ESTIMATION OF CENTER OF MASS VELOCITY BY RIGHT POSTERIOR SPINE ILIAC LANDMARK DURING COUNTERMOVEMENT JUMP

Hans-Joachim Menzel[1], André G.P. de Andrade[1], Fabíola Bertú[1], Túlio Banja[1,2], Erich Müller[3], Herbert Wagner[3]

[1]Federal University of Minas Gerais, Belo Horizonte, Brazil
[2]Federal University of Ceará, Fortaleza, Brazil
[3]University of Salzburg, Salzburg, Austria

When the impulse phase is proceeded by approach movement (e.g. volleyball spike jump), the vertical velocity of CoM at the beginning of the impulse phase must be known. To reduce the number of landmarks, the aim of this study was to verify the concordance between the velocity of CoM and the Right Posterior Spine Iliac at touchdown after flight phase. Ten female volleyball players of the first national volleyball league of Austria performed ten maximal CMJ without arm movement. Paired t-test was used to compare velocities between the two methods. No significant differences between the methods with maximal individual differences lower than 0.1m/s at touchdown could be found. If only the landing velocity at touchdown must be known, it seems to be sufficient to determine the velocity of Right Posterior Spine Iliac landmark.

KEY WORDS: Center of mass velocity, single point, countermovement jump

INTRODUCTION: Based on the impulse-momentum relation, the use of a force platform is the most reliant and precise method to determine the change of velocity during ground contact and therefore widely applied for the analysis of vertical jumps (Linthorne, 2001; Hatze, 1998). These jumps can be divided in one leg and two leg jumps, and in standing vertical jumps (e.g. countermovement jump - CMJ) and those with negative vertical velocity of Center of Mass (CoM) at the beginning of the impulse phase (e.g. volleyball spike jump). For two leg vertical jumps the analysis of bilateral differences may be important for performance optimization (Wagner et al., 2009) or reduction of injury risk (Murphy, Connolly, & Beynnon, 2003). However, when the impulse phase is proceeded by one or more approach steps like the volleyball spike jump, the vertical landing velocity of CoM at the beginning of the impulse phase (v_{on}) must be known, not only to calculate the take off velocity (v_{off}) but also to determine kinetic variables like vertical breaking and acceleration impulses, their durations and bilateral differences. The determination of the landing velocity of CoM requires a kinematic analysis and the application of an anthropometric model where a significant number of landmarks must be fixed at the subject's body and digitalized. Using the VICON 3-D motion capture system (*Vicon Peak, Oxford, UK*) the 14 segment model requires 54 reflexive markers. Apart from the possibility that markers could come off, the whole procedure is rather work intensive and has a model inherent systematic error. To reduce the number of markers if only the CoM should be analyzed, some authors suggest the use of markers fixed at the pelvis (Thirunarayan et al., 1996; Vanrenterghem et al., 2010). This strategy has been proved to be useful for gait analysis (Gard, Miff & Kuo, 2004), but no information could be found if it also leads to reliable and precise information about CoM velocity during vertical jumps. Therefore, the aim of this study was to verify during CMJ the concordance between the velocity of CoM using the model (Dempster & Gaughran, 1967) implemented in the VICON 3-D motion capture system and the velocity of the Right Posterior Spine Iliac (RPSI) which is one landmark of this model. CMJ was chosen because the initial velocity at the beginning of the movement is always zero of both points.

METHODS: Ten female volleyball players of the first national volleyball league of Austria (age: 19,6 ± 2,2 years, body mass: 71 ± 12 kg, body height: 1,80 ± 0,06 m) with no lower limbs injury history participated in the study. According to the VICON 3-D motion capture system (*Vicon Peak, Oxford, UK*) anthropometric data were collected and the landmarks fixed at the athlete's body. This set of landmarks allows the calculation of the CoM coordinates. One of these landmarks of the whole set is fixed at the Right Posterior Spine Iliac (RPSI). Following this procedure the athletes performed a 20 minutes preparatory activity, consisting of moderate intensity running, aerobic exercises and submaximal CMJ. The test protocol consisted of ten maximal CMJ without arm movement (hands fixed on the hips) with 1 min rest intervals between each jump to avoid fatigue effects. The jumps were recorded by 8 cameras of the VICON 3-D motion capture system at a frequency of 250 fps. Kinematic data were smoothed by a 2^{nd} order linear low pass *Butterworth* filter with cut frequency of 10 Hz. At the velocity-time characteristics of the CoM the following moments were determined for comparison with the velocities of RPSI: time of minimal velocity (t_{vmin}), time of maximal velocity (t_{vmax}), time of take off (t_{off}), and time of touch down (t_{td}). Figure 1 shows the velocity-time characteristics of CoM and RPSI and the time points for the comparison.

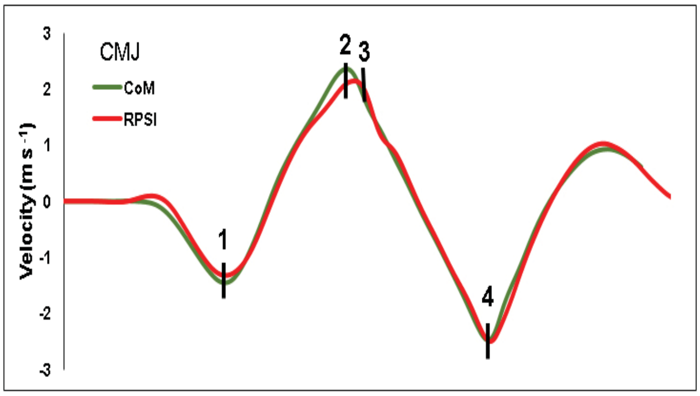

Figure 1 Velocity-time characteristics of CoM and RPSI and the moments for comparison (t_{vmin} (1); t_{vmax} (2); t_{off} (3); t_{td} (4).

For every subject and variable the mean of ten CMJ was calculated (Hsieh & Christiansen, 2010). Paired t-test was used to compare velocities between the two methods (RPSI vs. CoM). The significance level was $p < 0.05$ and the statistical program used was SPSS 18.0. For visualization of the differences of the two methods, Bland-Altman plots were employed (Hopkins, 2004) using Med Calc Statistical Software 14.8.1 (MedCalc Software bvba, Ostend, Belgium). These plots show the difference between the mean of the method that should be validated (RPSI) and the criterion method (CoM). Thus, the plots show the concordance between the methods (Gullstrand et al., 2009).

RESULTS: Table 1 shows descriptive statistics (mean ± sd), t-test significance level, systematic bias and Bland-Altman significance level and the four velocities. Bland-Altman plots are presented in Figure 2.

Table 1
Descriptive statistics, t-test significance, systematic bias and Bland-Altman significance.

Variables	(CoM)	RPSI	t –Test sig.	bias	Bland -Altman Sig.
V_{min} (m/s)	-1.267 (±0.20)	- 1.152 (±0.18)	0.055	-0.115	0.529
V_{max} (m/s)	2.4 (±0.13)	2.208 (±0.18)	0.002*	0.192	0.218
V_{off} (m/s)	2.201 (±0.15)	2.238 (±0.16)	0.283	-0.037	0.679
V_{td} (m/s)	-2.325 (±0.16)	-2.377 (±0.15)	0.142	0.07	0.645

* Significant differences p<0.05.

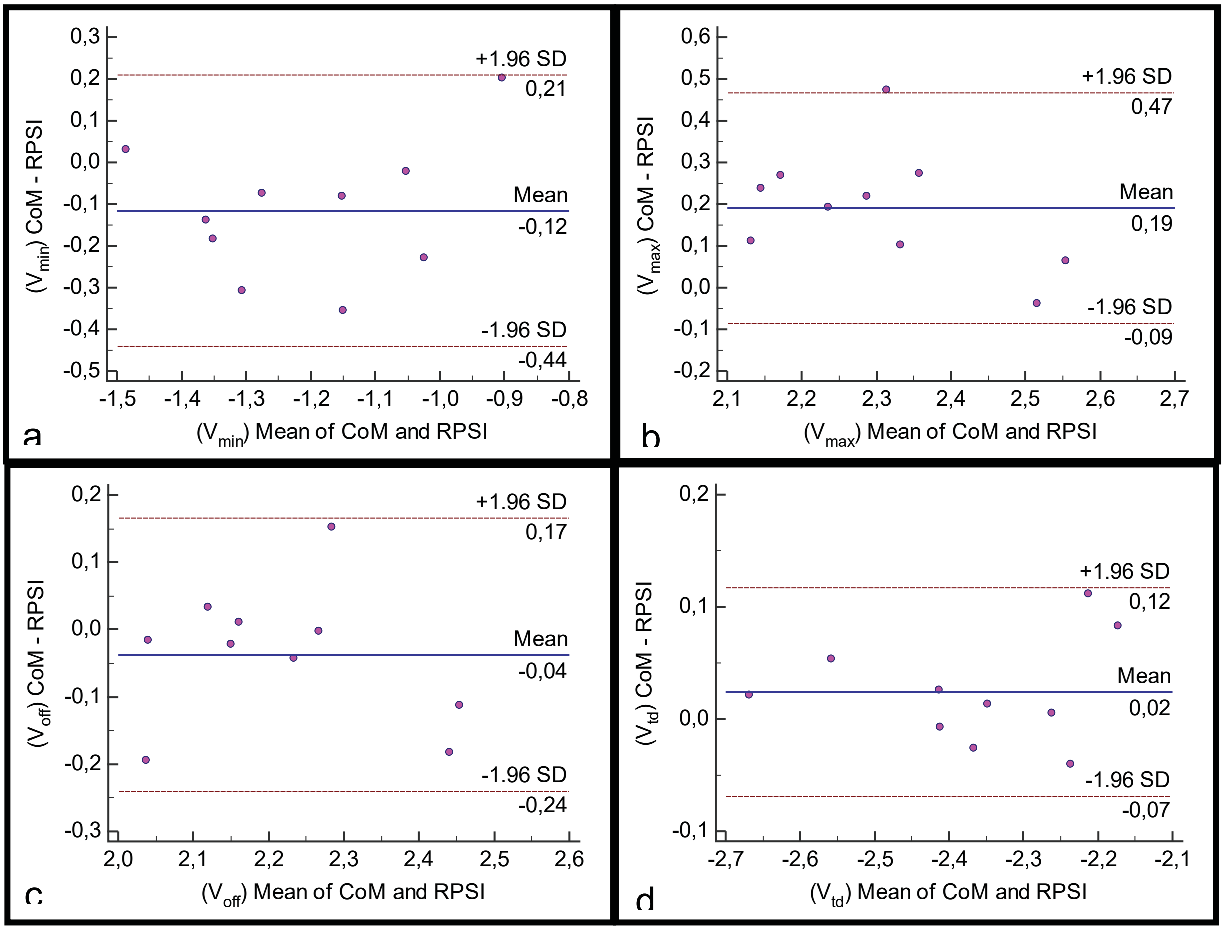

Figure 2: Bland-Altman plots for minimal (a), maximal (b), take off (c) and touchdown velocity (d).

DISCUSSION: Significant differences of about 0.2 m/s could be found for the maximal velocity (v_{max}), indicating that the maximal velocity of RPSI is slightly lower than maximal CoM velocity. Though no significant differences between the two methods (p = 0.055) could be identified concerning the minimal velocity (v_{min}), the results can be interpreted as a trend that minimal velocity of RPSI is also slightly lower (0.1m/s) than minimal CoM velocity. However, the mean difference between the velocities of CoM and RPSI at the beginning (t_{off}) and at the end of the flight phase (t_{td}) are nearly zero and absolute individual maximal differences are 0.2m/s for v_{off} (corresponding to a maximal difference of about 4 cm of jump height for takeoff velocities of 2.2 m/s) and less than 0.1m/s for v_{td}.
Since jump height depends on the square value of takeoff velocity, non significant differences of takeoff velocity may result in significant differences of jump height. This may explain why different authors (Aragón-Vargas, 1996; Kibele, 1998; Street et al., 2001) reported significant differences of jump height calculated by CoM and hip point (Ranavolo et al., 2008). No significant differences between the methods could be found between for the velocity at touchdown (v_{td}). This result is important if an approach movement proceeds the impulse phase, e.g. as it occurs during the volleyball spike jump, where the landing velocity at the beginning of the impulse phase must be known to determine take off velocity and breaking and acceleration impulses of both legs. In this case it does not seem to be necessary to apply the full body model to calculate the CoM velocity. Instead, it should be sufficient to determine the velocity of RPSI landmark at touchdown.

CONCLUSION: If an impulse phase is proceeded by an approach movement and starts with a negative vertical velocity of CoM (e.g. volleyball spike jump), the landing velocity at touchdown must be known. At least for CMJ without arm movement it does not seem to be necessary to determine CoM velocity using a 14 segment model which requires 54 landmarks. That way, the analysis procedure can be optimized by the determination of the velocity of Right Posterior Spine Iliac landmark. Nevertheless it should be verified if these results can be confirmed for CMJ with arm movement and if these results are also valid for approach of volleyball skipe jump.

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