

Research article  
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## Reliability of kinematics and kinetics associated with Horizontal Single leg drop jump assessment. A brief report.

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### Abstract

Determining the reliability of a unilateral horizontal drop jump for displacement provided the focus for this research. Eighteen male subjects were required to step off a 20cm box and land on a force plate with one leg and thereafter jump for maximal horizontal displacement on two different days. Dependent variables from the jump assessment included mean and peak vertical (V) and horizontal (H) ground reaction forces (GRF) and impulses, horizontal displacement and contact time. The between-trial variability of all kinematic and kinetic measures was less than 7%. The most consistent measure over both trials was the horizontal displacement jumped (1.2 to 1.4%) and the most variable were the contact time the first day (6.5%) and peak HGRF the second day (4.3%). In all cases there was less variation associated with the second rather than the first day. In terms of test-retest variability the percent changes in the means and coefficient of variations (CVs) were all under 10%. The smallest changes in the mean (0.43 %), least variation (< 2.26 %) and second highest intraclass correlation co-efficient (ICC = 0.95) were found for horizontal displacement jumped. The highest ICC (0.96) was found for horizontal impulse. Given the reliability of the single leg drop jump, it may offer better prognostic and diagnostic information than that obtained with bilateral vertical jumps.

**Key words:** Ground reaction force, impulse, assessment.

### Introduction

There is a preoccupation in the literature to use vertical bilateral jumps as measures of leg power for the purpose of athlete assessment, performance monitoring, talent identification and in some instances predict readiness for training or recovery from rehabilitation (Arteaga et al., 2000; Cornwell et al., 2002; Knudson et al., 2001; Russell et al., 2006). However, most human movement involves muscles preloading during the eccentric phase and horizontal and vertical propulsive forces (stretch-shorten cycle – SSC), and unilateral propulsion. Movement assessment that incorporates such criteria may be of better prognostic/diagnostic value to the strength conditioner or clinician. One jump that fulfils the above criteria is a single leg drop jump for horizontal displacement (SLDJ) as it is a unilateral jump involving both vertical and horizontal propulsive forces that also involves pre-load and unilateral propulsion. Given that this is a new form of assessment it is important to quantify its reliability. With this in mind the purpose of this paper was to calculate the

between-trial and test-retest reliability of a number of kinematic and kinetic variables associated with SLDJ performance.

### Methods

#### Subjects

Eighteen male subjects volunteered to participate in this research. The subjects were involved in a wide variety of sports that predominantly involved the lower body and had reported no leg injuries in the previous six months. Their age, body mass and height were  $22 \pm 2.5$  yrs,  $80.4 \pm 9.4$  kg and  $1.80 \pm 0.07$  m, respectively (mean  $\pm$  SD). All subjects signed an informed consent form prior to participation in this research. The Human Subject Ethics Committee, Auckland University of Technology, approved all the procedures undertaken.

#### Equipment

Data was collected using a force plate (Type 9287 B; Kistler, Switzerland) set into the floor in accordance with the manufacturers instructions and provided a landing surface of 60 x 90 cm. An x, y, z orthogonal coordinate system was used to describe forces (F) relative to the force plate. The sign convention designated vertical upward (Fz), lateral (Fx), and anterior (Fy) forces as positive. Sampling of the three force components began when a threshold value of 10 N was attained for the VGRF. The GRF were sampled with a CIO-DAS 16/330 analog-to-digital converter (Computer Boards Inc. Middleboro, MA, USA) at a rate of 500 Hz for three seconds. A Labview software program (National Instruments, California) was used to acquire, store, and analyze GRF data. Displacement was measured using a tape measure (Fibreglass, Western Australia).

#### Testing procedures

Testing procedures were conducted twice within a period of four weeks. Subjects were instructed not to perform any heavy leg training in the two days prior to the test day. Subject preparation was individualised according to personal preferences, but typically involved a period of jogging and stretching. Familiarisation with the jump procedure involved twelve warm-up jumps and then a number ( $4 \pm 2$  trials) of higher intensity SLDJ jumps on each leg until the subject felt comfortable with the technique. The subjects were asked to replicate this procedure on the second testing occasion which occurred within

**Table 1.** Between-trial mean, standard deviation (SD) and coefficient of variation (CV) for the jump variables tested each day.

Variables	Day 1 N = 18			Day 2 N = 18		
	Mean	SD	CV	Mean	SD	CV
Displacement (cm)	171	15	1.4	172	15	1.2
CT (s)	.41	.06	6.5	.39	.04	4.1
Impulse H (Ns)	-139	26	5.6	-140	22	3.8
Impulse V (Ns)	463	99	4.5	437	72	3.6
Mean HGRF (N)	-363	58	6.0	-386	58	4.1
Mean VGRF (N)	1135	153	3.8	1130	116	3.3
Peak HGRF (N)	-630	102	5.6	-674	97	4.3
Peak VGRF (N)	1880	247	5.6	1928	219	4.1
RC (cm·s <sup>-1</sup> )	426	73	6.1	453	68	4.0

seven days of the first testing occasion.

### Jump assessment

The jumps were performed from a 20 cm high step-up box adjacent to the force plate. A height of 20cm was selected as most subjects could perform a single leg jump to this height and therefore the loading during landing was not over and above what the athletes were accustomed to. Subjects were asked to step down from the box with their hands affixed to their hips (minimising contribution of arms to leg extensor assessment), onto one leg and thereafter jump for horizontal displacement landing on two feet. The instructions were to “minimize contact time and maximise horizontal displacement”. The horizontal displacement was measured with a tape from toe-off to the heel of the foot landing closest to the force plate. The force plate was marker taped at 2cm intervals to insure easy observation of landing and minimise error. The jump was performed with both legs with the aim to find a plateau in jump performance but with a minimum of four jumps and a maximum of six jumps. The starting leg was randomized.

### Data analysis

For each subject the two longest jumps were identified and averaged for all the variables of interest and thereafter used for analysis. Such an approach is commonly used in field based assessment especially dealing with large subject numbers (Maulder and Cronin, 2005; Parker-Simpson and Cronin, 2006). The variables that were chosen for analysis were; jump displacement, ground contact time (CT), horizontal impulse (impulse H), vertical impulse (impulse V), horizontal mean force (mean HGRF), vertical mean force (mean VGRF), horizontal peak force (peak HGRF), vertical peak force (peak VGRF), and reactivity coefficient (RC). Reactivity coefficients (RC) were calculated according to the following formula (Young, 1995a, 1995b):  $RC = \text{Jump displacement} / \text{contact time}$ .

These variables were chosen as they have been investigated and reported extensively in the literature as important determinants of jumping and running performance, this study therefore quantifying the reliability of these variables in terms of single leg horizontal drop jump performance.

### Statistical analysis

No significant ( $p < 0.181$ ) between leg differences were observed for any of the measures therefore the data from both legs was pooled for analysis. Descriptive statistics

for all variables are represented as mean and standard deviations to indicate centrality and spread of results among subjects. Measures of reliability (difference in mean, CV and ICC) were determined using SPSS 14.0 (SPSS Inc., Chicago, Illinois). The CV (%) was calculated as the  $SD/\text{mean} \times 100$  and the ICC used was a two-tailed mixed consistency model. The CVs were calculated between trials (2). CVs and ICCs were calculated between testing occasions.

### Results

The mean and standard deviation for the nine variables measured for the jumps can be observed in Table 1. The between-trial variability (CV) of all kinematic and kinetic measures was less than 7%. The most consistent measure over both trials was the horizontal displacement (1.2 to 1.4%), and the most variable were the CT the first day (6.5%) and peak HGRF the second day (4.3%). In all cases there was less variation associated with the second day.

In terms of test-retest variability, the percent changes in the means and CVs were all under 10% (see Table 2). The smallest changes in the mean (0.43 %), least variation ( $< 2.26$  %) and second highest ICCs (0.95) were found for horizontal displacement. The highest ICC (0.96) was found for horizontal impulse. As can be observed from Tables 1 and 2, the RC is one of the less stable variables between trials and days.

### Discussion

The CV is a measure of absolute consistency. Some scientists have arbitrarily chosen an analytical goal of the CV being 10% or below but the merits of this value are the source of conjecture (Atkinson et al., 1998). Nonetheless, all dependent variables fell within the 10% criteria goal. The lowest between-trial variation for the SLDJ was found for jump displacement with a CV of 1.4% and 1.2% for day 1 and 2, respectively. Less between-trial variation was observed in all variables on the second testing occasion, possibly indicating that greater familiarization was needed to minimise learning effects. However, as compared to previous studies (Maulder and Cronin, 2005; Parker-Simpson and Cronin, 2006; Ross et al., 2002) examining the reliability of single legged horizontal jump tests and bilateral vertical jump heights to the reliability results of this study, the results were found to be similar.

**Table 2.** Test-retest percentage change in the mean, coefficient of variation (CV) and intraclass correlation coefficients (ICC) for the jump variables as calculated between two testing occasions.

Variable	% Change	CV(%)	ICC
Displacement (cm)	0.43	2.26	0.95
CT (s)	-2.47	5.04	0.90
Impulse H (Ns)	2.53	4.74	0.96
Impulse V (Ns)	1.16	8.28	0.84
Mean HGRF (N)	6.50	5.66	0.95
Mean VGRF (N)	2.81	5.74	0.74
Peak HGRF (N)	6.81	5.86	0.94
Peak VGRF (N)	4.60	5.71	0.84
RC (cm·s <sup>-1</sup> )	7.25	7.78	0.84

The ICC is a measure of relative consistency and denotes the degree to which individuals maintain their position in a sample with repeated measures. Though there are no preset standards for acceptable reliability measures, it has been suggested that ICC values above 0.75 may be considered reliable and this index should be at least 0.90 for most clinical applications (Walmsley et al., 1996). All ICC values (exception mean VGRF) in the present study, were greater than the 0.75 value suggested to denote acceptable reliability. This indicates a high degree of stability between testing days for the procedures and equipment used in this study. These values compare favourably to those cited in previous research concerning new testing procedures (Maulder and Cronin, 2005; Parker-Simpson and Cronin, 2006; Ross et al., 2002).

The horizontal RC was thought to be a measure that may provide insight into the stretch load tolerance and reactive capability of muscle not dissimilar to the vertical reactivity co-efficient (Young, 1995a, 1995b). It was proposed that such a measure may provide better prognostic and diagnostic information given its utilisation of horizontal and vertical GRF and unilateral SSC propulsion. However, prior to utilising this measure the reliability needed to be quantified. It can be observed from Tables 1 and 2 that this measure was less stable between trials and across days than most other measures. The reader needs to be cognizant of the variability of this and other measures prior to their use for assessment purposes.

## Conclusion

The use of unilateral horizontal assessment with some form of preload appears to better simulate human movement in terms of functional assessment of the leg extensors, as most forms of human locomotion involve propulsion of this nature. With this in mind, determining the reliability of such a jump was the focus of this research. It can be concluded that the between-trial and test-retest reliability of some variables (e.g. jump displacement) from the SLDJ test was equal and in many circumstances better than other tests of a similar nature reported in the literature. Given the use of the vertical RC in the literature, the reliability of the horizontal RC was of interest in this study. However, the horizontal RC was found to be less stable than most other measures. Better familiarisation and/or averaging data over a greater number of trials may result in greater reliability. Given these preliminary results there is a need for athletes, coaches, clinicians and

trainers to determine the practical or clinical significance of horizontal measures such as the reactivity co-efficient. Such information may: (1) quantify the relative significance of horizontal jumps in predicting athletic performance; (2) identify the specific deficiencies in leg power to improve individual deficiencies (i.e. compare left and right leg scores) and/or predict readiness to return to sport; (3) identify individuals who may be suited to particular playing positions; (4) talent identification; and, (5) monitor the effects of various training and rehabilitation interventions; to better effect than tests that solely assess vertical force/power production.

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### Key points

- There is a need for greater understanding and utilisation of assessment techniques that assess both the horizontal and vertical components of force/power production.
- The single leg drop jump is an assessment that exhibits high face validity (a unilateral jump involving both vertical and horizontal propulsive forces that also involves pre-load) but reliability needed to be quantified.
- The reliability of the many kinematic and kinetic variables quantified in this study were similar to those published in research in this area and future research needs to determine the clinical and practical significance of this test.

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