Reliability and Measurement of Inter-limb Asymmetries in 4 Unilateral Jump Tests in Elite Youth Female Soccer Players

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ABSTRACT

Purpose: The purpose of this study was to determine the within and between-session reliability, and inter-limb asymmetries, in four unilateral jump tests in elite youth female soccer players. Given the low plyometric training age and paucity of data for this population, this research study was warranted. **Methods:** Nineteen elite youth female soccer players (age: 10 ± 1.1 years; height: 141 ± 7.9 cm; body mass: 35 ± 7.1 kg) were recruited from an elite Tier 1 Regional Talent Centre of a professional soccer club. Tests included the single leg countermovement jump (SLCMJ), single leg hop, triple hop, and crossover hops for distance with reliability quantified via the coefficient of variation (CV), intraclass correlation coefficient (ICC), and standard error of the measurement (SEM). Inter-limb asymmetries were also calculated. **Results:** Both test sessions resulted in excellent within-session reliability (ICC range = 0.81-0.99; SEM range = 0.11-0.49; and CV range = 2.6-6.0%). Between-session reliability was deemed good to excellent (ICC range = 0.72-0.99 and pooled CV = 2.7-5.7%). Asymmetries were deemed small across both test sessions with the highest value reported in the SLCMJ (6.12%). **Conclusion:** Results highlight that unilateral jump tests can be considered a reliable test protocol in elite youth female soccer players, which is important considering youth athletes likely do not have a vast plyometric training age. Furthermore, inter-limb differences appear small in the present sample which may also be explained by their limited training age, given that asymmetries have previously been highlighted to be a product of limb function over time.

Key Words: Lower extremity, single leg, youth athletes

INTRODUCTION

Physical performance testing is a common component for strength and conditioning practitioners to undertake, allowing athletes' fitness capabilities to be effectively monitored which in turn may aid the decision-making process during the design of training interventions. Numerous factors must be considered when selecting appropriate fitness tests to measure performance including: age, equipment, environment, time, training age, and the reliability of the test itself need to be determined in order to assess if a given protocol is to be included or excluded from a test battery (5). Test reliability is crucial as this will enable practitioners to determine if the chosen assessment produces consistent results; thus, allowing results to be interpreted with confidence (33).

Jump testing is a common mode of assessment as it provides a relatively quick and reliable method for assessing the explosive capabilities of athletes (20,22,34). Sports such as soccer, basketball and volleyball, have used bilateral countermovement jumps (CMJ), drop jumps (DJ), and squat jumps (SJ) to assess lower limb power (13,26,35). However, many team sport actions (such as jumping, changing direction, and sprinting) occur unilaterally; thus, this provides additional considerations for test protocols taking place on one leg (5,30). Furthermore, given the multi-planar nature of team sports (12), testing protocols should reflect this also so that they can be considered ecologically valid for the population in question. Consequently, a variety of unilateral jump tests exist that enable the aforementioned factors to be accounted for. However, owing to the high degree of movement variability associated with jump testing (17), and the heightened instability of testing unilaterally, assessing the reliability of these tests becomes even more important. The single leg countermovement jump (SLCMJ) and a variety of hop tests (single leg hop, triple hop, and crossover hop) have been commonly used in the literature. Typically, test-retest reliability of these tests appears strong with intraclass correlation coefficient (ICC) values between 0.8-

0.98 (7,14,21,23,25,28,29,31). However, considerably less information exists about the reliability of these tests for youth athletes (9,24), especially those competing at the highest level in female youth soccer. Given that youth athletes likely have a lower plyometric training age than adults, additional reliability data on this population is warranted.

An additional advantage of selecting unilateral variations of these jump tests is that they also enable inter-limb asymmetries to be quantified. Recent literature has highlighted that unilateral jump testing is a useful method for quantifying between-limb differences (3,4,5). In addition, it has been suggested that assessing asymmetries from unilateral tests may be more applicable than their bilateral counterparts because no contribution from the other limb is present (2,5). This is compounded from research by Jordan et al. (17), who highlighted the changing nature of asymmetries during different phases of bilateral jumping before take-off. From a physical performance perspective, Maloney et al. (19) reported that inter-limb differences in jump height were an important factor in explaining slower change of direction times and additional negative associations between strength asymmetries and performance have also been noted (4). When considering injury risk, asymmetries of 15% have historically been suggested as a threshold to be mindful of (15,28). However, more recent research has proposed that patients are four times more likely to re-rupture their anterior cruciate ligament (ACL) if an asymmetry threshold of 10% is not met from hop testing as part of a return to sport criteria (18). Thus, the presence of inter-limb differences may have implications on physical performance and injury risk, indicating their quantification from unilateral jump testing is warranted.

Therefore, the aims of the present study were to report within and between-session reliability of four commonly used unilateral jump tests (SLCMJ, single leg hop, triple hop, and crossover hop for distance) in elite youth female soccer players. In addition, inter-limb differences were also quantified for all jump tests enabling the creation of a multi-directional asymmetry profile for this population.

METHODS

Subjects

Nineteen elite youth female soccer players (age: 10 ± 1.1 years; height: 141 ± 7.9 cm; body mass: 35 ± 7.1 kg), were recruited from a Tier 1 Regional Talent Centre (RTC) of a professional soccer club. Subjects were considered elite as this particular level is the highest standard of female youth club soccer in England. Players trained for at least 36 weeks per year and were required to partake in a minimum of one hour of structured strength and conditioning training per week. Emphasis at this age was placed on mastering fundamental movement patterns, building strong foundations, enhancing technical competency, and improving general motor control. All subjects were free from injury and any player who presented an injury resulting in more than one week of missed training prior to testing was excluded. Informed consent and PAR-Q forms were completed from all relevant parent/guardians as all participants were under the age of 18. Ethical approval was granted from the London Sports Institute ethics committee, Middlesex University.

Procedures

Participants were tested at the same time of day on three separate testing occasions, each separated by seven days. Session one was used to familiarize all participants with the test procedures, allowing them to practice each jump test as many times as they wanted. A particular emphasis was placed on landing mechanics, owing to the increased demand of having to land on one limb in the chosen tests. The next two sessions were used for official testing and data collection. All participants were asked not to participate in any strenuous exercise at least 24 hours prior to testing, and to ensure they wore the same footwear on each occasion to negate the effects of different shoe design and support structures. Both testing sessions took place on a third generation pitch, which subjects were used to training on twice weekly. Each test consisted of three trials on each limb with 60 seconds rest between trials, and 2-minutes rest between tests, to enable full recovery (28). All tests were conducted in a randomized, counter-balanced order, to negate any potential learning effects. Before familiarization and testing sessions, all participants completed a standardized warm-up protocol (Table 1), following the RAMP system as outlined by Jeffreys (16). This consisted of dynamic exercises progressing from low intensity and generic movements to higher intensity with more specific movement patterns. A 3-minute rest period was prescribed between the completion of the warm up and commencement of the first test.

*** INSERT TABLE 1 ABOUT HERE ***

Single leg countermovement jump (SLCMJ). Subjects stood in an upright position, hands on hips, with feet positioned hip width apart. One leg lifted off the floor to approximately mid shin height of the standing leg. Subjects then squatted to a self-selected depth followed by a quick upward vertical movement, jumping as high as possible. The jumping leg had to remain fully extended and hands fixed to hips; any deviation from this resulted in a retrial after a 60-second rest period. Jump height was calculated by the flight time method using the “My Jump” iPhone application, which has been shown to be a reliable method for quantifying this outcome measure (1).

Single Hop (for distance). Subjects begin by standing on a designated testing leg with hands on hips and their toes behind the starting line. Subjects were then instructed to hop as far forward as possible and land on the same leg (Figure 1). Upon landing, participants were required to 'hold and stick' their position for two seconds. Failure to stick the landing resulted in a void trial and a retrial after a 60-second rest. This was consistent across all trials for all hop tests. The distance hopped from the starting line to the point where the subject's landing heel hit in the final position was then recorded to the nearest centimeter using a standard measuring tape (also used for all hop tests).

Triple Hop (for distance). Subjects begin by standing on the designated testing leg, hands on hips with their toes behind the starting line. Subjects were instructed to take three maximal hops forward, landing on the same leg throughout and holding and sticking the 3rd contact for two seconds (Figure 1). The distance hopped from the starting line to the landing position of the subjects' heel of the same limb was then measured and recorded to the nearest centimeter.

Crossover Hop (for distance). Subjects began by standing on the designated testing leg, with their toes behind the starting line. If subjects were hopping with their right leg, they started the test on the right side of the measuring tape and vice versa if they started on the left limb. Subjects were instructed to take three consecutive maximal hops forward; each time crossing over an area measuring 15 cm wide landing on the same leg throughout (Figure 1). As per previous hop testing protocols, all subjects were required to stick the final landing for two seconds. The distance hopped from the starting line to the point where the subject's heel hit on completion of the third jump was measured and recorded to the nearest centimeter.

*** INSERT FIGURE 1 ABOUT HERE ***

Statistical Analyses

All data was initially computed as means and standard deviations (SD) in Microsoft Excel™. The coefficient of variation (CV) and standard error of the measurement (SEM) were used to quantify absolute reliability, whilst the intraclass correlation coefficient (ICC) with absolute agreement quantified relative reliability. Interpretation of ICC values was in accordance with previous research where values > 0.75 are considered 'excellent', 0.4-0.75 are considered 'good', and anything < 0.4 is considered 'poor' (10), and CV's were deemed acceptable if < 10% (6). Both within and between-session reliability were calculated with the CV being quantified in Microsoft Excel™ and all other statistics computed in SPSS (SPSS Inc., Chicago, IL, USA). In addition, the smallest worthwhile change (SWC) was calculated by multiplying the pooled SD by 0.2 (33), and then converted to a percentage. Finally, inter-limb asymmetries were calculated using the equation: (maximum value – minimum value)/maximum value x 100 which has been previously used in research for youth soccer athletes (27), and was quantified from an average of the three trials.

RESULTS

Within-session reliability for the first testing session was excellent (Table 2: ICC range = 0.82-0.99; SEM range = 0.11-0.42; and CV range = 2.6-6.0%). Within-session reliability for testing session two was also excellent (Table 3: ICC range = 0.81-0.99; SEM range = 0.16-0.49; and CV range = 2.8-5.4%). Between-session reliability for all hop tests was good to excellent (Table 4: ICC range = 0.72-0.99; pooled CV range = 2.7-5.7%; and SWC range = 2.35-5.95%). Inter-limb differences were ≤ 6.12% during both sessions for all tests (Tables 2 and 3).

*** INSERT TABLES 2-4 ABOUT HERE ***

DISCUSSION

The aims of the present study were to determine within and between-session reliability, and quantify inter-limb asymmetries from four unilateral jump tests in in elite youth female soccer players. Given the paucity of data about both reliability and asymmetries in this population, this research study was warranted.

Tables 2 and 3 highlight within-session reliability data for both data collection sessions. Cormack et al. (6) suggest that acceptable typical error (CV) values should fall below 10% and with the highest CV value of 6.0% reported across both sessions; within-session reliability was good to excellent. In general, the SLCMJ provided the smallest typical error (2.6-3.5%) and the crossover hop the largest (3.6-6.0%). Although anecdotal, when the repeated nature of the crossover hop is combined with the inclusion of some lateral movement, it is unsurprising that larger variability is seen within this test. However, all values are still deemed to be acceptable. A similar trend is followed when interpreting results from the ICC with the reliability of the SLCMJ near perfect (0.99). In contrast, the crossover hop showed ICC values of 0.82-0.83 on the right limb; however, reliability was notably better on the left side (0.93-0.94). Regardless, with results being interpreted in line with suggestions by Fleiss, (10), all values are still considered excellent.

Table 4 portrays between-session reliability results, highlighting that all jump tests had good to excellent levels of reliability when using the ICC (0.72-0.96). The single leg hop was shown to be one of the least reliable test between testing sessions (ICC = 0.72-0.76), perhaps indicating that there may have been a slightly larger learning effect compared to the other protocols. However, it should be acknowledged that the only value considered 'good' was close to the 0.75 threshold needed to be classed as 'excellent'. Pooled CV values followed a similar trend to the within-session results with the SLCMJ showing the greatest consistency

(2.7-3.2%) and the crossover hop showing the greatest variability (4.0-5.7%). However, all results should be interpreted with confidence which is important for this age group given their lack of experience with plyometric training. Furthermore, any recorded data from such tests can be used to monitor progress over time (33) or as outcome measures to assess the effectiveness of targeted training interventions (3).

Tables 2 and 3 also show inter-limb asymmetry data with results highlighting small between-limb differences for all tests (≤ 6.12%). Despite these small values, the SLCMJ would appear to demonstrate notably larger asymmetries (5.10-6.12%) than any of the horizontal hop tests (0.24-2.02%). When interpreting asymmetry data, it is essential to understand that an inter-limb difference can only be classified as 'real' if the value is greater than the intra-limb variability (8), which in the present study is represented by the typical error (CV). The only test to exhibit real asymmetries was the SLCMJ whereas between-limb differences in all other tests can be considered as natural variability during the testing process (3). Asymmetries have been suggested as being a by-product of repeated sporting actions that occur over time (11), and with a young population tested in the present study, it is possible that their training age was too low to impact any limb dominance issues, manifested during horizontal jump testing. Furthermore, although the SLCMJ highlighted real side-to-side differences, the values can still be considered small with asymmetry and injury literature suggesting values between 10-15% as being thresholds to be aware of (15,18,28). From a longitudinal perspective, practitioners should continue to monitor inter-limb asymmetries to ensure that these values and the natural variability during testing remain small (3,5). In addition, a sport such as soccer is characterised by limb dominance (12), so increased exposure to playing and training time may be a potential cause to increase inter-limb differences if they are not monitored closely and programmes manipulated accordingly. Given recent literature highlighted that larger asymmetries may be detrimental to performance (4), it is likely that monitoring asymmetries from a young age is a worthwhile process for practitioners.

PRACTICAL APPLICATIONS

The results from the present study highlight that unilateral jump tests are a reliable testing protocol for elite youth female soccer athletes, which is useful information given the lack of data in this population and their associated reduced plyometric training age. Inter-limb asymmetries appear small in this population which may be a by-product of a lower training age compared to adults. Practitioners can use this information to confidently incorporate unilateral jump testing with youth female athletes. However, it is still suggested that practitioners employ similar methods to quantify reliability data for their own athletes given test consistency may vary between populations. A final note of consideration is that if only one test was selected (due to time-constraints for example); the SLCMJ may be considered as the preferred choice for practitioners due to its ability to expose greater inter-limb asymmetries and stronger reliability than the horizontal hop tests.

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Table 1: Standardized warm up protocol followed prior to testing

Phase	Exercise or Drill	Prescription
Raise heart rate	Light jogging – forward, backwards, side shuffles	5 minutes
Activate and Mobilize	Mini-band lateral shuffle	1 x 8 each side
	Floor glute bridges	1 x 8
	Quadruped thoracic spine extension	1 x 6 each side
	Bodyweight squats	1 x 10
	Multi-planar lunge circuit	1 x 6 each side
	Single leg squat	1 x 5 each side
Potentiate	Single leg hop and stick	1 x 2 each side
	Triple hop (stick final landing)	1 x 2 each side
	Crossover hop (stick final landing)	1 x 2 each side
	Single leg countermovement jump	1 x 2 each side

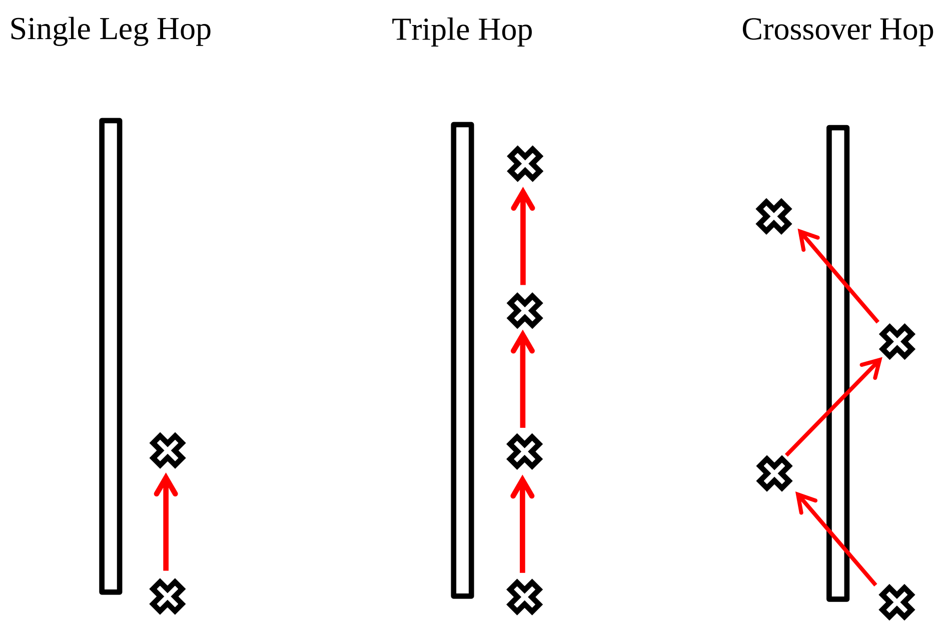

Figure 1: Schematic of horizontal hop tests showing number and direction of hops

Table 2: Mean data (cm) ± standard deviations (SD) for each trial during test session 1, inclusive of within-session reliability data and asymmetry values (calculated from mean scores).

Test	**Trial 1 (SD)**	**Trial 2 (SD)**	**Trial 3 (SD)**	**CV (%)**	**SEM (cm)**	**ICC (95% CI)**	**Mean Scores**	**Asymmetry (%)**
SLH (R)	114 ± 18.7	114 ± 17.3	115 ± 18	4.4	0.33	0.89 (0.79-0.95)	119.2 ± 17.4	1.16 ± 1.80
SLH (L)	116 ± 13.7	115 ± 15.3	117 ± 14.4	3.8	0.37	0.87 (0.74-0.94)	120.6 ± 14.8	
TH (R)	367 ± 56.9	370 ± 49.2	364 ± 48.2	3.0	0.25	0.94 (0.88-0.97)	377.4 ± 52.1	0.24 ± 3.32
TH (L)	360 ± 48.4	364 ± 46.1	372 ± 46.1	3.6	0.33	0.89 (0.79-0.95)	378.3 ± 47.4	
CH (R)	298 ± 54.3	299 ± 43.9	306 ± 53	6.0	0.42	0.82 (0.67-0.92)	319.6 ± 54.4	2.02 ± 3.54
CH (L)	308 ± 55.8	315 ± 61.3	315 ± 62.9	4.3	0.26	0.93 (0.86-0.92)	326.2 ± 59.4	
SLCMJ (R)	9.5 ± 2.6	9.5 ± 2.4	9.6 ± 2.5	2.6	0.11	0.99 (0.98-0.99)	9.8 ± 2.6	5.10 ± 0.14
SLCMJ (L)	9.2 ± 2.8	9.0 ± 2.8	9.0 ± 2.7	3.0	0.11	0.99 (0.97-0.99)	9.3 ± 2.8	

R = Right leg, L = left leg, CV = Coefficient of variation, SEM = Standard error of the measurement, ICC = Intraclass correlation coefficient, CI = confidence intervals, SA = Symmetry angle, SLH = Single leg hop, TH = Triple hop, CH = Crossover hop, SLCMJ = Single leg countermovement jump

Table 3: Mean data (cm) ± standard deviations (SD) for each trial during test session 2, inclusive of within-session reliability data and asymmetry values (calculated from mean scores).

Test	**Trial 1 (SD)**	**Trial 2 (SD)**	**Trial 3 (SD)**	**CV (%)**	**SEM (cm)**	**ICC (95% CI)**	**Mean Scores**	**Asymmetry (%)**
SLH (R)	118 ± 15.2	118 ± 13.4	116 ± 15.4	3.9	0.35	0.88 (0.76-0.95)	121.5 ± 14.3	0.82 ± 2.12
SLH (L)	116 ± 13.5	117 ± 11.4	115 ± 12.8	4.1	0.44	0.81 (0.64-0.91)	120.5 ± 11.3	
TH (R)	376 ± 42.5	372 ± 46.6	367 ± 40.8	3.6	0.35	0.88 (0.76-0.95)	381.4 ± 45.5	0.81 ± 2.62
TH (L)	366 ± 51.2	366 v 47.4	370 ± 44.0	3.3	0.49	0.92 (0.83-0.96)	378.3 ± 49.2	
CH (R)	308 ± 40.5	315 ± 47.1	315 ± 52.0	5.4	0.23	0.83 (0.69-0.93)	329.4 ± 44.6	0.33 ± 4.45
CH (L)	316 ± 54.4	315 ± 57.3	319 ± 54.4	3.6	0.19	0.94 (0.88-0.98)	328.3 ± 50.9	
SLCMJ (R)	9.5 ± 2.6	9.5 ± 2.5	9.6 ± 2.4	2.8	0.27	0.99 (0.97-0.99)	9.8 ± 2.5	6.12 ± 0.14
SLCMJ (L)	9.1 ± 2.7	8.8 ± 2.7	8.9 ± 2.8	3.5	0.16	0.99 (0.97-0.99)	9.2 ± 2.7	

R = Right leg, L = left leg, CV = Coefficient of variation, SEM = Standard error of the measurement, ICC = Intraclass correlation coefficient, CI = confidence intervals, SA = Symmetry angle, SLH = Single leg hop, TH = Triple hop, CH = Crossover hop, SLCMJ = Single leg countermovement jump

Table 4: Best scores for test sessions 1 and 2 ± standard deviations (SD), pooled coefficient of variation (CV) data, between-session intraclass correlation coefficient (ICC) data, and the smallest worthwhile change (SWC).

Test	**Best Scores (SD) Session 1**	**Best Scores (SD) Session 2**	**Pooled CV (%)**	**ICC (95% CI)**	**SWC (%)**
SLH (R)	119.2 ± 17.4	121.5 ± 14.3	4.1	0.76 (0.48-0.89)	2.63
SLH (L)	120.6 ± 14.8	119.4 ± 13.4	4.0	0.72 (0.40-0.88)	2.35
TH (R)	377.4 ± 52.1	381.4 ± 45.5	3.3	0.87 (0.71-0.95)	2.57
TH (L)	378.3 ± 45.0	378.3 ± 49.2	3.5	0.85 (0.65-0.94)	2.49
CH (R)	319.6 ± 54.4	329.4 ± 44.6	5.7	0.79 (0.54-0.91)	3.05
CH (L)	326.2 ± 60.4	328.3 ± 56.9	4.0	0.84 (0.64-0.94)	3.58
SLCMJ (R)	9.8 ± 2.6	9.8 ± 2.5	2.7	0.99 (0.98-0.99)	5.20
SLCMJ (L)	9.3 ± 2.8	9.2 ± 2.7	3.2	0.99 (0.98-0.99)	5.95

R = Right leg, L = left leg, SLH = Single leg hop, TH = Triple hop, CH = Crossover hop, SLCMJ = Single leg countermovement jump