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1 **Title**

2 Biomechanical Upper-Extremity Performance Tests And Isokinetic Shoulder Strength in

3 Collision and Contact Athletes

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29 **Abstract**

30 The aim of this study was threefold (1) to assess the reliability of three upper-extremity
31 performance tests: a countermovement push up, press jump and drop box land, performed
32 on a set of dual force plates (2) to examine whether there was an association
33 between isokinetic dynamometry and the performance tests in a non-injured cohort of
34 collision/contact athletes and (3) to establish a normal descriptive profile of the vertical
35 ground reaction forces from the performance tests, in a cohort of contact/collision athletes.
36 The study was split into two sub-sections; the inter-day reliability of three upper-extremity
37 performance tests (n=21) and a descriptive, correlation study investigating the
38 relationship between isokinetic dynamometry and performance tests metrics (n=39). We
39 used intraclass correlation coefficients (absolute agreement, 2-way mixed-effects
40 model) with 95% confidence intervals to quantify inter-day reliability of all variables. We used
41 Pearson correlation coefficients to investigate associations between isokinetic strength and
42 vertical ground reaction force asymmetry variables. Inter-day reliability was moderate-to-
43 excellent for the upper-extremity performance tests (ICC 0.67– 0.97). There was no
44 statistically significant correlation between external and internal rotational peak torque and
45 the variables of CPMU, PJ and BDL (r range= .02 – .24). These upper-extremity tests are
46 reliable for use with male contact/ collision athletes.

47

48 **Keywords**

49 Shoulder; return to sport criteria; upper-extremity performance tests; isokinetic dynamometry;
50 contact athletes; collision athletes.

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57 **Introduction**

58 The burden of shoulder injuries is high in collision and contact sports often resulting in
59 prolonged absence from play.^{1,2} Re-injury rates are particularly high in young collision and
60 contact athletes who have undergone surgical glenohumeral joint stabilisation (5.9% to
61 51%).³⁻⁵ These athletes usually return to sports within 3 to 9 months following shoulder
62 reconstruction and surgeons often rely solely on physical exams and time following surgery
63 to determine when patients are ready to return to sport (RTS).^{6,7} Most physicians do not
64 utilise sport-specific performance tests perhaps forgoing additional important feedback
65 regarding the feasibility of return to sport.⁶⁻⁸ The literature on upper-extremity performance
66 tests continues to evolve. However many of these functional tests are yet to be fully explored
67 in clinical practice with few studies examining the threshold at which they equate to
68 prognosis of re-injury.⁹ The criteria used to determine when an athlete is ready to RTS
69 should reflect the demands of that particular sport and any measure which helps to better
70 inform safer RTS should be investigated.¹⁰

71

72 Functional tests assess overall function, providing information on specialised movements in
73 sport, exercise, and occupations.^{11,12} For example the countermovement jump, a functional
74 performance test in the lower limb, is not an isolated assessment of knee function but often
75 considered a measurement of lower limb explosive power.^{11,12} There are number of upper
76 limb functional tests described in the literature.¹³⁻¹⁵ These tests are traditional field tests
77 aiming to mimic sport activities. Lower limb injury studies have highlighted the role of sport-
78 specific performance tests that assess components of strength and power (e.g. rate of force
79 development (RFD) and explosive strength) as potential prognostic factors for injury.¹⁶⁻¹⁸
80 These tests allow clinicians to identify modifiable (trainable) variables of strength that help
81 athletes prepare for return to sport.¹⁹ In the context of the upper limb, collision athletes in
82 particular, not only need to be strong but are often required to produce upper body force
83 quickly in activities such as tackling, being tackled, handing-off and falling to the ground.²⁰

84

85 We proposed that a cluster of tests that assessed upper body performance and strength during
86 closed kinetic chain movements may provide further insight into an athlete's shoulder and
87 upper body function. The primary aim of this study was to assess the reliability of three upper-
88 extremity performance tests performed on a set of dual force plates: a countermovement push
89 up (CMPU), press jump (PJ) and drop box land (BDL). The secondary aim of the study was
90 to investigate if an association existed between isokinetic dynamometry and the performance
91 tests in a normal, non-injured cohort of collision/contact athletes . The final aim was to
92 establish a normal descriptive profile of the vertical ground reaction forces from the
93 performance tests, in a cohort of collision athletes.

94

95 **Materials & Methods**

96 **Study Design**

97 This cross-sectional study was split into two sub-sections. Section one of the study assessed
98 the inter-day reliability of three upper-extremity performance tests. Section two used a
99 descriptive, correlation analysis to examine if an association existed between isokinetic
100 dynamometry and the performance tests in a normal, non-injured cohort of collision athletes.

101 **Participants**

102 A convenience sample of male participants, aged 18 to 40 years of age, who were participating
103 in competitive collision and/or contact sport locally, were invited to take part in the study.
104 Athletes that purposely hit or collide with each other or with inanimate objects were defined
105 as collision athletes (e.g. rugby).²¹ Athletes that routinely make contact with each other or with
106 inanimate objects but usually with less force than in collision sports were defined as athletes
107 who played contact sport (e.g. basketball).²¹ Athletes were classified as playing at a
108 competitive level if they actively competed in competition and/or were registered in a local,
109 regional or national federation. We excluded anyone with symptomatic upper limb pathology
110 that had been actively managed in the last 6 months or whom had undergone upper limb

111 surgery in the previous 12 months. If participants had a health condition that could explain
112 reduction in shoulder strength (e.g. inflammatory arthritis, neurological disorder), they also
113 were excluded. Baseline characteristics for both sub-study groups are shown in Table 1. The
114 testing took place at the xxxxx. The study was approved by the xxxxx.

115

116 **Test protocol**

117 The athlete's height, mass and dominant limb (defined as the preferred throwing
118 arm) were recorded before testing commenced. Prior to testing, participants
119 completed a standardised warm-up comprising two minutes of light jogging, five
120 body-weight squats and 20 shoulder internal and external rotations against light
121 (banded) resistance at 90° abduction. Participants first executed three upper-
122 extremity performance tests, in the sequence of C MPU, PJ, BDL, followed by
123 isokinetic strength testing. The order of tests were completed in this sequence for all
124 participants to mitigate the possible effects of fatigue on testing. For inter-day
125 reliability testing two testing sessions were completed with a 2-9 days interval
126 between sessions.

127

128 *Upper-extremity Performance Tests*

129 A retro-reflective marker (14 mm diameter) was attached to the skin over the 7th cervical
130 vertebra (C7). A 10-camera optical motion analysis system (200 Hz; Bonita B10, Vicon, UK)
131 was used to track the position of this marker during testing, and was synchronised with two
132 400x600 mm force platforms (1000 Hz; BP400600, AMTI, USA) used to collect vertical ground
133 reaction force (vGRF) data during the upper-extremity performance test exercises.

134

135 The three test exercises performed were the counter-movement push-up (C MPU), box drop
136 landing (BDL) and press-jump (PJ) (Figure 1). Three trials were performed for each exercise,
137 following two familiarisation trials. For the C MPU, the participant began in a push-up position

138 with arms fully extended, one hand on each force plate, 90° shoulder flexion, legs and torso
139 straight and feet together. Inter-hand distance was self-selected by the participant during the
140 practice trials and marked on the ground to ensure between-trial consistency (the same
141 distance was then used in the second testing session for those participating in the reliability
142 sub-study). The participant was cued to use a counter-movement and explode away from the
143 ground as quickly as possible, taking off with the elbows fully extended. No cues were given
144 regarding the landing. The participant returned to the starting position after completing the
145 movement. The starting position for BDL was identical to that for C MPU except that the hands
146 were placed on 20 cm raised boxes positioned 65 cm apart, lateral to the landing position. The
147 participant was cued to simultaneously drop off the box with both arms and decelerate
148 themselves as quickly as possible when they landed on the force plates, returning to a push-
149 up position with elbows fully extended and holding for two seconds before relaxing. For the
150 PJ, the participant positioned themselves as for the C MPU. They then lowered their body to a
151 press-up base position and held the position stationary for 1-2 seconds until cued by the
152 experimenter to explode away from the ground as quickly as possible, taking off with the
153 elbows fully extended (as for the C MPU). No cues were given regarding the landing, and the
154 participant returned to the starting position after completing the movement. The trial was
155 repeated for the PJ if any counter-movement was observed by the investigator prior to take-
156 off. A 30 second break was given between trials, in which the participant returned to a kneeling
157 or standing position to rest, and a 2-minute break was given between exercise tasks.

158

159 *Isokinetic Dynamometry*

160 Following the upper-extremity performance tests participants then performed concentric
161 shoulder internal rotation (IR) and external rotation (ER) isokinetic strength testing at 90°/s
162 (Cybex Humac NORM, Computer Sports Medicine, Inc., Soughton, MA, USA). We tested
163 the non-dominant limb first followed by the dominant limb to standardise testing order. While
164 studies have shown range of motion (ROM) difference according to hand dominance in
165 overhead athletes, this asymmetry has not been demonstrated in a cohort of contact

166 (soccer) athletes.^{22,23} Participants laid in the supine position with their elbow and shoulder in
167 line with the centre of rotation of the dynamometer (Figure 2). The upper limb was rested in
168 the rotation cuff pad, with the olecranon approximating the axis of the dynamometer and the
169 hand gripping the input shaft. ROM was set to 90° of ER and 60° of IR. Participants
170 performed a 5 repetition warm up of concentric-concentric external and internal rotation at
171 90°/s followed by a 60 second rest period. They then performed 2 sets of 5 maximal
172 repetitions with a 60 second rest period between sets .

173 **Data processing**

174 *Upper-extremity Performance Tests*

175 C7 marker trajectory data were filtered using a zero-lag Butterworth filter with a corner
176 frequency of 15 Hz. *Jump height* was calculated for the CMPU and PJ as the change in vertical
177 position of the C7 marker from the instant of take-off (vGRF < 10 N) to the maximum height
178 reached during the aerial phase of the movement.

179

180 The take-off phase was defined for the CMPU as the period from the onset of the downwards
181 counter-movement to the instant of take-off, and for the PJ as the period from the onset of
182 upwards vertical movement of C7 to the instant of take-off. *Peak force* for each side during
183 this phase was extracted. The CMPU take-off phase was divided into three sub-phases based
184 on C7 vertical velocity: eccentric acceleration (C7 moving downwards with increasing velocity
185 at the start of the counter-movement), eccentric deceleration (C7 moving downwards with
186 decreasing velocity – ‘braking’) and concentric (C7 moving upwards prior to take-off)¹⁹. The
187 *impulse* from each upper limb during the eccentric deceleration phase and concentric phase
188 was calculated by integrating vGRF. As the entirety of the PJ take-off phase is concentric (C7
189 moving upwards), impulse for each upper limb was calculated for the phase as a whole. The
190 landing phase was defined as the first 2 s after the instant of landing (vGRF >10). Peak force
191 during this phase (*landing peak force*) was extracted for the CMPU and both peak force and
192 impulse were extracted for the BDL.

193

194 All force and impulse variables were divided by body mass before analysis. Absolute inter-
195 limb asymmetries were calculated for all variables as:

$$196 \quad AbsAsymmetry = \left(1 - \frac{\textit{Minimum of Dominant and Nondominant limb}}{\textit{Maximum of Dominant and Nondominant limb}}\right) \times 100$$

197 This metric quantifies the percentage asymmetry for each individual for the relevant variable,
198 regardless of whether the maximum value was obtained on the dominant or on the non-
199 dominant limb, and thus avoids the requirement to select an arbitrary reference limb for the
200 calculation.²⁴

201

202 *Isokinetic dynamometry*

203 All torques were gravity-corrected. Peak torques in internal rotation and external rotation
204 were extracted from the working sets and divided by body mass prior to analysis. Absolute
205 inter-limb asymmetries were calculated as for the upper-extremity performance test
206 variables.

207 **Statistical analysis**

208 Analyses were conducted in SPSS (version 26.0, USA) and MATLAB (version 2018a,
209 MathWorks, USA). Descriptive statistics were calculated for all variables, and all dependent
210 variables were tested for normal distribution and homogeneity of variance using the one-
211 sample Kolmogorov–Smirnov test and the Levene’s test. As no significant deviations from
212 normality or homogeneity of variance were identified, parametric statistical models were
213 used. Summary statistics are reported as mean ± standard deviation (SD). We used
214 intraclass correlation coefficients (ICCs) (average measurement, absolute agreement, 2-way
215 mixed-effects model) with 95% confidence intervals to quantify inter-day reliability of all
216 variables. Values less than 0.50 were indicative of poor reliability, values between 0.50 were
217 0.75 indicated moderate reliability, values between 0.75 and 0.90 indicated good reliability,
218 and values greater than 0.90 indicated excellent reliability.²⁵ Absolute reliability was

219 assessed by calculating the standard error of measurement (SEM) and minimum detectable
220 change (MDC). SEM values were calculated as follows: $SEM = SD \times \sqrt{(1 - ICC)}$, with SD
221 refers to all measurements in the sample (both test and retest measurements). The SEM
222 was used to calculate MDC values²⁶. We used the Pearson correlation coefficient (r) to
223 investigate associations between isokinetic and vGRF asymmetry variables. Significance
224 was accepted at $\alpha = 0.05$.

225

226 **Results**

227 *Inter-day reliability analysis*

228 The results of the inter-day reliability analysis for the vertical ground reaction forces of three
229 upper-extremity performance tests are summarised in Table 2. These results confirm
230 moderate-to-excellent reliability of these tests. The ICCs for the variables of the CMPU were
231 between 0.70 (0.23,0.88) and 0.97 (0.92,1.00), for the variables of PJ were between 0.86
232 (0.67,0.94) and 0.90 (0.75,0.96) and for the BDL variables were between 0.67 (0.19,0.87)
233 and 0.87 (0.69,0.95). Landing impulse on the CMPU and BDL demonstrated moderate
234 reliability (0.70 (0.23,0.88) and 0.73 (0.33,0.89) for the dominant arm respectively) with the
235 remaining variables demonstrating good-to-excellent reliability (> 0.80).

236

237 *Descriptive correlation analysis*

238 Normal values and 95% confidence intervals are reported for the isokinetic internal and
239 external rotational peak torque and CMPU, PJ and BDL variables in Table 3. Absolute inter-
240 limb asymmetry was between 4% and 11% for vGRF variables, with standard deviations of
241 3-8% for participants. Jump height was 10.9 (± 3.5) cm for the CMPU and a 9.1 (± 3.8) cm for
242 the PJ. Isokinetic external rotation peak torque was 44.8 (± 8.2) N.m.kg⁻¹ on the dominant
243 side and 44.6 (± 7.4) N.m.kg⁻¹ on the non-dominant side while internal rotation peak torque
244 was 59.5 (± 11.1) N.m.kg⁻¹ on the dominant side and 58.8 (± 13.8) N.m.kg⁻¹ on the non-
245 dominant side.

246 There was no statistically significant correlation between IR and ER peak torque and the
247 variables of the three jump tests (Table 4).

248 **Discussion**

249 This study showed good-to-excellent inter-day-test reliability (ICCs 0.80- 0.97) for the
250 majority of the time series data of the three novel upper-extremity performance tests. The
251 landing impulse variables of the CPMU and BDL demonstrated moderate levels of reliability
252 (ICCs 0.67 – 0.79). These results suggest that the CPMU, PJ and BDL assessed on a dual
253 force plate system, are reliable tests for use with male collision athletes. To our knowledge
254 we are the first to examine the relationship between isokinetic strength testing for the
255 shoulder and vGRFs from upper limb performance tests performed on a dual force plate
256 system. Our findings show there is no significant relationship between external and internal
257 rotational peak torque and the variables of CPMU, PJ and BDL. This observation suggests
258 that these upper-extremity performance tests have potential to add new insight into an
259 athlete's upper body function and readiness to return to sport. The descriptive data may be
260 used as a comparative baseline for injured athletes.

261 Disruption to the subscapularis muscle during the open surgical approach, shoulder
262 immobilisation, pain and muscle atrophy may all contribute to reduction in strength
263 experienced after surgical shoulder stabilisation procedures. In collision and contact sports
264 the shoulder must withstand large external forces. For example shoulder forces in a rugby
265 tackle are reported to be as high as 1.95 and 2.31 body weight ²⁷. The proposed upper-
266 extremity performance tests assess neuromuscular function, including an evaluation of
267 muscle properties (e.g. coupled eccentric/concentric muscle actions) and asymmetries on
268 landing tasks and may assist in identifying trainable deficits and managing the complexities
269 of the return to sport transition. Future prospective studies are first required to assess
270 whether any deficits are present in an injured cohort.

271

272 Kinematic and ground reaction force data concerning closed-chain upper-extremity tests is
273 scarce when comparing our study to previous literature. The Athletic Shoulder test (ASH)
274 has been recently described to assess maximal voluntary contractions of isometric upper

275 limb force, in three long lever positions²⁸. The ASH test is performed on a force plate and
276 aims to replicate the shoulder muscle contraction required by collision athletes in the tackle
277 position²⁸. It is a long lever upper limb isometric test in contrast to the performance tests
278 described in this study. Kock et al²⁹ examined the ground reaction force variables of a clap
279 push-up and 3 box drop push ups from various heights. They found no significant peak
280 vGRF magnitude or timing differences between exercises and demonstrated values of peak
281 vGRF similar to our studies (6.4 – 6.8 N.kg⁻¹, normalised to body mass to allow between-
282 group comparisons). Moore et al.³⁰ examined the kinematics and vGRFs of the dominant
283 upper limb only in the same 4 plyometric push ups variations in recreationally active adult
284 males. They found peak vGRFs (6.8 - 7.6 N.kg⁻¹) greater than those of our study or reported
285 by Kock et al.²⁹

286

287 The reliability of the upper-extremity performance tests compare favourably to the reliability
288 of isokinetic dynamometry, the current preferred measurement for quantifying muscle
289 strength in the upper limb^{31,32}. Van Meetran et al³³ demonstrated ICCs of between 0.69 –
290 0.92 in isokinetic muscle strength measurements of the shoulder. They also compare
291 favourably with the reliability measurements reported for other upper quadrant functional
292 tests^{34–36}. However, they are smaller than those published for the ASH test (ICC 0.96 to
293 0.98). This is likely due to the more dynamic nature of our performance tests. The reliability
294 of the C MPU, PJ and BDL tests are similar to that of the equivalent in the lower limb
295 (counter movement jump, squat jump and drop jump)^{37,38}. The ICCs were lowest (0.67-0.79)
296 for the landing impulse variables of our tests. Participants were allowed to self-select their
297 landing technique from the C MPU and PJ which may have contributed to lower ICC scores.
298 MDC is useful in a monitoring context to establish a meaningful change. The present data
299 establishes the reliability and smallest worthwhile change between sessions, which may be
300 useful to practitioners in order to effectively monitor changes associated with rehabilitation
301 and performance.

302

303 The upper-extremity performance tests did not appear to be related to shoulder rotational
304 strength. This observation may be for a number of reasons. Rotational strength may not
305 correlate directly with the ability to produce force in the push horizontal plane. However
306 studies have examined electromyography activity and recruitment of the rotator cuff muscles
307 during exercises in the push horizontal plane such as the bench press³⁹. They have
308 demonstrated significantly higher posterior rotator cuff (supraspinatus, infraspinatus and
309 teres minor) activity during bench press hypothesising that the rotator cuff provides shoulder
310 joint support by preventing the prime movers that flex the humerus from translating the
311 humeral head anterior on the glenoid fossa in the bench press³⁹. Perhaps another reason
312 the performance tests show no correlation with rotational strength is that other variables
313 such as trunk and hip control in the kinetic chain may influence the outcome of the tests
314 described. The Upper Quarter Y-Balance Test (UQYBT), a closed kinetic chain reaching
315 test, did not directly correlate with shoulder isometric strength, however was significantly
316 associated (albeit it weak) with dynamic tests involving core stability⁴⁰. These findings would
317 support the theory that other variables within the kinetic chain play a part in closed kinetic
318 chain upper quadrant tests.

319

320 **Limitations**

321 This study used athletes across a variety of collision and contact sports which may influence
322 our results. Additionally, while the means, MDC and SEM presented in this study represent
323 healthy male collision and contact athletes, it is likely that different sporting populations
324 present with different normative data. The interpretation of our results is limited to a healthy
325 sample. We cannot extrapolate the results to injured athletes and this remains an area for
326 further study. In this study we only report the kinetic data. The addition of kinematic data
327 could add more meaningful information about participants' ability to absorb energy and
328 distribute force on landing tasks.

329

330 **Conclusion**

331 In contrast to isokinetic testing, the CMPU, PJ and BDL tests offer a performance
332 assessment paralleling the dynamic, closed-chain movement experienced in collision sport
333 such as falling and distributing force. The inter-day reliability was moderate-to-excellent and
334 there was no significant relationship between external and internal rotational peak torque
335 and these tests. Further research using prospective study designs is required to assess the
336 validity of the upper-extremity performance tests in an injured population. We also suggest
337 that these tests are not used in isolation but form part of a cluster of tests of shoulder
338 function including assessment of rotational strength, ROM and joint position sense, to
339 ensure a comprehensive overview of all of the components relevant to the maintenance of
340 shoulder stability.

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358 **Practical Implications:**

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- The countermovement push up, press jump and drop box land tests performed on a
360 set of dual force plates offer a reliable way to identify modifiable (trainable) variables
361 of strength that may help collision athletes prepare for return to sport.
 - The tests poorly correlate with isokinetic dynamometry and therefore have potential
362 to add new insight into an athlete's upper body function and readiness to return to
363 sport.
364
 - The tests should form part of a cluster of tests of shoulder function including
365 assessment of rotational strength, ROM and joint position sense, to ensure a
366 multifaceted approach for return to sport screening following shoulder stabilisation in
367 contact and collision athletes.
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380 **Data availability request:**

381 The data that support the findings of this study are available from the corresponding author
382 upon request

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515 **TABLES**

516 **Table 1** Baseline characteristics of A) reliability study and B) descriptive correlation study

	Reliability Study	Descriptive, Correlation Study
Sport		
n	21	39
%Gaelic	19%	38%
%Rugby	19%	33%
%Soccer	38%	13%
%Mixed Martial Arts	0%	8%
%Multiple	10%	3%
%Hurling	5%	3%
%Basketball	0%	3%
%Field Hockey	10%	0%
Level of Participation		
n	21	39
%Recreational	86%	72%
%Semi-Professional	14%	28%
Dominance		
n	21	39
%Right	90%	82%
%Left	10%	18%

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Table 2 Inter-day reliability with their 95 % CI for the vertical ground reaction forces of the upper-extremity performance tests

	Intra Session Reliability (Test-retest)							
	Dominant				Non-Dominant			
	ICC (95% CI)	SEM	MDC90	MDC95	ICC (95% CI)	SEM	MDC90	MDC95
Counter Movement Push Up (n=21)								
Jump Height (cm)	0.85 (0.64,0.94)	1.21	2.82	3.35				
Take off peak force (N.kg ⁻¹)	0.84 (0.6,0.93)	0.33	0.77	0.92	0.92 (0.76,0.97)	0.26	0.62	0.73
Landing Peak force (N.kg ⁻¹)	0.80 (0.50,0.92)	1.17	2.74	3.26	0.83 (0.57,0.93)	1.17	2.72	3.26
Take Off Eccentric Deceleration Phase Impulse (kN.s)	0.97(0.92,1.00)	0.04	0.09	0.11	0.97 (0.93,0.99)	0.03	0.08	0.09
Take Off Concentric Impulse (kN.s)	0.86(0.65,0.94)	0.10	0.24	0.28	0.86(0.66,0.94)	0.10	0.23	0.27
Landing Impulse (kN.s)	0.70(0.23,0.88)	0.05	0.11	0.13	0.79(0.49,0.92)	0.04	0.10	0.12
Press Jump (n=21)								
Jump Height (cm)	0.87(0.63,0.95)	0.94	2.19	2.60				
Take off peak force (N.kg ⁻¹) (kN.s)	0.90(0.75,0.96)	0.20	0.47	0.46	0.89(0.72,0.95)	0.20	0.46	0.54
Take Off Concentric Impulse (kN.s)	0.86(0.67,0.94)	0.15	0.35	0.42	0.90(0.75,0.96)	0.09	0.22	0.26
Box Drop Land (n=21)								
Landing Peak force (N.kg ⁻¹)	0.80(0.52,0.92)	1.18	2.75	3.26	0.87(0.69,0.95)	0.96	2.24	2.66
Landing Impulse (kN.s)	0.73(0.33,0.89)	0.07	0.17	0.20	0.67(0.19,0.87)	0.06	0.14	0.17

CI=confidence interval. ICC=intraclass correlation coefficient. MDC= minimum detectable change. SEM= standard error of measurement.

Table 3 Normal values in an non-injured cohort

Measure	Limb Normative Data		
	Mean +/- SD (95% Confidence Interval)		
	Dominant	Non- Dominant	Absolute Asymmetry
Counter Movement Push Up (n=39)			
Jump Height (cm)	10.7 +/- 3.5 (9.5, 11.9)		
Take off peak force (N.kg-1)	6.0 +/- 1.1 (5.7, 6.4)	6.0 +/- 1.0 (5.7, 6.3)	4.0 +/- 2.8 (3.1, 4.9)
Landing Peak force (N.kg-1)	13.0 +/- 4.3 (11.6, 14.4)	12.9 +/- 4.3 (11.5, 14.3)	11.2 +/- 8.1 (8.6, 13.8)
Take Off Eccentric Deceleration Phase Impulse (kN.s)	0.6 +/- 0.3 (0.5, 0.6)	0.6 +/- 0.3 (0.5, 0.6)	4.1 +/- 3.0 (3.2, 5.1)
Take Off Concentric Impulse (kN.s)	1.7 +/- 0.8 (1.4, 2.0)	1.7 +/- 0.8 (1.5, 2.0)	4.2 +/- 2.6 (3.3, 5.1)
Press Jump (n=35)			
Jump Height (cm)	9.0 +/- 3.8 (7.8, 10.3)		
Take off peak force (N.kg-1)	5.5 +/- 0.9 (5.2, 5.8)	5.5 +/- 0.8 (5.2, 5.8)	4.2 +/- 2.9 (3.2, 5.2)
Take Off Concentric Impulse (kN.s)	2.1 +/- 1.1 (1.7, 2.5)	2.1 +/- 1.1 (1.7, 2.5)	3.9 +/- 2.7 (3.0, 4.9)
Box Drop Land (n=39)			
Landing Peak force (N.kg-1)	15.1 +/- 3.4 (14.0, 16.3)	15.5 +/- 3.8 (14.3, 16.8)	10.6 +/- 8.5 ((7.9, 13.4)
Landing Impulse (kN.s)	1.8 +/- 0.2 (1.7, 1.9)	1.8 +/- 0.2 (1.7, 1.8)	5.9 +/- 5.4 (4.2, 7.7)

Table 4 Pearson Correlation and P Values

	Correlation Coefficient (r) and P value			
	IR Peak Torque		ER Peak Torque	
	r	P value	r	P value
Counter Movement Push Up (n=39)				
Take off peak force	.03	.838	-.20	.232
Landing Peak force	.07	.689	.24	.147
Take Off Eccentric Deceleration Phase Impulse	-.06	.710	-.16	.319
Take Off Concentric Impulse	.21	.219	.03	.859
Landing Impulse (kN.s)	-.11	.503	.15	.374
Press Jump (n=35)				
Take off peak force	-.16	.337	-.10	.538
Take Off Concentric Impulse	-.15	.405	.06	.745
Box Drop Land (n=39)				
Landing Peak force	.04	.823	.02	.915
Landing Impulse	.07	.657	.21	.208

IR= Internal Rotation. ER= External Rotation.

Figure 1 *Upper-extremity Performance Tests*

A) Counter Movement Jump



B) Press Jump



C) *Box Drop Land*



Figure 2 Setup for Isokinetic Shoulder Internal and External Using an Isokinetic Dynamometer



FIGURES

Figure 1 *Upper-extremity Performance Tests*

Figure 2 *Setup for Isokinetic Shoulder Internal and External Using an Isokinetic Dynamometer*