Seasonal Variation of Inter-limb Jumping Asymmetries in Youth Team-sport Athletes

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Abstract

The main objective of the present study was to provide seasonal variation data for inter-limb asymmetry in youth elite team-sport athletes. Fifty-nine players performed the single leg countermovement jump (SLCMJ) and the one leg hop for distance (OLHT) tests during pre-season, mid-season and end-season. A repeated-measures analysis of variance was conducted to determine magnitude differences in asymmetry scores between time points. Kappa coefficients (κ) were calculated to determine the levels of agreement for the direction of asymmetry. When comparing inter-limb asymmetry magnitudes across the season, the SLCMJ test showed significantly higher asymmetries at mid-season in comparison with pre-season and end-season (p<0.01, d=-1.03 for pre to mid; p<0.01, d=1.12 for pre to end). However, OLHT inter-limb asymmetry magnitude remained consistent throughout the season (ES range=-0.02 to -0.06). For the direction of asymmetry, levels of agreement ranged from poor to slight in the SLCMJ (k=-0.10 to 0.18) and in the OLHT (k=-0.21 to 0.18). No significant differences were found between mean asymmetry values at any time point or for either test when comparing males and females. In conclusion, jump height asymmetry during the SLCMJ was the only metric to show significant magnitude changes across the season.

Key words: Imbalances; between-limb differences; jumping; youth; longitudinal tracking.

Introduction

In recent years, inter-limb asymmetries defined as the difference in performance or function between limbs (Bishop, Read, Lake, et al., 2018; Keeley et al., 2011) has been a popular research topic. Given the rising interest in this area, an abundance of studies have reported the prevalence of between limb differences across a range of physical abilities such as strength (Dos'Santos, Thomas, Jones, et al., 2017; Sato & Heise, 2012), power (Bishop, Read, McCubbine, et al., 2018; Lockie et al., 2014), speed (Exell et al., 2017; Haugen et al., 2018) and change of direction (COD) speed (Bishop, Turner, Maloney, et al., 2019). Inter-limb asymmetries have also been frequently reported in team sports such as soccer (Bishop, Read, McCubbine, et al., 2018; Bishop, Turner, Maloney, et al., 2019; Bishop, Brashill, Abbott, et al., 2019; Rago et al., 2020), rugby (Marshall et al., 2015), netball (Dos'Santos et al., 2019) handball (Madruga-Parera et al., 2019, 2020), basketball (Fort-Vanmeerhaeghe et al., 2015, 2016) or rink hockey (Arboix-Alió et al., 2018, 2020). These sports are characterized by high-intensity unilateral actions such as sprinting, jumping and CODs which often occur during the most decisive moments in competition (e.g., contests for the ball, scoring opportunities or offensive and defensive actions) (Faude et al., 2012; Loturco et al., 2019). Consequently, the prevalence of these high-intensity unilateral actions are likely to result in the development of inter-limb asymmetries (Maloney et al., 2017). Some of the most used tests to detect inter-limb asymmetries in team sports are the single leg countermovement jump (SLCMJ), the one leg hop test for distance or the 180º change of direction tests (Virgile & Bishop, 2021).

The assessment of inter-limb asymmetries has been used mainly in the field of rehabilitation, but also in injury prevention where despite being a controversial topic (Bishop, Turner, & Read, 2018), previous research has suggested a 10-15% threshold of inter-limb asymmetry in strength and power to be considered as 'normal physiological variability' in team sports (Fort-Vanmeerhaeghe et al., 2015, 2016; Hewit et al., 2012). Recently however, studies investigating the relationship between inter-limb asymmetries and physical performance in healthy athletes has increased among the scientific community. Some evidence shows that inter-limb asymmetries result in decreased jump height (Bishop, Read, McCubbine, et al., 2018; Fort-Vanmeerhaeghe, Bishop, et al., 2020) or COD speed times (Bishop, Read, Brazier, et al., 2019; Bishop, Brashill, Abbott, et al., 2019; Maloney et al., 2017), and are associated with decreased sprinting speed (Fort-Vanmeerhaeghe, Bishop, et al., 2020). In contrast, other studies have shown no relationship between lower-limb asymmetries and physical performance (Dos'Santos, Thomas, A. Jones, et al., 2017; Lockie et al., 2014).

A common theme in the aforementioned literature, is that they only report the magnitude of asymmetry at a single time point, while longitudinal tracking of inter-limb differences throughout a competitive season in both magnitude and direction have been more scarce. To the authors' knowledge, there are only three studies that have reported seasonal variation of asymmetry in healthy athlete populations. Firstly, Pichardo et al. (2019) investigated the effects of resistance training compared to combined resistance and weightlifting training on motor tasks in youth males aged 12-14 from a secondary school. Both interventions lasted for 28 weeks, with testing performed at pre, mid (14-weeks) and post (28-weeks) interventions. Significant changes were reported in asymmetry for single leg broad jump, isometric mid-thigh pull and the Y-balance test. Moreover, no significant changes in asymmetry were found in the resistance training group. However, when weightlifting training was combined, significant reductions in asymmetry were evident in peak force during the mid-thigh pull test.

Similarly, Bishop et al. (2020), analyzed seasonal variation data for the magnitude and direction (indication as to which is the highest performing limb, right or left) of asymmetry in elite male academy soccer players (under-23) during pre, mid and end of season time points. While the magnitude of asymmetry showed only trivial to small changes throughout the season (ES range = -0.43 to 0.05), Kappa coefficients showed poor to substantial levels of agreement

(Kappa range = 0.06 to 0.77) for the direction of asymmetry indicating that asymmetries often 'switched sides' throughout the competitive season. In addition, Bishop et al. (2020) investigated the seasonal variation of inter-limb asymmetries in professional cricket players. The magnitude of asymmetry only showed significant changes in the unilateral CMJ test for jump height (ES = 0.72). When considering the direction of asymmetry, levels of agreement again ranged from poor to substantial in the unilateral CMJ (Kappa = -0.21 to 0.72), fair to substantial in the unilateral drop jump (Kappa range = 0.33 to 0.74) and slight to moderate during the 505 test (Kappa range = 0.06 to 0.44).

In this sense, whilst useful information can be obtained from longitudinal data of magnitude and direction, this data is not apparent in youth sporting populations, which seems like a useful line of investigation, given that asymmetry has been previously suggested to be a potential injury risk factor (Fort-Vanmeerhaeghe, Mila-Villarroel, et al., 2020; Read et al., 2018). From this limited evidence, only male youth populations have been tested (Bishop, Read, Bromley, et al., 2020; Bishop, Read, Chavda, et al., 2020). However, there is a lack of studies about the variation of asymmetries across the season in females and also how they differ between genders.

Given the task-specific nature of asymmetries in both magnitude and directionality across different skills (Bishop et al., 2021; Bishop, Read, McCubbine, et al., 2018; Dos'Santos, Thomas, A. Jones, et al., 2017; Maloney et al., 2017) and across the competitive season of team sports athletes (Bishop, Read, Bromley, et al., 2020; Bishop, Read, Chavda, et al., 2020) researchers have suggested the importance of obtaining asymmetry data for more than a single test and at different time points to show the "full picture" of asymmetries throughout the season (Bishop, Read, Chavda, et al., 2019; Loturco et al., 2018). This provides practitioners useful information to prepare their players for the different game demands and also adapt the training to the time of the season. Therefore, the main purpose of this study was to provide seasonal variation data for inter-limb asymmetry in youth elite team-sport athletes. In addition, the secondary objective of this study was to compare inter-limb asymmetries between genders. Our primary hypothesis was that young elite athletes would present meaningful differences in both the magnitude and direction of asymmetries throughout the competitive season.

Materials and Methods

A repeated measures design over three time points (pre, mid and end of season) during the course of a competitive season (2017-2018) in young elite sports-team athletes was conducted to examine the seasonal variation data for the magnitude and direction of inter-limb asymmetry. Vertical and horizontal unilateral jump data was collected and inter-limb asymmetry monitored from the single leg countermovement jump (SLCMJ) and the one leg hop for distance (OLHT) tests during pre-season (September), mid-season (January) and end of season (May).

Subjects

Fifty-nine elite youth team-sport players from basketball (17 females), volleyball (11 females and 9 males) and handball (12 females and 10 males), volunteered to participate in this study (Table 1). Subjects were eligible for inclusion if they were elite team-sports players between 14-18 years old. Exclusion criteria for athletes were being injured (unable to compete) during the three testing points. All of the subjects were actively participating in a four-year national professional development program training and studying in the same high-performance sports center, in [blinded]. This group of athletes usually begins the season in the high-performance center following the school season, that is, from mid-September to mid-June. Outside of this period (off-season), most athletes compete nationally and internationally. During the school period they usually compete from October to April May, although as they are team sports the calendar varies according to the results. During the season, routine training did not differ between groups and consisted of 8-10 sessions (90-120 minutes per session), two of which were dedicated towards structured strength and conditioning training. In addition, they played a weekend match, totaling approximately 16-20 hours of combined training and competition per week. Biological maturation was calculated in a non-invasive manner using a regression equation comprising measures of age, body mass, standing height, and sitting height (Mirwald et al., 2002). Written informed consent was provided from all subjects (and their guardians for any player under the age of 18), and each player was also cleared to participate in testing by the club's medical department. This study was approved by the [blinded] Ethics Committee and conformed to the recommendations of the Declaration of Helsinki.

** PLEASE INSERT TABLE 1 ABOUT HERE **

Procedures

One week before the first data collection session, participants were familiarized with the testing procedures enabling them to practice each test an unlimited number of times, until the lead researcher considered their technique appropriate for data collection. Prior to each data collection, all participants completed the same standardized warm-up in groups of 3-4 athletes consisting of 7-minutes of light multi-directional runs, 3-minutes of calisthenics (e.g. walking lunges, high knee lifts, side steps) and 3-minutes of maximal and progressive intensity actions, including changes of direction, jumps, and accelerations/decelerations. Following the general warm-up, subjects were re-introduced to the testing procedures and were allowed to perform three maximal-effort practice trials on each limb, for both tests. All tests were performed on a single day, starting with the SLCMJ and ending with the OLHT. Consistent feedback was provided to ensure proper technique.

Single Leg Countermovement Jump

Subjects were instructed to stand on one leg with hands on hips, descend into a countermovement of self-selected depth, and then rapidly extend the stance leg to jump as high as possible in the vertical direction (Meylan et al., 2009). The swing of the opposite leg prior to the jump was not allowed and was closely monitored by the lead researcher. Athletes were also instructed to land on both feet simultaneously. A trial was considered successful if the hands remained on the hips throughout the trial and no knee bend was allowed during flight time. The SLCMJ height was calculated from flight time (Jump Height = 9.81 * (flight time)^2 / 8) (Bosco et al., 1983) with a contact mat system (Chronojump Boscosystem, Barcelona, Spain). Chronojump-Boscosystem system has been proven as a valid (ICC = 0.95) and reliable (ICC = 0,90) assessment tool to measure vertical jump (de Blas et al., 2012). Moreover, it's microcontroller margin of error has been shown 0.1%. For the three trials of each jump, subjects started with their preferred leg and the order of the right and left legs was alternated thereafter. Each trial was separated by a 60-s recovery period.

One Leg Hop for Distance Test

All participants were asked to hop as far as possible, taking off and landing on the same foot and keeping their balance on this foot for 2 seconds after landing. To facilitate body balance, participants performed the OLHT with free arm movement. The swinging of the opposite leg prior to the jump was not allowed. For the two trials of each jump, participants started with their preferred leg and the order of the right and left legs were alternated thereafter. If participants performed 2 invalid jumps with one leg, they had the opportunity to perform as many trials as necessary until they kept their balance. Each trial was separated by a 30-s recovery period.

Statistical Analyses

All data were initially recorded as means and standard deviations (SD) in Microsoft Excel and later transferred to SPSS (Version 20 for Windows; SPSS Inc. Chicago, IL, USA). The

Kolmogorov-Smirnov test was used to check the normality of the tested parameters. In addition, within-session reliability of test measures was analyzed at each time point using two-way random intraclass correlation coefficient (ICC) with an absolute agreement (95% confidence intervals) and coefficient of variation (CV). For interpretation, intraclass correlation coefficient (ICC) values were > 0.9 = excellent, 0.75-0.9 = good, 0.5-0.75 = moderate, and < 0.5 = poor (Koo & Li, 2016) and CV values were considered acceptable if < 10% (Cormack et al., 2008).

For the purpose of identifying inter-limb asymmetry magnitude between limbs, it was calculated the asymmetry index (ASI) using the following formula (Bishop et al., 2016; Impellizzeri et al., 2007):

$$\text{ASI\%} = \frac{\textbf{Highest Performing Limb – Lowest Performing}}{\textbf{Highest Performing Limb}}\ \mathbf{x\ 100}$$

The highest performing limb (HPL) was defined as the side with the highest or furthest value in each jump. The mean of the two (OLHT) or three (SLCMJ) trials was used to index asymmetry analyses. Additionally, inter-limb asymmetry z-scores were calculated, with the aim to identify which athletes had asymmetries higher than the group average, in line with a recent suggestion on this topic (Dos'Santos et al., 2020; Nimphius et al., 2016). In this regard, "small to moderate" asymmetries (population mean + smallest worthwhile change (SWC) (0.2 × between-subject SD)) and "high to very high" asymmetries (population mean + (1.0 × between-subject SD) were considered.

A repeated-measures analysis of variance was conducted to determine differences in asymmetry scores between time points, with statistical significance set at $p < 0.05$. The magnitude of change was calculated between time points using Cohen's *d* effect sizes with 95% confidence intervals (Cohen, 1988). These were interpreted in line with Hopkins et al. (Hopkins et al., 2009) and considered as: < 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.

Kappa coefficients (κ) were calculated to determine the levels of agreement for how consistently an asymmetry favored the same side (direction of asymmetry) when comparing the different time points measured. Kappa values were interpreted in line with suggestions from Viera and Garret (2005), and considered as: ≤ 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 (Cohen, 1960).

Results

Reliability data are presented for each time point in Table 2. Almost all the tests showed excellent within-session ICC values (≥ 0.9) and had acceptable consistency with CV values < 10%.

** PLEASE INSERT TABLE 2 ABOUT HERE **

Mean inter-limb asymmetry magnitude for each time point, with accompanying effect sizes are presented in Table 3. In addition, Table 4 shows asymmetry thresholds calculated on the population mean + SWC (small to moderate asymmetries) and mean + SD (high to extreme asymmetries). When comparing inter-limb asymmetry throughout the season in the whole group, the SLCMJ test showed augmented significant differences at mid-season (20.16 ± 12.98) in comparison with pre-season (9.59 ± 6.36) and end-season (8.29 ± 7.56) in the whole group ($p < 0.01$, $d = -1.03$ for pre to mid; $p < 0.01$, $d = 1.12$ for mid to end). In addition, these significant differences were also shown when differentiating by males ($p < 0.05$, $d = 0.99$ for pre to mid; $p < 0.05$, $d = 1.09$ for mid to end) and females ($p < 0.01$, $d = -1.02$ for pre to mid; $p < 0.01$, $d = 1.12$ for mid to end). Otherwise, OLHT inter-limb asymmetry magnitude didn't show significant changes through the season for the whole group and when differentiating by gender. When comparing the differences between males and females, no significant differences were found in mean asymmetry at any time point or for both tests between males and females.

** PLEASE INSERT TABLE 3 ABOUT HERE **

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Kappa coefficients and the descriptors of how consistently the asymmetry favoured the same limb between time points are presented in Table 5. For the direction of asymmetry, levels of agreement ranged from poor to slight in the SLCMJ (-0.10 to 0.18) and in OLHT (-0.21 to 0.18) in the whole group. Related to this, thirty-three of the fifty-nine players (55.9 %) for the SLCMJ and thirty-four of the fifty-nine players (57.62 %) for the OLHT that participate on the current study switch the dominant leg between right and left limbs thorough the different testing points. When comparing the direction of asymmetry in males, levels of agreement ranged from poor to slight in SLCMJ (-0.10 to 0.19) and from slight to moderate in OLHT (0.08 to 0.50). Likewise, females showed levels of agreement ranging from poor to fair in SLCMJ (-0.14 to 0.25) and from slight to fair in OLHT (0.04 to 0.23).

** PLEASE INSERT TABLE 5 ABOUT HERE **

Additionally, comparing SLCMJ and OLHT asymmetries, it can be observed that rarely favored the same side between tests (Kappa = -0.09 to 0.13), indicating different directionality depending on the test. Figure 1 and Figure 2 show the individual asymmetries for each test in the different of the season with positive values indicating right limb dominance and negative values indicating a left limb dominance.

** PLEASE INSERT FIGURE 1 ABOUT HERE **

** PLEASE INSERT FIGURE 2 ABOUT HERE **

Discussion

The main findings of this study showed that the magnitude of SLCMJ test showed significantly higher asymmetries at mid-season in comparison with pre-season and end-season. However, the magnitude of asymmetry in OLHT showed no significant differences throughout the season. In addition, the direction of asymmetry varied considerably with poor to moderate levels of agreement for both jump tests throughout the season. These findings reinforce the greater sensitivity of the SLCMJ compared to the OLHT when detecting the magnitude of asymmetry, and that monitoring of the direction of asymmetry is key in determining the fluctuating nature of limb dominance characteristics over time.

Only SLCMJ height asymmetry showed significant differences throughout the season, with an increase in the magnitude at mid-season in comparison with pre-season and end-season in the whole group and when differentiating by males and females. Otherwise, OLHT asymmetry values showed no significant differences throughout the season. This finding reinforces that the magnitude of asymmetry may vary depending on the task used and that the SLCMJ may be more sensitive for detecting changes in asymmetry over time (Bishop, Weldon, Hughes, et al., 2020). The difficulty in landing on one foot (OLHT) might be the explanation for these findings. Furthermore, Kotsifaki et al. (2020) recently suggested that OLHT distance is not overly sensitive for detecting deficits at the knee joint during rehabilitation test protocols (Kotsifaki et al., 2020). Thus, practitioners should be cautious in interpreting the OLHT magnitudes and concluding that inter-limb asymmetry is consistent. When analyzing the direction of the asymmetry, the present results show high variability between time points for both tests in the whole group and when differentiating between males and females. These results are in agreement with previous research (Bishop, Read, Chavda, et al., 2020; Pichardo et al., 2019) that observed high variability in the direction of jump asymmetry throughout the season. Therefore, it is suggested that the direction of asymmetry can be more explanatory in monitoring inter-limb asymmetries across the season, compared to the magnitude of asymmetry.

Classically, asymmetry magnitude is carried out using the previously described ASI (Impellizzeri et al., 2007). In our study, and in agreement with previous research (Fort-Vanmeerhaeghe et al., 2015; Fort-Vanmeerhaeghe, Bishop, et al., 2020; Fort-Vanmeerhaeghe, Mila-Villarroel, et al., 2020), unilateral vertical jump reflects considerably greater asymmetries (8.29-20.16%) than horizontal jumping (4.87-5.13%) in youth team sports. The largest inter-limb asymmetry detected from the SLCMJ in this study is in agreement with the 10-15% threshold of potential risk of injury described by previous literature (Hewit et al., 2012; Paterno et al., 2010, 2007). However, recently the analysis of inter-limb magnitude asymmetry using z-scores has been proposed with the aim to identify which athletes had asymmetries higher than the group average (Dos'Santos et al., 2020; Nimphius et al., 2016). Using z-scores as a method of data analysis can be very useful for practitioners since it establishes asymmetry thresholds within the same population. In the present study, greater amount of athletes failed in to the "extreme or high" asymmetry group at mid-season for the SLCMJ (n = 12) compared to the OLHT (n = 2), thus, again demonstrating the higher sensitivity of SLCMJ in monitoring larger inter-limb asymmetries.

Another of the main findings of this study were the significant increase of SLCMJ asymmetry values in mid-season (20.16 ± 12.98) compared to pre (9.59 ± 6.36; $p < 0.01$ and $d = -1.03$) and end-season (8.29 ± 7.56; $p < 0.01$ and $d = 1.12$). These increases could be explained by the particular characteristics of the sample. The participants in this study were youth elite team-sport athletes who reside in a high-performance center for much of the season. These athletes, regardless of the sport they competed at, had a strength and conditioning training routine in order to reduce injury risk that involves high training volumes (> 16 h per week among 14-18-year-old team sport athletes) (Rose et al., 2008). However, just before mid-season testing (Christmas holidays), most of them (90%) were called up to their respective national teams and spent 2-3 weeks in national training camps, without any structured strength and conditioning training. This particular scenario may explain the elevated SLCMJ asymmetry values during the mid-season. Moreover, although the magnitude of asymmetry was similar between the pre (9.59 ± 6.36) and end (8.29 ± 7.56) season, there was still a high level of inconsistency in the direction of asymmetry throughout the season (Kappa range = -0.21 to 0.50). However, in the present study, caution should be placed when interpreting the consistency of magnitude of asymmetry because the direction of asymmetry was low between the different moments of the season (as shown by Kappa values). This suggests that the HPL often fluctuated between time points. As such, if we do not monitor the direction of asymmetry, we may be missing large shifts in the magnitude. For example, if monitoring the magnitude only, a change from 8% to 9% appears to be very small. In contrast, if the HPL has changed, this actually represents a 17% shift in asymmetry, which is only accounted for if the direction of imbalance is monitored.

In the present study we have also evaluated the inter-limb asymmetries differences between genders. No significant diffferences were found in the unilateral jumping asymmetry between males and females. In addition, limb dominance was fluctuant across the three time points in both sexes. To the best of our knowledge, there are no previous studies that compare asymmetry variation across the season between males and females. However, despite the novelty of the gender comparison, the direction of asymmetry variability across the season is in concordance with previous research (Bishop, Read, Chavda, et al., 2020; Bishop, Weldon, Hughes, et al., 2020; Pichardo et al., 2019), where kappa values were low across the season. Related to this, and in both sexes, Kappa coefficients values highlighted the variable nature of the direction of asymmetry throughout the competitive season.

Beyond the usefulness of these findings, we recognize some limitations that should be mentioned when interpreting the current results. Firstly, training or competition load data was not available throughout the present study; thus, understanding why such variations occurred in the direction of asymmetry is challenging. Current evidence has shown how excessive and rapid increases in training or competition loads can result in a major injury incidence (Gabbett, 2016). Therefore, further studies should also analyze the relationship between imbalances and external match load (i.e., distance covered, amount of high-speed running, etc.) in order to better understand the relevance of asymmetry on match performance in team-sport players. Secondly, although this study collected data at three time points, it is plausible that more frequent testing is required to fully elucidate the longitudinal asymmetry trend throughout a season. Third, this study gathered the participants from the different sport disciplines such as basketball, volleyball and handball. However, a discrepancy of the number of the participants between genders in each sport discipline. For instance, there were 17 females in basketball, but no males. This discrepancy may influence to the result of asymmetry. Finally, future work could aim to compare asymmetry measures by competitive level and playing position. This may help to identify at what competitive stage to target possible training interventions as well as whether functional asymmetries are more prevalent to certain playing positions or positional demands.

Conclusions and Practical Applications

This study showed that the magnitude of asymmetry in SLCMJ remained inconsistent, demonstrating significant differences between periods with an increase at mid-season. In addition, the current study also reported misleading asymmetry consistence using OLHT, if not looking at directionality of asymmetry. However, when analyzing the directionality, high variability in limb dominance was evident in both horizontal and vertical unilateral jumping tests. Therefore, it is suggested that if practitioners wish to monitor jumping asymmetries in different time points, it is recommended to first consider the direction of the asymmetry instead of the magnitude, in order to determine limb dominance consistency. Alternatively, the use of z-score of inter-limb asymmetries for an specific population, may be useful for practitioners in order to identify which athletes displays higher asymmetries than average. Due to the high variability in asymmetry values (magnitude and direction) between tests and time points, inter-limb asymmetry interpretation should never be done in isolation, and a complete neuromuscular profile for both limbs should be obtained using a variety of tests and time point measurements. In addition, when time is limited for practitioners, the SLCMJ test may be a low cost and easy strategy to detect inter-limb asymmetry (magnitude and direction), with the intention to guide the training interventions in elite youth team-sports players.

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Conflict of Interest Disclosure

None of the authors has a conflict of interest to declare, and all authors were involved in the study design, data collection and interpretation, and contributed to the writing of the manuscript.

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Table 1. Subjects characteristics by sex.

	Total (n = 59)	**Males (n = 19)**	**Females (n = 40)**
Age (years)	15.73 ± 1.08	16.22 ± .99	15.50 ± 1.06
Height (m)	1.80 ± 0.08	1.86 ± 0.08	1.78 ± 0.07
Body mass (kg)	68.41 ± 10.67	75.55 ± 12.45	65.03 ± 7.90
BMI ($kg \cdot m^2$)	20.95 ± 2.24	21.73 ± 2.79	20.59 ± 1.85
Training experience (years)	6.43 ± 2.74	5.23 ± 3.52	6.98 ± 2.14
Years post-PHV*	2.81 ± 1.74	2.15 ± 2.44	3.13 ± 1.19

* estimation of biological age (Mirwald et al., 2002).

Table 2. Descriptive statistics and reliability measures for SLCJ tests at pre, mid and end of season time points.

Test	**Males**						**Females**					
	Pre-season		**Mid-season**		**End-season**		**Pre-season**		**Mid-season**		**End-season**	
	ICC (95% CI)	CV (%)	ICC (95% CI)	CV (%)	ICC (95% CI)	CV (%)	ICC (95% CI)	CV (%)	ICC (95% CI)	CV (%)	ICC (95% CI)	CV (%)
SLCMJ Right	0.93 (0.86-0.97)	3.02	0.84 (0.67-0.96)	4.61	0.93 (0.85-0.97)	2.31	0.92 (0.86-0.95)	2.27	0.94 (0.91-0.97)	2.96	0.92 (0.86-0.95)	2.04
SLCMJ Left	0.92 (0.83-0.97)	0.67	0.901 (0.79-0.96)	0.87	0.89 (0.78-0.96)	1.21	0.88 (0.79-0.93)	2.34	0.92 (0.87-0.96)	0.90	0.92 (0.86-0.95)	1.25
OLHT Right	0.88 (0.58-0.96)	2.17	0.92 (0.79-0.97)	2.88	0.79 (0.30-0.92)	2.03	0.66 (0.35-0.82)	2.43	0.88 (0.69-0.84)	2.43	0.86 (0.77-0.94)	4.62
OLHT Left	0.87 (0.64-0.95)	3.08	0.87 (0.66-0.95)	2.07	0.93 (0.44-0.98)	2.95	0.83 (0.60-0.92)	1.72	0.86 (0.72-0.93)	2.47	0.92 (0.42-0.97)	3.85

Key: SLCMJ = Single leg countermovement jump; OLHT = One leg hop test; ICC = intraclass correlation coefficient; CI = confidence intervals; CV = coefficient of variation.

Table 3. Mean inter-limb asymmetry ± SD and effect size (95% confidence intervals) data between pre, mid and end-season.

Test	Pre-season	Mid-season	End-season	Pre to Mid *d* (CI)	Pre to End *d* (CI)	Mid to End *d* (CI)
SLCMJ (Males)						
HPL	0.18 ± 0.03	0.18 ± 0.03	0.21 ± 0.03†§	-0.16 (-0.69 to 0.38)	-0.59 (-1.12 to -0.03)	-0.43 (-0.96 to 0.12)
LPL	0.16 ± 0.03	0.14 ± 0.03*	0.18 ± 0.03†¥	0.52 (-0.03 to 1.05)	-0.65 (-1.19 to -0.09)	-1.14 (-1.69 to -0.55)
ASI (%)	10.64 ± 8.29	20.49 ± 11.37*	9.60 ± 8.45§	-0.99 (-1.53 to -0.41)	0.12 (-0.41 to 0.66)	1.09 (0.49 to 1.63)
SLCMJ (Females)						
HPL	0.13 ± 0.03	0.142 ± 0.06*	0.15 ± 0.03†¥	-0.33 (-0.69 to 0.05)	-0.70 (-1.08 to -0.32)	-0.38 (-0.75 to -0.01)
LPL	0.12 ± 0.02	0.11 ± 0.03	0.14 ± 0.03†¥	0.28 (-0.10 to 0.64)	-0.82 (-1.20 to -0.43)	-0.96 (-1.34 to -0.56)
ASI (%)	9.09 ± 6.13	20.00 ± 13.82†	7.67 ± 7.08¥	-1.02 (-1.40 to -0.62)	0.21 (-0.16 to 0.58)	1.12 (0.72 to 1.51)
SLCMJ (Total)						
HPL	0.15 ± .033	0.16 ± .03*	0.17± .034†¥	-0.25 (-0.56 to 0.05)	-0.54 (-0.84 to -0.23)	-0.31 (-0.61 to -0.01)
LPL	0.13 ± .029	0.12 ± .031†	0.15 ± .033†¥	0.30 (-0.01 to 0.60)	-0.61 (-0.92 to -0.30)	-0.87 (-1.19 to -0.55)
ASI (%)	9.59 ± 6.36	20.16 ± 12.98†	8.29 ± 7.56¥	-1.03 (-1.35 to -0.70)	0.19 (-0.12 to 0.49)	1.12 (0.78 to 1.44)
OLHT (Males)						
HPL	1.89 ± 0.14	1.88 ± 0.23	1.98 ± 0.18*§	0.05 (-0.48 to 0.59)	-0.56 (-1.09 to 0.01)	-0.48 (-1.02 to 0.07)
LPL	1.79 ± 0.17	1.78 ± 0.21	1.89 ± 0.22§	0.05 (-0.48 to 0.58)	-0.52 (-1.05 to 0.03)	-0.51 (-1.04 to 0.04)
ASI (%)	4.92 ± 3.95	5.23 ± 5.93	4.86 ± 5.13	-0.06 (-0.59 to 0.47)	0.01 (-0.52 to 0.55)	0.07 (-0.47 to 0.60)
OLHT (Females)						
HPL	1.49 ± 0.15	1.58 ± 0.15†	1.58 ± 0.17†	-0.60 (-0.97 to -0.22)	-0.56 (-0.97 to -0.22)	0.01 (-0.37 to 0.37)
LPL	1.42 ± 0.15	1.49 ± 0.14	1.49 ± 0.17	-0.48 (-0.85 to -0.10)	-0.43 (-0.80 to -0.06)	0.00 (-0.37 to 0.37)
ASI (%)	4.85 ± 4.96	4.81 ± 4.50	5.25 ± 3.90	0.01 (-0.36 to 0.38)	-0.09 (-0.46 to 0.28)	0.10 (-0.47 to 0.26)
OLHT (Total)						
HPL	1.62 ± 0.24	1.68 ± 0.22*	1.71 ± 0.25†	-0.26 (-0.56 to 0.05)	-0.36 (-0.66 to -0.05)	-0.12 (-0.43 to 0.18)
LPL	1.54 ± 0.24	1.59 ± 0.21	1.63 ± 0.26*	-0.22 (-0.52 to 0.08)	-0.36 (-0.66 to -0.05)	-0.17 (-0.47 to 0.14)
ASI (%)	4.87 ± 4.61	4.95 ± 4.97	5.13 ± 4.30	-0.02 (-0.32 to 0.29)	-0.06 (-0.36 to 0.25)	-0.04 (-0.34 to 0.26)

SLCMJ = Single leg countermovement jump; OLHT = One leg hop test; HPL = Highest Performing Limb; LPL = Lowest Performing Limb; *d* = Cohen's effect size
*_Significantly different from preseason ($p < 0.05$)
†_Significantly different from preseason ($p < 0.01$)
§_Significantly different from mid-season ($p < 0.05$)
¥_Significantly different from mid-season ($p < 0.01$)

Table 4. Z-scores of inter-limb asymmetries for the study population (n=59).

Asymmetry threshold	Pre-season	Mid-season	End-season
SLCMJ:			
"Small to moderate" (n)	10.96 (22)	22.76 (23)	9.13 (19)
"High to very high" (n)	16.43 (9)	33.14 (12)	15.82 (8)
OLHT:			
"Small to moderate" (n)	5.73 (19)	9.13 (10)	5.99 (22)
"High to very high" (n)	9.41 (6)	19.70 (2)	9.43 (9)

SLCMJ = Single leg countermovement jump; OLHT = One leg hop test; n = number of athletes where the asymmetry is higher than the threshold.

Table 5. Kappa coefficients and descriptive levels of agreement for the changes in vertical and horizontal jump asymmetry across pre, mid and end-season.

Asymmetry metric	Pre to Mid	Pre to End	Mid to End
SLCMJ			
Males	-0.10 (poor)	0.19 (slight)	-0.10 (poor)
Females	0.25 (fair)	0.14 (slight)	-0.14 (poor)
Total	0.18 (slight)	0.18 (slight)	-0.10 (poor)
OLHT			
Males	0.50 (moderate)	0.08 (slight)	0.11 (slight)
Females	0.04 (slight)	0.24 (fair)	0.19 (fair)
Total	-0.21 (poor)	0.18 (slight)	0.17 (slight)

SLCMJ = Single leg countermovement jump; OLHT = One leg hop test.

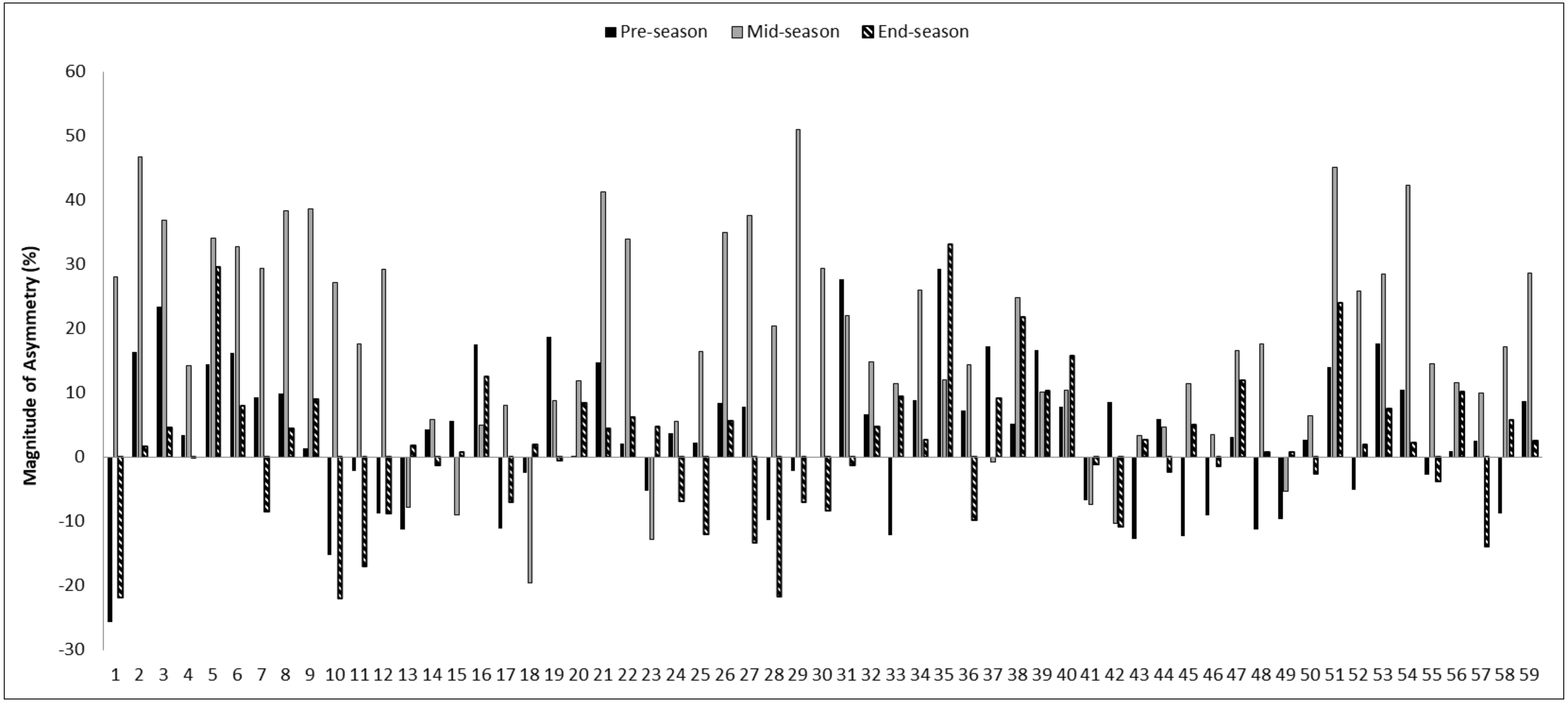

Figure 1. Individual asymmetry data for jump height during the single leg countermovement jump during pre, mid and end of season time points.

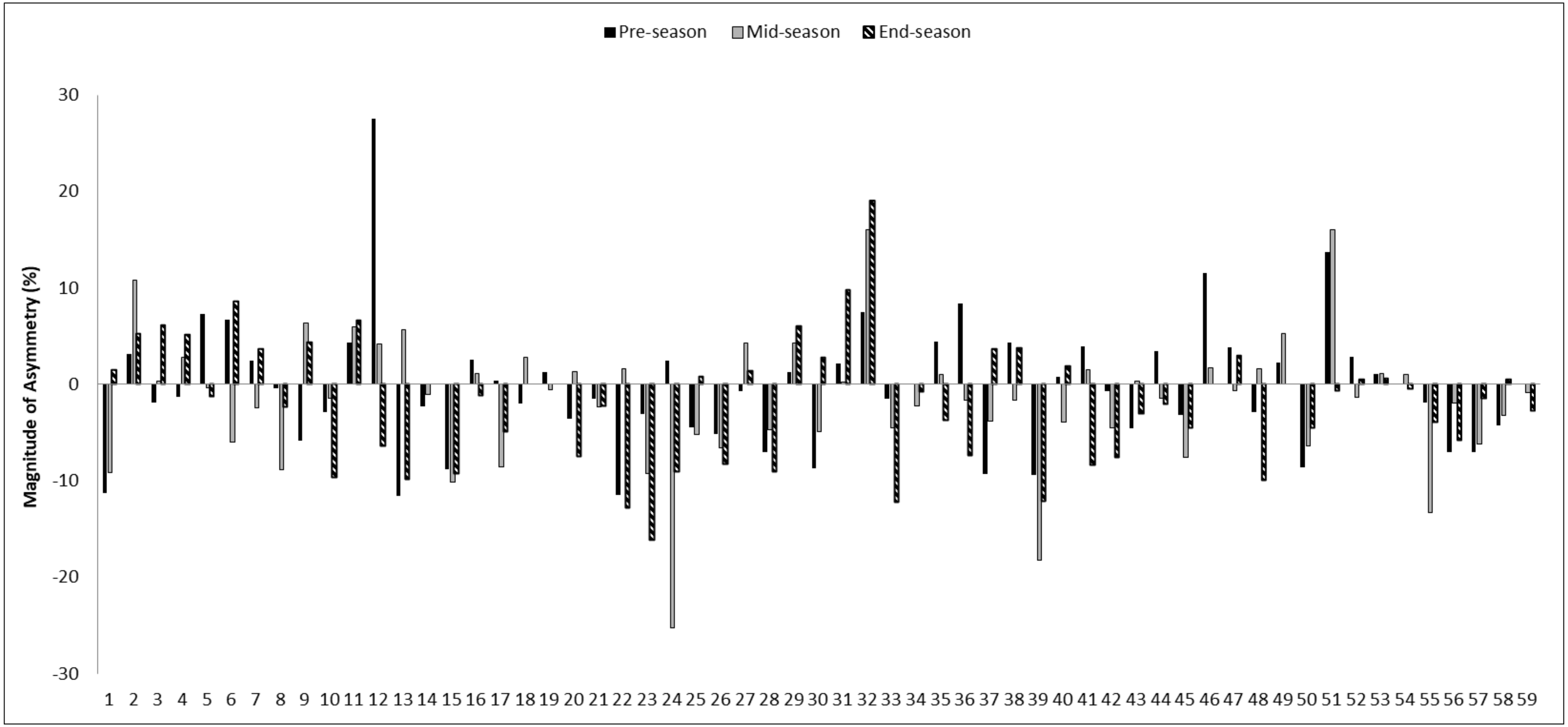

Figure 2. Individual asymmetry data for jump distance during the one-legged hop test during pre, mid and end of season time points.