert Table 3 about here *****

Tables 4-6 show performance scores of high and low asymmetry groups for pre, mid and end-season respectively. Significant differences in asymmetry were found between groups for all jump metrics ($p < 0.01$) at each time-point. At the end-season, DJ height asymmetry was significantly associated with slower 10 m ($p < 0.05$; $d = -1.15$), 505 left ($p < 0.05$; $d = -0.96$) and 505 right ($p < 0.01$; $d = -1.40$) performance. No other significant differences in speed or CODS were present between groups. Finally, mean and individual inter-limb asymmetry values are presented in Figure 1 (unilateral CMJ) and Figure 2 (unilateral DJ). Mean asymmetry values were relatively consistent for both jump tests; however, large within-group variability was present for all metrics.

***** Insert Tables 4-6 and Figures 1 and 2 about here *****

Discussion

The aims of the present study were twofold: 1) to determine the association between jump asymmetry and measures of speed and CODS performance at different time points during a competitive soccer season and, 2) to determine if any observed changes in asymmetry were associated with changes in speed and CODS performance. Results showed no significant correlations between jump asymmetry and the aforementioned measures of athletic performance during pre or mid-season. However, significant correlations were evident between DJ height asymmetry and 10 m sprint (ρ = 0.62; p = 0.006) and 505 time on the right limb (ρ = 0.65; p = 0.003), at the end-season time point. No significant correlations were present between changes in jump asymmetry and changes in any athletic performance measure. In addition, Kappa coefficients ranged from poor to substantial in their levels of agreement across the different test metrics, with no consistent pattern observed between respective time points measured during the season. When using the median split analysis, the low asymmetry group (when split using DJ height asymmetry) were significantly faster during the 10 m sprint and 505 on both limbs.

Significant large associations were evident in the current study between unilateral DJ height asymmetry and 10 m sprint (ρ = 0.62; p < 0.01) and 505 right time (ρ = 0.65; p < 0.01) at the end of season only, indicating that larger jump height asymmetries are associated with slower acceleration and CODS performance. This is supported in part by existing comparable research which has shown that larger DJ height asymmetries are associated with reduced speed and CODS performance (7,28). In addition, it is possible that previous studies investigating the association between asymmetry and athletic performance have been influenced by the time of year they undertook testing. Given the inconsistency in significant correlations found across time points in the present study, this seems like a plausible suggestion. Where the present study improves on the existing literature base, is by reporting these associations at multiple time points over the course of a competitive season. Whilst fully explaining why these relationships are not consistent at each time point is challenging, the variable nature of asymmetry is likely to be a significant factor, given this has been commonly reported in recent literature on the topic (1,2,3,25,27). This is supported by viewing Tables 4-6, which show the SD is often quite large relative to the mean for the asymmetry scores, in both the high and low asymmetry groups. Furthermore, Figures 1 and 2 show that the individual asymmetry scores are also highly variable, regardless of test, metric or time point throughout the season.

A key strength of the current study is the inclusion of repeated measurements throughout the season to examine how changes in jump asymmetry are associated with changes in athletic performance tasks. Results showed no significant relationships were present, and these data are further supported by the Kappa coefficients which indicated varying and inconsistent levels of agreement between changes in jump asymmetry and changes in performance tests (Table 2). In addition, only concentric impulse showed substantial agreement (Kappa = 0.64) between changes in asymmetry and changes in 505 on the right limb, but this was only in the first half of the season. Cumulatively, these data further support the notion that changes in jump asymmetry are largely unrelated to changes in athletic performance tasks, and may well be a natural and possibly transient consequence of competing regularly in a single sport throughout a competitive season (18). In addition, it is now well established that between-limb differences are highly task-specific (2,3,5,14,25,30). Our results further support this notion, and also indicate that to more fully examine the effects of asymmetry on athletic performance, between-limb differences may need to be measured during the performance task itself (i.e., sprinting).

To further examine if players with greater jump asymmetry displayed lower performances during athletic performance tasks, the present study also used a median split analysis, splitting the sample into high and low asymmetry groups. At the end of the season, the low asymmetry group for unilateral DJ height were significantly faster in 10 m linear sprint and 505 on both limbs. However, no other between-group differences were observed for any other metrics or at other time-points during the season. Further to this, even when moderate effects were observed between groups (e.g., at mid-season for 30 m times, when splitting via unilateral CMJ height asymmetry; ES = -0.77), the confidence intervals show that the range of differences could be anything from large reductions to trivial increases (-1.73 to 0.19). This provides further support that asymmetry and athletic performance measures are most likely independent of each other, and observed scores should be interpreted on an individual basis (1,2,3).

It is important that some limitations are acknowledged in the present study. Firstly, although the present study collected data at three time points, it is plausible that more frequent testing is required to fully elucidate the interaction between asymmetry and measures of athletic performance. The variable nature of asymmetry is well-documented (1,3,14,25,27); thus, more regular testing may provide a clearer picture of the interaction between asymmetry and athletic performance. Secondly, training load data was not collected as part of the current investigation; thus, explaining the changing nature of asymmetry and performance scores is hard to do. Future research should aim to establish the association between jump asymmetry and training or competition load data, in order to better understand the interaction between asymmetry and in-game soccer demands. In addition, practitioners should also consider the efficacy of their training interventions in relation to changes in asymmetry over time. This would provide meaningful information as to the effectiveness of S&C training, if the intention was to minimize existing inter-limb differences. Finally, it is worth noting that this study was slightly under-powered, by virtue of having 18 subjects present for testing across all time points. However, individual asymmetry data has been provided (which is a strength of the present study) and highlights the varying nature of asymmetry regardless of the time of year and is in line with recent suggestions for this topic (1,2,3).

Practical Applications

The present study showed that although significant and sometimes large associations were shown between jumping asymmetries and speed and CODS performance tasks, this only occurred at individual time points, and these relationships are not consistent over time. When measured longitudinally, asymmetry measured via jump tests, appears to be largely independent from running based measures of athletic performance (sprints, CODS), likely due to the large variability and inconsistency in agreement between test sessions. Put simply, the data from the current study indicate that, if jumping asymmetry increases during a pre-defined period, it does not dictate that sprint and CODS will be negatively affected. Therefore, the practice of measuring asymmetry during jump testing (used as surrogate measures of physical capacity) for the purposes of monitoring performance during speed and CODS cannot be recommended. Furthermore, given the longitudinal findings in the present study, it is hard to suggest that jump asymmetry measured using commonly applied metrics should be reduced through the use of targeted training programs in the hope that it may indirectly enhance speed or CODS performance. Therefore, it is suggested that if practitioners wish to monitor jumping asymmetries longitudinally, this should be considered only in the context of measuring changes in jump performance. Alterations in asymmetry throughout a soccer season could be a result of reductions in jump performance of the dominant or stronger limb, especially during times of fixture congestion.

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Table 1. Within-session reliability data for test measures at pre, mid and end of season time points.

Test/Metric	Pre-season		Mid-season		End-season	
	CV (%)	*ICC (95% CI)*	*CV (%)*	*ICC (95% CI)*	*CV (%)*	*ICC (95% CI)*
UCMJ:						
Jump height-L (m)	9.28	0.94 (0.88-0.98)	5.34	0.97 (0.94-0.99)	7.90	0.93 (0.85-0.97)
Jump height-R (m)	10.96	0.86 (0.68-0.94)	4.27	0.97 (0.93-0.99)	9.63	0.80 (0.57-0.92)
CON impulse-L (N·s)	7.48	0.95 (0.90-0.98)	4.22	0.97 (0.94-0.99)	6.55	0.88 (0.73-0.95)
CON impulse-R (N·s)	9.24	0.92 (0.82-0.97)	4.78	0.94 (0.87-0.98)	7.82	0.75 (0.49-0.90)
UDJ:						
Jump height-L (m)	5.32	0.96 (0.92-0.99)	5.70	0.98 (0.96-0.99)	6.38	0.97 (0.94-0.99)
Jump height-R (m)	6.05	0.97 (0.93-0.99)	6.00	0.96 (0.92-0.99)	7.30	0.93 (0.84-0.97)
RSI-L	6.43	0.95 (0.88-0.98)	5.12	0.97 (0.93-0.99)	4.95	0.96 (0.92-0.99)
RSI-R	6.55	0.97 (0.92-0.99)	6.62	0.95 (0.90-0.98)	6.38	0.88 (0.74-0.95)
Linear Speed:						
10m (s)	3.50	0.79 (0.51-0.92)	3.88	0.63 (0.18-0.85)	3.68	0.87 (0.71-0.95)
30m (s)	1.80	0.89 (0.70-0.96)	1.72	0.93 (0.84-0.97)	2.31	0.94 (0.87-0.98)
CODS:						
505-L (s)	1.52	0.94 (0.82-0.98)	1.05	0.97 (0.91-0.99)	1.80	0.81 (0.50-0.93)
505-R (s)	1.07	0.97 (0.93-0.99)	0.93	0.98 (0.94-0.99)	1.80	0.88 (0.69-0.96)

CV = coefficient of variation; ICC = intraclass correlation coefficient; CI = confidence intervals; UCMJ = unilateral countermovement jump; L = left; R = right; m = metres; CON = concentric; N·s = Newton seconds; UDJ = unilateral drop jump; RSI = reactive strength index; s = seconds; CODS = change of direction speed.

Table 2. Mean test scores ± standard deviations (SD) for pre, mid and end of season, and Cohen's *d* effect sizes (95% confidence intervals).

Fitness Test	Mean ± SD *(Pre-season)*	Mean ± SD *(Mid-season)*	Mean ± SD *(End-season)*	Effect Size *(Pre-Mid)*	Effect Size *(Pre-End)*	Effect Size *(Mid-End)*
UCMJ:						
Jump height-L (m)	0.17 ± 0.04	0.15 ± 0.03[a,c]	0.17 ± 0.03	-0.57 (-1.23 to 0.10)	0.00 (-0.65 to 0.65)	0.67 (0.00 to 1.34)
Jump height-R (m)	0.17 ± 0.03	0.15 ± 0.02[b,c]	0.17 ± 0.02	-0.78 (-1.46 to -0.11)	0.00 (-0.65 to 0.65)	1.00 (0.31 to 1.69)
CON impulse-L (N·s)	118.8 ± 27.2	101.6 ± 17.1[b,d]	124.0 ± 14.8	-0.76 (-1.43 to -0.08)	0.24 (-0.42 to 0.89)	1.40 (0.67 to 2.13)
CON impulse-R (N·s)	121.6 ± 23.4	100.4 ± 14.7[b,d]	121.4 ± 12.8	-1.08 (-1.78 to -0.39)	-0.01 (-0.66 to 0.64)	1.52 (0.78 to 2.27)
UDJ:						
Jump height-L (cm)	21.0 ± 4.0	20.5 ± 5.0	21.5 ± 5.3	-0.11 (-0.76 to 0.54)	0.11 (-0.55 to 0.76)	0.19 (-0.46 to 0.85)
Jump height-R (cm)	21.0 ± 4.4	20.6 ± 4.3	21.4 ± 3.8	-0.09 (-0.75 to 0.56)	0.10 (-0.56 to 0.75)	0.20 (-0.46 to 0.85)
RSI-L	1.28 ± 0.23	1.37 ± 0.23	1.49 ± 0.26[b,e]	0.39 (-0.27 to 1.05)	0.86 (0.17 to 1.54)	0.49 (-0.17 to 1.15)
RSI-R	1.29 ± 0.28	1.36 ± 0.26	1.45 ± 0.17[b]	0.26 (-0.40 to 0.92)	0.69 (0.02 to 1.36)	0.41 (-0.25 to 1.07)
Linear Speed:						
10m (s)	1.76 ± 0.09	1.77 ± 0.08	1.78 ± 0.12	0.12 (-0.54 to 0.77)	0.19 (-0.47 to 0.84)	0.10 (-0.56 to 0.75)
30m (s)	4.15 ± 0.15	4.17 ± 0.17	4.23 ± 0.26	0.12 (-0.53 to 0.78)	0.38 (-0.28 to 1.04)	0.27 (-0.38 to 0.93)
CODS:						
505-L (s)	2.34 ± 0.12	2.30 ± 0.11	2.23 ± 0.08[b,e]	-0.35 (-1.01 to 0.31)	-1.08 (-1.78 to -0.38)	-0.73 (-1.40 to -0.05)
505-R (s)	2.32 ± 0.12	2.30 ± 0.12	2.23 ± 0.10[b]	-0.17 (-0.82 to 0.49)	-0.81 (-1.49 to -0.13)	-0.63 (-1.30 to 0.04)
CODD-L (s)	0.57 ± 0.12	0.53 ± 0.12	0.45 ± 0.14[b]	-0.33 (-0.99 to 0.32)	-0.92 (-1.61 to -0.23)	-0.61 (-1.28 to 0.05)
CODD-R (s)	0.56 ± 0.11	0.53 ± 0.12	0.45 ± 0.11[b,e]	-0.26 (-0.92 to 0.40)	-1.00 (-1.69 to -0.31)	-0.69 (-1.37 to -0.02)

[a] = significantly different from pre-season ($p < 0.05$); [b] = significantly different from pre-season ($p < 0.01$); [c] = significantly different from end-season ($p < 0.05$); [d] = significantly different from end-season ($p < 0.01$); [e] = significantly different from mid-season ($p < 0.05$).

UCMJ = unilateral countermovement jump; L = left; R = right; m = metres; N·s = Newton seconds; UDJ = unilateral drop jump; RSI = reactive strength index; s = seconds; CODS = change of direction speed; CODD = change of direction deficit.

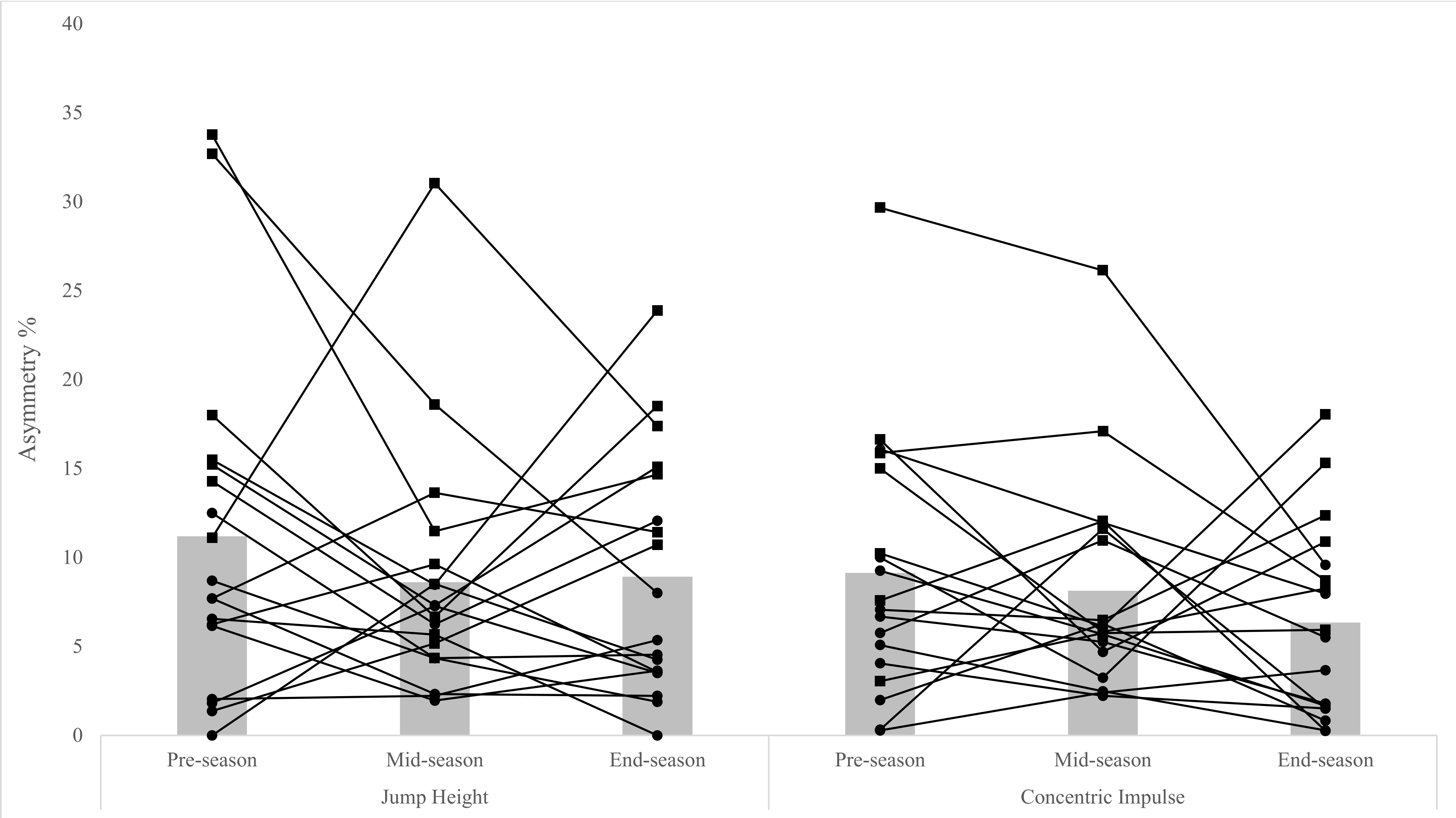

Figure 1. Mean and individual inter-limb asymmetry values for unilateral countermovement jump metrics at pre, mid and end of season.

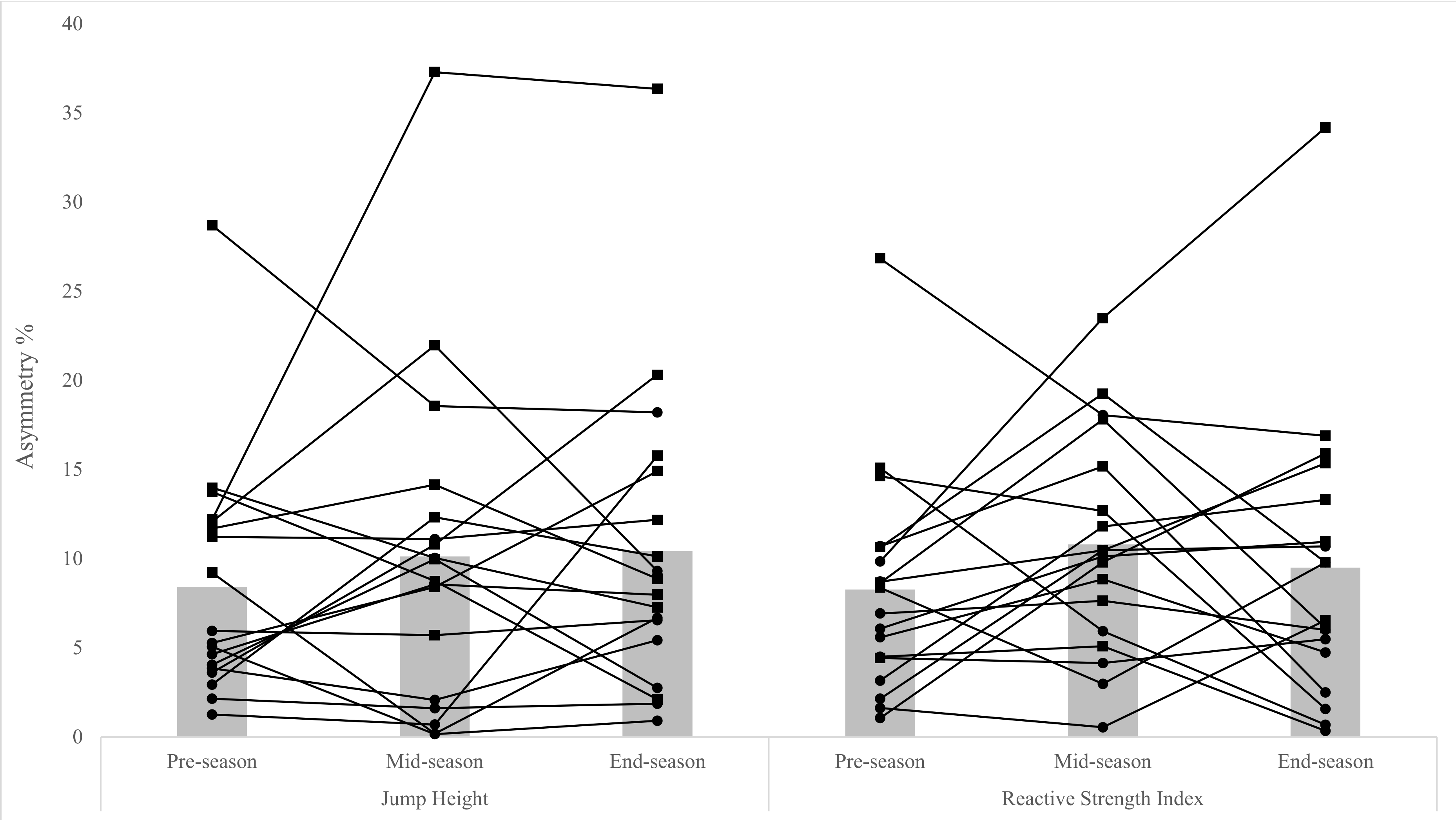

Figure 2. Mean and individual inter-limb asymmetry values for unilateral drop jump metrics at pre, mid and end of season.

Table 3. Kappa coefficients and descriptive levels of agreement for the changes in asymmetry during both jump tests and changes in performance between time points.

Asymmetry Metric	10m	30m	505-L	505-R	CODD-L	CODD-R
UCMJ Jump Height:						
Pre-Mid	0.36 (Fair)	0.07 (Slight)	0.16 (Slight)	0.40 (Fair)	0.11 (Slight)	0.16 (Slight)
Pre-End	0.12 (Slight)	0.46 (Moderate)	0.16 (Slight)	0.30 (Fair)	-0.16 (Poor)	0.30 (Fair)
Mid-End	0.56 (Moderate)	0.33 (Fair)	-0.44 (Poor)	-0.56 (Poor)	-0.44 (Poor)	-0.56 (Poor)
UCMJ CON Impulse:						
Pre-Mid	0.36 (Fair)	-0.14 (Poor)	0.26 (Fair)	0.64 (Substantial)	0.11 (Slight)	0.40 (Fair)
Pre-End	-0.07 (Poor)	0.07 (Slight)	0.28 (Fair)	-0.01 (Poor)	0.25 (Fair)	-0.01 (Poor)
Mid-End	-0.40 (Poor)	-0.11 (Poor)	-0.39 (Poor)	-0.17 (Poor)	-0.03 (Poor)	-0.17 (Poor)
UDJ Jump Height:						
Pre-Mid	-0.19 (Poor)	-0.07 (Poor)	-0.06 (Poor)	-0.16 (Poor)	0.29 (Fair)	-0.16 (Poor)
Pre-End	0.44 (Moderate)	0.33 (Fair)	-0.33 (Poor)	-0.22 (Poor)	-0.67 (Poor)	-0.22 (Poor)
Mid-End	0.11 (Slight)	0.11 (Slight)	0.00 (Poor)	0.33 (Fair)	0.00 (Poor)	0.11 (Slight)
UDJ RSI:						
Pre-Mid	0.16 (Slight)	0.25 (Fair)	0.13 (Slight)	0.00 (Poor)	0.07 (Slight)	0.00 (Poor)
Pre-End	-0.33 (Poor)	-0.33 (Poor)	-0.33 (Poor)	0.00 (Poor)	0.00 (Poor)	0.00 (Poor)
Mid-End	-0.11 (Poor)	-0.33 (Poor)	0.22 (Fair)	0.33 (Fair)	0.00 (Poor)	0.11 (Slight)

L = left; R = right; UCMJ = unilateral countermovement jump; CON = concentric; UDJ = unilateral drop jump; RSI = reactive strength index; CODD = change of direction deficit.

Table 4. Mean inter-limb asymmetry, performance test scores ± standard deviations and Cohen's *d* effect sizes (95% confidence intervals) between high and low asymmetry groups ($n = 9$ per group) during pre-season.

Jump Test/Metric	Asymmetry (%)	10m (s)	30m (s)	505-L (s)	505-R (s)	CODD-L (s)	CODD-R (s)
UCMJ Jump Height:							
High asymmetry	17.97 ± 9.06	1.79 ± 0.10	4.19 ± 0.07	2.33 ± 0.10	2.33 ± 0.12	0.53 ± 0.13	0.54 ± 0.12
Low asymmetry	4.40 ± 3.03**	1.74 ± 0.08	4.12 ± 0.12	2.34 ± 0.14	2.32 ± 0.13	0.61 ± 0.11	0.59 ± 0.10
Effect size (*d*)	-2.01 (-3.14 to -0.88)	-0.55 (-1.49 to 0.39)	-0.48 (-1.41 to 0.46)	0.08 (-0.84 to 1.01)	-0.08 (-1.00 to 0.84)	0.66 (-0.28 to 1.61)	0.45 (-0.48 to 1.39)
UCMJ CON Impulse:							
High asymmetry	14.48 ± 6.64	1.78 ± 0.11	4.18 ± 0.18	2.34 ± 0.10	2.31 ± 0.09	0.55 ± 0.14	0.53 ± 0.10
Low asymmetry	3.81 ± 2.57**	1.75 ± 0.07	4.12 ± 0.11	2.34 ± 0.14	2.34 ± 0.15	0.59 ± 0.11	0.59 ± 0.12
Effect size (*d*)	-2.12 (-3.27 to -0.96)	-0.33 (-1.26 to 0.60)	-0.40 (-1.34 to 0.53)	0.00 (-0.92 to 0.92)	0.24 (-0.68 to 1.17)	0.32 (-0.61 to 1.25)	0.54 (-0.40 to 1.48)
UDJ Jump Height:							
High asymmetry	13.20 ± 6.31	1.79 ± 0.10	4.17 ± 0.16	2.34 ± 0.12	2.35 ± 0.11	0.55 ± 0.14	0.56 ± 0.13
Low asymmetry	3.65 ± 1.34**	1.74 ± 0.08	4.13 ± 0.14	2.33 ± 0.12	2.31 ± 0.13	0.59 ± 0.11	0.57 ± 0.10
Effect size (*d*)	-2.09 (-3.24 to -0.94)	-0.55 (-1.49 to 0.39)	-0.27 (-1.19 to 0.66)	-0.08 (-1.01 to 0.84)	-0.33 (-1.26 to 0.60)	0.32 (-0.61 to 1.25)	0.09 (-0.84 to 1.01)
UDJ RSI:							
High asymmetry	12.60 ± 5.88	1.77 ± 0.12	4.15 ± 0.19	2.33 ± 0.12	2.32 ± 0.13	0.56 ± 0.14	0.55 ± 0.12
Low asymmetry	3.94 ± 2.07**	1.76 ± 0.07	4.16 ± 0.11	2.34 ± 0.12	2.34 ± 0.12	0.58 ± 0.12	0.58 ± 0.10
Effect size (*d*)	-1.96 (-3.09 to -0.84)	-0.10 (-1.03 to 0.82)	0.06 (-0.86 to 0.99)	0.08 (-0.84 to 1.01)	0.16 (-0.77 to 1.09)	0.15 (-0.77 to 1.08)	0.27 (-0.66 to 1.20)

** significantly different between groups ($p < 0.01$).

L = left; R = right; UCMJ = unilateral countermovement jump; CON = concentric; UDJ = unilateral drop jump; RSI = reactive strength index; s = seconds; CODD = change of direction deficit.

Table 5. Mean inter-limb asymmetry, performance test scores ± standard deviations and Cohen's *d* effect sizes (95% confidence intervals) between high and low asymmetry groups (n = 9 per group) during mid-season.

Jump Test/Metric	Asymmetry (%)	10m (s)	30m (s)	505-L (s)	505-R (s)	CODD-L (s)	CODD-R (s)
UCMJ Jump Height:							
High asymmetry	12.88 ± 7.72	1.78 ± 0.11	4.24 ± 0.20	2.29 ± 0.10	2.28 ± 0.09	0.51 ± 0.12	0.50 ± 0.10
Low asymmetry	4.33 ± 1.79**	1.76 ± 0.05	4.11 ± 0.13	2.32 ± 0.13	2.33 ± 0.15	0.56 ± 0.12	0.57 ± 0.14
Effect size (*d*)	-1.53 (-2.58 to -0.48)	-0.23 (-1.16 to 0.69)	-0.77 (-1.73 to 0.19)	0.26 (-0.67 to 1.19)	0.40 (-0.53 to 1.34)	0.42 (-0.52 to 1.35)	0.58 (-0.37 to 1.52)
UCMJ CON Impulse:							
High asymmetry	12.08 ± 6.37	1.77 ± 0.11	4.21 ± 0.18	2.31 ± 0.10	2.32 ± 0.12	0.53 ± 0.13	0.55 ± 0.13
Low asymmetry	4.17 ± 1.56**	1.76 ± 0.04	4.14 ± 0.17	2.30 ± 0.13	2.29 ± 0.13	0.54 ± 0.12	0.53 ± 0.12
Effect size (*d*)	-1.71 (-2.78 to -0.63)	-0.12 (-1.05 to 0.80)	-0.40 (-1.33 to 0.53)	-0.09 (-1.01 to 0.84)	-0.24 (-1.17 to 0.69)	0.08 (-0.84 to 1.00)	-0.16 (-1.09 to 0.77)
UDJ Jump Height:							
High asymmetry	16.24 ± 8.91	1.78 ± 0.10	4.17 ± 0.23	2.32 ± 0.08	2.32 ± 0.11	0.54 ± 0.12	0.54 ± 0.11
Low asymmetry	4.02 ± 3.80**	1.76 ± 0.06	4.18 ± 0.10	2.28 ± 0.14	2.28 ± 0.13	0.53 ± 0.13	0.53 ± 0.14
Effect size (*d*)	-1.78 (-2.88 to -0.69)	-0.24 (-1.17 to 0.68)	0.06 (-0.87 to 0.98)	-0.35 (-1.28 to 0.58)	-0.33 (-1.26 to 0.60)	-0.08 (-1.00 to 0.84)	-0.08 (-1.00 to 0.84)
UDJ RSI:							
High asymmetry	15.47 ± 4.50	1.77 ± 0.10	4.19 ± 0.24	2.30 ± 0.10	2.29 ± 0.09	0.53 ± 0.11	0.53 ± 0.09
Low asymmetry	6.12 ± 3.27**	1.77 ± 0.05	4.16 ± 0.08	2.30 ± 0.13	2.31 ± 0.15	0.54 ± 0.13	0.55 ± 0.16
Effect size (*d*)	-2.38 (-3.58 to -1.17)	0.00 (-0.92 to 0.92)	-0.17 (-1.09 to 0.76)	0.00 (-0.92 to 0.92)	0.16 (-0.76 to 1.09)	0.08 (-0.84 to 1.01)	0.15 (-0.77 to 1.08)

** significantly different between groups ($p < 0.01$).

L = left; R = right; UCMJ = unilateral countermovement jump; CON = concentric; UDJ = unilateral drop jump; RSI = reactive strength index; s = seconds; CODD = change of direction deficit.

Table 6. Mean inter-limb asymmetry, performance test scores ± standard deviations and Cohen's *d* effect sizes (95% confidence intervals) between high and low asymmetry groups (n = 9 per group) during end-season.

Jump Test/Metric	Asymmetry (%)	10m (s)	30m (s)	505-L (s)	505-R (s)	CODD-L (s)	CODD-R (s)
UCMJ Jump Height:							
High asymmetry	14.64 ± 4.80	1.80 ± 0.12	4.24 ± 0.22	2.25 ± 0.09	2.23 ± 0.11	0.45 ± 0.14	0.43 ± 0.11
Low asymmetry	3.22 ± 1.62**	1.76 ± 0.12	4.21 ± 0.30	2.21 ± 0.07	2.24 ± 0.10	0.45 ± 0.15	0.48 ± 0.11
Effect size (*d*)	-3.19 (-4.58 to -1.80)	-0.33 (-1.26 to 0.60)	-0.11 (-1.04 to 0.81)	-0.50 (-1.43 to 0.44)	0.10 (-0.83 to 1.02)	0.00 (-0.92 to 0.92)	0.45 (-0.48 to 1.39)
UCMJ CON Impulse:							
High asymmetry	10.79 ± 3.86	1.78 ± 0.11	4.23 ± 0.22	2.23 ± 0.10	2.23 ± 0.11	0.45 ± 0.14	0.44 ± 0.10
Low asymmetry	1.89 ± 1.70**	1.77 ± 0.13	4.22 ± 0.30	2.23 ± 0.06	2.25 ± 0.10	0.45 ± 0.15	0.47 ± 0.12
Effect size (*d*)	-2.98 (-4.33 to -1.64)	-0.08 (-1.01 to 0.84)	-0.04 (-0.96 to 0.89)	0.00 (-0.92 to 0.92)	0.19 (-0.74 to 1.12)	0.00 (-0.92 to 0.92)	0.27 (-0.66 to 1.20)
UDJ Jump Height:							
High asymmetry	16.22 ± 8.54	1.84 ± 0.13	4.27 ± 0.26	2.26 ± 0.05	2.30 ± 0.11	0.42 ± 0.16	0.46 ± 0.15
Low asymmetry	4.61 ± 2.70**	1.72 ± 0.07*	4.18 ± 0.26	2.19 ± 0.09*	2.18 ± 0.05**	0.48 ± 0.12	0.46 ± 0.07
Effect size (*d*)	-1.83 (-2.93 to -0.73)	-1.15 (-2.15 to -0.15)	-0.35 (-1.28 to 0.58)	-0.96 (-1.94 to 0.01)	-1.40 (-2.44 to -0.37)	0.42 (-0.51 to 1.36)	0.00 (-0.92 to 0.92)
UDJ RSI:							
High asymmetry	15.20 ± 7.62	1.77 ± 0.12	4.20 ± 0.24	2.23 ± 0.09	2.24 ± 0.12	0.46 ± 0.12	0.47 ± 0.13
Low asymmetry	3.77 ± 2.49**	1.79 ± 0.13	4.25 ± 0.29	2.22 ± 0.07	2.23 ± 0.10	0.44 ± 0.16	0.45 ± 0.10
Effect size (*d*)	-2.02 (-3.15 to -0.88)	0.16 (-0.77 to 1.09)	0.19 (-0.74 to 1.11)	-0.12 (-1.05 to 0.80)	-0.09 (-1.01 to 0.83)	-0.14 (-1.07 to 0.78)	-0.17 (-1.10 to 0.75)

** significantly different between groups ($p < 0.01$); * significantly different between groups ($p < 0.05$).

L = left; R = right; UCMJ = unilateral countermovement jump; CON = concentric; UDJ = unilateral drop jump; RSI = reactive strength index; s = seconds; CODD = change of direction deficit.