VERTICAL POWER-FORCE-VELOCITY PROFILING: RELIABILITY COMPARISON OF MULITPLE- AND TWO-POINT METHODS

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Power-Force-velocity (P-F-v) profiling is an approach used for performance diagnostics to assess an athlete's anaerobic performance level. The aim of the study was to determine and compare the test-retest reliability of the 5p-method and the 2p-method for a group of sport students. With respect to the 2p-method this was the first study to determine the reliability using an independent data-set for vertical jumps. Acceptable reliability (ICC > 0.78, CV < 7.6%, no significant differences) was obtained for the variables F_0, v_0 and P_{max} obtained through the 5p-method. Using the 2p-method acceptable reliability was just found for the variables F_0 and P_{max}. Therefore, the use of the 5p-method is recommended for performance diagnostics and derived individualized training regimes based on these P-F-v profiling results, as well as for research on this topic involving populations similar to sport students.

KEYWORDS: performance diagnostics, vertical jumps, P-F-v profiling, reliability

INTRODUCTION: The ability to produce high mechanical power during ballistic push-offs for body acceleration is considered a performance determinant of various dynamic and team sports (Samozino et al., 2014). Consequently, jump height (JH) is one of the most important and frequently used variables to assess an athlete's anaerobic performance level. However, the relationship between JH and lower limb peak power output is not perfect, and therefore JH alone is not a sufficient indicator for performance diagnostics (Morin, Jimenez-Reyes, Brughelli, & Samozino, 2019). Power output is the rate at which work is done, calculated as the product of force (F) and movement velocity (v) which are applied at the propulsive phase of a jump (Cormie, McGuigan, & Newton, 2011). However the individual ratio of F and v (i.e. power composition), known as Power-Force-velocity (P-F-v) profile has an influence on the performance outcome (Morin & Samozino, 2016). Therefore, the approach of P-F-v profiling developed by Samozino, Morin, Hintzy, and Belli (2008) provides more discriminating information about the athlete's power output capabilities than simply the JH. P-F-v profiles are characterized through a linear relationship between the force and velocity determined from jumps with different load conditions (Jaric, 2015).
Extensive research has been done to determine the number of jumps and the magnitude of the loading conditions necessary to establish the linear relationship of force and velocity. The use of five or more additional loads (5p-method) is considered to be the gold standard (García-Ramos, Pérez-Castilla, & Jaric, 2018). However, the 5p-method is time consuming due to the amount of jump conditions needed (Jaric, 2016). Hence, the use of only two jump conditions (2p-method) could serve as a practical alternative. The reliability of the 2p-method has never been reported for vertical jumps independently from a 5p-method. Previous studies collected data via multiple point methods and used two points out of five to establish the 2p-method. Their results suggest that the 2p-method is reliable when using two jumps with distinctive load conditions (e.g. 0kg and 75kg) (García-Ramos, Pérez-Castilla, et al., 2018; Janicijevic et al., 2019). More specifically, the 2p-method was considered reliable when using the two most distant data-points from the 5p-method. Nevertheless, the 2p-method seems inconsistent with the 5p-method because of higher sensitivity to potential measurement errors from using only two jump conditions (Zivkovic, Djuric, Cuk, Suzovic, & Jaric, 2017).Only one previous study used a leg-cycle ergometer and obtained acceptable reliability for an independent 2p-method (García-Ramos, Torrejon, Morales-Artacho, Perez-Castilla, & Jaric, 2018). However, when assessing the methods, the independent 2p-method is preferable over the 2p-profile created out of the 5p-method, since the overall test setup is not similar: e.g. the psychological requirements (i.e. motivation, focus) of executing four maximal jump efforts is much less than that required to execute ten. Therefore, there is a paucity of evidence regarding the reliability

of the independent 2p-method using vertical jumps. Hence, the aim of this study was to determine and compare the test-retest reliability of P-F-v outcome variables (F_0, v_0, P_{max}, Sfv) obtained through the 5p-method and the 2p-method in an independent setting.

METHODS: Fifteen male sport students (mean ± SD; age = 25.3 ± 2.7 years, body mass = 80.7 ± 12.0 kg; body height = 1.80 ± 0.08 m) volunteered to participate in this study. This sample was similar to previous populations used for investigating P-F-v profiling (García-Ramos, Pérez-Castilla, et al., 2018; Janicijevic et al., 2019). A randomized counterbalanced repeated-measured design was used to determine the test-retest reliability of the outcome variables obtained through the 5p- and the independent 2p-method. All participants performed five test sessions in three consecutive weeks. The first test session (week one) was used to familiarize the participants to the testing procedure which included jumps with the load conditions: 0%, +20%, +40%, +60%, and +80% of bodyweight (BW). In the second week, two test sessions (test and retest) using either the 5p- or 2p-method were conducted. In week three, two test sessions of the remaining method were performed (test and retest). Between the two test sessions within each week, a minimum rest of 24 h and maximum rest of 48 h was allotted.

Before each test session, participants performed a standardized warm-up, followed by three minutes of rest. The 5p-method testing consisted of two squat-jumps, each at loads of 0%, +20%, +40%, +60%, and 80% of BW, while the 2p-method included only two squat-jumps each at 0%, and +80% of BW. During all jumps, participants were asked to jump as high as possible from a pre-defined squat-depth (controlled via laser beam). The jumps with additional load were performed using a barbell placed on the participant's shoulders. Four minutes of rest were given between each load condition and one minute between squat-jumps of the same load.

JH was calculated from net impulse, derived from vertical force plate records (1000 Hz)(Kibele, 1998). The linear relationships of the 2p- and 5p-method were created using the greater JH of the two trials per load condition. Further, Samozino's Simple Method was used to compute the mean force (F_{mean}) and mean velocity (v_{mean}) of the propulsive phase of each jump (Samozino et al., 2008). The P-F-v profile variables (F_0, v_0, P_{max} and Sfv) were computed from the resulting 2p- and 5p-method linear models.

The magnitude of the variables from the 5p and 2p-method are presented as group means and SD for test and retest. The test-retest reliability of the P-F-v-profiling variables (F_0, v_0, P_{max} and Sfv), obtained from the 5p- and 2p-method was evaluated through the coefficient of variation (CV) based on the typical error of measurement, the relative change in the mean (= mean of change between test and retest over all participants) (CIM), and the intra-class correlation coefficient (ICC, model 3.1). The statistical analysis of the reliability was performed using a custom spreadsheet (Hopkins, 2000). The reliability of the outcome variables was considered acceptable if the CV was less than 10% (Cormack, Newton, McGuigan, & Doyle, 2008). ICC was evaluated with the ratings of "excellent" (≥ 0.9), "good" (0.75 – 0.89), and "not acceptable" (≤ 0.74) (Koo & Li, 2016). A paired-samples t-test was performed to evaluate significant differences in the magnitude of the outcome variables between test and retest using SPSS (version 26.0).

RESULTS: Acceptable reliability was determined using the 5p-method for the variables F_0, v_0 and P_{max}, but not for Sfv (CV = 12.1), although the Sfv ICC was classified as "good" (Table 1). Using the 2p-method, acceptable reliability was obtained only for F_0 and P_{max}. The ICCs reported for v_0 and Sfv were considered "not acceptable". Furthermore, the CV of Sfv was unacceptably high. (CV = 13.3) No significant differences were found between test and retest in any of the outcome variables of both investigated P-F-v profiling methods. Learning effects are considered negligible because of the low (statistically irrelevant) increase of CIM (max. + 1.8%) from test to retest.

Table 1. Reliability and Magnitude of the P-F-v-profile variables obtained through the 5p- and 2p-method (n = 15)

Method	Variable	Test	Retest	CIM % (95% CI)	CV_{TE} % (95% CI)	ICC (95% CI)
5p	F_0 [N/kg]	30.6 ± 4.0	30.0 ± 3.3	-1.7 (-5.4, 2.0)	4.7 (3.4, 7.4)	0.87 (0.65, 0.95)
	v_0 [m/s]	3.04 ± 0.47	3.08 ± 0.46	1.6 (-4.3, 7.2)	7.6 (5.6, 11.8)	0.78 (0.47, 0.92)
	P_{max} [W/kg]	22.9 ± 2.1	22.9 ± 2.5	0.2 (-3.4, 3.8)	4.5 (3.3, 7.2)	0.82 (0.54, 0.94)
	Sfv [Ns/m/kg]	10.5 ± 3.0	10.1 ± 2.5	-3.8 (-13.2, 5.7)	12.1 (8.9, 19.0)	0.82 (0.54, 0.93)
2p	F_0 [N/kg]	30.9 ± 2.9	30.9 ± 3.7	0.0 (-3.8, 3.8)	4.8 (3.5, 7.6)	0.82 (0.55, 0.94)
	v_0 [m/s]	2.85 ± 0.27	2.90 ± 0.38	1.8 (-4.9, 8.1)	8.4 (6.0, 13.0)	0.52 (0.03, 0.81)
	P_{max} [W/kg]	21.9 ± 2.1	22.1 ± 2.1	1.0 (-2.5, 4.5)	4.5 (3.2, 7.0)	0.81 (0.52, 0.93)
	Sfv [Ns/m/kg]	10.9 ± 1.7	10.9 ± 2.6	-0.2 (-10.3, 10.6)	13.3 (9.7, 21.0)	0.59 (0.13, 0.84)

F_0 = theoretical maximum force; v_0 = theoretical maximum velocity; Pmax = maximum power; Sfv = F-v Slope; CIM = relative mean of change between test and retest over all participants; 95 % CI = 95% confidence interval; CV_{TE} = coefficient of variation based on typical error; ICC = intra-class correlation coefficient (3.1)

DISCUSSION: Extensive research has been done to determine the amount of jumps and optimum loading parameters for P-F-v profiling. The use of five or more jumps with the highest possible range of loading conditions is considered the gold-standard method (Pérez Castilla, García Ramos, Feriche, Padial, & Jaric, 2016). Nevertheless, the use of just two data-points has gathered more consideration due to less time-consuming test procedures. Previous studies have already investigated the reliability of 2p-methods using vertical jumps, but each of them created the 2p-profile out of the data-points from the 5p-method. One previous study created an independent 2p-profile using a leg-cycle ergometer and obtained acceptable test-retest reliability of the 2p-method (all parameters CV < 5%, ICC > 0.76) (García-Ramos, Torrejon, et al., 2018). Hence, the current study was the first one to use squat-jumps to determine the reliability of an independent 2p-method.
The results from the 2p-method of the current study only revealed acceptable reliability for the outcome-variables F_0 and P_{max}. The v_0 obtained from the 2p-method was reported with an "unacceptable" ICC and a CV near 10%. Alternatively, good reliability was determined for the 5p-method for all four P-F-v outcome variables (ICC > 0.78); however, the CV of v_0 and Sfv was near or higher than 10%. According to these results, v_0 and Sfv are the variables with the highest test-retest variability. Sfv is determined by F_0 and v_0 and therefore, a constant F_0 and a fluctuating v_0 consequently lead to an unstable Sfv and low reliability. Comparing the findings from García-Ramos, Pérez-Castilla, et al. (2018) with the findings from the current study, lower reliability was determined for all P-F-v outcome variables using an independent 2p-method. This comparison should be carefully considered because although the same statistical analysis was used (Hopkins, 2000), different methods and variables were used in the creation of the P-F-v-profiles. In the previous study, F_{peak} and v_{peak} were used because lower reliability was found by using mean-variables. Nevertheless, Morin and Samozino (2018) recommended the use of mean-variables because they represent the entire propulsive phase of a jump, whereas peak-variables specifically refer to a single point during the push-off. Therefore, in the current study F_{mean} and v_{mean} were calculated for creating the P-F-v profiles.
Previous studies recommended the 2p-method although acceptable reliability was not found for every P-F-v outcome variable and no independent 2p-P-F-v profile was created. We cannot support this recommendation because our results show low reliability for v_0 when using an independent 2p-method. F_0 and v_0 are the main and most important variables to assess the muscle mechanical capabilities through P-F-v profiling. This has important implications for individualized training prescription based on P-F-v profiles, but also for performing research (e.g. controlled interventions with P-F-v profiles as pre / post assessment. Therefore, for the investigated sample (sport students), using the 5p-method is recommended because v_0 has higher reliability than the 2p-method.

CONCLUSION: The use of multiple-point methods for P-F-v profiling in combination with Samozino's Simple Method is recommended due to higher test-retest reliability compared to 2p-methods. Multiple-point methods are less sensitive to measurement errors and therefore produce more precise models to use in the determination of maximal muscle mechanical capabilities. In summary, for this study population (sport students) the use of the 2p-method is not recommended since v_0 cannot be assessed reliable. It could be hypothesized, that cohorts with more jump experience compared to sport students could show better reliability for the 2p-method. However this hypothesis should be tested for an adequate sample.

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