CRITERION VALIDITY OF THE LOWER LIMB ISOKINETIC POWER-FORCE-VELOCITY PROFILING PARAMETERS IN ELITE ATHLETES

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The purpose of this study was to investigate the criterion validity of isokinetic leg press Power-Force-velocity (P-F-v) parameters. Forty elite athletes with diverse sporting backgrounds performed a maximal vertical squat jump test and an isokinetic leg press P-F-v profile test. The isokinetic leg press P-F-v profile consisted of leg-extension against 4 given velocity conditions: 0.1, 0.3, 0.7, and 1.2 m/s. Criterion validity was evaluated using correlation between squat jump height and each isokinetic P-F-v parameter (F_0, v_0, P_{max} and, Sfv). Nearly "good" (r > 0.815) correlations were found for P_{max}, whereas correlations between the remaining P-F-v parameters ranged from "poor" to "impractical" (r = 0.702–0.159). This result may fit the previous assumption of P-F-v profiles, that individuals express variable contributions of F_0 and v_0 for similar P_{max} values. Consequently evaluating criterion validity for these parameters (F_0 and v_0) is likely difficult and would be contrary to this P-F-v profile assumption.

KEYWORDS: leg press, squat jump, correlation, P-F-v parameters, profiling, isokinetic.

INTRODUCTION: Power-Force-velocity (P-F-v) profiles have become popular for testing athletes' physical performance and have been utilized for individualized training prescriptions (Jimenez-Reyes, Samozino, Brughelli, & Morin, 2017; Samozino, Rejc, Di Prampero, Belli, & Morin, 2012). Ballistic movements (e.g. jumping, throwing) have been proposed for P-F-v profiles tests (Rahmani, Morel, & Samozino, 2018; Samozino, 2018) based on the assumption that these movements depend directly on the mechanical capabilities of the neuromuscular system (Samozino, 2018). However, the P-F-v profiling approach has been recently questioned when performed with vertical jumps because task familiarity appears to substantially affect intra-subject reliability (Fessl, Wiesinger, & Kröll, 2022). In elite athletes, without specific experience in vertical jumping, test-retest reliability was less than acceptable (Lindberg, Solberg, Bjørnsen, et al., 2021; Valenzuela et al., 2020). Lindberg, Solberg, Bjørnsen, et al. (2021) sought new methods independent of such constraints and found that P-F-v profiling using leg press showed higher test-retest reliability than jumping P-F-v profiles. The better reproducibility of the leg press P-F-v profiles was attributed to a better standardization (fixed seat), less technical variation, and reduced coordinative demands compared to vertical jumps. Isokinetic leg press dynamometry could be another possible solution for increasing the sensitivity of P-F-v tests because highly standardized test movements require less coordinative demand. Furthermore, isokinetic dynamometry is considered to be highly reliable and the gold standard for strength testing (Dirnberger, Huber, Hoop, Kösters, & Müller, 2013). However, pneumatic or isokinetic leg press tasks differ biomechanically from ballistic movements, for example by their absence of the deceleration phase in ballistic movements, and range of motion in the hip and ankle joint is limited in leg-press movements (Lindberg, Solberg, Bjørnsen, et al., 2021). Consequently, when performing P-F-v testing using leg press there could be a reciprocal relationship between test sensitivity (increased reliability) and movement/sport specificity (decreased external validity) (Fritz, Kröll, & Schwameder, 2018). Despite the potential decrease in external validity, a positive relationship between lower-limb strength and vertical jump performance was found in several studies (Sheppard et al., 2008; Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004). To our knowledge, the criterion validity of leg-press P-F-v profiles has not been reported. Therefore, we aimed to investigate (I) the criterion validity of the isokinetic leg press P-F-v parameters relative to squat jump height and (II) the effect of performance level upon test sensitivity.

METHODS: Forty elite athletes (22 males: 22.7 ± 3.6 years; 1.78 ± 0.06 m; 73.4. ± 13.5 kg; and 18 females: 22.3 ± 3.6 years; 1.66 ± 0.08 m; 61.3. ± 9.0 kg;) with different sporting backgrounds (karate, alpine skiing, ski jumping, track and field, triathlon, fist ball, wrestling, ski mountaineering, luge, bobsleigh, gymnastics, judo, sky-diving, road cycling, and rowing) volunteered to participated in this study. Participants were familiarized with the testing procedures by first performing the vertical jump test and 20 minutes later the isokinetic leg press P-F-v profile test within the same testing. All participants performed a standardized warm-up prior to each testing, followed by up to three warm-up vertical jumps. The vertical jump test consisted of three maximal squat jumps performed on a force plate (1000 Hz). Participants were instructed to jump as high as possible with hands hold on the hips. Jump height was calculated by integrating the vertical ground reaction force and the participant's body mass measured during the static squat position (Kibele, 1998). The trial with the greatest jump height was then used for the analysis. The P-F-v profile test consisted of concentric leg press movements against four different velocities (0.1, 0.3, 0.7, and 1.2 m/s) which cover the farthest possible range using the isokinetic device IsoMed2000. The range of motion was adjusted to 80°- 130° knee angle for each individual. Prior to the maximal test efforts participants were allowed to perform two to three submaximal repetitions to prepare and familiarize with the tested velocity. At each velocity condition four maximal concentric leg extensions were performed as fast and powerful as possible. Ground reaction forces were recorded (1000 Hz) over the entire leg press movement. Mean force and mean velocity including the acceleration and deceleration were calculated. The trial with the highest mean force at each velocity condition was used determine the leg press P-F-v parameters: F_0 (= theoretical maximal force), v_0 (= theoretical maximal velocity), P_{max} (= theoretical maximal power), and Sfv (= slope of the force-velocity relationship). according to Samozino (2018). All data are presented as group means ± standard deviation (SD). Data were checked visually and statistically using Shapiro Wilk tests for normality of distribution. Criterion validity was determined using spearman correlation coefficients between squat jump height and P-F-v parameters. Criterion validity was determined for all participants and between two performance groups. The two performance groups were separated by ranked jump heights: high performance group (HP = 11 best male + 9 best females based on jump height) and low performance group (LP = 11 lowest males + 9 lowest females based on jump height). The correlations were interpreted as "impractical" (< 0.45), "very poor" (0.45 – 0.70), "poor" (0.71 – 0.85), "good" (0.86 – 0.95), "very good" (0.96 – 0.995) or "excellent" (> 0.995) (Hopkins, 2015).

RESULTS: The jump height and P-F-v parameters of all participants (overall) and of the two performance groups: high performance (HP) and low performance (LP) are reported in table 1. "Impractical" correlations were found for v_0 and Sfv, while correlations for F_0 ranged from "very poor" (0.65) to "poor" (0.70) (table 2). The correlation between P_{max} and jump height ranged from "poor" to "good" (0.82-0.86). No meaningful differences were found between performance groups (HP and LP versus the overall group.

Table 1: Magnitudes presented as group means

	Overall	HP	LP
Parameter	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
Jump height [m]	0.34 ± 0.08	0.38 ± 0.08	0.30 ± 0.07
F_0 [N/kg^{-1}]	44.7 ± 8.3	46.7 ± 7.5	42.7 ± 8.7
v_0 [m/s^{-1}]	1.4 ± 0.2	1.5 ± 0.2	1.4 ± 0.1
P_{max} [W/kg^{-1}]	16.0 ± 2.9	17.0 ± 2.7	15.0 ± 2.8
Sfv [Ns/m/kg^{-1}]	31.7 ± 8.0	32.6 ± 8.0	30.8 ± 8.1

F_0 = theoretical maximum Force; v_0 = theoretical maximum velocity; Pmax = maximum Power; Sfv = F-v Slope; overall = all participants, HP = high performance group; LP = low performance group

DISCUSSION: "Good" criterion validity between jump height and leg press P-F-v parameters was observed only for theoretical maximal power (P_{max}). The remaining P-F-v parameters had "poor" to "impractical" correlations with squat-jump height. Substantially higher correlations were determined for F_0 than for v_0 and Sfv. No information could be found regarding criterion validity of P-F-v tests in literature.

Table 2: Spearman correlations between jump height and P-F-v parameters

	F_0	v_0	P_{max}	Sfv
Overall Jump height	0.70*	0.24	0.86*	0.42*
HP Jump height	0.68*	0.16	0.82*	0.41
LP Jump height	0.65*	0.21	0.83*	0.42

F_0 = theoretical maximum Force; v_0 = theoretical maximum velocity; Pmax = maximum Power; Sfv = F-v Slope; * = significant correlation; HP = high performance group; LP = low performance group

Interestingly, when considering reliability studies of different P-F-v tests, a similar pattern between reliability and validity is identifiable. Acceptable and better reliability was found for P_{max} and F_0, whereas v_0 and Sfv test-retest reliability appears to be unacceptable (Fessl et al., 2022; García-Ramos, Pérez-Castilla, & Jaric, 2018; Lindberg, Solberg, Bjørnsen, et al., 2021; Valenzuela et al., 2020). These distinct reliability results of the P-F-v parameters were attributed to the unbalanced distribution of the force and velocity data-points within the P-F-v profile (Lindberg, Solberg, Bjørnsen, et al., 2021). The data-points (force and velocity) of vertical jumps were located closer to the y- (F_0), than to the x-axis (v_0), resulting in a longer extrapolation distance to obtain the parameter v_0. Similar distribution was found in the current isokinetic leg press F-v data ranging from about 6%-50% of v_0 and 50%-95% of F_0. Consequently, v_0 is more prone to error caused by slight variations in the input (F-v) data-points. Hence, the extrapolation of the quasi-linear relationship between force and velocity, which serves as the basis for P-F-v profiles, seems to cause issues for test-retest reliability as well as for the validity of the P-F-v parameters. The inclusion of the acceleration and deceleration phases could be another reason for the insufficient correlations. Aside from methodological issues and the biomechanical differences between vertical jumps and leg press movements, we found "good" criterion validity for P_{max}. This result is in line with previous findings of strong correlations between jump height and mechanical power in unloaded vertical jumps (Aragón-Vargas & Gross, 1995; Barker, Harry, & Mercer, 2018). Furthermore, the finding that only P_{max} showed good criterion validity could also fit the original assumption made by Morin and Samozino (2016) that two athletes could have similar P_{max} values, but their individual contribution of F_0 and v_0 could be different. Hence, individuals inherently express variable contributions of F_0 and v_0 in P-F-v profiles, consequently evaluating criterion validity for these parameters would be contrary to this P-F-v assumption and anyway statistically unverifiable. P-F-v parameters have been frequently described as "maximal mechanical muscle capacities" (Jimenez-Reyes, Samozino, Pareja-Blanco, et al., 2017), which characterize neuromuscular system function (Morin & Samozino, 2016; Padulo et al., 2017). While this attribution of P-F-v profiling has been assumed, we could not find a concrete validation of this construct. Rather, it is still unknown if P-F-v parameters actually represent specific functional qualities of athletic performance. Nonetheless, intervention studies based on individual P-F-v profiles could be seen as an indirect construct validation of the P-F-v parameters (Jimenez-Reyes, Samozino, Brughelli, et al., 2017; Jimenez-Reyes, Samozino, & Morin, 2019; Lindberg, Solberg, Rønnestad, et al., 2021). Unfortunately, the results of these intervention studies are inconsistent, and the most recent one discredits the advantage of P-F-v profiles. Compared to traditional training programs, no meaningful effects were reported for individual training prescriptions based on P-F-v profiles (Lindberg, Solberg, Rønnestad, et al., 2021). Hence, the description and functional representation of P-F-v parameters require further investigation to validate these key assumptions of P-F-v profiling methods.

CONCLUSION: We found "good" criterion validity between P_{max} and jump height, supporting the utility of leg press P-F-v profiling. Furthermore, the lack of good validity for F_0 and v_0 is in line with the conceptual assumptions of P-F-v profiling. In comparison to previous studies using indirect validations of the P-F-v parameters, we call for deeper investigations into P-F-v profiling and functional interpretation.

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