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Title

Biomechanical Upper-Extremity Performance Tests And Isokinetic Shoulder Strength in Collision and Contact Athletes

Abstract

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

Keywords

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

Introduction

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

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

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

Materials & Methods

Study Design

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

Participants

A convenience sample of male participants, aged 18 to 40 years of age, who were participating in competitive collision and/or contact sport locally, were invited to take part in the study. Athletes that purposely hit or collide with each other or with inanimate objects were defined as collision athletes (e.g. rugby).[21] Athletes that routinely make contact with each other or with inanimate objects but usually with less force than in collision sports were defined as athletes who played contact sport (e.g. basketball).[21] Athletes were classified as playing at a competitive level if they actively competed in competition and/or were registered in a local, regional or national federation. We excluded anyone with symptomatic upper limb pathology that had been actively managed in the last 6 months or whom had under gone upper limb surgery in the previous 12 months. If participants had a health condition that could explain reduction in shoulder strength (e.g. inflammatory arthritis, neurological disorder), they also were excluded. Baseline characteristics for both sub-study groups are shown in Table 1. The testing took place at the xxxxx. The study was approved by the xxxxx.

Test protocol

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

Upper-extremity Performance Tests

A retro-reflective marker (14 mm diameter) was attached to the skin over the 7th cervical vertebra (C7). A 10-camera optical motion analysis system (200 Hz; Bonita B10, Vicon, UK) was used to track the position of this marker during testing, and was synchronised with two 400×600 mm force platforms (1000 Hz; BP400600, AMTI, USA) used to collect vertical ground reaction force (vGRF) data during the upper-extremity performance test exercises.

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

Isokinetic Dynamometry

Following the upper-extremity performance tests participants then performed concentric shoulder internal rotation (IR) and external rotation (ER) isokinetic strength testing at 90°/s (Cybex Humac NORM, Computer Sports Medicine, Inc., Soughton, MA, USA). We tested the non-dominant limb first followed by the dominant limb to standardise testing order. While studies have shown range of motion (ROM) difference according to hand dominance in overhead athletes, this asymmetry has not been demonstrated in a cohort of contact (soccer) athletes.[22,23] Participants laid in the supine position with their elbow and shoulder in line with the centre of rotation of the dynamometer (Figure 2). The upper limb was rested in the rotation cuff pad, with the olecranon approximating the axis of the dynamometer and the hand gripping the input shaft. ROM was set to 90° of ER and 60° of IR. Participants performed a 5 repetition warm up of concentric-concentric external and internal rotation at 90°/s followed by a 60 second rest period. They then preformed 2 sets of 5 maximal repetitions with a 60 second rest period between sets .

Data processing

Upper-extremity Performance Tests

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

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

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

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

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

Isokinetic dynamometry

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

Statistical analysis

Analyses were conducted in SPSS (version 26.0, USA) and MATLAB (version 2018a, MathWorks, USA). Descriptive statistics were calculated for all variables, and all dependent variables were tested for normal distribution and homogeneity of variance using the one-sample Kolmogorov–Smirnov test and the Levene's test. As no significant deviations from normality or homogeneity of variance were identified, parametric statistical models were used. Summary statistics are reported as mean ± standard deviation (SD). We used intraclass correlation coefficients (ICCs) (average measurement, absolute agreement, 2-way mixed-effects model) with 95% confidence intervals to quantify inter-day reliability of all variables. Values less than 0.50 were indicative of poor reliability, values between 0.50 were 0.75 indicated moderate reliability, values between 0.75 and 0.90 indicated good reliability, and values greater than 0.90 indicated excellent reliability.[25] Absolute reliability was assessed by calculating the standard error of measurement (SEM) and minimum detectable change (MDC). SEM values were calculated as follows: SEM = SD × √(1 – ICC), with SD refers to all measurements in the sample (both test and retest measurements). The SEM was used to calculate MDC values[26]. We used the Pearson correlation coefficient (r) to investigate associations between isokinetic and vGRF asymmetry variables. Significance was accepted at $\alpha = 0.05$.

Results

Inter-day reliability analysis

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

Descriptive correlation analysis

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

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

Discussion

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

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

Kinematic and ground reaction force data concerning closed-chain upper-extremity tests is scarce when comparing our study to previous literature. The Athletic Shoulder test (ASH) has been recently described to assess maximal voluntary contractions of isometric upper limb force, in three long lever positions[28]. The ASH test is performed on a force plate and aims to replicate the shoulder muscle contraction required by collision athletes in the tackle position[28]. It is a long lever upper limb isometric test in contrast to the performance tests described in this study. Kock et al[29] examined the ground reaction force variables of a clap push-up and 3 box drop push ups from various heights. They found no significant peak vGRF magnitude or timing differences between exercises and demonstrated values of peak vGRF similar to our studies (6.4 – 6.8 N.kg-1, normalised to body mass to allow between-group comparisons). Moore et al.[30] examined the kinematics and vGRFs of the dominant upper limb only in the same 4 plyometric push ups variations in recreationally active adult males. They found peak vGRFs (6.8 - 7.6 N.kg^{-1}) greater than those of our study or reported by Kock et al.[29]

The reliability of the upper-extremity performance tests compare favourably to the reliability of isokinetic dynamometry, the current preferred measurement for quantifying muscle strength in the upper limb[31,32]. Van Meetran et al [33] demonstrated ICCs of between 0.69 – 0.92 in isokinetic muscle strength measurements of the shoulder. They also compare favourably with the reliability measurements reported for other upper quadrant functional tests [34–36]. However, they are smaller than those published for the ASH test (ICC 0.96 to 0.98). This is likely due to the more dynamic nature of our performance tests. The reliability of the CMPU, PJ and BDL tests are similar to that of the equivalent in the lower limb (counter movement jump, squat jump and drop jump) [37,38]. The ICCs were lowest (0.67-0.79) for the landing impulse variables of our tests. Participants were allowed to self-select their landing technique from the CMPU and PJ which may have contributed to lower ICC scores. MDC is useful in a monitoring context to establish a meaningful change. The present data establishes the reliability and smallest worthwhile change between sessions, which may be useful to practitioners in order to effectively monitor changes associated with rehabilitation and performance.

The upper-extremity performance tests did not appear to be related to shoulder rotational strength. This observation may be for a number of reasons. Rotational strength may not correlate directly with the ability to produce force in the push horizontal plane. However studies have examined electromyography activity and recruitment of the rotator cuff muscles during exercises in the push horizontal plane such as the bench press[39]. They have demonstrated significantly higher posterior rotator cuff (supraspinatus, infraspinatus and teres minor) activity during bench press hypothesising that the rotator cuff provides shoulder joint support by preventing the prime movers that flex the humerus from translating the humeral head anterior on the glenoid fossa in the bench press[39]. Perhaps another reason the performance tests show no correlation with rotational strength is that other variables such as trunk and hip control in the kinetic chain may influence the outcome of the tests described. The Upper Quarter Y-Balance Test (UQYBT), a closed kinetic chain reaching test, did not directly correlate with shoulder isometric strength, however was significantly associated (albeit it weak) with dynamic tests involving core stability[40]. These findings would support the theory that other variables within the kinetic chain play a part in closed kinetic chain upper quadrant tests.

Limitations

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

Conclusion

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

Practical Implications:

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

Data availability request:

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

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TABLES

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%

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	MCD95
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*

	Limb Normative Data		
	Mean +/- SD (95% Confidence Interval)		
Measure	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	
Counter Movement Push Up (n=39)	r	*P* value	r	*P* value
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*