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VERTICAL AND HORIZONTAL ASYMMETRIES ARE RELATED TO SLOWER SPRINTING AND JUMP PERFORMANCE IN ELITE YOUTH FEMALE SOCCER PLAYERS

ABSTRACT

Inter-limb asymmetries have been shown to be greater during vertical jumping compared to horizontal jumping. Notable inter-limb differences have also been established at an early age in male youth soccer players. Furthermore, given the multi-planar nature of soccer, establishing between-limb differences from multiple jump tests is warranted. At present, a paucity of data exists regarding asymmetries in youth female soccer players and their effects on physical performance. The aims of this study were to quantify inter-limb asymmetries from unilateral jump tests and examine their effects on speed and jump performance. Nineteen elite youth female soccer players performed a single leg countermovement jump (SLCMJ), single, triple, and crossover hops for distance and a 20 m sprint test. Test reliability was good to excellent (ICC = 0.81-0.99) and variability acceptable (CV = 1.74-5.42%). A one-way ANOVA highlighted larger asymmetries from the SLCMJ compared to all other jump tests ($p < 0.05$). Pearson's correlations portrayed significant relationships between vertical asymmetries from the SLCMJ and slower sprint times ($r = 0.49-0.59$). Significant negative relationships were also found between horizontal asymmetries during the triple hop test and horizontal jump performance ($r = -0.47$ to -0.58) and vertical asymmetries during the SLCMJ and vertical jump performance ($r = -0.47$ to -0.53). The results from this study highlight that the SLCMJ appears to be the most appropriate jump test for identifying between-limb differences with values ~12% showing negative associations with sprint times. Furthermore, larger asymmetries are associated with reduced jump performance and would

25 appear to be direction-specific. Practitioners can use this information as normative data to be
26 mindful of when quantifying inter-limb asymmetries and assessing their potential impact on
27 physical performance in youth female soccer players.

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29 **Key Words:** Symmetry, speed decrements, jump performance, youth athletes

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44 INTRODUCTION

45 The notion of inter-limb asymmetries refers to the function of one limb in respect to the other
46 and has been a popular source of investigation in recent years. The majority of literature has
47 focused on the prevalence of between-limb differences in multiple testing modalities such as
48 isokinetic dynamometry (14,37), isometric squat or mid-thigh pulls (16,19), back squatting
49 (30,38), and a variety of jumping-based tasks (3,12,27,28). All of the aforementioned
50 methods have been shown to be sensitive when identifying differences between limbs in both
51 athlete and non-athlete populations. Furthermore, it has been stated that inter-limb
52 asymmetries may be a product of the time spent competing in the same sport (18,20).
53 However, their prevalence alone provides limited information as to whether targeted training
54 interventions may be required to minimise their presence. Consequently, understanding
55 whether inter-limb asymmetries have a detrimental impact on physical performance would
56 provide practitioners with more tangible information pertaining to their importance.

57 Jump protocols are a common modality for testing in youth soccer athletes (11,26,32,41,43),
58 most likely because of their ease of implementation (9) which is an important consideration
59 due to the reduced training age in youth athletes. This is supported by Read et al. (31) who
60 suggested that jump tests not only offer a viable method of quantifying inter-limb
61 asymmetries, but that many have successfully been used to prospectively identify athletes at
62 risk of injury (2,22,35). It was also suggested that unilateral jump tests may be the preferred
63 option when quantifying inter-limb differences due to their enhanced sensitivity for detecting
64 differences (10), which in part may be due to the heightened instability associated with single
65 leg tests. Additional literature has acknowledged that no contribution exists from the
66 opposing limb during unilateral tests; therefore, representing a more accurate interpretation of
67 ‘true asymmetries’ (4,9). In addition, because the relationship between multi-planar demands

68 of soccer and different jumping tasks is still unclear (21,28), more than one test should be
69 used to assess asymmetries.

70 Consequently, many unilateral jump tests have been incorporated in the literature to date.
71 Single leg countermovement jumps (SLCMJ) and single, triple, and crossover hops for
72 distance have all displayed strong reliability (ICC range = 0.89-0.99) (10,34,36); thus,
73 practitioners can be confident of their consistency during testing. Dos'Santos et al. (15)
74 recently reported that asymmetries during single and triple hops for distance were not
75 associated with slower change of direction speed times. However, the largest imbalance
76 reported can be considered small (6.25%), with larger deficits ($\geq 10\%$) potentially impacting
77 performance (7). Read et al. (33) investigated the effects of maturation on inter-limb
78 asymmetries using the SLCMJ and single leg hop for distance in elite youth male soccer
79 players. They found that SLCMJ landing forces were significantly higher in those who were
80 circa and post-peak height velocity (PHV). Asymmetries during the single leg hop for
81 distance were small, but reduced even further with age. Although useful, the aforementioned
82 evidence relates to male youth players and currently a paucity of data exists concerning youth
83 female soccer players. Thus, the quantification of inter-limb asymmetries from unilateral
84 jump tests and their relationship with physical performance would be a useful addition to the
85 literature for youth female athletes.

86 Therefore, the primary aim of this study was to assess the relationship between jumping
87 asymmetries and sprint and jump performance in elite youth female soccer players. This
88 could help to determine whether training interventions might be necessary to rectify existing
89 side-to-side differences. A secondary aim was to quantify inter-limb asymmetries from
90 multiple unilateral jump tests in order to provide an asymmetry profile that is currently
91 lacking in elite youth female soccer players.

92 **METHODS**

93 **Experimental Approach to the Problem**

94 After a separate habituation session, data were collected during a single session. The first
95 session allowed players to practice all tests an unlimited number of times until the
96 requirements were fully understood. During data collection, multi-planar jump tests were
97 used to quantify inter-limb asymmetries to represent ecological validity for the population in
98 question, whilst four sets of timing gates were used over 20 m. This enabled split times to be
99 measured for 5, 10, and 20 m sprints and subsequently, multiple relationships to be assessed
100 between asymmetry scores and sprint and jump performance. In addition, test variability was
101 quantified using the coefficient of variation (CV), noting that inter-limb differences are only
102 considered 'real' if greater than test variability (17).

103

104 **Subjects**

105 Nineteen elite youth female soccer players (age: 10 ± 1.1 years; height: 141 ± 7.9 cm; body
106 mass: 35 ± 7.1 kg), were recruited from a Tier 1 Regional Talent Centre (RTC) of a
107 professional soccer club. Players trained for at least 36 weeks per year and were required to
108 take a minimum of 2 x 30-minute structured strength and conditioning training sessions per
109 week. Emphasis at this age was placed on mastering fundamental movement patterns,
110 building strong foundations, enhancing technical competency, and improving general motor
111 control. All subjects were free from injury at the time of testing and informed consent and
112 PAR-Q forms were completed from all relevant parents or guardians as all participants were
113 under the age of 18. Ethical approval was granted from the London Sports Institute ethics
114 committee, Middlesex University.

115

116 **Procedures**

117 Subjects were tested at the same time of day on two separate testing occasions, each
118 separated by 72 hours. Session one was used to familiarize all subjects with the test
119 procedures, enabling them to practice each jump and sprint test as many times as they wanted;
120 although all players were instructed to practice each test a minimum of five times. The
121 second session was used for data collection and during the jump tests; a particular emphasis
122 was placed on landing mechanics, owing to the increased demand of having to land on one
123 limb. All participants were asked not to participate in any strenuous exercise at least 24 hours
124 prior to testing, and to ensure they wore the same footwear on each occasion to negate the
125 effects of different shoe design and support structures. Both sessions took place on a third
126 generation (3G) pitch, which subjects were used to training on twice weekly. Each jump test
127 consisted of three trials on each limb with 60 seconds rest between trials, and 2-minutes rest
128 between tests, in order to allow for full recovery (34). All tests were conducted in a
129 randomized, counter-balanced order, so as to negate any potential learning effects. Prior to
130 familiarization and testing sessions, all participants completed a standardized warm-up
131 protocol, following the RAMP system as outlined by Jeffreys (23). This consisted of dynamic
132 stretches such as multi-planar lunges, inchworms, and spiderman exercises before
133 progressing into practice jumps and sprints at 60, 80, and 100% of perceived maximum effort.
134 A 3-minute rest period was prescribed between the warm up and the first test.

135 *Single leg countermovement jump (SLCMJ).* Subjects stood in an upright position, hands on
136 hips, with feet positioned hip width apart. To begin the test, one leg was lifted off the floor to
137 approximately mid shin height of the standing leg. Subjects then performed a
138 countermovement to a self-selected depth followed by a quick upward vertical movement,

139 triple extending at the ankle, knee, and hip with the intention of jumping as high as possible.
140 The jumping leg had to remain fully extended and hands fixed to hips; any deviation from
141 this required the trial to be re-taken after a 60-second rest period. Jump height was calculated
142 by the flight time method using the “My Jump” iPhone application, which has been shown
143 previously to be a reliable method (1).

144 *Single leg hop (for distance)*. Subjects begin by standing on the designated testing leg with
145 their hands on hips and their toes behind the starting line. Subjects were then instructed to
146 hop as far forward as possible and land on the same leg. Upon landing, participants were
147 required to ‘hold and stick’ their position for two seconds. Failure to stick the landing
148 resulted in a void trial and the jump being retaken after a 60-second rest. This was consistent
149 across all trials for all hop tests. The distance hopped from the starting line to the point where
150 the subject’s landing heel hit in the final position was then recorded to the nearest centimetre
151 using a standard measuring tape fixed to the floor (also used for all hop tests).

152 *Triple hop (for distance)*. Subjects begin by standing on the designated testing leg, hands on
153 their hips with their toes behind the starting line. Subjects were instructed to take three
154 maximal hops forward (landing on the same leg throughout) with the intention of minimising
155 ground contact times after the first and second hops. When landing from the final hop,
156 subjects were required to ‘stick’ the landing and hold for two seconds. Failure to stick the
157 final landing resulted in a void trial and the jump being retaken after a 60-second rest. The
158 distance hopped from the starting line to the landing position of the subjects’ heel was then
159 measured and recorded to the nearest centimetre.

160 *Crossover hop (for distance)*. Subjects began by standing on the designated testing leg, with
161 their toes behind the starting line. If subjects were hopping with their right leg, they started
162 the test on the right side of the measuring tape and vice versa if they started on the left leg.

163 Subjects were instructed to take three consecutive maximal hops forward; each time crossing
164 over an area measuring 15 cm wide landing on the same leg throughout. As per previous hop
165 testing protocols, all subjects were required to stick the final landing for two seconds. Failure
166 to do so resulted in a void trial and the jump being retaken after a 60-second rest. The
167 distance hopped from the starting line to the point where the subject's heel hit on completion
168 of the third jump was measured and recorded to the nearest centimetre.

169 *5, 10, and 20 m Sprints.* Electronic timing gates (Brower Timing Systems, Utah, USA) were
170 positioned at 0, 5, 10, and 20 m to enable multiple splits to be measured during a single sprint.
171 Subjects started the test in a staggered 2-point stance with toes positioned 30 cm behind the
172 start line so as to not break the beam of the timing gates prior to the initiation of the test.
173 When ready, subjects sprinted through the final set of timing gates allowing for 5, 10, and 20
174 m split times which were recorded to the nearest hundredth of a second.

175

176 **Statistical Analyses**

177 All data was initially computed as means and standard deviations (SD) in Microsoft Excel™
178 and all additional analyses computed in SPSS (SPSS Inc., Chicago, IL, USA). All data were
179 checked for normality using the Shapiro-Wilk test and within-session reliability of test
180 measures were computed using intraclass correlation coefficient (ICC) with absolute
181 agreement and the CV. Interpretation of ICC values was in accordance with previous research
182 by Koo and Li, (24) where values > 0.9 = excellent, 0.75-0.9 = good, 0.5-0.75 = moderate,
183 and < 0.5 = poor and CV values were considered acceptable if < 10% (13,40). Inter-limb
184 asymmetries were quantified as the percentage difference between the two limbs (see
185 Equation) rather than using a reference value for limb dominance as has been previously
186 suggested (5,6). A one-way analysis of variance (ANOVA) was used to examine for potential

187 differences in asymmetry between jumping tasks with statistical significance set at $p < 0.05$.
188 Pearson's r correlation was utilised to determine the strength of the relationship between
189 asymmetries measured during each jump test and sprint times, and between asymmetry
190 scores and jump performance with statistical significance set at $p < 0.05$.

191

192 *Equation: $100/(\text{Max Value (right and left)} - \text{Min Value (right and left)}) + 100$ (6)*

193

194 **RESULTS**

195 All data were normally distributed ($p > 0.05$) and each test had acceptable between trial
196 consistency with all CV values $< 10\%$, and good or excellent ICC's (Table 1). Mean
197 asymmetry values are presented in Table 1 and the SLCMJ showed greater ($p < 0.05$) side-to-
198 side differences (approximately double) compared to all other jump tests. Correlations
199 between jump tests/asymmetries and sprint tests are shown in Table 2 and correlations
200 between asymmetries and jump performance in Table 3. Results indicated that larger vertical
201 asymmetries were associated ($p < 0.05$) with slower sprint times (Table 2). Asymmetries
202 during the triple hop test were associated ($p < 0.05$) with reduced horizontal jump
203 performance and vertical asymmetries were associated ($p < 0.05$) with reduced vertical jump
204 performance (Table 3). Individual asymmetry data have also been included (Figures 1-4).

205

206 *** INSERT TABLES 1-3 ABOUT HERE ***

207 *** INSERT FIGURES 1-4 ABOUT HERE ***

208

209 **DISCUSSION**

210 The aims of this study were to test for the presence of asymmetries during vertical and
211 horizontal jump tests in elite youth female soccer players and examine relationships between
212 asymmetries measured in these different tasks and sprint and jump performance. Results
213 indicated that asymmetry is task-dependent as the SLCMJ produced significantly greater
214 between-limb differences compared to all horizontal hop tests. Significant relationships were
215 also present between asymmetries in the SLCMJ and sprint times measured across distances
216 of 5, 10, and 20 m. No significant relationships were found between asymmetries during
217 horizontal hop tests and any of the sprint distances measured. Significant negative
218 relationships were also found for horizontal asymmetries in the triple hop test and horizontal
219 jump performance, and asymmetries in the SLCMJ and vertical jump performance.

220 The first point to consider from these results is that the SLCMJ produced significantly greater
221 asymmetries than all other jump tests which is in agreement with previous research. Lockie et
222 al. (25) reported asymmetries of 10.4 and 5.1% during the SLCMJ and single leg broad jump
223 respectively (also called single leg hop for distance). It is possible that vertical jumping may
224 be more sensitive at identifying asymmetries given that the results in the present study and
225 that of Lockie et al. (25) found inter-limb differences ~50% greater than any horizontal jump
226 test. Furthermore, the sample used in Lockie's study were adult male team sport athletes and
227 with a similar trend now found in the present study (from a completely different sample),
228 these results require an explanation. Intuitively, this seems quite difficult to fully explain;
229 however, considering children learn and practice horizontal hopping activities (such as hop
230 scotch) from an early age (39,42), it could be argued that these movement patterns are
231 practiced more than unilateral vertical jumping for youth athletes. This may explain why
232 inter-limb differences are notably less in horizontal jumping tasks; however, further research
233 is still warranted to fully corroborate this theory.

234 In addition to significantly larger inter-limb differences from the SLCMJ, this was the only
235 asymmetry that had significant correlations with sprint times (Table 2). Furthermore, all r
236 values from the SLCMJ asymmetry scores are positive, indicating that larger asymmetries
237 may be indicative of slower sprinting; noting that the fastest time is always desirable in sport.
238 Consequently, practitioners who measure between-limb asymmetries from jump tests should
239 be mindful of differences ~12% and aim to quantify whether they are associated with any
240 decrements in performance. This seems prudent advice given the notion that asymmetries >
241 10% have been suggested to potentially impact physical and sports performance (7,9) and the
242 results of the present study are in agreement with this consensus. Cumulatively, given that the
243 SLCMJ appears more sensitive at identifying inter-limb differences and shows stronger
244 relationships to decrements in sprint speed compared to horizontal hops, these results indicate
245 that the SLCMJ may be the most appropriate jump test to identify the prevalence of inter-
246 limb asymmetries in athletes.

247 When examining the role of inter-limb differences on jump performance, the results show
248 interesting findings (Table 3). Firstly, asymmetries from the triple hop test were significantly
249 associated with reduced performance in all horizontal jump tests, but no significant
250 correlations were found with the SLCMJ. In addition, asymmetries from the SLCMJ were
251 also significantly associated with reduced jump performance during vertical jumping only.
252 Recent literature has indicated that determinants of unilateral jump performance are
253 direction-specific (29), and it would appear that asymmetries may follow this trend as well.
254 Although anecdotal, it seems logical to assume that if asymmetries are minimised during
255 unilateral tests that jump performance may also improve (in the same direction). Given that
256 no contribution exists from the non-jumping leg during unilateral tests (9), a larger
257 asymmetry will naturally result in one limb performing poorly in respect to the other. What is
258 apparent from the present study is that horizontal jumping appears unaffected by vertical

259 asymmetries, and vice versa. Thus, with inter-limb differences being direction-specific, it is
260 suggested that soccer practitioners consider monitoring asymmetries in multiple directions
261 (9,31) with a view to reducing these differences to potentially enhance jump performance.

262 A further consideration relates to the individual nature of asymmetries. Firstly, it is
263 interesting to note that the single effort tests showed the greatest individual variation in
264 asymmetry scores (SLCMJ range = 0.0-36.4%; single leg hop range = 0.7-25%) compared to
265 the repeated effort tests (triple hop range = 0.3-14.2% and crossover hop range = 0.6-11.7%)
266 (Figures 1-4). Previous research has highlighted that the single leg hop is able to detect larger
267 asymmetries than other commonly used alternatives such as the triple hop or crossover hop
268 tests (35). Thus, it is plausible that between-limb differences may 'even out' during repeated
269 efforts by virtue of momentum being built throughout the test, although further research is
270 again required to fully corroborate this theory. In addition, there was variation in the direction
271 of asymmetry across tests for individual subjects (Figures 1-4). It is worth noting that this too
272 appears to be test-specific with only two subjects demonstrating larger scores on the same leg
273 for each test. This further highlights the individual nature of asymmetries and the requirement
274 for multiple tests (9,31) in order to better understand their prevalence and interaction with
275 physical performance.

276 When measuring asymmetries, practitioners should also be mindful of the scores in relation
277 to test variability (CV). Exell et al. (17) suggest that asymmetries can only be considered real
278 if inter-limb differences are greater than the variability during test protocols. In the present
279 study, all CV values were < 10% which is considered acceptable (13) and with each jump test
280 demonstrating a greater asymmetry score than the CV, these between-limb differences can be
281 considered real. Despite the prevalence of these asymmetries, it should be reiterated that only
282 differences in the SLCMJ were associated with sprint decrements; thus, their reduction could
283 be considered a viable aim during targeted training interventions. Furthermore, additional

284 factors such as technique and strength may be more prominent reasons why sprint decrements
285 exist (43); thus, coaches should consider the relevance of these when aiming to optimise
286 sprint performance.

287 When interpreting the findings of the current study, practitioners should be mindful of some
288 limitations. Firstly, these results are only applicable to youth female soccer players and future
289 research should aim to provide comparisons across gender and sports where possible. In
290 addition, the impact of jumping asymmetries on physical performance metrics should be
291 investigated across multiple age groups in youth female athletes; thus, highlighting the
292 impact that maturation may have. Read et al. (33) noted that landing force asymmetries
293 during the SLCMJ increased during maturation, but asymmetries in distance from the single
294 leg hop test actually decreased, and it would be useful to consider these results across
295 multiple age groups in female athletes.

296

297 **PRACTICAL APPLICATIONS**

298 Unilateral jump tests are easy to administer and ecologically valid, especially for team sport
299 athletes. The SLCMJ appears to be the most appropriate test for identifying inter-limb
300 asymmetries in youth female soccer players and these differences are associated with slower
301 sprint times. Consequently, practitioners should be mindful of between-limb differences $> 10\%$
302 considering the impact this may have on physical performance. This threshold may be used
303 cautiously to determine if training interventions are deemed necessary for the reduction of
304 asymmetry. Currently, little is known about strategies for the reduction of asymmetries;
305 however, recent literature highlighted that a combination of bilateral and unilateral strength
306 and jump training will likely assist in minimizing these differences (8). However, it was also
307 acknowledged that further interventions are required in order to fully comprehend the optimal

308 methods associated with the reduction of asymmetries; thus, further research is needed in this
309 area.

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465 Table 1: Mean scores (standard deviation), mean asymmetry percentages, and reliability data
 466 for each jump test ($N = 19$)

Test	Mean \pm SD	Asymmetry %	CV (%)	ICC (95% CI)
SLCMJ (R)	9.79 \pm 2.56	12.54*	2.82	0.99 (0.97-0.99)
SLCMJ (L)	9.29 \pm 2.79		3.51	0.99 (0.97-0.99)
SLH (R)	119.21 \pm 17.40	6.79	3.94	0.88 (0.76-0.95)
SLH (L)	120.58 \pm 14.84		4.18	0.81 (0.64-0.91)
THOP (R)	377.42 \pm 52.14	6.81	3.65	0.86 (0.76-0.95)
THOP (L)	378.26 \pm 45.04		3.37	0.92 (0.83-0.96)
XHOP (R)	319.58 \pm 54.43	5.81	5.42	0.83 (0.67-0.93)
XHOP (L)	326.21 \pm 60.43		3.66	0.94 (0.88-0.98)
5m	1.33 \pm 0.15	-	3.69	0.91 (0.84-0.99)
10m	2.21 \pm 0.22	-	2.72	0.94 (0.89-0.99)
20m	3.85 \pm 0.36	-	1.74	0.96 (0.94-0.99)
<p>* denotes significantly higher asymmetry value than all other jump tests ($p < 0.05$) CV = coefficient of variation, ICC = intraclass correlation coefficient, CI = confidence intervals, SLCMJ = single leg countermovement jump, SLH = single leg hop, THOP = triple hop, XHOP = crossover hop, R = right, L = left, m = metres</p>				

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471 Table 2: Correlations between speed tests and jump tests and asymmetry percentages

	SLH (R)	SLH (L)	SLH Asym	THOP (R)	THOP (L)	THOP Asym	XHOP (R)	XHOP (L)	XHOP Asym	SLCMJ (R)	SLCMJ (L)	SLCMJ Asym
5m	-0.30	-0.38	-0.33	-0.22	-0.39	0.35	-0.38	-0.35	0.25	-0.09	-0.27	0.49*
10m	-0.56*	-0.56*	0.12	-0.55*	-0.62**	0.25	-0.61**	-0.66**	0.14	-0.31	-0.49*	0.52*
20m	-0.75**	-0.59**	0.09	-0.70**	-0.59**	0.26	-0.71**	-0.75**	0.37	-0.57*	-0.68**	0.59**
<p>** denotes significant correlation at $p < 0.01$, * denotes significant correlation at $p < 0.05$ SLH = Single leg hop, Asym = Asymmetry, THOP = Triple hop, XHOP = Crossover hop, SLCMJ = Single leg countermovement jump, R = Right, L = Left</p>												

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473 Table 3: Correlations between asymmetry percentages and jump test scores

	SLH (R)	SLH (L)	THOP (R)	THOP (L)	XHOP (R)	XHOP (L)	SLCMJ (R)	SLCMJ (L)
SLH %	-0.13	-0.23	-0.18	-0.12	-0.08	-0.12	-0.07	0.01
THOP %	-0.53*	-0.56*	-0.48*	-0.47*	-0.58**	-0.47*	-0.15	-0.33
XHOP %	-0.40	-0.46	-0.29	-0.43	-0.41	-0.45	-0.44	-0.38
SLCMJ %	-0.31	-0.14	-0.39	-0.33	-0.34	-0.45	-0.47*	-0.53*
<p>** denotes significant correlation at $p < 0.01$, * denotes significant correlation at $p < 0.05$ SLH = Single leg hop, THOP = Triple hop, XHOP = Crossover hop, SLCMJ = Single leg countermovement jump, R = Right, L = Left</p>								

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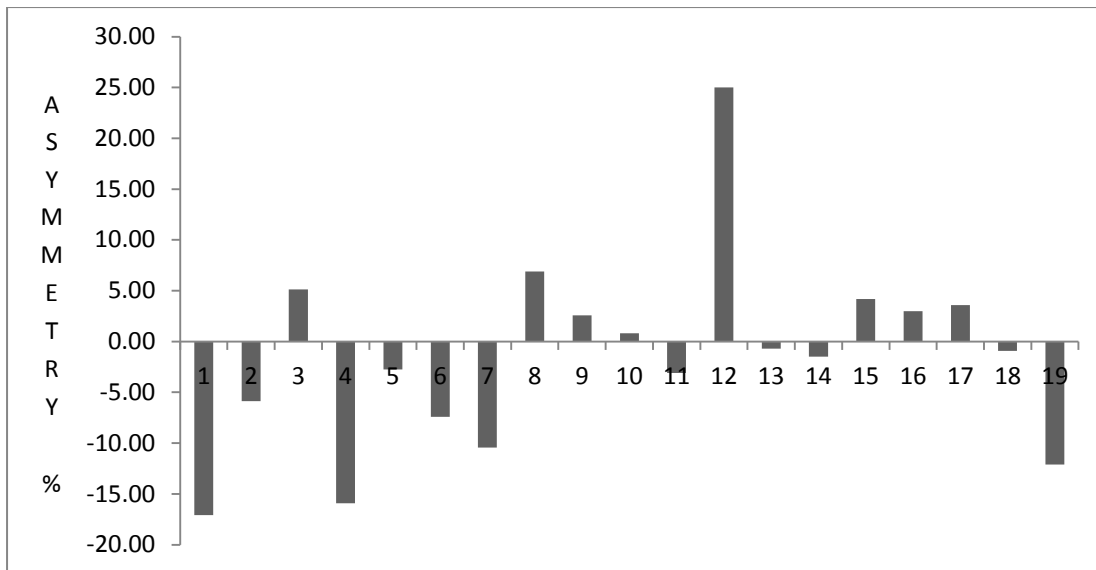


Figure 1: Individual asymmetry percentages for the single leg hop test (negative values are indicative of raw scores being greater on the left limb).

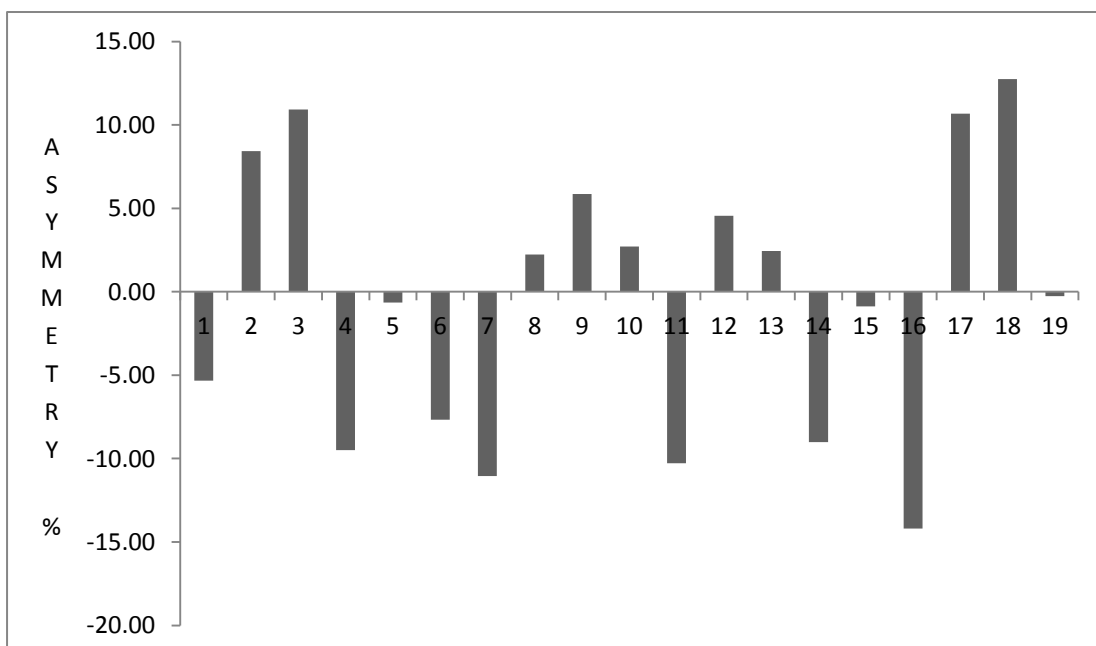


Figure 2: Individual asymmetry percentages for the triple hop test (negative values are indicative of raw scores being greater on the left limb).

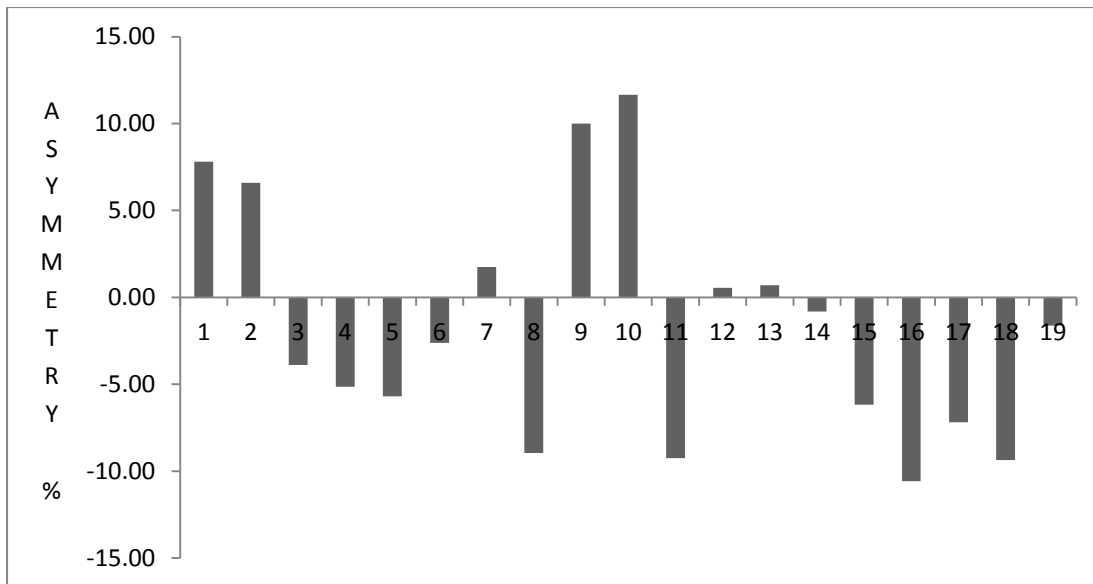


Figure 3: Individual asymmetry percentages for the crossover hop test (negative values are indicative of raw scores being greater on the left limb).

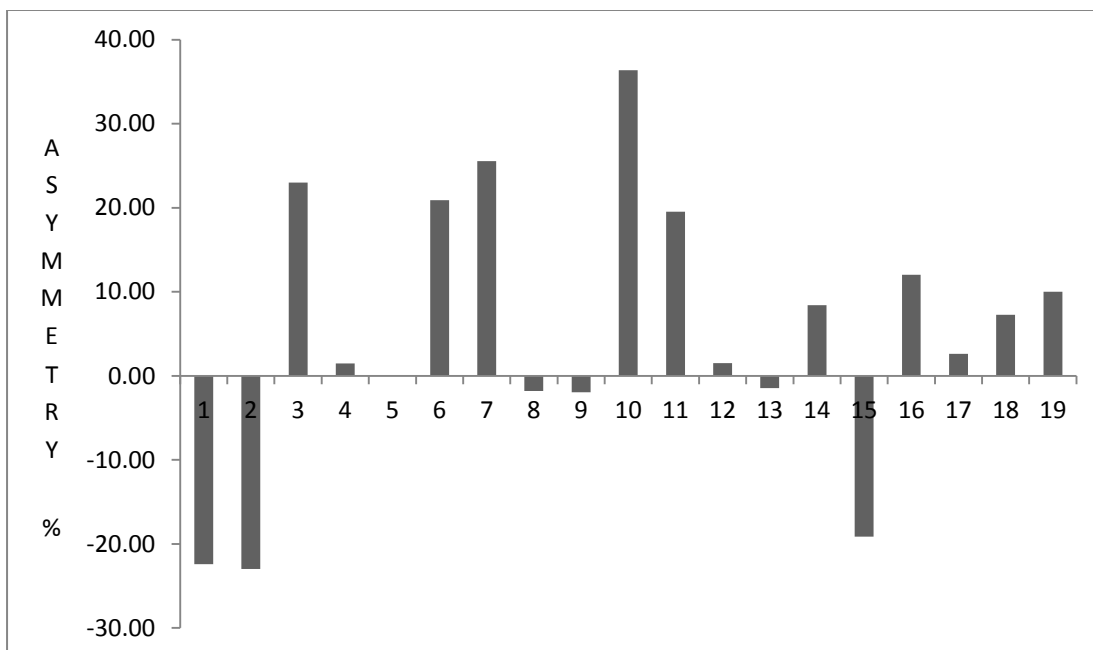


Figure 4: Individual asymmetry percentages for the single leg countermovement jump test (negative values are indicative of raw scores being greater on the left limb).