**Jumping Asymmetries are Associated with Speed, Change of Direction Speed, and Jump Performance in Elite Academy Soccer Players**

**ABSTRACT**

The aim of the present study was to establish inter-limb asymmetries across different age groups in elite academy male soccer players and to examine any relationships between asymmetry and measures of physical performance. Fifty-one players from an English Premier League soccer academy were split into under-23 (*n* = 21), under-18 (*n* = 14) and under-16 (*n* = 16) groups and performed bilateral and unilateral countermovement jumps, 5, 10 and 20 m sprints and a 505 change of direction speed tests. All tests showed low variability (CV ≤ 2.5%) and good to excellent reliability (ICC = 0.80-0.99). A one-way ANOVA showed that the under-23 group were significantly faster than the under-16 group during the 20 m sprint (2.90 vs 2.98s; *p* = 0.02; ES = 0.94). No other significant differences were present between groups. Inter-limb asymmetry was quantified from the single leg countermovement jump and no significant differences in the magnitude of asymmetry were present between groups. However, multiple significant correlations were present in each age group between asymmetry and physical performance tests, all of which were indicative of reduced athletic performance. Results from this study show that although inter-limb asymmetry scores are comparable across age groups in elite academy soccer players, differences as low as 5% are associated with reduced physical performance during jumping, sprinting, and change of direction speed tasks. This study suggests the importance of monitoring jump height asymmetries in elite academy soccer players.

**Key Words:** Athletic performance; inter-limb differences; monitoring

**INTRODUCTION**

Inter-limb asymmetries can be defined as the percentage difference between limbs when values are not equal during a given task (3,18) and has been a popular stream of investigation in recent years. Literature has indicated the necessity to investigate the association between asymmetry and measures of physical performance (5,25), given that their prevalence alone does little to further our understanding of their impact on athletic performance. In essence, it is likely that all athletes will exhibit some level of asymmetry (29); however, this may simply be a by-product of playing competitive sport over time (14,15,28). Thus, the correction of inter-limb asymmetries, without first establishing its relationship with key performance indicators may not be the most efficient use of practitioners’ time.

Within the available body of evidence, there is conflicting evidence about the impact inter-limb asymmetries have on athletic performance. Lockie et al. (23) reported jump height and distance asymmetries of 3.3-10.4% in the SLCMJ and single leg broad and lateral jumps in collegiate athletes. No significant correlations were shown between asymmetry on any of the jump tests and 5, 10, 20m sprint and 505 CODS performance. Similarly, Dos’Santos et al. (8) reported inter-limb differences of 5-6% in the single and triple hop tests also in collegiate athletes, with no significant correlations to two different CODS tasks. In contrast, Maloney et al. (24) showed that average jump height asymmetry of 13% from a single leg drop jump was significantly correlated (*r* = 0.6; *p* = 0.026) with two 90° cuts in recreationally active adults. Of note here, is that because the correlation was positive, the results suggest that larger asymmetries are indicative of slower CODS times. In line with this, a recent study by Bishop et al. (4) showed that jump height asymmetries of 12.5% were significantly associated with slower acceleration performance during the 5m (*r* = 0.49; *p* < 0.05), 10m (*r* = 0.52; *p* < 0.05), and 20m (*r* = 0.59; *p* < 0.01) sprints in youth female soccer players aged ~10 years. Furthermore, Bishop et al. (4) also showed that larger jump height and distance asymmetries (from the SLCMJ and triple hop tests) were also associated with reduced jump performance on both limbs (*r* = 0.47 to 0.58; *p* < 0.05). Thus, with this conflicting evidence, further research is warranted to establish the relationship between inter-limb asymmetry and athletic performance.

In addition to this conflicting evidence, there is a paucity of studies investigating how inter-limb asymmetries interact with performance between different chronological age groups. For example, Read et al. (29) showed that SLCMJ landing force asymmetry was significantly greater for circa and post-peak height velocity (PHV) soccer players compared to those who were pre-PHV (*d* = 0.41-0.43; *p* < 0.001). However, no differences were evident for horizontal hop and hold landing force, single leg hop for distance, or the Y-balance test. Meyers et al. (26) reported leg stiffness asymmetries during maximal sprinting over 35 m in school children at under-12, under-13, under-14, under-15 and under-16 age groups. Stiffness asymmetries ranged from 2.3-12.6%; however, regardless of magnitude, there was no association with sprint speed. In contrast, Rumpf et al. (31) reported asymmetries in work, also during maximal sprinting, of 26.4% for pre-PHV athletes which were significantly greater than the circa (14.7%) and post-PHV (17.3%) groups. Despite this evidence, attempting to establish whether these side-to-side differences are detrimental to physical performance is scarce over more than one age group.

Therefore, the aims of the present study were two-fold: 1) to quantify inter-limb asymmetries across different age groups in elite academy soccer players and, 2) establish the relationship between inter-limb asymmetries and measures of physical performance in all age groups. It was hypothesized that significant differences in asymmetry would exist between groups and that correlations would show that larger asymmetries are associated with reduced physical performance.

**METHODS**

**Experimental Approach to the Problem**

This study used a cross-sectional design and all data were collected in a single test session for each age group in a Category 1 soccer academy at a Premier League soccer club two weeks before the end of the competitive season. Testing included countermovement jumps (bilateral and unilateral), 5, 10 and 20 m sprints, and a 505 change of direction task. A specific familiarization session was not conducted, owing to the familiarity of test protocols which were frequently conducted for each age group throughout the competitive season. A standardized warm up protocol was conducted to ensure valid and reliable test data was collected. Furthermore, players refrained from strenuous physical activity for 48 hours before testing and were asked to eat according to their normal diet as well as refraining from caffeine in the preceding two hour period.

**Subjects**

Fifty-one elite male youth soccer players volunteered to participate in this study from three age groups: under-23 (*n* = 21; age: 19.8 ± 1.1 yr; height: 180.2 ± 6.5 cm; mass: 76.9 ± 8.5 kg), under-18 (*n* = 14; age: 17.5 ± 0.5 yr; height: 181.6 ± 8.6 cm; mass: 76.4 ± 7.4 kg), and under-16 (*n* = 16; age: 15.1 ± 0.7 yr; height: 174.8 ± 11.1 cm; mass: 66.1 ± 11.0 kg). Club policy required players to train 3-4 times per week for soccer practice and a minimum of two structured strength and conditioning training sessions per week, specific to each age group. Players were excluded if they were injured at the time of testing and informed consent was provided by all players in line with the club’s academy policy. In addition, consent for players under the age of 18 was also provided by a parent or guardian. Ethical approval was granted by the [\*\* DELETED FOR PEER REVIEW \*\*] research and ethics committee.

**Procedures**

All players undertook the same protocols before fitness testing, to ensure a standardized approach was adopted across groups. All tests were performed indoors on rubber flooring at the club’s training facility. Prior to testing, players performed a standardized warm up following the RAMP system as outlined by Jeffreys (17). A five minute slow jog was performed before a series of dynamic stretches that mobilized the ankles, hips and thoracic spine. This included one set of 10 repetitions of bodyweight squats, forward and lateral lunges, inchworms and spidermans. Practice trials were then conducted immediately after for each test at approximately 60, 80 and 100% of perceived maximal effort prior to data collection. A three minute rest period was provided after the last practice trial and the start of data collection. During data collection, three trials were completed for all tests with an average of all scores computed for subsequent data analysis.

*Countermovement Jump (CMJ) and Single Leg Countermovement Jump (SLCMJ).* Jump tests were conducted using an optical measurement system OptoJump™ (Microgate, Bolzano, Italy) which has reported near perfect reliability and been shown to be strongly correlated with force platforms for the assessment of jump height (12). For the CMJ, players were first required to step between the optical cells in a comfortable bilateral stance with hands fixed on hips. Upon instruction, players performed a countermovement by flexing at the hips and knees to a self-selected depth, before accelerating vertically into a jump as fast as possible. Similar procedures were completed for the SLCMJ. Players stood on the test leg in the center of the OptoJump™ with hands on hips and the knee of the non-jumping leg slightly flexed, so that the hovering foot was positioned at approximately mid-shin height of the jumping leg. Players again performed a countermovement to a self-selected depth, before jumping as fast as possible and landing on the same test leg. No swinging of the non-jumping leg was allowed. Jump height was recorded in centimeters (cm) for all trials. By virtue of the number of jumps conducted, the CMJ and SLCMJ were treated as separate tests. All CMJ were performed before then moving onto the SLCMJ protocols, which started with the left leg and were alternated until all trials were completed. Sixty seconds of rest was provided between all trials and three minutes of rest before starting the SLCMJ. If players flexed their knees or hands came off hips, the jump was deemed void and retaken after 60 seconds of rest.

*5, 10 and 20m Sprint.* Electronic timing gates (Brower Timing Systems, Utah, USA) were positioned at 0, 5, 10 and 20 m at a height of 1 m, enabling multiple splits to be measured during a single sprint. Players started the test in a staggered 2-point stance with toes positioned 0.3 m behind the start line so as to not break the beam of the timing gates prior to the initiation of the test. When ready, players sprinted through the final set of timing gates enabling split times to be recorded to the nearest hundredth of a second.

*505 Change of Direction Speed.* A distance of 15 m was measured and electronic timing gates were positioned at the 10 m mark and the 15 m point was positioned on the goal line to ensure that players had an obvious target as they approached the turning point. Players sprinted 15 m and then performed a 180° turn off both the right and left legs, with each trial alternating between limbs, to reduce the likelihood of fatigue impacting any of the results. The time started when players broke the electronic beam at the 10 m mark and after turning 180°, before sprinting back through the timing gates to complete a recorded distance of 10 m.

**Statistical Analyses**

All data were initially recorded as means and standard deviations (SD) in Microsoft Excel and later transferred to SPSS (version 24.0; SPSS, Inc., Armonk, NY, USA) for further analysis. All data were checked for normality using the Shapiro-Wilk test and within-session reliability of test measures were computed using a two-way random intraclass correlation coefficient (ICC) with absolute agreement (inclusive of 95% confidence intervals), the coefficient of variation (CV) and standard error of the measurement (SEM). Interpretation of ICC values was in accordance with previous research by Koo and Li, (19) where values > 0.9 = excellent, 0.75-0.9 = good, 0.5-0.75 = moderate, and < 0.5 = poor. CV was calculated using the formula: (SD/mean)\*100 and values were considered acceptable if < 10% (7). SEM was computed using the formula: SD\*√(1-ICC) (34).

Pearson’s *r* correlations were conducted to establish the relationship between inter-limb asymmetry scores and fitness test scores, with statistical significance set at *p* < 0.05. A one-way ANOVA was conducted to determine systematic bias between age groups for mean test scores and asymmetry values, with statistical significance set at *p* < 0.05. Magnitude of difference between groups was also computed via Cohen’s *d* effect sizes using the formula: (Meangroup1 – Meangroup2)/SDpooled. These were interpreted in line with Hopkins et al. (16) 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. Inter-limb asymmetries were computed using a standard percentage difference equation: 100/(max value)\*(min value)\*-1+100, which has been suggested to be accurate for the calculation of between-limb asymmetries for the SLCMJ (2,3), noting that only asymmetries from unilateral tests were calculated in the present study.

**RESULTS**

All data were deemed normally distributed (*p* > 0.05). Table 1 shows mean test scores and test reliability data for all players (*n* = 51). CV scores were deemed acceptable with all test variability ≤ 2.5% and all tests also showed good to excellent reliability (ICC = 0.80-0.99). Mean test scores and effect sizes for each age group are presented in Table 2. The under-23 group were significantly faster than the under-16 (*p* = 0.02) over 20 m; no other significant differences between groups were found. When comparing effect sizes, trivial to moderate differences were evident between all group comparisons.

Figure 1 shows the inter-limb asymmetry values for each group. No significant differences between groups were evident; however, there was a small effect size (0.34) between under-23 and under-18 groups, and between the under-18 and under-16 groups (0.40). A moderate effect size (0.70) was shown between the under-23 and under-16 groups. Table 3 shows Pearson’s *r* correlations between inter-limb asymmetry scores and fitness test data. Significant negative correlations were shown for all age groups between asymmetry and jump performance (*r* = -0.51 to -0.77; *p* ≤ 0.05), and significant positive correlations were shown with linear speed (*r* = 0.54 to 0.87; *p* ≤ 0.05) and CODS (*r* = 0.61 to 0.85; *p* ≤ 0.05) performance.

\*\*\* INSERT TABLES 1-2 ABOUT HERE \*\*\*

\*\*\* INSERT FIGURE 1 ABOUT HERE \*\*\*

\*\*\* INSERT TABLE 3 ABOUT HERE \*\*\*

**DISCUSSION**

The aims of the present study were to establish inter-limb asymmetry scores from the SLCMJ in elite male academy soccer players across different age groups and determine the relationship between those asymmetries and measures of physical performance. Although no significant differences in jump height asymmetry were present between groups, effect sizes were small to moderate between groups. Significant relationships were present when examining the effects of asymmetry on speed, CODS and jump performance, suggesting that larger asymmetries were associated with reduced athletic performance in all age groups.

Table 2 shows mean fitness test data for each age group and the accompanying effect sizes between groups. The only significant difference between groups was during the 20 m sprint between the under-23 and under-16 groups (2.90 vs 2.98s; *p* = 0.02; effect size = 0.94). Intuitively, given the physical maturity of the under-23 group in comparison to the under-16’s, it seems logical to assume that these players would be able to sprint faster (21,22). This is supported in previous research by Gissis et al. (11) who showed that elite soccer players outperformed younger players on key performance indicators such as 10 m sprint speed. However, Gissis et al. (11) also showed that elite players significantly outperformed younger and less experienced players during a maximal isometric strength task, rate of force development, and jump height during the squat and drop jump tests. Thus, the lack of significance across all other fitness parameters in the present study is somewhat surprising. Despite no further significant differences between groups, moderate effect sizes were evident between the under-23 and under-16 groups for 10 m (0.91), SLCMJ on both legs (0.72-0.74) and 505 on the right side (0.67). In addition, the only moderate effect size between the two older groups was for 20 m (0.71), with all other variables showing trivial to small differences. Following this line of results, comparisons between the under-18 and under-16 groups showed one moderate effect size of 0.71 for the SLCMJ on the right leg, with all other differences being trivial to moderate.

Figure 1 shows the magnitude of jump height asymmetry for each age group during the SLCMJ test. No significant differences were present between groups; however, effect sizes were small to moderate (0.34-0.70). The under-16 group showed the largest asymmetry scores (9.02%) but also showed the greatest variability in asymmetry (as represented by the largest SD), which in turn may help to explain the lack of significant difference in asymmetry between groups. In addition, the physical maturity of the younger group may offer a potential reason for this increased asymmetry and variability. Gerodomis et al. (10) compared movement variability during vertical jumping in youth, adolescent and adult basketball players, and found the greatest variability in the youngest group of players. Read et al. (29) highlighted that jumping asymmetries ~10% may be established as early as 10-11 years of age. Furthermore, Fousekis et al. (9) reported that asymmetry has been shown to reduce with training age in professional soccer players. Therefore, in the present sample, it is possible that the older group had been in the academy system longer than the younger players and thus, had a greater training age resulting in lower jump height asymmetries. In addition, previous research has suggested that 10% could be considered a threshold that practitioners should aim for when reducing between-limb differences to reduce injury risk (20,30). Thus, with the under-16 group approaching 10%, practitioners should be mindful of this threshold and consider training strategies to ensure that these side-to-side differences do not increase further. Research from Bazyler et al. (1) showed that peak force asymmetries were smaller in stronger recreational athletes, suggesting that increased strength may be beneficial for reducing existing side-to-side differences. Therefore, and in accordance with the youth physical development model (21,22), athletes from the age of 15+ should make strength training a key priority and this may serve to simultaneously reduce inter-limb asymmetries.

Further to the magnitude of asymmetries, Table 3 shows the correlations between jump height asymmetry during the SLCMJ test and fitness test scores for each age group. Regardless of age group, all correlations with speed and CODS data were positive, indicating that larger asymmetries were associated with slower speed and CODS performance. In addition, all correlations with bilateral and unilateral jump tests were negative, again indicating that larger asymmetries were associated with reduced jump height. Thus, all significant relationships indicate that larger between-limb differences are associated with reduced athletic performance in elite male academy soccer players.

Jump height asymmetries for the under-16 group showed some strong relationships with speed (*r* = 0.79 to 0.86; *p* < 0.01) and 505 (*r* = 0.63 to 0.85; *p* < 0.01) tests. Multiple significant correlations were shown for the under-23 group, most notably with unilateral jump height (*r* = -0.52 to -0.77; *p* < 0.05), 20 m (*r* = 0.71; *p* < 0.01) and 505 (*r* = 0.61 to 0.71; *p* < 0.01). Finally, the under-18 group also showed significant relationships with unilateral jump height (*r* = -0.58; *p* < 0.05), 5 m (*r* = 0.60; *p* < 0.05) and 20 m (*r* = 0.56; *p* < 0.05). Previous research has reported equivocal findings when assessing the relationship between jumping asymmetries and measures of athletic performance. For example, Lockie et al. (23) showed that jump height and distance asymmetries of 3.3-10.4% had no association with speed or CODS performance. This was also supported by Dos’Santos et al. (8) who showed that distance asymmetries from the single and triple hop tests had no relationship with CODS performance during two different tasks. In contrast, Maloney et al. (24) showed that jump height asymmetries (from the unilateral drop jump) were associated with slower CODS performance (*r* = 0.6; *p* = 0.026), but not associated with jump performance. In addition, recent research from Bishop et al. (4) showed that jump height asymmetries from the SLCMJ were also associated with slower 5, 10 and 20m sprint performance (*r* = 0.49 to 0.59; *p* < 0.05) as well as reduced unilateral jump height (*r* = -0.47 to -0.53; *p* < 0.05). Given the conflicting evidence, it is somewhat surprising to see such strong correlations with a vast array of fitness tests. Providing a definitive conclusion for why these relationships exist is challenging. However, soccer players have been shown to jump up to 10-15 times in a game (27) and perform high intensity actions (such as acceleration and changing direction) up to 168 times in matches (33). Therefore, optimizing performance during these actions would appear to be crucial for soccer performance and it seems prudent to suggest that the reduction of asymmetries may be warranted (discussed in the practical applications section).

The present study was not without some limitations. Firstly, maturational status was not monitored in the under-16 group; thus, an assumption was made that players were no longer circa peak height velocity. Given the associated ‘clumsy stage’ with maturation (21,22,29), it is possible that late developers were included in the younger group and may have contributed to the higher asymmetry scores than the older groups. Secondly, inter-limb asymmetries have been shown to be highly task-specific (2,23,24,29) and the present study only measured these differences during a single test and time point. Future research should aim to monitor asymmetries longitudinally and determine the relationship between changes in asymmetry and changes in measures of performance. Doing so will enable practitioners to more closely determine the relevance of existing imbalances in their athletes. From a soccer perspective, practitioners should also aim to establish the relationship between asymmetry and in-game variables (such as minutes played, distance, high speed running, etc.) in order to understand the relevance of competition load on inter-limb differences.

In summary, the results of the present study show no significant differences exist between age groups when quantifying jump height asymmetries. However, the current study does indicate that small asymmetries (5-10%) were associated with impaired athletic performance. Therefore, monitoring asymmetries with a potential view to their reduction would appear an appropriate recommendation for elite male academy soccer players.

**PRACTICAL APPLICATIONS**

Given the strength of correlations between asymmetry and physical performance measures in the present study, it seems prudent to suggest training methods which can reduce inter-limb asymmetries. Previous research has highlighted that bilateral strength training (1), unilateral strength and power training (13) and a combination of both (32) can effectively reduce inter-limb differences. Furthermore, Bishop et al. (6) suggested that the addition of unilateral exercises to more traditional bilateral-based training programs, may be beneficial for soccer players given many actions are performed unilaterally (such as sprinting, changing direction and kicking). Thus, whilst bilateral strength and jumping exercises may provide a solid foundation for soccer players and team sport athletes, the addition of exercises such as split squats, step ups and single leg squats (for strength) and multi-directional unilateral jumps will likely assist in the overall strength and conditioning of soccer players, as well as the reduction of inter-limb asymmetries. However, it should be noted that these suggestions have yet to be empirically evaluated in enough depth.

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Table 1: Mean test scores ± standard deviations (SD) and reliability data for all players.

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| --- | --- | --- | --- | --- |
| Fitness Test | Mean ± SD | CV (%) | ICC (95% CI) | SEM |
| CMJ (cm) | 37.88 ± 3.97 | 2.47 | 0.97 (0.96-0.99) | 0.69 |
| SLCMJ-L (cm)  SLCMJ-R (cm) | 23.85 ± 3.48  23.45 ± 3.30 | 1.98  2.02 | 0.99 (0.98-0.99)  0.99 (0.98-0.99) | 0.35  0.33 |
| 5 m (s)  10 m (s)  20 m (s) | 0.98 ± 0.05  1.70 ± 0.06  2.93 ± 0.10 | 2.50  1.74  1.05 | 0.87 (0.80-0.92)  0.90 (0.84-0.94)  0.95 (0.92-0.97) | 0.02  0.02  0.02 |
| 505-L (s)  505-R (s) | 2.48 ± 0.07  2.48 ± 0.08 | 1.95  1.83 | 0.80 (0.68-0.88)  0.85 (0.76-0.91) | 0.03  0.03 |
| CV = coefficient of variation; ICC = intraclass correlation coefficient; CI = confidence intervals; SEM = standard error of measurement; CMJ = countermovement jump; cm = centimeters; SLCMJ = single leg countermovement jump; L = left; R = right; m = meters; s = seconds. | | | | |

Table 2: Mean fitness testing data ± standard deviations (SD) for each age group and effect sizes between groups.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Fitness Test | Under-23 | Under-18 | Under-16 | Effect Size  U23 vs. U18 | Effect Size  U23 vs. U16 | Effect Size  U18 vs. U16 |
| CMJ (cm) | 38.83 ± 4.02 | 37.69 ± 4.30 | 36.80 ± 3.52 | 0.27 | 0.53 | 0.23 |
| SLCMJ-L (cm)  SLCMJ-R (cm) | 24.88 ± 3.18  24.31 ± 2.83 | 24.08 ± 3.25  24.07 ± 2.54 | 22.30 ± 3.71  21.80 ± 3.97 | 0.22  0.08 | 0.72  0.74 | 0.51  0.71 |
| 5 m (s)  10 m (s)  20 m (s) | 0.98 ± 0.04  1.68 ± 0.04  2.90 ± 0.06\* | 0.97 ± 0.05  1.70 ± 0.07  2.92 ± 0.11 | 0.98 ± 0.05  1.73 ± 0.07  2.98 ± 0.11 | 0.22  0.36  0.71 | 0.00  0.91  0.94 | 0.20  0.43  0.55 |
| 505-L (s)  505-R (s) | 2.46 ± 0.06  2.46 ± 0.08 | 2.50 ± 0.07  2.49 ± 0.08 | 2.48 ± 0.08  2.51 ± 0.07 | 0.31  0.38 | 0.29  0.67 | 0.27  0.27 |
| \* significantly faster than under-16 group (*p* = 0.02)  CMJ = countermovement jump; cm = centimeters; SLCMJ = single leg countermovement jump; L = left; R = right; m = meters; s = seconds. | | | | | | |

ES = 0.34 (small)

ES = 0.70 (moderate)

ES = 0.40 (small)

Figure 1: Mean inter-limb asymmetry values from the SLCMJ test for each age group, inclusive of standard deviations (error bars) and effect sizes (ES) between groups.

Table 3: Pearson’s *r* correlations between jump height asymmetry from the SLCMJ test and fitness tests across age groups.

|  |  |  |  |
| --- | --- | --- | --- |
| Fitness Test | Under-23 | Under-18 | Under 16 |
| CMJ | -0.23 | -0.47 | -0.73\*\* |
| SLCMJ-L  SLCMJ-R | -0.52\*  -0.77\*\* | -0.58\*  -0.40 | -0.51\*  -0.54\* |
| 5 m  10 m  20 m | 0.43  0.54\*  0.71\*\* | 0.60\*  0.49  0.56\* | 0.86\*\*  0.87\*\*  0.79\*\* |
| 505-L  505-R | 0.61\*\*  0.71\*\* | 0.13  0.15 | 0.63\*\*  0.85\*\* |
| \*\* statistically significant at *p* < 0.01; \* statistically significant at *p* < 0.05  CMJ = countermovement jump; SLCMJ = single leg countermovement jump; L = left; R = right. | | | |