ACCURACY AND PRECISION OF THE KINETIC ANALYSIS OF DROP JUMP PERFORMANCE

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The aims of this study were to quantify (a) the accuracy and precision of measuring drop jump (DJ) performance kinetically and (b) the influence of the starting technique on those values. A 14-camera 3D motion analysis system and the double force plate technique were used simultaneously to obtain vertical displacements of centre of mass (CM) for comparison. Ten physically active male subjects performed DJs with 3 different techniques: stepping forward, with a small jump upwards, and flexing one knee before dropping. In total, 90 DJs were analyzed, 30 of each type. Small bias was obtained showing good accuracy as well as small typical error for jump height in all starting techniques. Our data indicates that double force plate technique can be used confidently for DJ analysis regardless of the starting technique.

KEY WORDS: technique, force plate, biomechanics, centre of mass, plyometrics.

INTRODUCTION: Drop jumps (DJ) are a popular form of plyometric training in athletes preparing for explosive activities (Walsh, Arampatzis, Schade & Bruggemann, 2004), and have also been used for testing purposes. During landing, large forces are developed and are eccentrically absorbed by the engaged muscles, producing enhancement through adaptation (Walsh et al., 2004). It should be noted that the type of start technique for the DJ can affect the actual drop height of the jump: Stepping forward is usually taught as the correct approach (where the athlete just drops from a box assuring a free fall from that height). However, techniques involving flexing one knee before dropping (protective) and a small jump upwards (active) have also been used when teaching a correct approach, which can result in a lower and higher than intended drop height, respectively. The use of force plates with appropriate software to analyze mechanical performance in these types of jumps, can provide instant feedback to coaches. Nevertheless, jump height calculations may lack accuracy and precision due to several reasons (Street, McMillan, Board, Rasmussen & Heneghan, 2001), including the inability of the instruments to identify slow motions performed before dropping in the bending knee and stepping forward techniques. The aims of this study were to quantify the accuracy and precision of the double force plate technique (Baca, 1999), by comparing the differences in the vertical displacement of the trajectory of the centre of mass (CM) obtained simultaneously by kinetic and kinematic methods, and to determine the influence of the jump technique on these differences. In this case, a kinematic method was used as the reference measurement.

METHODS: Ten healthy, physically active men, (body mass (BM) = 81.5 ±6.7 kg, age = 31.20 ±6.44, height= 182.0 ±7.4 cm) who were familiar with DJ techniques volunteered for the study. Subjects were instructed to perform DJs for maximum height off a 0.4 m box. Each subject performed three DJ trials for each different technique (bending one knee, stepping forward and jumping upwards) in a randomized order with their hands on their waists throughout the whole movement. A trial was considered successful when both feet clearly landed wholly on the surface of the force plate during both foot-force plate contacts. For each trial, two vertical CM displacements were obtained (kinetic and kinematic) as well as a number of other descriptive variables (Table 1). Comparisons were performed between the different jump techniques.
Kinematic variables were measured using a 14-camera Vicon 3D motion analysis system sampling at 500 Hz. (MX-13, OMG, England). Passive reflective markers were placed according to the 39-marker full-body Plug-in Gait model and the kinematic data recorded was used to calculate the CM displacement. Kinetic variables were measured using two multi

component force plates (Kistler type 9287, Switzerland) sampling at 500 Hz, one with a 0.4 m metallic drop box on top and the second for landing. These force plates were aligned with a 3 mm gap between the shortest sides and each was covered with a competition quality rubber mat (Mondo, Italy). The force plates were zeroed before every trial with the drop box on top. The synchronization between the kinematic and kinetic data was performed by the MX system (Vicon, OMG, England). Subjects performed a self selected warm up before the trials, which included a number of practice DJs. DJs were performed from a stationary position, with the tip of their toes aligned with the edge of the box. Hands were placed on the waist throughout the entire jump execution. Measurements started when the subject was waiting for the testers command, maintaining a stationary position on the box for at least a second before jumping; this was to ensure accurate body weight (BW) data and initial CM height, as well as providing the start of the calculations with a reliable initial vertical velocity of 0 m/s.

The vertical components of the ground reaction force (GRF) from each force plate (F_{Z1} and F_{Z2}) and CM_Z (vertical coordinate of the kinematically calculated CM displacement) were used for analysis. The F_Z data of the airborne phases was defined as the data below a threshold set to 20 N, which was replaced by zeroes before adding them to obtain a unique F_Z. The obtained force was then smoothed using a zero-lag, 4th order Butterworth low-pass filter (Winter, 2009), with a cut-off frequency of 24 Hz (Yu, 1996; 1999). The CM_Z trajectory was then calculated by double integration, using the equation described by Baca (1999):

$$CM_{Z(t)} = CM_{Z0} + \frac{1}{BM} \iint [F_{Z(t)} - BW] dt = CM_{Z0} + \int V_{Z(t)}\, dt$$

$$BM = \frac{BW}{g} = \frac{1}{g\,(b-a)} \int_a^b F_{Z(t)} dt$$

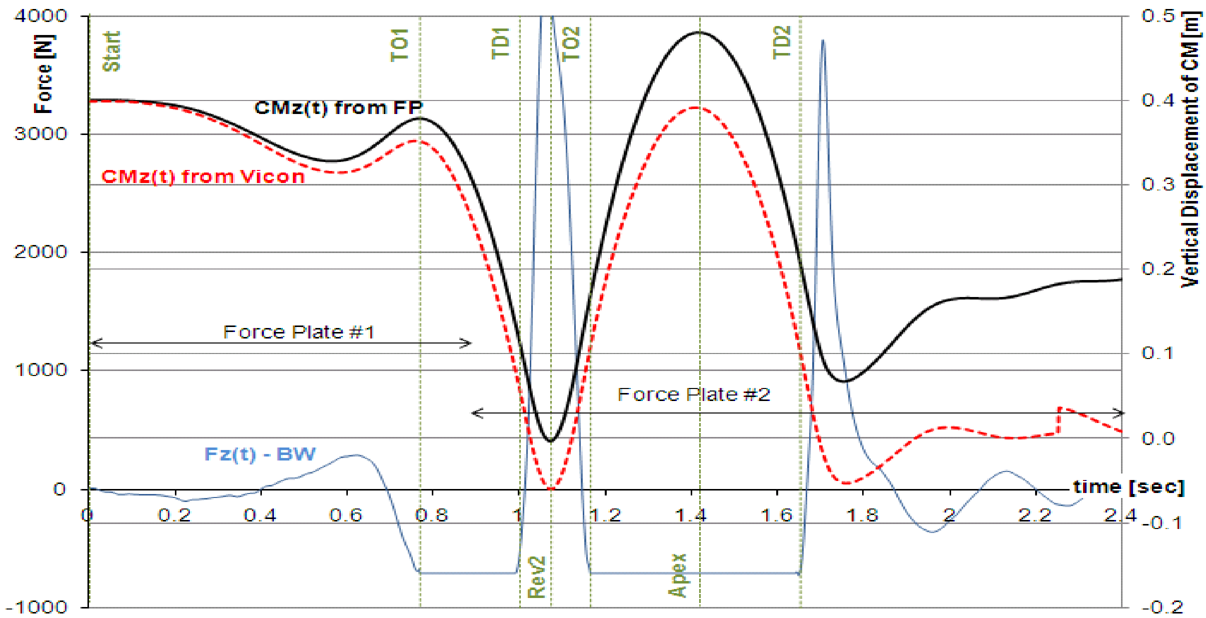


Figure 5: One subject's time histories of the Net F_Z and Net CM_Z calculated by both methods, showing the instants of the Table 1 (differences have been exaggerated).

The integration interval (a,b) was manually selected in each trial, aiming to get the largest portion of the stationary readings prior to the jump. Initial CM_{Z0} was set to the box height: 0.4 m. The start of the movement was also selected manually (Baca, 1999), by selecting the last stationary instant prior to any changes in F_Z readings. Integration was numerically performed using Boole's rule (2012) with the resulting curve compared against the curve simultanously obtained by Vicon, which was subtracted by the initial CM height (averaged in (a, b)), in the same way done to obtain BW and BM, to allow point-to-point comparisons (Figure 1).

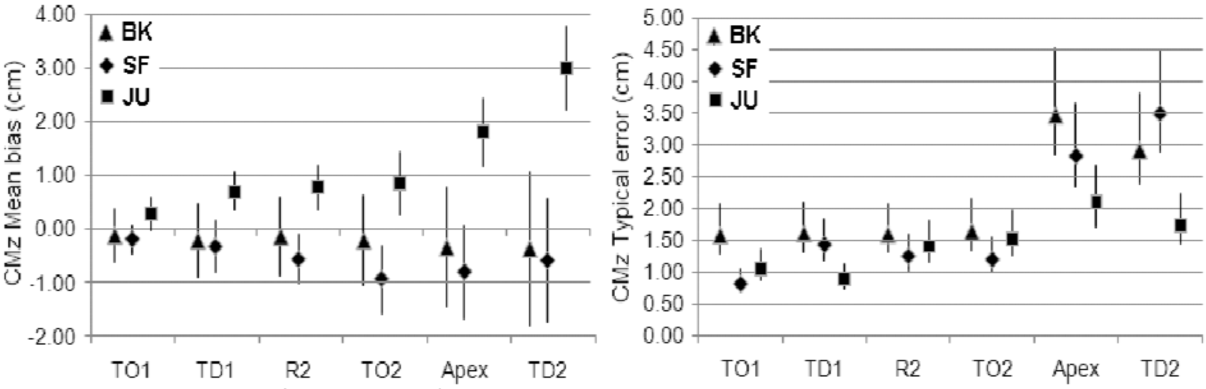
Although 6 points were chosen (Table 1) to describe the CM_z trajectory, the Apex (maximum jumping height) was identified as the most important performance measure of this set.

Table 1: DJ events in chronological order.

Event	Force Plate #	Symbol
Start of the movement on the box	1	Start
Take-Off from the box	1	TO1
Touch Down at floor level	2	TD1
Reverse at floor level	2	Rev2
Take-Off at floor level	2	TO2
Maximum Jump Height (apex)	2, flight	Apex
Final Touch Down at floor level	2	TD2

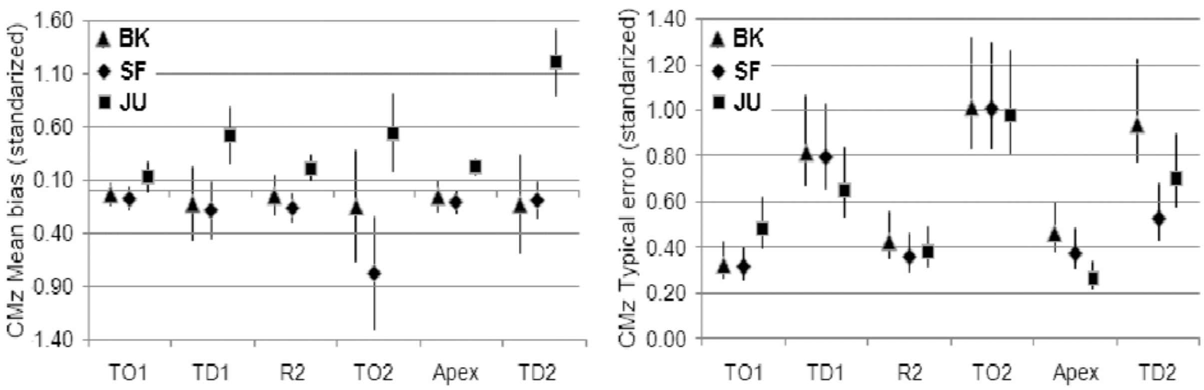
The curves were grouped by pairs for the 3 DJ techniques, and analyzed by a custom-made spreadsheet, which extracted CG_Z for both methods, at each event described in Table 1. A spreadsheet (Hopkins, 2000) was used to obtain the mean bias (absolute and standardized) of each technique to quantify accuracy; and the absolute typical error, which represents the typical amount by which a repeated measurement deviates from the true value (precision).

RESULTS: Two jumps were discarded from the analysis due to the participant not holding a stationary position before TO1. Figure 2 shows the mean bias and typical error (with 90% confidence limits) for each of the techniques in raw units, calculated at every instant described in Table 1. Figure 3 shows the standardized mean bias and typical errors (with 90% confidence limits) of each technique, calculated at every instant described in Table 1.



BK: bending one knee; SF: stepping forward; JU: jumping upwards.

Figure 6: Mean bias and typical error (with 90% confidence limits) of each technique.



BK: bending one knee; SF: stepping forward; JU: jumping upwards.

Figure 7: Standarized mean bias and typical error (with 90% confidence limits) of each technique.

DISCUSSION:

The absolute bias is less than 1 cm for all jump techniques and events except for the Apex and TD2 in JU (Figure 2), which tends to increase with time from the Start. This may be due to drift, double integration errors (Street et al., 2001) and/or variations in the height of starting jump. The greater bias seen in JU may be due to variations in the height of starting jump. Similarly, the typical error is also larger in the last 2 events for all the start techniques. According to the modified Cohen scale (Hopkins, 2000) and using the normalized measurements of accuracy and precision (Figure 3), bias is at least small for all events including the Apex for all techniques (except TO2 for SF and TD2 for JU).

CONCLUSION: Visual inspection of the standardized bias and typical errors suggest that there are no differences in accuracy or precision for any of the different starting techniques when comparing kinematic and kinetic analysis except for Apex and TD2 for the JU technique. This indicates that the double force plate technique of analysing SF and BK DJs could be considered to display similar accuracy as the kinematic method. Special attention should be given while testing to ensure the subject is motionless prior to TO1. In addition, a criterion should be set to automatically determine the start of the jump and hence, the start of the calculations. Executing the whole movement in as short as possible a time will also help to minimize errors by potentially reducing time associated drift in the force plates. More research is needed to identify and correct for other source of errors.

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