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1 **Test- Re- Test Reliability and Normative Values of Neuromuscular Performance**
2 **Tests in U-18 and U-23 English Premier League Academy Football Players. Part**
3 **1: Countermovement Jump Measures.**

4

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20 **Abstract**

21

22 *Purpose:* To examine the test- re- test reliability and normative values of CMJ
23 measures in elite-level U-18 and U-23 academy football players. *Methods:* 36 players
24 performed 3 CMJ tests on dual force plates on two separate test days ('test' and 're-
25 test') 7 days apart across consecutive in-season microcycles. 101 variables were
26 analysed, of which 34 were identified as principle measures, based on use in previous
27 research and practice. Relative (ICC, \pm 95% CI) and absolute (CV%, SEM and MDC)
28 reliability were analysed for three methods: Best_{JH}, Mean_{JH} and within-session.
29 *Results:* Overall, relative reliability was *good to excellent* for Best_{JH} and Mean_{JH} and
30 *moderate to excellent* for within-session. 27 (Best_{JH} and within-session) and 28
31 (Mean_{JH}) of the 34 principle variables had *good* absolute reliability (CV% < 10%).
32 Overall, force and power measures had better reliability than velocity, RFD and
33 impulse measures, but absolute force measures had strong correlations with body
34 weight, which effected reliability. *Conclusions:* Both Best_{JH}, and Mean_{JH} methods can
35 be used reliably for CMJ monitoring purposes in these cohorts. Of the most widely
36 used variables in research and practice, eccentric deceleration RFD had a high MDC
37 (~60%), which might render it unsuitable for detecting subtle changes to movement
38 strategy or neuromuscular status in young football players. Conversely, eccentric
39 duration and FT:CT had lower MDC values (~ 20%), supporting their use in practice.
40 Practitioners should use relative- as opposed to absolute- force measures.
41 Collectively, these results can be used to inform decisions relating to CMJ variable
42 selection in practice.

43

44 **Key Words**

45

46 Minimal Detectable Change, Neuromuscular Fatigue, Athlete Monitoring, Force Plate,
47 Ground Reaction Force

48

49 **Introduction**

50

51 The countermovement jump (CMJ) and isometric tests of posterior chain (IPCS), hip
52 abductor (IABS) and hip adductor (IADS) strength are routinely used to profile
53 neuromuscular capacity and detect changes to neuromuscular status in football
54 players ¹⁻⁷. Recent advancements to the portability of diagnostic equipment and
55 automation of force – time curve analysis have increased the popularity of these tests
56 in practice ⁸. Indeed, periodic CMJ testing is compulsory for English Premier League
57 (EPL) affiliated academies according to Elite Player Performance Plan (EPPP)
58 regulations, and previous research points to CMJ testing as the most commonly used
59 response- to- load measure in football ¹.

60

61 Positive correlations are consistently reported between CMJ performance measures
62 and sprint acceleration, maximal running velocity, and change of direction
63 performance ^{9,10}. For example, McFarland and colleagues ¹⁰ reported *moderate*
64 correlations between CMJ performance and 10 m speed, 30 m speed and change of
65 direction (COD) performance in young football players. Findings were attributed to the
66 contributory effects that stretch shortening cycle qualities exert on both CMJ and sport-
67 specific speed performance. Therefore, it could be surmised that changes to CMJ
68 performance can give rise to similar changes to speed and COD performance ⁹.
69 Consequently, CMJ measures are widely used to profile neuromuscular performance

70 and inform decisions relating to physical performance programming in young football
71 players ⁵.

72

73 CMJ measures are also used to signal neuromuscular fatigue (NMF; i.e., specific
74 reduction to the maximal force generating capacity of muscle) in practice. Indeed,
75 reductions to CMJ performance are reported to manifest for ~ 72 h following elite-level
76 U-18 ^{4,6,11}, and senior professional ^{2,12} football match play. Time-dependent CMJ
77 measures are considered to be particularly useful for this purpose because NMF is
78 reported to induce changes to movement strategy independent of changes to jump
79 height (JH) ^{3,13,14}. For example, perturbations to JH and flight time: contraction time
80 ratio (FT:CT) are reported following football ⁶ and Australian Football (AFL) ¹³ training
81 and match play, but greater and longer-lasting changes are reported to FT:CT ^{6,13}.
82 Consequently, the CMJ is widely used to indicate player readiness (i.e., denoting the
83 interplay between 'fitness' and 'fatigue' ^{15,16}) in practice, and inform decisions relating
84 to training and match load planning in young football players ^{1,5}.

85

86 Despite widespread use, no data are available to report the test- re- test reliability of
87 CMJ, IPCS, IABS or IADS measures in EPL under 18 (U-18) and under 23 (U-23)
88 football players. Such data will help practitioners to distinguish between meaningful
89 adaptive and maladaptive changes to neuromuscular performance and the natural
90 variability associated with these tests ⁸. This, in-turn, will facilitate improved decision
91 making relating to player performance programming and training and match load
92 planning. Moreover, no published normative data are available for these tests in these
93 cohorts. Accordingly, the aims of this investigation were to examine the test- re- test
94 reliability and normative values for these measures in U-18 and U-21 EPL academy

95 football players. Part 1, herein, examines CMJ measures, and part 2 examines
96 isometric strength measures.

97

98 **Methods**

99

100 ***Study Design***

101

102 Thirty-six players from the U-18 ($n = 20$, age = 17.0 ± 0.7 ; height = 1.82 ± 0.07 m; body
103 mass = 73.5 ± 76 kg) and U-23 ($n = 16$, age = 19.6 ± 1.2 ; height = 1.81 ± 0.06 m; body
104 mass = 75.8 ± 8.1 kg) age groups from an EPL category 1 academy participated in
105 this investigation. Testing was conducted in an environmentally controlled
106 performance centre located at the team's training facility. To examine test-re-test
107 reliability, players attended two testing sessions at 09:00 on consecutive Friday
108 mornings (i.e., 'test' and 're-test' days), spanning similar single-game microcycles
109 during the in-season period. Weekly training and match distribution and load were
110 consistent for both weeks across the experimental period. Consistent with previous
111 scientific research literature, we reasoned that collecting data the day before match
112 day (MD), (i.e., MD-1) related to when player 'fatigue' was lowest during the training
113 week ¹⁷.

114

115 Prior to all testing, players performed a standardised warm-up consisting of ~ 4 min of
116 dynamic mobility exercises (3 X 10 m heel flicks, hamstring kicks and walking lunges
117 with a 10 m walk recovery between repetitions), followed by three warm-up CMJ's at
118 60%, 80% and 100% of perceived maximal effort, separated by ~ 30 s. Test order for
119 the CMJ, IPCS and isometric adductor and abductor strength tests were randomised

120 for both testing dates. All players had routinely performed the monitoring tests ~ 2
121 times per week for at least one full competitive season and were therefore considered
122 to be highly familiar with all testing protocols. Ethical approval was provided by the St
123 Marys University, Twickenham, UK Human Research Ethics Committee.

124

125 ***Countermovement Jump***

126

127 Countermovement jump testing was performed on dual force plates (ForceDecks
128 FD4000, Vald Performance, Brisbane, AU), sampling at 1000 Hz. Force-time curves
129 were analysed automatically using proprietary software (ForceDecks Version
130 2.0.8000, Vald Performance, Brisbane, AU) according to methods described
131 previously^{8,18}. Prior to statistical analysis, 34 bilateral CMJ variables (i.e., derived from
132 the total vertical ground reaction force) were selected for analysis from the eccentric,
133 concentric, flight and landing phases of the CMJ and included in the main results
134 section. Variable selection was based on use in similar scientific research literature⁸
135 and known use in practice. Reliability data for a further 67 variables (101 variables in
136 total, including 70 bi-lateral, 31 unilateral variables, and 5 'asymmetry' variables are
137 available in a supplementary file (****INSERT LINK TO SUPPLEMENTARY FILE 1
138 HERE ****).

139

140 Prior to each testing day, a known weight (20 kg) was used to test the accuracy of
141 force measurement, with ± 0.1 kg considered to be a good level of measurement error
142⁸. The force plates were zeroed prior to all measures. Each player was asked to stand
143 still on the force plates with their hands on their hips for ~ 5 s until a stable body mass
144 was recorded prior to jumping. Players then performed three maximal CMJ trials, each

145 separated by ~ 15 s. They were required to keep their hands on their hips for the
146 entirety of each jump and were cued to 'jump maximally: as high as they could and to
147 land on the force plates' as per previous scientific research⁸. Players were then asked
148 to reposition their feet between repetitions. All jump testing was conducted by the
149 same experienced practitioner. In cases where a measurement error was observed
150 (i.e., 'tucking' or 'piking' the legs during the flight phase, a double contact prior to
151 jumping, or if they did not land on the force plates), data were omitted, and the player
152 was asked to perform another repetition.

153

154 ***Statistical Analysis***

155

156 Descriptive statistics (means, 95% confidence intervals (CI), \pm standard deviation
157 (SD)) were calculated at U-18, U21 and combined group (i.e., U-18 and U-21 players
158 combined) levels. Reliability was examined using three methods: single output for
159 each variable taken from the trial with the best jump height ($Best_{JH}$), mean output for
160 each variable taken from the mean of three trials ($Mean_{JH}$) and within-session. The
161 assumption of normality was examined using the Shapiro-Wilk test. Heteroscedasticity
162 was examined using Pearson's correlation coefficient and systematic bias between
163 'test' and 're-test', was examined using a paired samples *t*-test. Relative reliability was
164 examined using intra-class correlation coefficients (ICC) as previously described^{19,20}
165 and reported with 95% CI. The ICC were interpreted as: *poor* = < 0.50; *moderate* =
166 0.50 – 0.74; *good* = 0.75 – 0.89 and *excellent* = > 0.9²¹. Absolute reliability was
167 examined using coefficient of variation (CV; %), standard error of measurement (SEM;
168 $SD\sqrt{1-ICC}$), and minimal detectable change (MDC; $SEM*1.96*\sqrt{2}$)²² methods.
169 Consistent with previous scientific literature, we applied an arbitrary threshold of <

170 10% to define a CV as *good*²³. Finally, a Pearson's R correlation was used to examine
171 the correlation between body weight and each CMJ variable. All statistical tests were
172 conducted in *R* (version 4.0.0, R Foundation for Statistical Computing, Vienna,
173 Austria).

174

175 **Results**

176

177 ***Descriptive Statistics***

178

179 Descriptive statistics for CMJ variables for U-18, U-21, combined age group and
180 goalkeeper groups are presented in table 1, below. Overall, there was a trend for force-
181 dependent, time- dependent and performance- orientated CMJ variables to improve
182 with training age and for greater jump performance measures in goalkeepers.

183

184 *** *INSERT TABLE 1 HERE****

185

186 ***Relative Reliability***

187

188 Of the 34 principle CMJ variables analysed, 6 and 28 variables had *good* and *excellent*
189 relative reliability for both the Best_{JH} (ICC range = 0.20) and Mean_{JH} (ICC range =
190 0.17) methods and 4, 15 and 15 variables had *moderate*, *good* and *excellent* within-
191 session (ICC range = 0.38) reliability respectively (Table 1).

192

193 ***Absolute Reliability***

194

195 Of the 34 principle CMJ variables analysed 27 variables had CV's < 10% using the
196 Best_{JH} (CV range = 23.4%), and within-session (CV range = 51.6%) methods; and 28
197 variables had CV's < 10% using the Mean_{JH} (CV range = 24.6%) method (Table 2).
198 There was a trend for higher CVs using the within-session method.

199

200 *** INSERT TABLE 2 HERE ***

201

202 Overall there was a trend for absolute force- dependent variables to correlate more
203 strongly with player body weight (*supplementary file 1*).

204

205 **Discussion**

206

207 To the authors knowledge this is the first investigation to examine the test-re-test
208 reliability and normative data for a broad spectrum of widely used CMJ measures in
209 elite-level U-18 and U-23 EPL academy football players. This provides researchers
210 and practitioners alike with an ecologically valid resource to help inform CMJ variable-
211 selection for performance and longitudinal monitoring purposes.

212

213 The first aim of this investigation was to examine the test- re- test reliability of CMJ
214 variables for elite-level U-18 and U-23 EPL academy football players. Reliability was
215 examined using three methods: Best_{JH}, Mean_{JH}, and within-session. Overall, we report
216 *moderate to excellent* relative reliability and *good* absolute reliability for the 34 principle
217 CMJ variables using these methods (Table 2). The second aim was to report the
218 normative CMJ variable data for the U-18, U-23, combined (i.e., U-18 + U-23) and
219 goalkeeper sub-groups (Table 1). Unsurprisingly we observed a trend for CMJ

220 measures to improve with age (i.e., U-23 > U-18). For example, on average, concentric
221 peak force, eccentric peak force, peak power, concentric duration, eccentric duration,
222 eccentric deceleration RFD and jump height measures were greater for the U-23 group
223 than the U-18 group (Table 1). Goalkeepers demonstrated the greatest jump height
224 performance, which is likely explained by position-specific factors (i.e., the jump-
225 dominant demands of goalkeeper training and match play) giving rise to more
226 advanced neuromuscular adaptations that serve to improve jump capabilities. Indeed,
227 on average, mean concentric power was higher for goalkeepers than outfield players,
228 which likely contributes to this finding (Table 1).

229

230 Importantly, we report similarly high levels of relative and absolute reliability using both
231 the Best_{JH} and Mean_{JH} methods. Most principle CMJ variables demonstrated *good* to
232 *excellent* relative reliability and *good* absolute reliability using these methods (Table
233 2). Nonetheless, there are some subtle differences between our findings and those
234 reported previously ^{3,8}. Recently, Howarth and colleagues ⁸ examined the interday
235 reliability of similar CMJ variables in senior professional Rugby Union players and
236 reported better absolute reliability for the Mean_{JH} method than the Best_{JH} method.
237 Moreover, the absolute reliability of CMJ variables herein appear to be slightly lower
238 than what has been reported previously ^{3,8}. Though discrepancies between our
239 findings and others might be explained by sport related differences between cohorts,
240 it is likely that several other factors contribute. For example, Wren and colleagues ²⁴
241 reported a reduction to CMJ kinematic variability with increasing training age in young
242 athletes, and Nibali and colleagues ²⁵ reported a reduction in the variability of jump
243 kinematics with increased performance level (i.e., professional athletes > college
244 athletes > high school athletes). Consequently, it is possible that senior professional

245 and older athletes examined previously ^{3,8} exhibit less movement and performance
246 variability during the CMJ than the younger athletes examined herein. Indeed, these
247 factors might help to explain the better absolute reliability reported previously ^{3,8} and
248 why relative reliability was typically lowest for the within-session method herein (Table
249 2). Notwithstanding, our results indicate efficacy for both the Best_{JH} and Mean_{JH}
250 methods in U-18 and U-23 EPL academy football players.

251

252 Several variables relating to CMJ movement strategy have demonstrated merit in
253 signalling NMF ^{13,26}, chronic adaptations to training ^{27,28}, deceleration ability ²⁹ and
254 have been shown to relate to previous injury ³⁰ in football players. Of these measures,
255 eccentric deceleration RFD, eccentric duration and FT:CT have received particular
256 research attention and consequently, are now widely used in practice ⁸. Consistent
257 with similar investigations ^{3,8,25} we report *good to excellent* relative reliability for these
258 variables and CV's of ~ 8% (FT:CT and eccentric duration) and ~ 22% (eccentric
259 deceleration RFD). Recent scientific literature suggests that variables with low
260 absolute reliability might have merit in practice if the stimulus (i.e., football match play)
261 results in a change to the variable that is greater than the associated CV ⁸. To that
262 end, we encourage practitioners to consider the MDC statistic when selecting CMJ
263 variables (Table 2). For example, despite having *excellent* relative reliability, we report
264 an MDC of ~ 60% for eccentric deceleration RFD which might render it unsuitable for
265 detecting subtle changes to neuromuscular status in young football players.
266 Comparatively, we report MDC's closer to 20% for eccentric duration and FT:CT,
267 which likely makes them more suitable for this purpose (Table 2).

268

269 A novel aspect of this investigation is that we examined the correlation between CMJ
270 variables and body weight. Overall, we observed strong correlations between absolute
271 force variables and body weight and weak correlations between relative force- and
272 time dependent- variables and body weight (*supplementary file 1*). For example,
273 absolute eccentric mean force had *good to excellent* reliability and a *perfect* correlation
274 ($r = 1.00$) with body weight. Conversely, relative eccentric mean force had *good to*
275 *excellent* reliability and a weak correlation ($r = 0.13$) with body weight. Interestingly,
276 adjusting mean eccentric force from absolute to relative terms changed the ICC from
277 second highest of 101 variables (0.99; *excellent*) to second lowest (0.70; *moderate*).
278 Consequently, it appears that body weight exerts an important effect on the reliability
279 of force- dependent measures. Indeed, though we report that most absolute force
280 variables are highly reliable, a large component of this reliability might be explained
281 by the contribution of body weight alone. Accordingly, on balance and to ensure
282 reliability, we advocate the use of relative as opposed to absolute force dependent
283 CMJ measures in practice.

284

285 **Practical Applications**

286

287 CMJ variable selection should be based on a number of factors including relative and
288 absolute reliability, MDC and conceptual efficacy⁵. Indeed, chosen variables should
289 have a sound biological basis that theoretically links what is being measured to a
290 desirable performance outcome, and / or be sensitive to training- and match- load
291^{5,15,16}. We have reported the reliability and MDC for a wide range of CMJ variables that
292 practitioners can use to inform variable selection. However, it is beyond the scope of
293 this investigation to examine their conceptual efficacy. Therefore, we encourage

294 practitioners to review the scientific literature examining the typical magnitude of
295 change for CMJ variables following football training and / or match play. This can then
296 be considered alongside the MDC values presented herein to support decision making
297 relating to variable selection. To that end, we note the need for further scientific
298 research of this type in elite-level young football players and suggest that future
299 research examines the acute (i.e., pre- to- post- match) and longitudinal (i.e., cross-
300 season) changes to CMJ variables in these cohorts to help in this regard.

301

302 Based on the work of Cormack and colleagues²³, we applied an arbitrary threshold of
303 10% to define absolute reliability but acknowledge that higher CV's might be
304 acceptable for measures that are particularly sensitive to changes in neuromuscular
305 status⁸. Overall, consistent with previous work²³, we consider 10% to be a useful
306 threshold when the objective is to detect subtle day- to- day changes to neuromuscular
307 status²³ (i.e., for longitudinal player monitoring^{13,26}). Again, to help in this regard, we
308 encourage practitioners to consider the MDC statistic to support CMJ variable
309 selection.

310

311 Unfortunately, we only examined male players and acknowledge that our findings are
312 not generalisable across female cohorts. As such, we encourage similar research to
313 be urgently conducted in equivalent female cohorts.

314

315 **Conclusion**

316

317 Widely used CMJ variables typically have *moderate* to *excellent* relative reliability and
318 *good* absolute reliability using the Best_{JH}, Mean_{JH} and within-session methods in elite-

319 level young football players. Overall, force- and power- orientated measures have
320 better reliability than velocity-, RFD- and impulse- orientated measures. However,
321 force- dependent measures correlate very strongly with body weight, which appears
322 to effect reliability. Consequently, practitioners are advised to use relative as opposed
323 to absolute force measures. Of the commonly used movement strategy variables in
324 practice, eccentric deceleration RFD might be limited by low absolute reliability and a
325 large MDC. Finally, practitioners are reminded to consider the conceptual basis of
326 measures alongside these reliability data to make better informed decisions relating
327 to variable selection.

328

329 **Declarations**

330

331 All authors report that they have no conflicting interests.

332

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334

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337

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430 **Table 1**, Descriptive statistics for countermovement jump (CMJ) variables for U-18, U-
431 23, Combined (U-18 + U-23) and Goalkeeper groups. Data are presented as Mean,
432 95% confidence intervals (CI) \pm standard deviation (SD). *Abs*; absolute; *Con*,
433 concentric; *CT*, contraction time; *CM*, countermovement; *Dec*, deceleration; *Dur*,
434 duration; *Ecc*, eccentric; *FT*, flight time, *FT: CT*, flight time: contraction time; *F*, force;
435 *Imp*, impulse; *IM*, impulse momentum; *Mvt*, movement; *P*, power; *Rel*, Relative; *RFD*,
436 rate of force development; *RSI*, reactive strength index; *V*, velocity.

CMJ Variable	U-18 (n = 20)	U-23 (n = 16)	Combined (n = 36)	Goalkeepers (n = 6)
Body Weight (N)	728 (691 - 764) ± 82	733 (698 - 768) ± 71	730 (705 - 755) ± 76	806 (756 - 855) ± 62
CM Depth (cm)	-32.7 (-35.7 - -29.7) ± 6.9	-30.3 (-34 - -26.6) ± 7.6	-31.5 (-33.9 - -29.2) ± 7.2	-39.8 (-44.7 - -34.8) ± 6.2
Con Dur (ms)	253 (236 - 269) ± 38	228 (210 - 247) ± 38	241 (228 - 253) ± 39	265 (244 - 285) ± 26
Con Imp 100ms (N.s)	109 (95 - 124) ± 33	129 (110 - 148) ± 38	119 (107 - 131) ± 37	113 (97 - 129) ± 20
Con Mean F (N)	1562 (1440 - 1685) ± 280	1705 (1559 - 1851) ± 298	1634 (1538 - 1729) ± 293	1726 (1568 - 1884) ± 197
Con Mean P (W)	2313 (2110 - 2515) ± 462	2572 (2283 - 2861) ± 589	2442 (2267 - 2618) ± 537	2641 (2278 - 3004) ± 453
Con Peak F (N)	1979 (1816 - 2143) ± 373	2173 (1948 - 2399) ± 461	2076 (1938 - 2215) ± 424	2116 (1973 - 2258) ± 178
Con Peak V (m/s)	2.82 (2.77 - 2.87) ± 0.12	2.85 (2.75 - 2.96) ± 0.22	2.84 (2.78 - 2.89) ± 0.17	2.94 (2.76 - 3.11) ± 0.21
Ecc Braking Imp (N.s)	67.6 (61.9 - 73.3) ± 13.1	73.5 (64.4 - 82.6) ± 18.6	70.6 (65.3 - 75.8) ± 16.1	90.5 (79.3 - 101.7) ± 14
Ecc Dec RFD Abs. (N/s)	8533 (6569 - 10497) ± 4481	11879 (8072 - 15687) ± 7771	10206 (8096 - 12317) ± 6461	8520 (7419 - 9621) ± 1376
Ecc Dec RFD Rel. (N/s/Kg)	7.25 (6.89 - 7.6) ± 0.8	7.37 (6.75 - 7.99) ± 1.26	7.31 (6.97 - 7.65) ± 1.04	8.6 (7.98 - 9.22) ± 0.78
Ecc Dur (ms)	479 (444 - 514) ± 80	423 (394 - 453) ± 60	451 (427 - 476) ± 75	480 (412 - 547) ± 85
Ecc Mean Braking F (N)	1007 (926 - 1089) ± 186	1079 (996 - 1162) ± 169	1043 (985 - 1101) ± 178	1168 (1056 - 1280) ± 140
Ecc Mean F (N)	729 (693 - 765) ± 83	734 (699 - 770) ± 72	732 (707 - 757) ± 76	807 (758 - 857) ± 62
Ecc Mean P Abs. (W)	536 (503 - 569) ± 75	546 (507 - 585) ± 80	541 (516 - 566) ± 76	706 (637 - 776) ± 87
Ecc Mean P Rel. (W/Kg)	7.25 (6.89 - 7.6) ± 0.8	7.37 (6.75 - 7.99) ± 1.26	7.31 (6.97 - 7.65) ± 1.04	8.6 (7.98 - 9.22) ± 0.78
Ecc Peak F (N)	1924 (1741 - 2106) ± 417	2156 (1911 - 2400) ± 499	2040 (1887 - 2192) ± 467	2112 (1964 - 2260) ± 185
Ecc Peak V (m/s)	-1.28 (-1.36 - -1.2) ± 0.18	-1.39 (-1.49 - -1.3) ± 0.19	-1.34 (-1.4 - -1.27) ± 0.19	-1.6 (-1.7 - -1.5) ± 0.13
Ecc: Con Mean F	48.2 (46.4 - 50) ± 4.1	45 (42.4 - 47.6) ± 5.3	46.6 (45 - 48.2) ± 4.9	48.4 (46.4 - 50.3) ± 2.4
Ecc: Con Peak P	0.46 (0.42 - 0.5) ± 0.1	0.56 (0.41 - 0.71) ± 0.3	0.51 (0.43 - 0.58) ± 0.23	0.59 (0.43 - 0.76) ± 0.21
F at Peak P Abs. (N)	1655 (1535 - 1776) ± 275	1829 (1669 - 1989) ± 326	1742 (1641 - 1843) ± 309	1824 (1664 - 1983) ± 200
F at Peak P Rel. (N/Kg)	1.27 (1.18 - 1.36) ± 0.21	1.49 (1.32 - 1.66) ± 0.35	1.38 (1.28 - 1.48) ± 0.3	1.26 (1.16 - 1.36) ± 0.13
F at Zero V (N)	1910 (1731 - 2088) ± 407	2094 (1874 - 2314) ± 448	2002 (1861 - 2143) ± 431	2072 (1921 - 2223) ± 189
FT (ms)	562 (546 - 578) ± 37	582 (564 - 600) ± 37	572 (560 - 584) ± 38	603 (567 - 639) ± 44
FT: CT	0.72 (0.66 - 0.77) ± 0.12	0.87 (0.8 - 0.94) ± 0.14	0.79 (0.74 - 0.84) ± 0.15	0.77 (0.69 - 0.85) ± 0.1
JH - FT (cm)	38.9 (36.6 - 41.1) ± 5.1	41.7 (39.1 - 44.3) ± 5.3	40.3 (38.5 - 42) ± 5.3	44.8 (39.7 - 49.9) ± 6.4
JH - IM (cm)	37.7 (36.3 - 39.2) ± 3.4	39 (36 - 42) ± 6.1	38.4 (36.8 - 40) ± 4.9	41.3 (36.3 - 46.2) ± 6.2
Landing RFD (N/s)	117224 (90548 - 143901) ± 60870	82289 (70087 - 94491) ± 24902	99757 (83741 - 115772) ± 49028	259958 (20132 - 499784) ± 299726
Mvt Start to Peak F (s)	0.6 (0.55 - 0.65) ± 0.11	0.49 (0.44 - 0.53) ± 0.1	0.54 (0.51 - 0.58) ± 0.12	0.54 (0.36 - 0.72) ± 0.22
Mvt Start to Peak P (s)	0.73 (0.67 - 0.78) ± 0.13	0.61 (0.57 - 0.66) ± 0.09	0.67 (0.63 - 0.71) ± 0.12	0.73 (0.62 - 0.84) ± 0.14
Peak Landing F (N)	4328 (3829 - 4826) ± 1138	3779 (3391 - 4167) ± 792	4053 (3726 - 4381) ± 1003	5244 (3813 - 6676) ± 1789
Peak P Abs. (W)	4038 (3752 - 4325) ± 654	4365 (3929 - 4801) ± 890	4202 (3945 - 4458) ± 785	4766 (4096 - 5436) ± 837
Peak P Rel. (W / kg)	54.38 (52.07 - 56.69) ± 5.26	58.32 (53.58 - 63.06) ± 9.68	56.35 (53.76 - 58.94) ± 7.91	57.72 (52.36 - 63.07) ± 6.69
RSI Modified	0.55 (0.51 - 0.59) ± 0.09	0.67 (0.6 - 0.74) ± 0.15	0.61 (0.56 - 0.65) ± 0.14	0.64 (0.56 - 0.72) ± 0.1

439 **Table 2**, Best_{JH}, Mean_{JH} and Within-Session reliability of countermovement jump
440 (CMJ) variables. Data are presented as relative reliability: *ICC*, intraclass correlation
441 coefficient (\pm 95% CI) and absolute reliability: *CV*, coefficient of variation; *SEM*,
442 standard error of measurement and *MDC%*, minimal detectable change (percent).
443 *Abs*; absolute; *Con*, concentric; *CT*, contraction time; *CM*, countermovement; *Dec*,
444 deceleration; *Dur*, duration; *Ecc*, eccentric; *FT*, flight time, *FT: CT*, flight time:
445 contraction time; *F*, force; *Imp*, impulse; *IM*, impulse momentum; *Mvt*, movement; *P*,
446 power; *Rel*, Relative; *RFD*, rate of force development; *RSI*, reactive strength index; *V*,
447 velocity.
448

CMJ Variable	ICC (95% CI)	Best _{JH}		Mean _{JH}		Within-Session	
		CV; SEM; MDC%	ICC (95% CI)	CV; SEM; MDC%	ICC (95% CI);	CV; SEM; MDC%	
Body Weight (N)	0.99 (0.99 - 1.00)	1.1; 7.84; 2.9	0.99 (0.99 - 1.00)	1.1; 7.84; 2.9	1.00 (1.00 - 1.00)	0; 0; 0	
CM Depth (cm)	0.93 (0.88 - 0.96)	-8.3; 2.74; -23.1	0.93 (0.88 - 0.96)	-8.3; 2.74; -23.1	0.83 (0.65 - 0.91)	-8; 2.62; -22.1	
Con Dur (ms)	0.95 (0.91 - 0.97)	5.1; 12.5; 14.2	0.95 (0.91 - 0.97)	5.1; 12.5; 14.2	0.86 (0.76 - 0.92)	5.8; 14.3; 16.2	
Con Imp 100ms (N.s)	0.96 (0.92 - 0.97)	8.7; 10.1; 24	0.96 (0.94 - 0.98)	8; 8.8; 22.3	0.92 (0.88 - 0.95)	9.2; 10; 25.6	
Con Mean F (N)	0.98 (0.96 - 0.99)	3.7; 61.6; 10.4	0.98 (0.97 - 0.99)	3.2; 51.1; 8.9	0.96 (0.93 - 0.98)	3.4; 53.4; 9.3	
Con Mean P (W)	0.96 (0.93 - 0.98)	6.2; 150; 17.2	0.96 (0.93 - 0.98)	6; 141; 16.7	0.95 (0.92 - 0.97)	5.1; 117; 14	
Con Peak F (N)	0.95 (0.92 - 0.97)	6.1; 126; 16.8	0.97 (0.94 - 0.98)	4.8; 96; 13.3	0.93 (0.90 - 0.96)	5.2; 105; 14.4	
Con Peak V (m/s)	0.83 (0.70 - 0.90)	3.5; 0.1; 9.8	0.83 (0.71 - 0.91)	3.7; 0.1; 10.2	0.87 (0.81 - 0.92)	2.4; 0.07; 6.6	
Ecc Braking Imp (N.s)	0.91 (0.85 - 0.95)	10.7; 7.84; 29.7	0.93 (0.88 - 0.96)	10.2; 6.54; 28.4	0.62 (0.47 - 0.75)	18.4; 11.69; 50.9	
Ecc Dec RFD Abs. (N/s)	0.95 (0.92 - 0.97)	20.5; 1995; 56.9	0.96 (0.93 - 0.98)	18.5; 1579; 51.2	0.92 (0.87 - 0.95)	21.8; 1876; 60.5	
Ecc Dec RFD Rel. (N/s/Kg)	0.95 (0.92 - 0.97)	21.9; 2.61; 60.8	0.96 (0.93 - 0.98)	20.2; 2.1; 56.1	0.92 (0.87 - 0.95)	23.5; 2.45; 65.2	
Ecc Dur (ms)	0.88 (0.78 - 0.93)	8.1; 37.5; 22.5	0.88 (0.78 - 0.93)	8.1; 37.5; 22.5	0.82 (0.73 - 0.89)	8.5; 39.1; 23.7	
Ecc Mean Braking F (N)	0.95 (0.92 - 0.97)	5.1; 53.9; 14.2	0.96 (0.93 - 0.98)	4.3; 43.3; 12	0.84 (0.75 - 0.90)	6.5; 65.3; 18	
Ecc Mean F (N)	0.99 (0.99 - 1.00)	1.1; 7.88; 2.9	1.00 (0.99 - 1.00)	1; 7.73; 2.9	1.00 (1.00 - 1.00)	0.1; 0.91; 0.3	
Ecc Mean P Abs. (W)	0.93 (0.88 - 0.96)	6.3; 36; 17.6	0.92 (0.85 - 0.95)	7.1; 37.8; 19.8	0.75 (0.55 - 0.86)	7.6; 40.5; 21.1	
Ecc Mean P Rel. (W/Kg)	0.91 (0.84 - 0.95)	6.1; 0.45; 16.8	0.89 (0.80 - 0.94)	7; 0.49; 19.4	0.68 (0.47 - 0.81)	7.7; 0.54; 21.5	
Ecc Peak F (N)	0.96 (0.93 - 0.98)	6.4; 130; 17.7	0.96 (0.93 - 0.98)	5.7; 110; 15.8	0.90 (0.83 - 0.94)	6.5; 126; 18.1	
Ecc Peak V (m/s)	0.79 (0.64 - 0.88)	-10.4; 0.14; -28.7	0.89 (0.81 - 0.94)	-6.8; 0.1; -19	0.72 (0.50 - 0.84)	-7.2; 0.11; -20	
Ecc: Con Mean F	0.94 (0.90 - 0.97)	3.4; 1.61; 9.4	0.94 (0.90 - 0.97)	3.4; 1.61; 9.4	0.89 (0.81 - 0.93)	3.2; 1.54; 9	
Ecc: Con Peak P	0.97 (0.96 - 0.99)	9.7; 0.05; 26.8	0.97 (0.95 - 0.98)	9.9; 0.05; 27.5	0.82 (0.66 - 0.9)	15.3; 0.07; 42.3	
F at Peak P Abs. (N)	0.99 (0.97 - 0.99)	2.8; 49.6; 7.8	0.98 (0.97 - 0.99)	2.9; 49; 8	0.94 (0.87 - 0.97)	3.6; 60.9; 9.9	
F at Peak P Rel. (N/Kg)	0.98 (0.96 - 0.99)	4.4; 0.06; 12.2	0.97 (0.95 - 0.99)	4.7; 0.06; 13.1	0.88 (0.78 - 0.94)	6.4; 0.08; 17.8	
F at Zero V (N)	0.95 (0.92 - 0.97)	6.5; 129; 17.9	0.95 (0.92 - 0.97)	6.2; 118; 17.2	0.92 (0.86 - 0.95)	6.2; 117; 17.1	
FT (ms)	0.93 (0.87 - 0.96)	2.5; 14.4; 7	0.92 (0.86 - 0.96)	2.6; 14.8; 7.3	0.88 (0.82 - 0.93)	2.3; 12.8; 6.3	
FT: CT	0.91 (0.84 - 0.95)	8.1; 0.06; 22.4	0.94 (0.89 - 0.97)	6.2; 0.05; 17.1	0.90 (0.85 - 0.94)	6.1; 0.05; 16.9	
JH - FT (cm)	0.93 (0.87 - 0.96)	5.1; 2.06; 14.2	0.92 (0.87 - 0.96)	5.3; 2.06; 14.6	0.89 (0.83 - 0.93)	4.5; 1.76; 12.5	
JH - IM (cm)	0.84 (0.73 - 0.91)	7.3; 2.72; 20.1	0.84 (0.72 - 0.91)	7.6; 2.74; 21.1	0.86 (0.80 - 0.92)	5.2; 1.85; 14.4	
Landing RFD (N/s)	0.97 (0.95 - 0.98)	24.5; 31626; 67.8	0.97 (0.94 - 0.98)	25.6; 26980; 71.1	0.77 (0.67 - 0.85)	51.6; 54984; 143	
Mvt Start to Peak F (s)	0.81 (0.67 - 0.89)	14.8; 0.08; 41	0.89 (0.80 - 0.93)	10.3; 0.05; 28.7	0.77 (0.67 - 0.86)	12.8; 0.06; 35.6	
Mvt Start to Peak P (s)	0.87 (0.77 - 0.92)	8.9; 0.06; 24.6	0.92 (0.86 - 0.96)	6.3; 0.04; 17.6	0.85 (0.78 - 0.91)	7.2; 0.05; 19.9	
Peak Landing F (N)	0.92 (0.86 - 0.95)	10.4; 444; 28.8	0.92 (0.86 - 0.95)	10.4; 444; 28.8	0.69 (0.56 - 0.80)	16.7; 708; 46.3	
Peak P Abs. (W)	0.98 (0.96 - 0.99)	3.9; 165; 10.8	0.98 (0.96 - 0.99)	4.2; 172; 11.6	0.97 (0.94 - 0.98)	3.1; 126; 8.5	
Peak P Rel. (W / kg)	0.95 (0.92 - 0.97)	4.2; 2.32; 11.6	0.95 (0.91 - 0.97)	4.5; 2.44; 12.5	0.94 (0.88 - 0.96)	3.2; 1.71; 8.8	
RSI Modified	0.93 (0.88 - 0.96)	7.7; 0.05; 21.4	0.94 (0.89 - 0.96)	7.6; 0.04; 21.2	0.91 (0.86 - 0.94)	7; 0.04; 19.4	