THE EFFECTS OF A COMPETITIVE SOCCER MATCH ON JUMP PERFORMANCE AND INTER-LIMB ASYMMETRIES IN ELITE ACADEMY SOCCER PLAYERS

ABSTRACT

The purpose of the present study was to investigate the effects of a competitive soccer match on jump performance and inter-limb asymmetries over incremental time points during a 72-hour (h) period. Fourteen elite adolescent players from a professional English category three academy performed single leg countermovement jumps (SLCMJ) pre, post, 24, 48, and 72-h post-match on a single force platform. Eccentric impulse, concentric impulse, peak propulsive force, jump height, peak landing force, and landing impulse were monitored throughout. Inter-limb asymmetries were also calculated for each metric as the percentage difference between limbs. Significant negative changes ($p < 0.05$) in jump performance were noted for all metrics at all time points, with the exception of jump height. Inter-limb asymmetries were metric-dependent and showed very large increases, specifically post-match, with a trend to reduce back towards baseline values at the 48-h time point for propulsive-based metrics. Asymmetries for landing metrics did not peak until the 24-h time point and again reduced towards baseline at 48-h. The present study highlights the importance of monitoring distinct jump metrics, as jump height alone was not sensitive enough to show significant changes in jump performance. However, inter-limb asymmetries were sensitive to fatigue with very large increases post-match. More frequent monitoring of asymmetries could enable practitioners to determine whether existing imbalances are also associated with reductions in physical performance or increased injury risk.

Key Words: Performance monitoring, imbalances, recovery

26 **INTRODUCTION**

27 During match play, soccer athletes are required to perform repeated high intensity, intermittent, and

28 multi-directional actions in unpredictable environments. Specifically, jogging, sprinting, jumping, and

29 changes of direction are common in soccer which frequently require high levels of unilateral force

30 production (3,32,37). Mohr et al. (33) documented approximately 1300 individual or combinations of

31 these actions throughout match-play, which have been shown to occur and subsequently change on

32 average every five seconds. With players consistently required to perform these actions and react to

33 external stimuli such as opponents and ball trajectory to name just a couple, asymmetrical loading is a

34 natural consequence; thus, inter-limb asymmetries are likely a by-product of the sport which has been

35 shown in comparable team sport athletes (23). In addition, the action of kicking is also likely to

36 contribute to inter-limb differences in soccer players due to the inherent nature of the non-kicking limb

37 required to stabilize each player (and thus absorb ground reaction force) during the action itself.

38 Furthermore, inter-limb asymmetries have been negatively associated with sports performance markers

39 (6,9,25,31), in addition to increased injury risk about the hip (5), knee (14) and ankle (18). Thus,

40 quantifying and monitoring changes in asymmetry could be deemed important to both maximize

41 physical performance and reduce potential injury risk.

42 The relationship between fatigue and physical performance has been found increasingly important as

43 reduced physical performance inclusive of: total distance covered, high speed running, sprint distance,

44 accelerations, and decelerations (1,45) have also been noted during the latter periods of each half.

45 Chronic effects of neuromuscular fatigue have also been shown to remain up to 48 hours post-match

46 (2,27,44). Within the available literature, simulated match protocols have been utilized to induce player

47 fatigue and monitor both their acute and chronic effects on performance. Significant intra-limb

48 decreases of 13-15% in functional hamstrings to quadriceps strength ratio (H:Q) have been shown

49 following the Loughborough intermittent shuttle test and a soccer-specific aerobic field test,

50 respectively (10,43). Soccer players are generally involved in > 70 matches per season with ~3-6

51 training sessions every week, leaving little time for recovery (27,41). Thus, the time course of residual

52 periods where elevated asymmetry may be present also requires examination to inform training

53 prescription and identify vulnerable periods where players may be at a greater risk of injury.

54 Previous studies have focused on the use of isokinetic dynamometry to measure inter-limb asymmetries

55 (14,16,43). Although useful, isokinetic assessments involve isolated joint actions under the constraints

56 of laboratory conditions and are likely to be time-inefficient in comparison to alternative field-based

57 tests. More recent investigations have highlighted the use of unilateral jump tests to quantify

58 asymmetries in soccer players such as the single leg countermovement jump (SLCMJ) and various hop

59 tests (9). Bishop et al. (9) reported jump height asymmetries of ~12% in youth female players from the

60 SLCMJ, which were double that of any horizontal hop tests. Furthermore, these inter-limb differences

61 were associated with reduced sprint ($r = 0.49$ to 0.59) and jump performance ($r = -0.47$ to -0.58)

62 suggesting that players with smaller asymmetries outperformed those with larger differences. However,

63 test protocols in the aforementioned study were performed when players were fresh. At present, the

64 association between side-to-side differences and fatigue in soccer is particularly scarce with studies

65 only using simulated protocols to induce fatigue (10,16,29,43). These protocols exclude the auxiliary

66 actions synonymous with soccer (such as physical duals); thus, not providing a true representation of

67 the demands of competitive match-play.

68 Therefore, the first aim of the present study was to quantify inter-limb asymmetries in a cohort of elite

69 academy soccer players. The second aim was to determine the effects that a competitive soccer match

70 has on these side-to-side differences. The final aim was to monitor these asymmetries over a 72-h

71 period, which would provide an insight into the relationship between asymmetries, fatigue, and

72 recovery. It was hypothesized that asymmetries would significantly increase post-match with notable

73 reductions seen throughout the 72-h recovery period.

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78   **METHODS**

79   **Experimental Approach to the Problem**

80   This study examined the acute effects of a single 90-minute soccer match during the in-season period

81   on inter-limb asymmetries in elite male youth soccer players throughout a 72-h time period.

82   Asymmetries were measured using the SLCMJ with all testing conducted on a uniaxial force platform.

83   The SLCMJ had been included in previous strength and conditioning programs bi-weekly for up to six

84   weeks pre-testing, ensuring that all players were fully familiar with the testing protocols. In addition, a

85   complete simulated familiarization session was carried out seven days prior to the experimental trial.

86   Assessments were conducted at scheduled intervals: two hours pre-match, one hour post-match and 24-

87   h, 48-h, and 72-h post-match. To limit external influences, subjects were asked to maintain regular diet

88   and sleeping habits throughout the duration of the study, (details of which were previously provided to

89   players as part of the club's in-house player development program). Within-session reliability was

90   computed three ways at each time point, noting that reliability of some force platform metrics have been

91   affected when athletes are in a fatigued state (21).

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93   **Subjects**

94   Fourteen elite adolescent male soccer players (age: 17.6 ± 0.5 yr; body mass: 63.2 ± 6.7 kg; height: 1.77

95   ± 0.8 m) from a professional English category three academy volunteered to participate in this study.

96   All subjects were regularly completing six hours of technical soccer training and three hours of

97   supplementary strength and conditioning training per week. All subjects had a minimum soccer specific

98   and resistance training age of two years. All participants were free from injury and illness at the time of

99   testing and for the duration of the study period. Parental and participant consent was obtained prior to

100   commencement of the study owing to the participant age and ethical approval was granted from the

101   appropriate institutional review board.

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103   **Procedures**

104 *Single Leg Countermovement Jumps (SLCMJ).*

105 Participants stood on the center of a force plate (400 series performance force plate; Fitness Technology,

106 Australia) operating at 600 Hz, motionless for 2-seconds enabling their system mass to be calculated.

107 Upon instruction, subjects performed a countermovement to a self-selected depth followed immediately

108 by triple extending at the ankles, knees, and hips performing a maximal effort vertical jump. Instructions

109 were to "jump as fast and as high as possible after my countdown". Subjects were required to keep their

110 hands on hips and legs fully extended at all times during the flight phase of the jump; any deviation

111 from these resulted in a void trial and subsequently retaken after a 30-second rest period. The non-

112 jumping limb was required to remain slightly flexed at the hip and knee so that the foot was hovering

113 approximately parallel to the mid-shin of the jumping limb, with no swinging allowed. This was

114 monitored closely by an accredited strength and conditioning coach to ensure consistency throughout

115 all testing protocols. Prior to the assessment protocol, participants completed a standardized warm up

116 consisting of lower body dynamic stretches (multi-planar lunges, inchworms, 'world's greatest stretch'

117 and squat variations) and practice jumps at 60, 80, and 100% of maximum perceived effort. For data

118 collection, all subjects performed three trials on each limb at each time point, separated by a 30-second

119 rest period between each trial.

120 Force-time data were analyzed to obtain the dependant variables and manually extracted before being

121 transferred to a personal computer at 600 Hz though USB, which was initially examined through custom

122 made software (Ballistic measurement system, XPV7; Fitness Technology, Australia). The dependant

123 variables for the propulsive phase were: eccentric impulse (the sum of impulse from the end of

124 unweighting period up until the end of the braking phase), concentric impulse (the sum of impulse from

125 the end of the braking phase up until take off), peak force (maximum force obtained during the

126 propulsive phase of the jump), and jump height (jump height was calculated using the velocity at take-

127 off). For the landing phase: landing impulse (the sum of impulse upon landing up until peak landing

128 force) and peak landing force (maximum force obtained during the landing phase of the jump) were all

129 later calculated in Microsoft Excel with force thresholds calculated from body weight $\pm$ 5 standard

130 deviations (SD) (11,17,36).

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Statistical Analysis

All statistical analysis was completed using SPSS Statistics software (version 21.0; SPSS, Inc., Armonk, NY, USA) with data presented as mean ± SD. The normality of data was identified using the Shapiro-Wilk test. Previous research has highlighted reduced consistency and reliability when interpreting athlete data in a fatigued state (12); thus, reliability was computed at each time point. Reliability was calculated for each metric using the coefficient of variation (CV), a two-way random intraclass correlation coefficient (ICC) with absolute agreement and 95% confidence intervals, and the standard error of the measurement (SEM). CV were calculated in Microsoft Excel using the formula (SD/average)*100 and the SEM computed via the formula $SD*\sqrt{(1-ICC)}$. ICC's ≥ 0.70 and CV < 10% were considered acceptable (4,12). A one-way repeated measures ANOVA was used to compare the dependant variables in relation to each time point with statistical significance accepted at $p < 0.05$ and post-hoc Bonferroni testing was used when differences were identified. Cohen's d effect sizes (ES) were calculated to determine magnitude of change and interpreted in line with previous suggestions: trivial = < 0.35; small = 0.35-0.80; moderate = 0.80-1.5; large = > 1.5 (40). Finally, inter-limb asymmetries were quantified using a standard percentage difference method: 100/(max value)*(min value)*-1+100 in line with previous suggestions (8), and the change in asymmetries were reported at each time as a percentage change relative to the baseline value.

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160 **RESULTS**

161 **Within-session Reliability**

162 Upon further analysis illustrated in Table 1, it was found that the majority of metrics demonstrated

163 acceptable reliability and consistency in values. However, jump height and peak landing GRF were

164 found to show notably lower reliability (ICC ≤ 0.69), in addition to landing impulse and concentric

165 impulse which demonstrated remarkably high variability (CV range = 18 to 30%) across a variety of

166 different time points.

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168 *** INSERT TABLE 1 ABOUT HERE ***

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170 **Change in Mean Scores**

171 A representation of all mean data and their subsequent changes in performance for each time point are

172 shown in Table 2. Group means were found to significantly ($p < 0.05$) decrease from baseline at all time

173 points for eccentric impulse, peak propulsive GRF and landing impulse, and significantly increase for

174 peak landing GRF. Significant decreases were also found from post and 24-h to 48-h and 72-h for

175 eccentric impulse and peak propulsive GRF. Further significant decreases were noted between 48-h to

176 72-h on the left side only for eccentric impulse and propulsive peak GRF. Finally, jump height was only

177 found to be significantly reduced on the left side between post to 24-h and increased between 24-h to

178 72-h.

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180 *** INSERT TABLE 2 ABOUT HERE ***

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182 **Change in Inter-limb Asymmetries**

183 Inter-limb asymmetry values for each time point are shown in Table 3 and Figure 1. SLCMJ mean

184 asymmetries significantly increased ($p < 0.05$) from pre to post and/or 24-h for concentric and eccentric

185 impulse, peak propulsive GRF, and peak landing GRF with small to large ES (0.37-3.15). Significant

186   reductions in asymmetry were shown from post and 24-h to 48-h and 72-h for eccentric impulse, peak

187   propulsive GRF and peak landing GRF.

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189   *** INSERT TABLE 3 AND FIGURE 1 ABOUT HERE ***

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205 **DISCUSSION**

206 The aim of the present study was to quantify inter-limb asymmetries and jump performance in elite

207 academy soccer players before and after a match at incremental time points. Significant changes in side-

208 to-side differences and jump performance were observed at various time points with a trend for the

209 largest asymmetries and reduction in jump performance evident immediately post-match. As per the

210 hypothesis, inter-limb asymmetries returned to a similar level as the pre-match values at the 48-h time

211 point; however, jump performance for multiple metrics was still significantly reduced. These results

212 indicate that assessing multiple metrics during jump performance may be a more sensitive means of

213 identifying a player's readiness to recover in comparison to asymmetry alone.

214 Table 1 shows reliability data for CMJ metrics at all time points. The relevance here being that when

215 players have competed (and are in a fatigued state), this may impact the reliability of collected data;

216 thus, understanding its usability was required. Noting that CV values were considered acceptable if <

217 10%, the only metrics to consistently show acceptable CV were peak force (right), landing impulse

218 (right) and peak landing force (both). Typically, there was a trend for test variability to be lower at

219 baseline prior to the match; thus, the effects of a competitive soccer match may have had a detrimental

220 effect on the reliability of some metrics (e.g., eccentric impulse). However, it is important to highlight

221 that concentric impulse and jump height showed the largest variability (CV range = 18 to 30%); thus,

222 practitioners should be mindful of such metrics if monitoring unilateral jump performance during the

223 recovery period post-matches. Furthermore, when investigating 72-h in particular, it was clear to see

224 that due to the addition of a light tactical training session on the afternoon of 48-h, the reliability of

225 some metrics (such as jump height) were again detrimentally affected. Due to the constraints of

226 congested fixtures which is associated with professional soccer, it was not possible to allow these

227 players three days of recovery. Given the variation in metric reliability across time points, this further

228 supports the notion that in-depth jump analysis is key when interpreting real change (12,20,21).

229 Table 2 shows the mean scores for all jump metrics. Previously, it has been reported that impairment

230 of neuromuscular function is present up to 72-h post-match, with the 0 to 24-h showing the greatest

231   reduction in jumping and aerobic performance (12,20,29,42). Results from the present study showed

232   that only concentric impulse and jump height were fully recovered on both limbs at the 48-h time point,

233   with the remaining metrics still exhibiting significant differences from baseline two days post-match.

234   Notably, of all the metrics analysed, eccentric impulse and peak propulsive GRF yielded the greatest

235   significant change in means over the course of 24-h post-match (d range: post = 5.78-3.40, 24-h = 4.56-

236   2.99). A reduction in eccentric impulse capacity at all time points compared to baseline, likely resulted

237   in athletes altering their jump strategy, allowing time to produce the necessary force without

238   significantly affecting jump height in a fatigued state; thus, warranting the investigation of further

239   metrics other than jump height alone (13,20,21). Furthermore, jump height was shown to have no

240   significant decreases in performance post-match; rather, a small, non-significant increase was actually

241   seen on the left side at this time point. These results perhaps suggest that jump height maybe not be

242   sensitive enough to detect significant immediate change as athletes may mask fatigue by compensating

243   using different strategies (as discussed previously). When considering the landing metrics, landing

244   impulse and peak landing GRF were both sensitive enough to show large significant increases in force-

245   time data at each time point compared to baseline, which has also been shown in comparable research

246   (35). Although challenging to explain with certainty, it seems plausible to suggest that a loss of

247   neuromuscular control may explain why significant increases in landing forces were experienced. The

248   effects of a competitive match clearly resulted in 'heavier landings' which represent a serious

249   consideration for practitioners. Given that previous research has identified landing mechanics as being

250   a potential risk factor for injury (15,19,24), practitioners could consider landing-based metrics as useful

251   markers of readiness to train during the recovery process.

252   Table 3 and Figure 1 show the changing nature of inter-limb asymmetries at each time point. Initially,

253   ECC impulse and peak propulsive GRF showed the highest pre-match leg asymmetries (14.24 and

254   14.71, respectively). These were shown to significantly elevate immediately post-match increasing 2.25

255   and 2.16 times greater than baseline with large ES (d = 3.15 and 2.80, respectively), then plateauing

256   over the succeeding 24-h before returning to near baseline 48-h. Notably, jump height was found to

257   display the greatest change in asymmetry, increasing immediately post-match by 3.7 times greater than

258 pre-match, representing a moderate ES ($d = 1.18$). This is particularly striking as this metric showed

259 just a 4.65% asymmetry value pre-match, which can be considered small (7). The relevance being that

260 this has the potential to mislead practitioners unless monitored throughout the time course of 24 to 48-

261 h. Furthermore, given that jump height also showed high variability (CV range = 18 to 30%), this further

262 highlights the need to monitor multiple metrics during jump profiling, and not rely solely on outcome

263 measures. Interestingly, landing metrics were found to take longer to exhibit their peak leg asymmetries;

264 exponentially worsening until 24-h where both metrics climbed to 2.24 and 2.11 times greater than

265 baseline displaying large to moderate ES for landing impulse ($d = 1.7$) and peak landing GRF ($d =$

266 1.38), respectfully.

267 When interpreting asymmetries in a more general manner, previous research has highlighted the test

268 and metric-specific nature of asymmetries (9,14,23,26,28,39), and to the authors' knowledge, this is the

269 first study to examine the effects of competition on inter-limb asymmetries in an elite soccer population.

270 Previous research has suggested that 15% might be a threshold where the risk of injury increases (26);

271 however, more recent suggestions advocate 10% as a target to aim for (28,34). When this conflicting

272 evidence is considered and the test-specific nature of asymmetries is deliberated, it seems prudent to

273 suggest that multiple metrics be considered to further our understanding of how inter-limb asymmetries

274 interact with measures of physical performance and injury risk. In the present study, the largest inter-

275 limb differences were noted for peak propulsive force and eccentric impulse (Figure 1). Noting that

276 these metrics can only be obtained from a force platform and showed a trend to exhibit substantially

277 greater differences than the outcome measure of jump height, it is suggested (where possible) that the

278 monitoring of inter-limb differences is conducted using force platforms. As a final point, it is worth

279 noting that it is unlikely that elite soccer players will be granted three days of recovery after matches.

280 With a light tactical training session prescribed after the 48-h time point, this may explain the

281 subsequent increase in asymmetries at 72-h. The results highlight the importance of frequent asymmetry

282 monitoring, which has been emphasized in previous literature (7,35).

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285 **PRACTICAL APPLICATIONS**

286 The findings of the present study highlight the changing nature of jump performance and inter-limb

287 asymmetries after a competitive soccer match. Strength and conditioning coaches should consider using

288 the unilateral CMJ in addition to or in place of the more commonly accepted neuromuscular fatigue

289 monitoring method of bilateral CMJ. Noting that many of the actions in soccer occur unilaterally (such

290 as sprinting, changing direction, and kicking), it seems logical to suggest that unilateral jump profiling

291 serves as an ecologically valid means for soccer athletes. In addition, given the previously reported

292 associations between inter-limb asymmetries and reduced physical performance and injury risk,

293 frequent monitoring of side-to-side differences may provide practitioners with a true picture of the

294 interaction between asymmetry and performance or injury risk. The relevance here being that literature

295 pertaining to the longitudinal tracking of asymmetry is scarce. Finally, with leg asymmetries highlighted

296 up to 72-h, this insight can further objectively enlighten the coaching staff on player welfare and

297 subsequently inform their approach to adapting training loads on an individual level; thus, improving

298 training quality, player readiness and ultimately, match performance.

REFERENCES

1. Akenhead R, Hayes PR, Thompson KG, and French D. Diminutions of acceleration and deceleration output during professional football match play. *J Sci Med Sport* 16: 556-561, 2013.

2. Ascensão A, Rebelo A, Oliveira E, Marques F, Pereira L, and Magalhães J. Biochemical impact of a soccer match - analysis of oxidative stress and muscle damage markers throughout recovery. *Clin Biochem* 41: 841-851, 2008.

3. Bangsbo J, Mohr M, and Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. *J Sports Sci* 24: 665-674, 2006.

4. Baumgartner TA, and Chung H. Confidence Limits for Intraclass Reliability Coefficients. *Meas Phys Edu Exerc Sci* 5: 179-188, 2001.

5. Belhaj K, Meftah S, Mahir L, Lmidmani F, and Elfatimi A. Isokinetic imbalance of adductor–abductor hip muscles in professional soccer players with chronic adductor-related groin pain. *Eur J Sport Sci* 16: 1226-1231, 2016.

6. Bell DR, Sanfilippo JL, Binkley N, and Heiderscheit BC. Lean mass asymmetry influences force and power asymmetry during jumping in collegiate athletes. *J Strength Cond Res* 28: 884-891, 2014.

7. Bishop C, Turner A, and Read P. Effects of inter-limb asymmetries on physical and sports performance: A systematic review. *J Sports Sci* 36: 1135-1144, 2018.

8. Bishop C, Read P, Lake J, Chavda S, Turner A. Inter-limb asymmetries: Understanding how to calculate differences from bilateral and unilateral tests. *Strength Cond J* (Published ahead of print).

9. Bishop C, Read P, McCubbine J, and Turner A. Vertical and Horizontal Asymmetries are Related to Slower Sprinting and Jump Performance in Elite Youth Female Soccer Players: *J Strength Cond Res* (Published ahead of print).

10. Camarda SR, and Denadai BS. Does muscle imbalance affect fatigue after soccer specific intermittent protocol? *J Sci Med Sport* 15: 355-360, 2012.

11. Chavda S, Bromley T, Jarvis P, Williams S, Bishop C, Turner A, Lake J, and Mundy P. Force-time characteristics of the countermovement jump: Analyzing the curve in excel. *Strength Cond J* 40: 67-77, 2018.

12. Cormack SJ, Newton RU, McGuigan MR, and Cormie P. Neuromuscular and endocrine responses of elite players during an Australian rules football season. *Int J Sports Physiol Perform* 3: 439-453, 2008.

13. Cormie P, McBride JM, and McCaulley GO. Power-Time, Force-Time, and Velocity-Time Curve analysis of the countermovement jump: Impact of training: *J Strength Cond Res* 23: 177-186, 2009.

14. Croisier J-L, Ganteaume S, Binet J, Genty M, and Ferret J-M. Strength imbalances and prevention of hamstring injury in professional soccer players: A prospective study. *Am J Sports Med* 36: 1469-1475, 2008.

15. Dai B, Mao D, Garrett WE, and Yu B. Anterior cruciate ligament injuries in soccer: Loading mechanisms, risk factors, and prevention programs. *J Sport Health Sci* 3: 299-306, 2014.

16. Delextrat A, Baker J, Cohen DD, and Clarke ND. Effect of a simulated soccer match on the functional hamstrings-to-quadriceps ratio in amateur female players: H:Q ratio in female soccer players. *Scand J Med Sci Sports* 23: 478-486, 2013.

17. Dos'Santos T, Jones PA, Comfort P, and Thomas C. Effect of different onset thresholds on isometric mid-thigh pull force-time variables. *J Strength Cond Res* 31: 3463-3473, 2017.

18. Fousekis K, Tsepis E, and Vagenas G. Intrinsic risk factors of non-contact ankle sprains in soccer: A prospective study on 100 professional players. *Am J Sports Med* 40: 1842-1850, 2012.

19. Gardiner JC, Weiss JA, and Rosenberg TD. Strain in the human medial collateral ligament during valgus loading of the knee. *Clin Orthop Rel Res* 391: 266-274, 2001.

20. Gathercole R, Sporer B, Stellingwerff T, and Sleivert G. Alternative countermovement jump analysis to quantify acute neuromuscular fatigue. *Int J Sports Physiol Perform* 10: 84-92, 2015.

21. Gathercole RJ, Stellingwerff T, and Sporer BC. Effect of acute fatigue and training adaptation on countermovement jump performance in elite snowboard cross athletes: *J Strength Cond Res* 29: 37-46, 2015.

22. Gibson NE, Boyd AJ, and Murray AM. Countermovement jump is not affected during final competition preparation periods in elite rugby sevens players. *J Strength Cond Res* 30: 777-783, 2016.

23. Hart NH, Nimphius S, Weber J, Spiteri T, Rantalainen T, Dobbin M, and Newton RU. Musculoskeletal asymmetry in football athletes: A product of limb function over time. *Med Sci Sports Exerc* 48: 1379-1387, 2016.

24. Hewett TE, Myer GD, and Ford KR. Decrease in neuromuscular control about the knee with maturation in female athletes. *J Bone Joint Surg* 86: 1601-1608, 2004.

25. Hoffman JR, Ratamess NA, Klatt M, Faigenbaum AD, and Kang J. Do bilateral power deficits influence direction-specific movement patterns? *Res Sports Med* 15: 125-132, 2007.

26. Impellizzeri FM, Rampinini E, Maffiuletti N, and Marcora SM. A vertical jump force test for assessing bilateral strength asymmetry in athletes. *Med Sci Sports Exerc* 39: 2044-2050, 2007.

27. Ispirlidis I, Fatouros IG, Jamurtas AZ, Nikolaidis MG, Michailidis I, Douroudos I, Konstantinos M, Athanasios C, Elias K, Ioannis K, Vassilios K, and Kiriakos T. Time-course of changes in inflammatory and performance responses following a soccer game. *Clin J Sport Med* 18: 423-431, 2008.

28. Kyritsis P, Bahr R, Landreau P, Miladi R, and Witvrouw E. Likelihood of ACL graft rupture: Not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture. *Brit J Sports Med* 50: 946–951, 2016.

29. Magalhães J, Rebelo A, Oliveira E, Silva JR, Marques F, and Ascensão A. Impact of Loughborough Intermittent Shuttle Test versus soccer match on physiological, biochemical and neuromuscular parameters. *Eur J Appl Physiol* 108: 39-48, 2010.

30. Malone JJ, Murtagh CF, Morgans R, Burgess DJ, Morton JP, and Drust B. Countermovement jump performance is not affected during an in-season training microcycle in elite youth soccer players: *J Strength Cond Res* 29: 752-757, 2015.

31. Menzel H-J, Chagas MH, Szmuchrowski LA, Araujo S, de Andrade A, and de Jesus-Moraleida FR. Analysis of lower limb asymmetries by isokinetic and vertical jump tests in soccer players. *J Strength Cond Res* 27: 1370-1377, 2013.

32. Mohr M, Krustrup P, and Bangsbo J. Fatigue in soccer: A brief review. *J Sports Sci* 23: 593-599, 2005.

33. Mohr M, Krustrup P, and Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519-528, 2003.

34. Myer GD, Paterno MV, Ford KR, Quatman CE, and Hewett TE. Rehabilitation after anterior cruciate ligament reconstruction: Criteria-based progression through the return-to-sport phase. *J Orthop Sports Phys Ther* 36: 385-402, 2006.

35. Oliver J, Armstrong N, and Williams C. Changes in jump performance and muscle activity following soccer-specific exercise. *J Sports Sci* 26: 141-148, 2008.

36. Owen NJ, Watkins J, Kilduff LP, Bevan HR, and Bennett MA. Development of a criterion method to determine peak mechanical power output in a countermovement jump. *J Strength Cond Res* 28: 1552-1558, 2014.

37. Rampinini E, Coutts A, Castagna C, Sassi R, and Impellizzeri F. Variation in top level soccer match performance. *Int J Sports Med* 28: 1018-1024, 2007.

38. Read P, Oliver J, De Ste Croix M, Myer G, and Lloyd R. Consistency of field-based measures of neuromuscular control using force-plate diagnostics in elite male youth soccer players. *J Strength Cond Res* 30: 3304-3311, 2016.

39. Read P, Oliver J, De Ste Croix M, Myer G, and Lloyd R. The effects of maturation on measures of asymmetry during neuromuscular control tests in elite male youth soccer players. *Ped Exerc Sci* 30: 168-175, 2017.

40. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. *J Strength Cond Res* 18: 918-920, 2004.

404   41. Scott BR, Lockie RG, Knight TJ, Clark AC, and Janse de Jonge X. A comparison of methods
405   to quantify the in-season training load of professional soccer players. *Int J Sports Physiol*
406   *Perform* 8: 195-202, 2013.

407   42. Silva JR, Rebelo A, Marques F, Pereira L, Seabra A, Ascensão A, and Magalhaes J.
408   Biochemical impact of soccer: An analysis of hormonal, muscle damage, and redox markers
409   during the season. *Appl Physiol Nut Metabol* 39: 432-438, 2014.

410   43. Small K, McNaughton L, Greig M, and Lovell R. The effects of multidirectional soccer-specific
411   fatigue on markers of hamstring injury risk. *J Sci Med Sport* 13: 120-125, 2010.

412   44. Thomas K, Dent J, Howatson G, and Goodall S. Etiology and recovery of neuromuscular
413   fatigue following simulated soccer match-play. *Med Sci Sports Exerc* 45: 955-964, 2017.

414   45. Weston M, Batterham AM, Castagna C, Portas MD, Barnes C, Harley J, and Lovell R.
415   Reduction in physical match performance at the start of the second half in elite soccer. *Int J*
416   *Sports Physiol Perform* 6: 174-182, 2011.

417   Table 1: Within-session reliability data for unilateral countermovement jump metrics at pre, post, 24, 48 and 72 hours post-match.

CMJ Metric	Pre	Post	24-h	48-h	72-h
Eccentric impulse (R)					
CV (%)	6.61	9.21	11.78	12.12	8.50
ICC (95% CI)	0.95 (0.82-0.99)	0.96 (0.87-0.99)	0.98 (0.97-0.99)	0.95 (0.34-0.99)	0.90 (0.45-0.97)
SEM	2.74	2.43	2.25	4.06	3.87
Eccentric impulse (L)					
CV (%)	8.76	10.59	13.12	11.94	11.39
ICC (95% CI)	0.93 (0.77-0.98)	0.89 (0.65-0.96)	0.97 (0.89-0.99)	0.84 (0.69-0.96)	0.97 (0.80-0.99)
SEM	3.51	3.22	2.24	6.18	2.32
Concentric impulse (R)					
CV (%)	18.25	17.99	20.95	21.04	21.18
ICC (95% CI)	0.77 (0.42-0.92)	0.76 (0.42-0.92)	0.89 (0.69-0.97)	0.74 (0.38-0.91)	0.71 (0.32-0.89)
SEM	13.92	10.94	9.34	15.20	15.21
Concentric impulse (L)					
CV (%)	20.29	20.73	22.48	23.97	20.73
ICC (95% CI)	0.85 (0.55-0.95)	0.77 (0.29-0.92)	0.75 (0.27-0.92)	0.84 (0.52-0.95)	0.77 (0.27-0.92)
SEM	11.43	11.29	12.47	12.41	11.22
Peak force (R)					
CV (%)	5.52	8.15	9.67	8.35	7.91
ICC (95% CI)	0.80 (0.58-0.95)	0.92 (0.77-0.97)	0.95 (0.87-0.99)	0.56 (0.11-0.83)	0.85 (0.60-0.95)
SEM	41.05	29.48	26.57	78.83	40.04
Peak force (L)					
CV (%)	10.38	10.68	14.33	12.28	11.55
ICC (95% CI)	0.89 (0.86-0.99)	0.95 (0.84-0.98)	0.92 (0.78-0.99)	0.90 (0.78-0.99)	0.99 (0.96-0.99)
SEM	33.69	21.43	35.70	46.13	12.75
Jump height (R)					
CV (%)	19.51	29.29	19.68	22.19	23.48
ICC (95% CI)	0.89 (0.71-0.96)	0.69 (0.27-0.89)	0.92 (0.78-0.97)	0.89 (0.71-0.96)	0.77 (0.43-0.92)
SEM	0.01	0.03	0.01	0.01	0.02

Jump height (L)					
CV (%)	22.15	30.00	25.80	24.23	30.00
ICC (95% CI)	0.85 (0.25-0.96)	0.60 (0.20-0.86)	0.86 (0.60-0.95)	0.72 (0.31-0.90)	0.57 (0.17-0.85)
SEM	0.02	0.04	0.02	0.02	0.04
Landing impulse (R)					
CV (%)	8.96	8.13	7.64	7.05	8.71
ICC (95% CI)	0.68 (0.28-0.88)	0.63 (0.20-0.86)	0.57 (0.11-0.84)	0.58 (0.12-0.84)	0.65 (0.23-0.87)
SEM	1.41	1.69	1.72	1.42	1.72
Landing impulse (L)					
CV (%)	8.96	8.13	16.18	14.81	15.00
ICC (95% CI)	0.81 (0.52-0.93)	0.84 (0.59-0.95)	0.70 (0.32-0.89)	0.81 (0.53-0.93)	0.81 (0.54-0.93)
SEM	1.09	1.10	2.79	1.76	1.93
Peak landing force (R)					
CV (%)	7.48	7.63	7.93	8.86	7.80
ICC (95% CI)	0.90 (0.73-0.97)	0.93 (0.78-0.98)	0.89 (0.70-0.96)	0.88 (0.67-0.96)	0.91 (0.75-0.97)
SEM	62.36	64.96	86.78	91.96	74.32
Peak landing force (L)					
CV (%)	7.48	7.63	8.63	5.72	5.86
ICC (95% CI)	0.74 (0.25-0.94)	0.71 (0.32-0.89)	0.83 (0.26-0.98)	0.64 (0.21-0.87)	0.69 (0.27-0.90)
SEM	101.77	134.15	134.76	109.92	119.97

CMJ = countermovement jump; R = Right; L = Left; CV = coefficient of variation; ICC = intraclass correlation coefficient; CI = confidence interval; SEM = standard error of the measurement.

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423   Table 2: Mean unilateral countermovement jump data ± standard deviations for pre, post, 24, 48 and 72 hours post-match.

CMJ Metric	Pre	Post	24-h	48-h	72-h
ECC impulse-R (Ns)	173.68 ± 11.67 [bcde]	135.54 ± 12.48 [ac]	134.96 ± 15.90 [abd]	152.88 ± 18.52 [abc]	141.24 ± 12.00 [a]
ECC impulse-L (Ns)	135.54 ± 13.28 [bce]	92.17 ± 9.76 [ade]	95.56 ± 12.53 [ade]	130.97 ± 15.64 [bce]	110.52 ± 12.59 [abcd]
CON impulse-R (Ns)	157.64 ± 28.77 [b]	124.96 ± 22.47 [a]	135.11 ± 28.30	141.17 ± 29.70	132.19 ± 28.00 [a]
CON impulse-L (Ns)	147.49 ± 29.92 [bce]	112.35 ± 23.29 [a]	110.51 ± 24.84 [a]	129.87 ± 31.13	112.35 ± 23.29 [a]
Peak force-R (N)	1679.1 ± 92.73 [bcde]	1278.52 ± 104.23 [ade]	1280.76 ± 123.89 [ade]	1428.09 ± 119.25 [abc]	1325.51 ± 104.79 [abc]
Peak force-L (N)	1432.16 ± 100.66 [bcde]	871.36 ± 93.08 [ade]	903.53 ± 129.51 [ade]	1206.53 ± 148.10 [abce]	1052.69 ± 121.58 [abcd]
Jump height-R (m)	0.19 ± 0.04	0.19 ± 0.06	0.16 ± 0.03	0.16 ± 0.04	0.17 ± 0.04
Jump height-L (m)	0.19 ± 0.07	0.20 ± 0.06 [c]	0.16 ± 0.04 [be]	0.17 ± 0.04	0.20 ± 0.06 [c]
Landing impulse-R (Ns)	29.38 ± 2.22 [bc]	31.18 ± 2.15 [ae]	31.68 ± 5.13 [ae]	30.27 ± 4.04 [c]	29.57 ± 4.44 [bc]
Landing impulse-L (Ns)	27.83 ± 2.49 [bce]	34.08 ± 2.77 [a]	36.20 ± 2.61 [abd]	31.14 [abc]	31.33 ± 2.90 [a]
Peak landing force-R (N)	2662.81 ± 199.21 [bcde]	2963.55 ± 212.91 [ace]	3271.16 ± 259.30 [abd]	2983.55 ± 264.37 [ace]	3195.73 ± 249.12 [abd]
Peak landing force-L (N)	2811.71 ± 179.22 [bcde]	3263.55 ± 249.10 [ace]	3823.25 ± 329.77 [abd]	3217.99 ± 184.23 [ace]	3703.72 ± 216.87 [abd]

CMJ = countermovement jump; ECC = eccentric; CON = concentric; R = Right; L = Left; [a] = significantly different from pre-match value; [b] = significantly different from post-match value; [c] = significantly different from 24-h match value; [d] = significantly different from 48-h match value; [e] = significantly different from 72-h match value.

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429 Table 3: Inter-limb asymmetry values (reported as percentages) for unilateral countermovement jump data pre, post, 24, 48 and 72 hours post-match and Cohen's

430 *d* effect sizes reported relative to pre-match values.

| Asymmetry %	Pre	Post	24-h	48-h	72-h
ECC impulse	14.24 [bce]	32.00 [ade]	29.20 [ade]	14.33 [bc]	21.75 [abc]
Effect size		3.15	2.80	0.01	1.36
CON impulse	7.73 [c]	10.50	18.50 [a]	9.88	15.19
Effect size		0.31	1.02	0.30	0.84
Peak force	14.71 [bc]	31.85 [ade]	29.45 [ade]	15.51 [bc]	20.58 [bc]
Effect size		2.80	2.23	0.12	0.96
Jump height	4.65 [e]	17.22	6.52 [e]	5.47	20.49 [ac]
Effect size		1.18	0.50	0.23	2.05
Peak landing impulse	5.89 [c]	8.51 [cde]	13.14 [abde]	4.03 [bc]	5.61 [bc]
Effect size		0.62	1.71	-0.47	-0.07
Peak landing force	7.22 [ce]	9.13 [ce]	15.22 [abd]	7.29 [ce]	13.72 [abd]
Effect size		0.32	1.38	0.01	1.19

ECC = eccentric; CON = concentric; [a] = significantly different from pre-match value; [b] = significantly different from post-match value; [c] = significantly different from 24-h match value; [d] = significantly different from 48-h match value; [e] = significantly different from 72-h match value.

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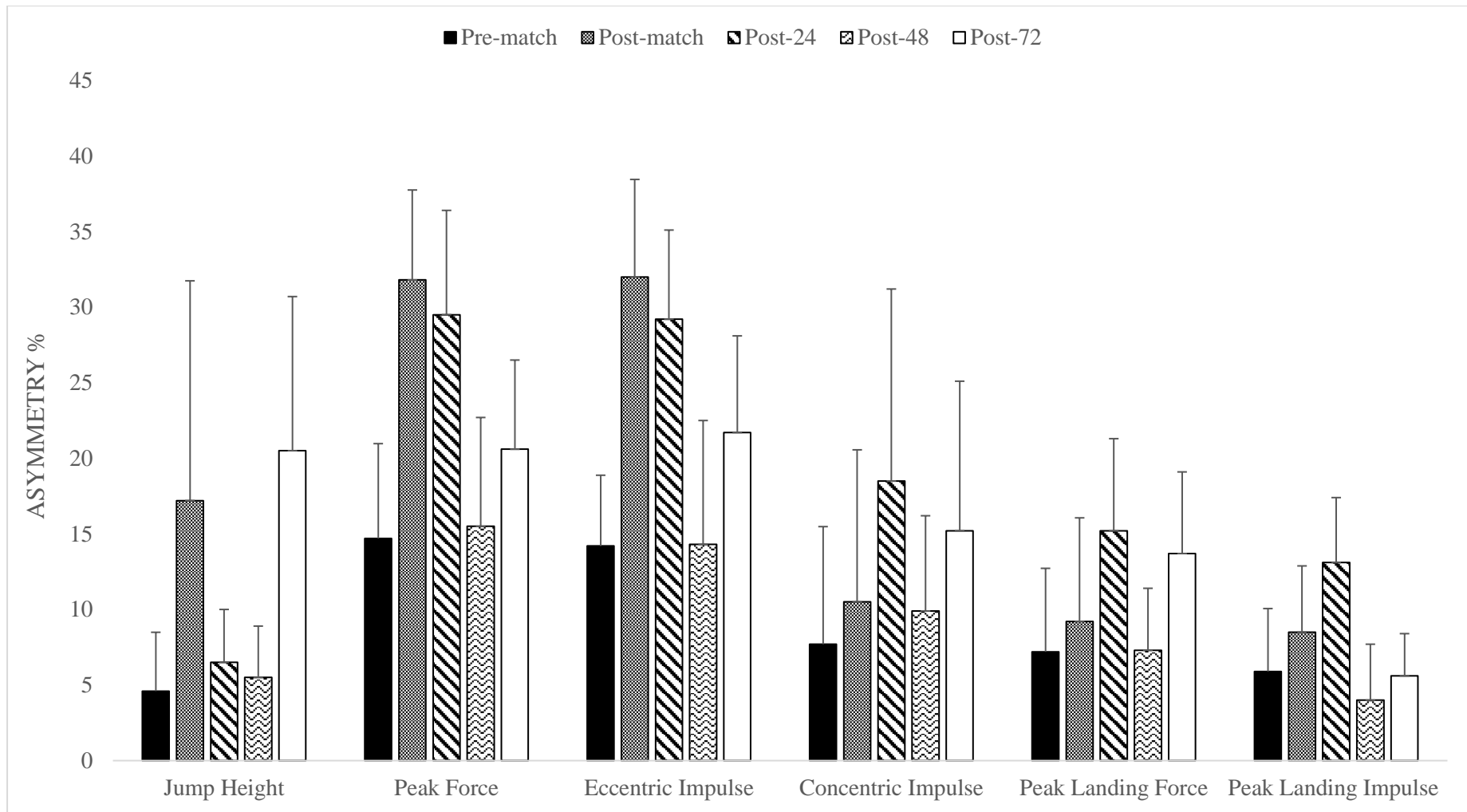
Figure 1: Inter-limb asymmetry values and standard deviations (error bars) for SLCMJ metrics at pre, post, 24, 48 and 72 hours post-match.