THE 2D TROCHANTER TRACKING METHOD: A LOW COST ALTERNATIVE WHEN ASSESSINGVERTICAL POWER-FORCE-VELOCITY PROFILES?

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Power force velocity profiles of ballistic push offs are increasingly more used for the purpose of performance assessment. The main input parameter for such profiles is jump height. This study aims to propose and validate a simple low cost method for calculating jump heights based on 2D tracking of the trochanter. Furthermore a comparison with the existing low cost time in air method was carried out. Twelve athletes performed squat jumps on a force platform and were simultaneously filmed with a high speed camera. The error analysis depicted increased accuracy and precision as well as slightly stronger relation to the criterion for the 2D trochanter tracking compared to the time in air method. The result can be explained by the fact that the landing position of the athlete has no influence on the jump height calculation when using the trochanter tracking method.

KEY WORDS: vertical jump, strength training, concurrent validity.

INTRODUCTION: The ability to produce high mechanical power output during ballistic push-offs is one of the main physical performance determinants in many sports. Therefore, analyzing power force velocity profiles of athletes is a valuable tool with respect to performance assessment and long term monitoring (Morin & Samozino, 2016). The method recently developed and validated is based on rather simple measurements obtained in field conditions. The input data measurement necessary to correctly determine a vertical profile are the athlete`s body mass, the squat jump push-off distance and the jump height (measured under a spectrum of loading parameters) (Samozino et al., 2014; Samozino, Morin, Hintzy, & Belli, 2008; Samozino, Rejc, Di Prampero, Belli, & Morin, 2012).

A specifically developed iPhone app (*My Jump 2,* carlos-balsalobre.com, Spain) incorporated the above mentioned power-force-velocity calculations and serves therefore a suitable low cost tool for performance analysis. The underlying calculation of jump height is based on the time in air method (TiA) and has been successfully validated recently (Balsalobre-Fernandez, Glaister, & Lockey, 2015). The TiA method is known to be valid as long as the time the centre of mass travels upwards equals the time it travels downwards, which is only mandated if the athlete takes off and lands in the same body position (Aragón, 2000). While performing the profiling with high performance athletes of the associated “Olympic Training Centre” we observed that those prerequisites for TiA can be undermined under certain circumstances: i) some athletes depict strongly habituated jumping and landing techniques. Ski jumpers for instance are used to land in a partially crouched body position. A movement instruction to perform the landing in the same position as the take-off may negatively influence their performance because of disturbing their habituated movement pattern. ii) When athletes with a history of lower limb injuries (i.e. many alpine ski racers) perform loaded squat jumps the landing poses a problem. We therefore recently developed a device which catches the additional weight shortly after passing the “top dead centre”. However, the catching of the weight incorporates the prerequisites for a successful TiA calculation (i.e. undefined delay of the centre of mass downward travel time). Consequently, an alternative low cost approach in cases, where the TiA method reaches its limit, could be valuable.

A kinematic method for center of mass motion during vertical jumping without a whole body marker set is the “Pelvic Kinematic Method” introduced by Chiu and Salem (2010). The pelvis centre of mass was reconstructed from retro-reflective marker placed around the pelvis. Vertical jump height was determined from the peak height of the pelvis centre of mass minus the standing height. Compared with the ground reaction force impulse method the proposed method demonstrated concurrent validity (Chiu & Salem, 2010). A modified pelvic kinematic method by using only one marker (e.g. greater trochanter) could simplify 2D video analysis of jump performance too. Such an approach potentially bypasses problems of the

TiA method and provides an alternative low cost tool for jump performance analysis under loaded conditions (i.e. no need for motion capture system or force plates).
Therefore, the aim of this study was to analyse the concurrent validity of the *"TiA Method"* and the 2D based *"Trochanter Tracking Method"* for assessing vertical jump height in unloaded and loaded conditions against a force plate criterion method.

METHODS: Twelve male professional power sport athletes (soccer, karate, judo) with experience in loaded jumping gave written informed consent for participation in this study. The participants completed a standard 15-min warm up. Then, each participant performed in total twelve jumps from the squat position: two jumps without extra load; ten jumps with five different extra loads (individually adjusted, ranging from 20 kg to 100 kg). The initial squat position of each jump was controlled via laser beam based on a beforehand determined individually comfortable start position at approximately 90° knee flexion. The vertical jumps were performed standing on two force platforms (AMTI; Watertown, MA; sampling at 1000 Hz) while simultaneously being recorded with a low resolution 640 x 360 Pixel JVC GC-PX10 high-speed camera at 250 fps.
For determining the jump height by tracking the trochanter displacement (h_{TROTRA}) a single reflective marker was placed at the athlete's left great trochanter. The data obtained from the high speed camera were analysed using open-license video analysis software (Tracker 4.96 for Windows). The calibration of the 2D video analysis was achieved by a 100 cm reference object placed at the same distance from the camera as the marker. For the calculation of h_{TROTRA} the difference of the trochanter position in vertical direction between the maximum height during the jump and the moment of take-off was considered.
The jump height based on the time in air method (h_{TiA}) was calculated using the equation $h = gt^2/8$ as described earlier (Balsalobre-Fernandez et al., 2015). Flight times from the analysis of the force platform data were used to calculate h_{TiA}.
As a criterion variable, jump height was determined using the take-off velocity calculated from the force plate data (h_{TOVEL}) (Chiu & Salem, 2010). Vertical ground-reaction force was integrated using the trapezoid method from the start of the movement until take off. Impulse from the left and right force platform were calculated independently and summed. Take-off velocity was calculated from impulse divided by body mass, and jump height calculated using standard equations of motion (Kibele, 1998). The calculations from the force platform data (h_{TiA} and h_{TOVEL}) were performed in Visual 3D (Version 5, C-Motion Inc., Rockville, MD, USA).
For validation purpose an error analysis between h_{TOVEL} and h_{TROTRA} as well as h_{TOVEL} and h_{TiA} was performed: For each of the 144 analysed jumps the error was defined as the difference between the criterion (h_{TOVEL}) and the respective method (h_{TROTRA}, h_{TiA}). The methods' accuracy was defined as the mean of the errors and the precision as the standard deviation of the errors across all jumps. Pearson's linear correlation coefficient (r) between the jump heights of the criterion and the respective method was used to quantify the concurrent validity. To complement the validation, Bland-Altmann plots were created, giving an appropriate representation of the agreement between the two respective methods (Bland & Altman, 1986).

RESULTS: With respect to the error analysis almost perfect accuracy for h_{TROTRA} (Figure 1; .001 m) was observed, whereas h_{TiA} (Figure 2; .013 m) overestimated jump height slightly. The precision was increased when using h_{TROTRA} (.013 m) compared to h_{TiA} (.022 m). The regression model for the 144 jumps indicated a strong relation between the criterion and the respective method. However, h_{TROTRA} (Figure 1; $R^2 = .97$; $p<.001$) showed a slightly stronger relation to the criterion compared to h_{TiA} (Figure 2; $R^2 = .93$; $p<.001$).

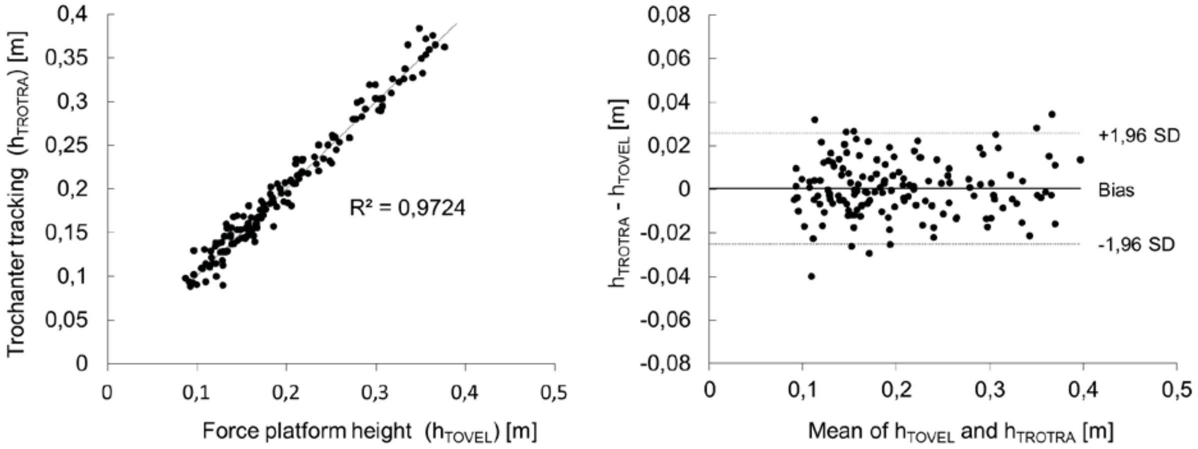

Figure 1: Concurrent validity between the take-off velocity based criterion method (h_{TOVEL}) and the proposed "Trochanter tracking" method (h_{TROTRA})

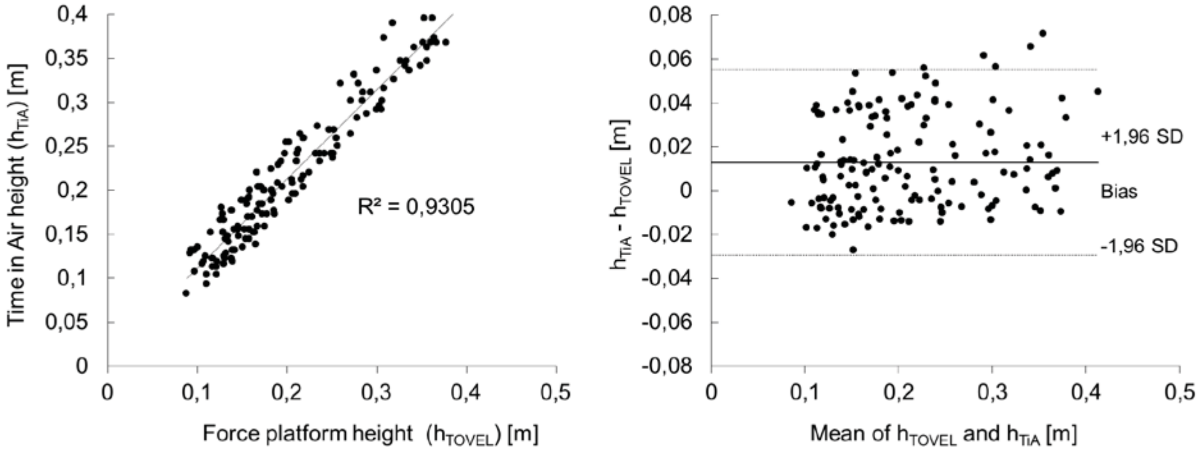

Figure 2: Concurrent validity between the take-off velocity based criterion method (h_{TOVEL}) and the widely used "Time in air" method (h_{TiA})

DISCUSSION: Although for both methods a strong linear relationship was observed, the h_{TROTRA} method compared to the h_{TiA} method seems to be advantageous. The subject performed unloaded and loaded jumps during the experiment with the instruction to jump as high as possible from a predefined static squat position without additional counter movement. The landing was not constraint and is therefore in opposite to the h_{TiA} validation paper by Balsalobre et al (2015), where the landing was constraint to the same position as the take-off. Therefore, in some jump executions the time the centre of mass travels upwards did not equal the time of travelling downwards, which leads to a lack of precision and slightly reduced accuracy for the h_{TiA} method (Aragón, 2000). One could speculate that this effect is more pronounced when jumping with higher loads. However, the Bland-Altman plot in Figure 2 does not support this assumption: The jumps with lower heights represent those with the highest extra loads; since no increased error was observed among those jumps a load dependency of the h_{TiA} error is not obvious. Additional individual analysis indicated that the error in TiA is most likely subject dependent.

The h_{TROTRA} method was found to be highly valid in measuring the jump height of loaded and unloaded squat jump as they are usually used for analyzing power force velocity profiles of athletes (Morin & Samozino, 2016). Due to the nature of the approach, considering only the upward phase of the jump, the "Trochanter tracking" method is robust against what's happening after passing the top dead centre (Chiu & Salem, 2010). This can be an important issue when profiling athletes, who can jump but not land with additional weight (e.g. due to injury history) or athletes with specifically habituated landing techniques (e.g. ski-jumpers).

PRACTICAL PERSPECTIVES AND CONCLUSION: The commercially available iPhone app *My Jump 2* (carlos-balsalobre.com, Spain) serves an excellent low cost tool for an analysis of athlete's leg extension performance properties. The App bribes with simple usability (i.e. only searching for the take-off and landing frame per jump) and the automatic calculation of the profiles, which is based on published work (Samozino et al., 2008). However, the used method for calculating the jump height reaches its limit when athletes are not able to perform jumps with the same centre of mass upward and downward travel time as shown in this study. A potential solution, which is highly valid for such cases, was found in the "Trochanter tracking" method. From a technical perspective the iOS App *Video Physics™* (Vernier Software & Technology, Beaverton, USA) already implemented features, which make a smartphone or tablet based 2D kinematic analysis feasible. However, this app does not use the possibility of recording videos with up to 250 fps and is therefore not suitable for jump height analysis.

My Jump 2 already uses the Apple high speed mode. An incorporation of the 2D Trochanter tracking method to the already existing TiA method would serve a valuable extension to the app. The user could individually decide whether using a very simple, but constraint method (landing behaviour) or a method, which does not count for the downward phase. Latter is more precise with the drawback of some additional, but manageable data acquisition and analysing efforts: placing a marker on the trochanter; placing a calibration object; digitizing the calibration object (2 points); digitizing the trochanter within the two considered frames (take-off and reversal point).

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