

# A METHOD COMPARISON OF FORCE PLATFORM AND ACCELEROMETER MEASURES IN JUMPING

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The purpose of this study was to compare force calculated using accelerometer data from the SHIMMER device, with force platform data on countermovement and drop jumps. Twelve physically active adults performed 5 counter movement jumps and 5 drop jumps from a height of 0.30 m. An accelerometer was attached near the participant's centre of mass and simultaneous force and acceleration data were obtained for the jumps. Minimum eccentric force and peak concentric force were calculated concurrently for countermovement jumps and peak landing forces were calculated concurrently for drop jumps. The results showed moderate to poor levels of agreement in forces and a consistent systematic bias between the results from the force platform and accelerometer.

**KEY WORDS:** accelerometer, force platform, counter movement jumps, drop jumps, validation.

**INTRODUCTION:** Techniques in sports such as basketball, volleyball and gymnastics often involve variations of the drop jump (DJ) or countermovement jump (CMJ). In addition these types of jump are routinely used to monitor levels of performance in sports training and conditioning. The force platform is a generally accepted instrument for determining performance in DJ and CMJ, (Kenny et al. 2011). While the force platform provides a good measure of the ground reaction force acting at the foot ground interface, it is generally accepted that this represents the resultant force acting on the whole body centre of mass (CoM) (Linthorne, 2001). Alternatively the force acting on the CoM may be estimated by attaching accelerometer near the CoM and multiplying the measured acceleration by the body mass. There are an increasing number of wireless sensor technologies on the market in recent years which provide tri-axial accelerometry. These wireless sensor technologies are useful in sport biomechanics applications since they provide high frequency signals and allow subjects to perform normal movements with little encumbrances. There is also the added benefit of performing the exercise in an ecologically valid environment rather than in a laboratory.

Recently McMaster et al, (2013) compared accelerometer and force platform measures during jumping and found moderate levels of agreement between devices when measuring vertical peak force. Similarly, Crewther et al, (2011) examined vertical forces in squats and found moderate to high correlations between forces from an accelerometer and force platform. By contrast, Castagna et al, (2013) found very good agreement between devices in determining flight times in vertical jumps. Other studies have examined force platform and accelerometer data on postural stability (Seimetz, Tan, Katayama & Lockhart, 2012), and balance in elderly inpatients (Lindemann, Moe-Nilssen, Nicolai, Becker & Chiari, 2012) and found poor to fair agreement between devices. There is limited data that supports the use of the accelerometry as an acceptable alternative to force platform for evaluating CoM forces during jumping and to date, no studies have compared the SHIMMER device with force platform. Therefore the aim of this experiment was to evaluate the SHIMMER device accelerometer estimates of CoM force against more generally accepted force platform.

**METHODS:** Twelve volunteers, 6 females (age  $25 \pm 2$  years, height  $1.71 \pm 0.06$  m, mass  $68.18 \pm 6.18$  kg; mean  $\pm$ SD) and 6 males (age  $22.67 \pm 3.5$  years, height  $1.78 \pm 0.05$  m, mass  $74.43 \pm 6.45$  kg; mean  $\pm$ SD), who were injury free at the time of testing, participated in the study. Ethical approval was granted by the local University Research Ethics Committee and all participants completed an informed consent form before testing. All participants were familiar with CMJ and DJ. Participants' height and mass was measured. The height of the centre of mass was estimated as 57% of total height for males, and 55% for females

(McGinnis, 2013). This is equivalent to just below the waist at the navel on all participants. The SHIMMER accelerometer was attached to each participant at this point.

Participants performed a standardised warm up consisting of 3 minutes of running at a self-selected, comfortable pace followed by two sets of ten dynamic stretches (forward and sideways hip swings, bodyweight squats, lunges) and submaximal attempts at double leg and single leg drop jumps. After the standardised warm up, subjects performed 5 CMJs and 5 DJs from a 0.30 m height. A rest interval of 30 seconds was used between trials of the same jumps type and 3 minutes between jump types to avoid residual effects of fatigue on performance (Read & Cisar, 2001). The CMJs involved the subject standing on the force platform then squatting down to self-selected position and jumping up, making sure to land back down on the force platform, hands on hips at all times throughout the jump, no tucking motion in the air and the aim of the jump is to minimise contact time while also attempting to achieve maximal height (Young, Pryor & Wilson, 1995). Similar instructions were given when performing the DJ (Young, et al., 1995).

After acquiring the data from the accelerometer, the resultant acceleration ( $a_R$ ) was calculated using the acceleration from the X, Y and Z axis in the following formula:

$$a_R = \sqrt{a_X^2 + a_Y^2 + a_Z^2}$$

This resultant acceleration was then multiplied by the mass of the subject to give the resultant force ( $F_{AR}$ ) from the accelerometer:

$$F_{AR} = m \times a_R$$

For the force platform, the resultant Force ( $F_{FPR}$ ) was calculated using the force from the X, Y and Z axis in the following formula:

$$F_{FPR} = \sqrt{(F_{FPX})^2 + (F_{FPY})^2 + (F_{FPZ})^2}$$

The best trial for each type of jump was selected for analysis. This trial was identified from the flight time of the jump based on the force platform data. The corresponding accelerometer trace was then analysed alongside the force platform trace.

Synchronization between the force platform and accelerometer was achieved by setting the sampling rate of each device to 1 kHz and matching the events of the peak force/acceleration on landing. These were easily identified from the force and accelerometer data sets. A 2 second resting period was given to each subject to allow the force platform and accelerometer to stabilize before performing each jump. The jumps were performed on dual AMTI OR6-5 force platforms. Both the accelerometer and force platform data sets were filtered using a Butterworth filter with a cut-off frequency of 10 Hz. A cut off frequency of 10 Hz was shown to be the best cut off frequency when analysing accelerometer data (Wundersitz, Netto, Aisbett & Gastin, 2014).

The minimum eccentric force and the peak concentric force were the dependent variables calculated for the CMJ. The dependent variables calculated for the DJ were the Peak Forces (PF) on take-off and landing. All data was analysed statistically using SPSS for Windows software. Force platform and accelerometer data sets were compared using Bland-Altman plots (Bland & Altman, 1986) and interclass correlation coefficients (ICCs) with 95% Confidence Intervals (CI) (Atkinson & Nevill, 1998). Means were compared using Student t-tests with alpha set at 0.05. Relative reliability was also investigated for both instruments using ICC with 95% CI.

**RESULTS:** Table 1 shows the mean results ( $\pm$ SD) for all variables for CMJ. The minimum eccentric force returned an ICC of 0.936; however the peak concentric force returned an ICC

of much lower at 0.602. A significant systematic bias was observed between force platform and accelerometer measures (Table 1). The greatest percentage difference between methods was found for the peak concentric force with a 35.8% difference found for CMJ. The mean results ( $\pm$ SD) for all variables for DJ are shown in Table 2. The Initial PF returned an ICC of 0.768, while the final PF ICC was much lower at 0.404. The percentage difference between methods was very large for both PFs in the DJ with differences of 30.9% and 53.6% respectively.

**Table 1**  
**Comparison of Force Plate and Accelerometer for Counter Movement Jumps**

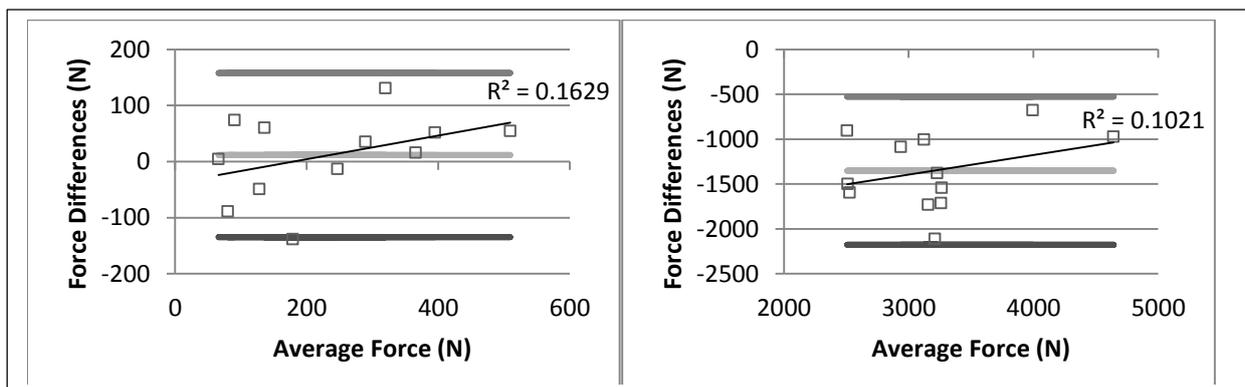
	<i>Min.Eccentric Force</i>	<i>Peak Concentric Force</i>
Force Plate $\pm$ SD (N)	239 $\pm$ 162	1727 $\pm$ 359.52*
Accelerometer $\pm$ SD (N)	228 $\pm$ 133	2346 $\pm$ 746.33
% Difference	4.8	35.8
Systematic Bias (N)	11	-619
ICC	0.936	0.602
(95% CI)	(0.780 – 0.982)	(-0.268 – 0.889)

\*Denotes  $p < 0.001$

**Table 2**  
**Comparison of Force Plate and Accelerometer for Drop Jumps**

	<i>Peak Force Take-off</i>	<i>Peak Force Landing</i>
Force Plate $\pm$ SD (N)	3378 $\pm$ 1077*	2521 $\pm$ 714*
Accelerometer $\pm$ SD (N)	4422 $\pm$ 1185	3872 $\pm$ 586
% Difference	31.9	53.6
Systematic Bias (N)	-1044	-1351
ICC	0.768	0.404
(95% CI)	(-0.193 – 0.950)	(-0.89 – 0.813)

\*Denotes  $p < 0.001$



**Figure 1: (a) Bland-Altman Plot of Minimum Eccentric Force during CMJs. (b) Bland-Altman Plot of Peak Force during DJs**

**DISCUSSION:** The results of this investigation generally showed significantly higher estimations in peak forces for resultant accelerometer data compared to the resultant force platform data in both the CMJs and DJs. For CMJs the results showed good agreement between the accelerometer and force platform for minimum force in the eccentric phase of the jump. The ICCs and limits of agreement were low to moderate for peak concentric force in the CMJ and peak forces at take-off and landing in the DJ. These differences can be attributed to the fact that resultant accelerometer data was compared to resultant force platform data, rather than the vertical component of the devices. This is due to the fact that

when the subject begins the jump they lean forward and the orientation of the accelerometer changes. Correcting the force components of the accelerometer arising from axis orientation shifts presents technical challenges when using accelerometry that are avoided when using the fixed axis set up of a ground mounted force platform. This change in orientation of the accelerometer can be measured by utilizing the gyroscope functionality in the SHIMMER device, which would accurately denote which axis of the device was registering the vertical acceleration and allow correct recalculation of forces relative to the inertial axis. Thus by utilizing the gyroscope data in the analysis of the acceleration and transferring the vertical components from the X and Z planes to the Y plane, the actual vertical component of the jump can be measured and compared with the vertical component (Z) of the force platform. The apparent over-estimation of the accelerometer compared with the force platform may also be caused by high frequency vibrations of the device that occur during rapid movements and changes of direction. Despite low pass filtering some of these high frequency accelerations remain, causing higher calculated peak forces from the accelerometer.

**CONCLUSION:** Due to the fact that only the resultant acceleration and force was analysed a consistent systematic difference exists between devices. This study identified that the acceleration measured using the SHIMMER device cannot be used interchangeably with the force calculated using the force platform. However further research can be done into the use of the SHIMMER device with the added functionality of the gyroscope to analyse the results more accurately and achieve the vertical component only of the acceleration of the body.

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