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Title: Concurrent validity and reliability of a single short all-out cycle test for the determination of maximal power output in physically active male and female adults

Running title: Validity and reliability of single all-out test

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Abstract

This study sought to determine the concurrent validity and reliability of 6-s peak power test [6PT]) on an air and magnetically braked cycle ergometer (Wattbike). Firstly, 17 physically active male and female adults performed 6PT and force-velocity test (FVT), consisting of 3 short all-out cycle sprints against 3 different loads on an electromagnetically braked cycle ergometer (Power Max), on the same day in part 1 of the study (i.e., concurrent validity). Subsequently, 11 out of those participants performed the respective tests on three different days (a total of 6 measurements for each participant) in part 2 of the study (i.e., inter-day reliability). The order of the tests was counterbalanced in both parts of the study, and maximal power output (MPO) and peak power output (6PP) derived from FVT and 6PT, respectively, were retained for the subsequent analyses. A high correlation between MPO and 6PP (r = 0.97, [95%CI: 0.90-0.99], $p < 0.01$) was observed with the standard error of the estimate of 59.7 W in part 1 of the study. Moreover, excellent inter-day reliability was confirmed for both tests in part 2 of the study (coefficient of variation: MPO = 2.08% [95%CI: 1.56-3.28%], 6PP = 2.81 [95%CI: 2.11-4.43%]; intraclass correlation coefficient: MPO = 0.987 [95%CI: 0.959-0.996], 6PP = 0.965 [95%CI: 0.899-0.990]). This study showed that a valid and reliable value is obtained from a single short all-out cycle test (i.e., 6PT), which would enable a frequent follow-up of power production capacity of individuals.

Key Words: Short maximal efforts, Single vs. Multiple sprints, Performance monitoring, Cycle sprint

標題：単発ペダリングテストの妥当性及び再現性の検証

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抄録

本研究は、単発の全力ペダリングテストと複数の全力ペダリングから成る無酸素パワーテスト（Force-velocity test; FVT）との比較、及び両テストの再現性を検証することを目的とした。運動習慣を有する健常男女 17 名（男性 12 名、女性 5 名、33 ± 6 歳、171 ± 8 cm、68 ± 9 kg)が比較検証の実験（パート 1)、11 名（男性 9 名、女性 2 名、33 ± 7 歳、171 ± 8cm、70 ± 6kg）が両テストの再現性を検証する実験（パート 2）にそれぞれ参加した。パート 1 では、被験者は、異なる負荷に対して 10 秒以内の全力ペダリングを 3 回繰り返す無酸素パワーテスト（FVT; Power Max V3 Connect、負荷システム：電磁ブレーキ）及び単発の 6 秒全力ペダリングテスト（6 秒ピークパワーテスト[6PT]; Wattbike pro、負荷システム：空気抵抗及びマグネット）を 1 時間以上の間隔を設けて同日に実施した。パート 2 では、被験者は各テストを 48 時間以上の間隔を設けて 3 回実施した。両実験とも、クロスオーバーデザイン（カウンターバランス）を用いた。また、評価項目は FVT の負荷—回転数の関係から算出される最大パワー（MPO)、及び 6PT におけるピ

ークパワー（6PP）とした。パート 1 では、線型回帰分析及び推定量の標準誤差（SEE）、パート 2 では、変動係数（CV）及び級内相関係数（ICC）をそれぞれ算出した。また、各結果の 95%信頼区間（CI）も併せて算出した。

FVT と 6PT の間には非常に強い相関（r= 0.97, 95%CI: 0.90-0.99, p < 0.01, SEE: 59.7 W）が確認された（パート 1）。また、3 日間にわたる日間変動において、両テストともに非常に高い再現性を示した（CV: MPO = 2.08% [95%CI: 1.56-3.28%], 6PP = 2.81 [95%CI: 2.11-4.43%]; ICC: MPO = 0.987 [95%CI: 0.959-0.996], 6PP = 0.965 [95%CI: 0.899-0.990]、パート 2）。本研究では、1)単発の全力ペダリングテストは FVT の代わりとなり得ること、2)両テストの再現性が非常に優れていることが明らかになった。これらの結果から、単発の 6 秒全力ペダリングテストにより、精度よくトレーニングの進捗をモニタリングできることが示唆された。

Introduction

Power production capacity of skeletal muscle is largely determined by the maximal amount of adenosine triphosphate (ATP) re-synthesised through anaerobic energy pathways (i.e., phosphocreatine degradation and glycolysis)[1]. It is likely one of the essential components for sporting success considering that athletes are often required to produce high power output (e.g., jumping, sprinting) in the majority of sports[2,3]. It has been frequently assessed via the determination of maximal power output (MPO) during short all-out cycle exercises[4], and MPO has been associated with other form of performance such as vertical jump height of athletes with various competitive levels and sporting disciplines[5-7].

Traditionally, MPO is calculated theoretically based on force-velocity relationships derived from multiple short maximal sprints[6,8-13]. While performing multiple sprints against different loads enables one to understand force-velocity profile of individuals, it can be a time-consuming procedure including warm-ups and three to eight short (e.g., 6 s) maximal sprints interspersed with several minutes of recovery[4,7-12,14]. Moreover, such procedures may cause some degree of neuromuscular fatigue[4], and have a negative impact on subsequent exercise testing or training.

In recent years, an air and magnetically braked cycle ergometer (i.e., Wattbike) has been increasingly utilized in both field and research settings with individuals from various sporting backgrounds[15-18]. The Wattbike was developed with British Cycling for training and testing purposes[19], and it has a suitable power output range (0-3760 W) for short-duration high-intensity exercise training and testing[20]. While the reliability of the ergometer has been repeatedly shown in power produced during 30-s all-out[20], 4-min maximal effort[15] or 6-min steady-state cycling[21] with coefficient of variations (CV) of 2.3 to 6.7%[15,20,21], most of the studies recruited trained cyclists[15,20,21] and the variability may increase when less experienced individuals are tested. Indeed, the CV of untrained subjects was higher than that of trained cyclists (6.7 vs. 2.6%) during steady-state cycling[21]. Furthermore, limited studies examined the validity and reliability of the ergometer during non-constant-load (all-out) cycling[17,20,22]. Driller et al.[20] examined the reliability of a 30-s sprint test (i.e., Wingate test) on the Wattbike in highly trained cyclists over 3 consecutive weeks, and observed CVs of 4.9 and 2.4% with intraclass correlation coefficient (ICC) values of 0.97 and 0.99 for peak and average power outputs, respectively. Furthermore, Wehbe et al.[22] showed excellent inter-day reliability of a 6-s peak power test (6PT) across 3 different occasions with mean CV and ICC being 3.0% and 0.96, respectively, in professional male Australian rules footballers. While their findings suggest that a reliable result can be also obtained from non-cyclists (i.e., running-based athletes), they had their athletes perform 6PT twice and adopted better of the 2 sprint efforts[22], which could partially explain their excellent reliability. In terms of the validity, Herbert et al.[17] compared peak power output achieved during 6PT on the Wattbike with those derived from 30-s and 6-s modified Wingate tests on a friction-loaded cycle ergometer (i.e., Monark ergometer), and they confirmed high correlations (r = 0.90 to 0.95) between the peak power output obtained during 6PT and those achieved in the two Wingate tests. Considering the self-powering system of the Wattbike (i.e., no electric power source will be required), 6PT on the ergometer can provide a useful option to assess anaerobic performance[23] especially in practical settings (e.g., sporting fields). Nevertheless, Herbert et al.[17] employed a fixed load for the Wingate tests (7.5% of body mass [BM]) and only 9 physically active males with power output range of approximately 800 to 1400 W were tested. Therefore, it remains unknown whether 6PT could provide a comparable result to a force-velocity test (FVT) consisting of multiple sprints against different loads on a more traditional (e.g., electromagnetically braked) cycle ergometer in different populations (e.g., individuals with different power output range, or female participants). If the main aim of testing is not to determine force-velocity profile but to simply assess anaerobic performance (power production capacity) of individuals, 6PT may be a preferred option especially in field settings.

In short, this study aimed to compare the values obtained from 6PT and FVT (part 1), and examine inter-day variability of the respective tests (part 2). Based on the previous studies (albeit limited) demonstrating the validity[17)] and the reliability[22)] of 6PT on the Wattbike, it was hypothesized that 6PT would be highly associated with FVT, and show good to excellent reliability.

Methods and Materials

Experimental Design

This study comprises of two parts. In the first part, we compared peak power output (6PP) obtained from 6-s peak power test (6PT) with maximal power output (MPO) achieved in force-velocity test (FVT), whereas the reliability of the two tests were examined in the second part of the study. This study was approved by the Institutional Research Ethics Committee (IRB approval number: 2021-038).

Part 1

Participants

17 healthy adults (males:12, females:5, 33 ± 6 years, 171 ± 8 cm, 68 ± 9 kg) participated in part 1 of the study. Most of them were recreationally active performing endurance and/or resistance exercise training approximately 2 to 3 times per week. Participants were included if they were not a competitive cyclist and free from musculoskeletal injury,

cardio-metabolic disease or any other diseases that would preclude them from performing all-out sprints. They were asked to refrain from any strenuous exercise 48 h prior to a measurement day, and to finish a meal at least 2 to 3 h before a test. They were fully informed of the methods and purposes of the study beforehand and agreed to participate.

Procedures

All participants performed FVT on an electromagnetically braked cycle ergometer (Power Max V3 Connect, Konami Holdings Corporation, Tokyo, Japan), and 6PT on an air and magnetically braked cycle ergometer (Wattbike Pro, Wattbike Ltd, Nottingham, UK). They performed both tests on the same day, and the order of the tests was counterbalanced (i.e., 8 participants started from FVT, while other 9 participants started from 6PT). A minimum of 1-h rest was set between the two tests to minimize any residual fatigue resulting from the preceding all-out efforts[24)], and then they performed the remaining test. Before performing those tests, they first measured their body mass (BM) on a bio-impedance meter (Inbody770, Inbody Japan, Tokyo, Japan), and did a 5-min warm-up on the same cycle ergometer (Power Max V3 Connect) irrespective of the testing order. The 5-min warm-up consisted of cycling against 1 kilopond (kp) at approximately 60 revolutions per min (rpm) with two 3-s maximal sprints at the 2^{nd} and 4^{th} mins to familiarize themselves with all-out sprints. They then either performed FVT or 6PT according to their allocation.

Force-velocity test (FVT)

FVT consisted of three maximal sprints against three different loads separated by 2-min passive rest in a load-increasing order. The first load was determined based on BM and sex of participants, whereas the second and third loads were determined according to the peak rpm achieved in the preceding sprint, all of which were automatically determined via the built-in software of the ergometer (Power Max V3 Connect) (Table 1). Before each sprint, participants were given 3-s countdown and then performed a maximal sprint in a standing position. They cycled with all-out efforts until rpm reached the highest value (sampled at 10 Hz), which was typically observed within 5 s (Table 1). After the completion of three sprints against three different loads, the relationship between three different loads and rpms was determined via a linear regression equation for all participants (r^2 = 0.98 to 1.00).

$$y = -ax + b\ (a > 0, b > 0, a{:}\ slope, b{:}\ intercept)$$

Power output achieved with each load was calculated as follows[25)]:

$$Power\ output\ (W) = load\ (kp) \times cadence\ (rpm) \times 0.98$$

where 0.98 indicates gravitational acceleration (m/s^2). MPO for each participant was then determined based on the linear relationship between three pairs of loads and rpms using the least-squares method as previously described (Fig. 1)[9,25,26]. The electromagnetically braked cycle ergometer employed in this study has been widely utilized for both testing and training purposes in athletes and healthy individuals[25,27-30].

Please insert Fig.1 here

6-s peak power test (6PT)

Wattbike utilizes a combination of air and magnetic resistance where air braking mechanism controls the airflow entering the flywheel, and two magnetic sensors fixed to the crank regulate the application of resistive force to the flywheel axle. The Wattbike calculates power output by determining the chain tension via a strain gauge (which is bonded to the chain) at a sampling rate of 100 Hz using the following formula:

$$P[W] = (F[N] \times l[m])/t[s]$$

where P[W] is power output per revolution, F[N] is average force per crank revolution, l[m] is a crank length of 0.17 m and t[s] is the time taken to complete a crank revolution. Angular velocity was measured twice per crank revolution[17,21]. Air resistance (levels 1 to 10) was determined according to BM and sex of participants which was automatically set via the built-in software of the ergometer, whereas magnetic resistance was set at level 1 out of 7 for all participants (Table 1). Participants were given 3-s countdown and then cycled for 6 s with all-out efforts in a standing position. The peak power output achieved over 6 s (6PP) was retained for the analysis[17)].

Please insert Table 1 here

Part 2

Participants

11 healthy adults (males: 9, females: 2, 33 ± 7 years, 171 ± 8 cm, 70 ± 6 kg) out of 17 participants who had completed the part 1 of the study, participated in part 2 of the study. They were asked to refrain from any strenuous exercise 48 h prior to a measurement day, and to finish a meal at least 2 to 3 h before a test. They were fully informed of the methods and purposes of the study beforehand and agreed to participate.

Procedures

The participants performed each test on three different occasions separated by at least 48 hours but maximum of 1 week. The order of tests was counterbalanced, that is, 6 of them started from FVT whereas 5 of them started from 6PT. Once they had completed either test, they then performed the remaining test (i.e., a total of six measurements for each participant). On each occasion, they first measured their BM on a bio-impedance meter (Inbody770), and loads of the respective tests were determined accordingly. The warm-up protocol and the procedures of each test were identical with those of the part 1. Regarding the FVT, a high linearity was confirmed between loads and rpms across the three measurement days (r^2 = 0.94 to 1.00). The positions of handlebars and saddles of the respective ergometers were determined on the first measurement day for each participant, and kept constant throughout the study period. All measurements were performed at a similar time of day (± 2 hours) for each participant to minimize the influence of circadian rhythm on maximal exercise performance[31)].

Statistical analyses

Part 1

All values are presented as means ± standard deviation (SD) unless otherwise stated. Firstly, Shapiro-Wilk test was performed to confirm all data were normally distributed. Interchangeability between the two tests (i.e., FVT and 6PT) was determined by a linear regression using least squares method with 95% confidence and prediction intervals. Subsequently, the residuals from the linear regression were plotted as a function of the predicted MPO to examine whether the error (residuals) was similar for all subjects[32)]. All statistics were run on Statistical Package for the Social Science (SPSS) software version 24 for Windows (SPSS Inc., IBM, Chicago, IL, USA), and the level of significance was set at $p < 0.05$.

Part 2

All values are presented as means ± SD unless otherwise stated. Firstly, Shapiro-Wilk test was performed to confirm all data were normally distributed. Power outputs achieved across the different measurement days were compared via a two-way (measurement day x test) repeated analysis of variance (ANOVA). Greenhouse-Geisser corrections were used if the violation of sphericity was detected. Inter-day reliability of the respective tests was analysed via an Excel spreadsheet available online[33)]. Typical error of measurement (TEM) was calculated by dividing the SD of the change score by $\sqrt{2}$, while CV was calculated as the SD of an individual's repeated measurement expressed as a percentage of his or her individual mean test score[34)]. Intraclass correlation coefficient (ICC) between the trials was also calculated. The results of ICC were regarded as poor, moderate, good and excellent reliability if the values were less than 0.5, between 0.5 and 0.75, between 0.75 and 0.90 and greater than 0.90, respectively[35)]. All reliability statistics were calculated in combination with 95% confidence intervals (CI). All statistics except the reliability measures were run on SPSS software version 24 for Windows, and the level of significance was set at $p < 0.05$.

Results

Part 1

The results of MPO and 6PP were 861 ± 221 W and 941 ± 201 W, respectively (MPO < 6PP, $p < 0.01$). There was a high correlation between MPO and 6PP (r = 0.97 [95%CI:

0.90-0.99], $p < 0.01$, Fig. 2A). Subsequently, it was confirmed that the error was similar across the participants when the residuals were plotted against the predicted MPO (Fig. 2B). The regression equation derived from the analysis was as follows;

$$MPO = 1.0587 \times 6PP - 135.57 \; (r^2 = 0.93, SEE = 59.7\ W)$$

Please insert Fig.2 here

Part 2

A 2-way repeated ANOVA revealed that there was no main effect of measurement day nor measurement day-by-test interaction effect in power output, whereas there was a significant main effect of test, and 6PP was significantly greater than MPO (absolute power: 964 ± 202 vs. 901±223 W, $p < 0.01$; relative to BM: 13.8 ± 2.1 vs. 12.8 ± 2.4 W/kg, $p < 0.01$). The reliability results of the two tests are summarized in Table 2.

Please insert Table 2 here

Discussion

The main findings of the current study are that 1) peak power output achieved in the single all-out cycle test (i.e., 6PT) is highly associated with MPO obtained from the multiple all-out sprints (i.e., FVT), and 2) the inter-day reliability of the two tests is excellent (ICC > 0.9, CV < 3%)[35]. From these findings, it can be argued that a valid and reliable assessment of power production capacity is achieved through a single 6-s all-out effort.

While 6PP has been shown to highly correlate (r = 0.90 to 0.95) with peak power output achieved in the Wingate tests against 7.5% BM on a Monark cycle ergometer[17)], Jaafar et al.[10)] demonstrated that optimal loads for the Wingate test were approximately equal to 10% BM and greater than 11% BM in recreational and trained subjects, respectively. Their findings indicate that peak power output achieved in the Wingate test against 7.5% BM was likely underestimated in the study by Herbert et al.[17)]. In contrast, we individualized loads according to the performance (rpm) of each participant during the FVT, and consequently, the optimal load (11.1 ± 1.6%, Table 1) was in line with the study by Jaafar et al.[10)]. Furthermore, while Herbert et al.[17)] tested only 9 physically active males with power output range of approximately 800 to 1400 W, we observed a higher correlation (r = 0.97) in 17 physically active males and females across a range of power including lower values (approximately between 550 and 1250 W, Fig. 2A). This suggests that the validity of 6PT is not impaired in different populations (i.e., mixed gender vs. males only). Moreover, we also confirmed that the residuals from the regression analysis were similar across the participants (Fig. 2B), indicating that the accuracy of the prediction (i.e., SEE) would not be influenced by power production capacity of individuals.

The reliability results of 6PT in the current study (Table 2) were equally excellent compared with those in the previous study studies[20,22]. Wehbe et al.[22] reported mean CV and ICC of 3.0% and 0.96, respectively, when 14 professional male Australian rules football players performed 6PT on 3 different occasions. Likewise, Driller et al.[20] tested 11 highly trained cyclists over 3 consecutive weeks and showed CVs of 4.9 and 2.4% with ICC values of 0.97 and 0.99 for peak and average power outputs during the 30-s Wingate test, respectively. While the current study employed a single 6PT, Wehbe et al.[22] had their participants perform 6PT twice (separated by 1-min active recovery) and better of the two was adopted. Since reliability is equally excellent between the current and previous[22] studies, it would be better to perform a single 6PT from a practical point of view. Furthermore, we observed comparable reliability to the study by Driller et al.[20] who tested highly trained cyclists, despite the fact that we recruited non-cyclists and the previous study[21] observed a higher CV in untrained subjects compared with trained cyclists (6.7 vs. 2.6%) during steady-state cycling. A possible candidate that explains comparable reliability between the current and previous[20] studies can be the duration of the test (6 vs. 30 s). It has been shown that a degree of pacing still occurs during all-out exercises especially when sprint duration is extended[36-38]. Therefore, a 30-s all-out exercise can result in a greater degree of pacing compared to a shorter (6 s) one, possibly leading to a larger amount of variability. Interestingly, Driller et al.[20] observed a higher

CV in peak (4.9%) than average (2.4%) power during the 30-s Wingate test. Higher and lower peak power outputs would inevitably result in greater and lesser degrees of drop-off in power towards the end of an all-out sprint, respectively (i.e., similar overall average power)[39]. This suggests that peak power may be more affected by subconscious pacing during a longer sprint. In any case, if the main aim of testing is to assess maximal power production capacity, a shorter sprint test should be preferable especially for non-cyclists. It should be pointed out that although a single sprint test (i.e., 6PT) may be more preferable from a practical point of view, the importance of FVT should not be overlooked since it enables scientists or practitioners to determine force-velocity profile of individuals, which seems to be particularly important in athletic populations[5-7]. Furthermore, the optimal load obtained from FVT (11.1 ± 1.6% of BM in the current study, Table 1) can be served as a reference value in a training setting[6]. Therefore, the choice of testing (i.e., FVT or 6PT) should be determined according to the main objective of test and those who perform it.

It is worth mentioning that 6PP was greater than MPO in both parts of the current study. The Wattbike directly measures power output with a strain gauge bonded to the chain, whereas the Power Max V3 Connect measures it at the flywheel level (i.e., it is the product of a given load [kp] and cadence). This methodological difference between the ergometers can be the main factor that explains the observed phenomenon[4]. Regardless of the methodologies, both ergometers showed excellent reliability and the differences in power output would not be a major issue, provided that the same ergometer is applied when testing the same individuals.

Finally, the main limitation of the current study is that we could not obtain data from athletic population. It has been shown that maximal power in cycling differs among sporting disciplines[5], and optimal load for maximal power is dependent upon training status[6,10]. These findings indicate that the relationship between MPO and 6PP in the current study (Figure 2A) may have been different with different populations. Therefore, it should be remembered that our data were obtained from physically active but non-athletic population, and care must be taken when applying our findings to athletic populations.

In conclusion, the current study has shown that a single 6-s all-out efforts (i.e., 6PT) can be used as an alternative to more traditional method (i.e., FVT) which requires participants to perform multiple sprints against different loads. In addition, both tests showed excellent inter-day reliability with the results being comparable to those obtained from highly trained cyclists[20] and professional Australian rules footballers [22].

Author contribution: TY and DY conceptualized and designed the study, while TY collected and analysed the data. TY drafted the initial manuscript, and TY and DY critically reviewed and revised it, and approved the final version of the manuscript.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

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Table 1. Parameters of the respective cycle tests in part 1 of the study

Force-velocity test	1st sprint	2nd sprint	3rd sprint
Power output (W)	643 ± 135	822 ± 210	852 ± 215
Power output (W/kg)	9.4 ± 1.3	12.0 ± 2.3	12.4 ± 2.4
Peak RPM	170 ± 19	139 ± 15	108 ± 8
Time to peak	4.2 ± 0.8	4.1 ± 0.8	4.4 ± 0.9
Load (kp)	3.8 ± 0.5	5.9 ± 1.0	8.0 ± 1.7
Relative load (%BM)	5.6 ± 0.4	8.7 ± 1.0	11.7 ± 1.8
Optimal load and MPO calculated from the force-velocity relationships			
Optimal Load (kp)		7.6 ± 1.5	
Optimal Load (%BM)		11.1 ± 1.6	
MPO (W)		861 ± 221	
MPO (W/kg)		12.5 ± 2.4	
6-s peak power test			
Peak Power output (W)		941 ± 201	
Peak Power output (W/kg)		13.8 ± 2.1	
Peak RPM		157 ± 10	
Air resistance (1-10)		3 ± 1	
Magnetic resistance (1-10)		1 ± 0	

Data are presented as means ± standard deviation. BM, body mass; MPO, maximal power output; RPM, revolutions per min.

Table 2. Inter-day reliability of the respective cycle tests across 3 measurement days

	MPO (W)	MPO (W/kg)	6PP (W)	6PP (W/kg)
TEM				
2-1	25.1 (17.6-44.1)	0.33 (0.23-0.59)	29.3 (20.4-51.3)	0.39 (0.27-0.68)
3-2	23.3 (16.3-40.9)	0.32 (0.23-0.57)	33.3 (23.3-58.5)	0.50 (0.35-0.88)
mean	24.2 (18.3-38.3)	0.33 (0.25-0.52)	31.4 (23.6-49.5)	0.45 (0.34-0.71)
CV				
2-1	2.09 (1.46-3.67)	1.92 (1.34-3.38)	2.58 (1.80-4.53)	2.62 (1.83-4.60)
3-2	2.11 (1.48-3.71)	2.22 (1.55-3.90)	2.63 (1.83-4.61)	2.98 (2.08-5.23)
mean	2.10 (1.58-3.32)	2.08 (1.56-3.28)	2.60 (1.96-4.11)	2.81 (2.11-4.43)
ICC				
2-1	0.990 (0.964-0.997)	0.986 (0.948-0.996)	0.984 (0.943-0.996)	0.975 (0.911-0.993)
3-2	0.992 (0.971-0.998)	0.987 (0.953-0.997)	0.979 (0.926-0.994)	0.956 (0.845-0.988)
mean	0.991 (0.973-0.997)	0.987 (0.959-0.996)	0.982 (0.946-0.995)	0.965 (0.899-0.990)

Data are presented as means ± 95% confidence interval. CV, coefficient of variation; ICC, intraclass correlation coefficient; MPO, maximal power output achieved in force-velocity test; 6PP, peak power output achieved in 6-s peak power test; TEM, typical error of measurement.

Figure legends

Fig. 1 Typical examples of force-velocity relationship (○) and force-power relationship (●) derived from a force-velocity test (FVT). V_0 is calculated by extrapolating zero force and F_0 by extrapolating zero velocity.

Fig. 2 Relationship between MPO and 6PP (A) and residuals of the linear regression as a function of predicted MPO (B). In Fig. 2A, thick dot-lines indicate 95% confidence intervals of the regression line, whereas thin dot-lines represent 95% prediction intervals of individual data. MPO, maximal power output achieved in force-velocity test; 6PP, peak power output achieved in 6-s peak power test.

Figure 1

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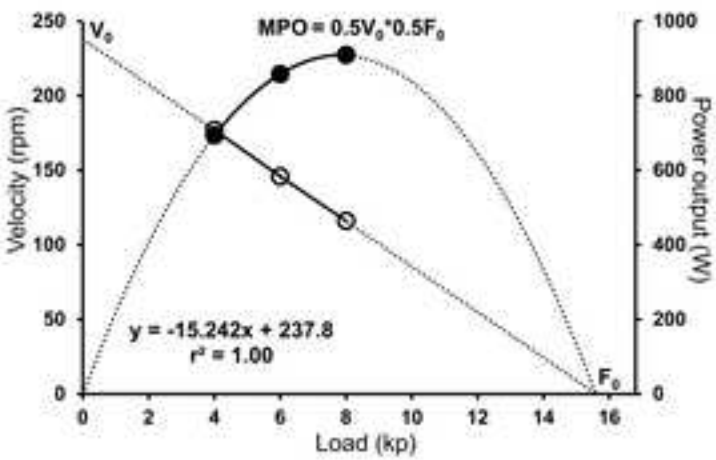

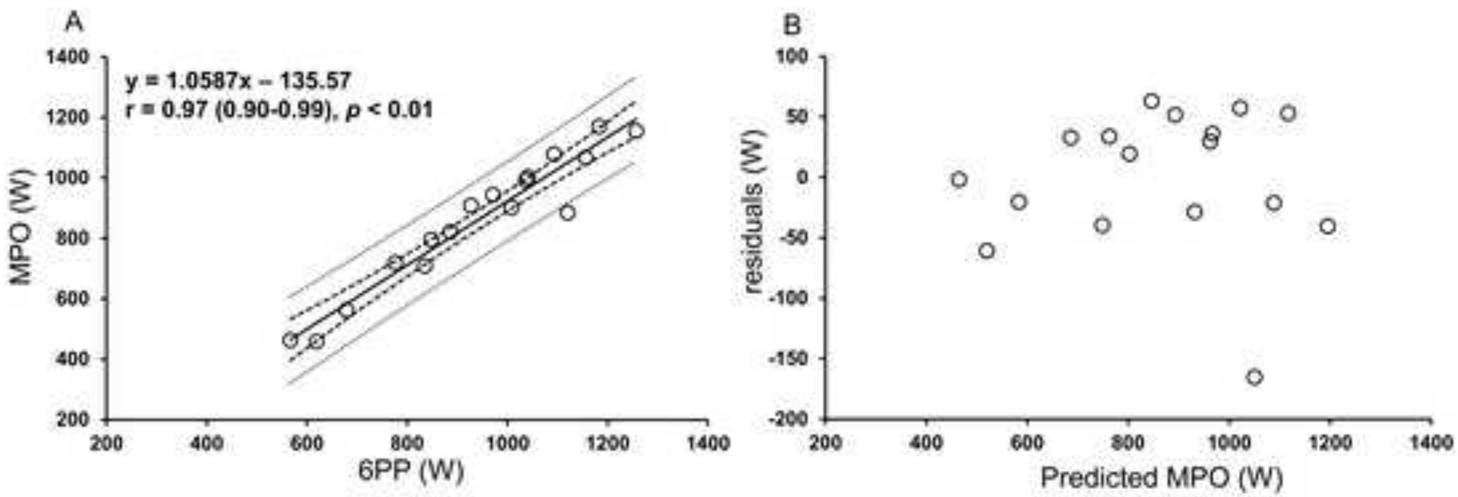
A
y = 1.0587x – 135.57
r = 0.97 (0.90-0.99), p < 0.01
MPO (W)
1400
1200
1000
800
600
400
200
200
400
600
800
1000
1200
1400
6PP (W)
B
residuals (W)
100
50
0
-50
-100
-150
-200
200
400
600
800
1000
1200
1400
Predicted MPO (W)