

Validation of a Six Second Cycle Test for the Determination of Peak Power Output

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The present study examined the agreement between peak power output during a standard Wingate anaerobic test (WAnT) and a six second 'all-out' test on a Wattbike Pro. Nine males (40.7 ± 19.4 yrs, 1.76 ± 0.03 cm, 82.11 ± 8.9 kg) underwent three testing protocols on separate days. The protocols consisted 30 second WAnT (WAnT30), a modified WAnT over 6 seconds (WAnT6) and a 6 second peak power test (PPT6). PPT6 was correlated with WAnT30 ($r = 0.9$; $p < 0.001$) with a mean bias of 105 W. PPT6 correlated with WAnT6 ($r = 0.95$; $p < 0.001$) with a mean bias of 74 W. WAnT6 correlated with WAnT30 ($r = 0.99$; $p < 0.001$) with a mean bias of 31 W. There was no difference in time to peak power between any trial. PPT6 resulted in significantly greater power outputs than in WAnT30 and WAnT6 ($p < 0.001$). We conclude that PPT6 and WAnT6 are valid measures of peak power output compared with WAnT30. This identifies that PPT6 and WAnT6 as short duration 'all-out' tests that have practical applications for

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researchers and coaches who wish to assess peak power output without the fatiguing effects associated with a standard WAnT.

KEYWORDS *Wattbike, Wingate anaerobic test (WAnT), rolling start, static start, fatigue.*

INTRODUCTION

Over the last three decades, athletes have become more powerful and athletic performances have continued to improve in conjunction with improvements in exercise training prescription. This has resulted in an increased interest in the measurement of maximal anaerobic capacity. Accurate anaerobic power assessment is paramount for athletes, as many sports involve repeated rapid rest to high intensity exercise transitions such as sprinting and jumping movements (Baker & Davies, 2002).

The Wingate anaerobic test (WAnT), first described in the paediatric work of Cumming (1973) and comprehensively investigated by Bar-or and colleagues (Bar-Or 1987; Inbar, Bar-Or, & Skinner, 1996) at the Wingate institute in Israel, has become the *sine qua non* for the determination of anaerobic power in the sports medicine laboratory. Testing procedure consists of pedalling with maximal 'all-out' effort for 30 s against a constant braking force (equal to 7.5% of the subject's body mass using a Monark cycle ergometer). Mean pedal rate is calculated for each 5 s interval. For the Monark cycle ergometer (Monark, Varberg, Sweden), power outputs are the product of braking force and pedal rate.

However, the WAnT it is not without criticism. Most team and racket sports require participants to produce maximal or near maximal sprints of very short durations (e.g. 1–7 s) (Wragg, Maxwell, & Doust, 2000; Bishop, Girard, & Mendez-Villanueva, 2011). Consequently, in cases where the primary outcome measure relates to the determination of peak power output (PPO) in an 'all-out' fashion, the 30 s WAnT is likely to be unduly stressful on the participant and furthermore prohibits the measurement of other maximal performance tests on the same day.

There are a number of commercially available cycle ergometers that allow the establishment of anaerobic power in the laboratory setting including electromagnetically braked and mechanically braked ergometers. The Wattbike (Wattbike Ltd, Nottingham, UK) is a combined air and magnetically resisted cycle ergometer that is commonly used in both gymnasias and exercise laboratories and endorsed by national cycling teams (Hopker, Myers, Jobson, Bruce, & Passfield, 2010). The Wattbike derives power output through the use of a load cell situated adjacent to the chain that calculates the sum of forces applied to the chain through the cranks. The air braking mechanism controls the flow of air entering the flywheel and is regulated by a gear lever with a range of increasing resistances from '1' through to '10'. Two magnetic sensors

fixed to the cranks permits the application of greater resistive force to the flywheel axle, which is achieved by clockwise rotation of a magnetic gear lever (with settings 1 through to 7). The Wattbike calculates power output by determining the chain tension over the load cell (sampled at 100 Hz) using the formula:

$$P[\text{W}] = (F[\text{N}] * l[\text{m}]) / t[\text{s}]$$

where $P[\text{W}]$ = power output per revolution, $F[\text{N}]$ = average force per crank revolution, $l[\text{m}] = 0.17$ m as a crank length, $t[\text{s}]$ = time taken to complete a crank revolution. The Wattbike measures angular velocity twice per crank revolution.

The validity and reliability of the Wattbike have been determined under constant load cycling across resistive forces ranging from 50–300 W with a reported Coefficient of variation (CV) of 2.6% (Hopker et al., 2010). Further to this, the reliability of a 30 s sprint exercise test shows acceptable agreement between repeated bouts conducted on separate days with a CV of 4.9% and intra class correlation coefficient (ICC) of 4.1 to 6.3% (Driller, Argus, & Shing, 2013). Information pertaining to the validity of the Wattbike to determine peak power output (PPO) over durations of less than 30 s is lacking in the scientific literature.

Therefore, the aim of the present study was to examine agreement between peak power output (PPO) determined by a 6 s all-out tests on Wattbike Pro and Monark cycle ergometers compared with criterion PPO determined during a 30 s Wingate anaerobic test (WAnT).

METHODS

Nine ($n = 9$) healthy, physically active volunteers (40.7 ± 19.4 yrs, 1.76 ± 0.03 cm, 82.11 ± 8.9 kg) gave their written informed consent. Participants arrived in the exercise physiology laboratory following an overnight fast and having abstained from strenuous exercise for a minimum of 48 hours. Participants were instructed to arrive in a hydrated state having abstained from caffeine and alcohol consumption for 36 hours. Ethical approval for the study was granted by UWS institutional ethics board.

Body mass (kg) was measured to the nearest 0.1 kg using a balance scale (Seca Vogel & Halke, Hamburg, Germany). Height was determined to the nearest 0.5 cm using a stadiometer (Seca Vogel & Halke, Hamburg, Germany). All participants performed a standard 30 s WAnT (WAnT30) 1 week before testing and were familiarized with the testing procedures of both ergometers to reduce any potential learning effect.

Prior to conducting each test, both Wattbike Pro and Monark cycle ergometers were calibrated according to manufacturers' guidelines. Each test

was preceded by a 5 min warm-up on the Wattbike Pro set at resistance level 8, corresponding to a Borg derived rating of perceived exertion (RPE) 11–13 (light to somewhat hard) incorporating two acceleration phases of ~3 s commencing after 90 and 180 s followed by a 5 min recovery. Participants then performed a WAnT30 or a modified Wingate test over 6 seconds (WAnT6) or a 6 second peak power test on the Wattbike (PPT6) with the three conditions performed in a random counterbalanced fashion. The geometry of both ergometers was matched for saddle height, seat-post angle (relative to crank fulcrum), handlebar height and distance to saddle. Saddle height was adjusted relative to the crank position and the foot was secured to a pedal with clips and participant's knee joint at almost full extension (approx. 170–180°).

Participants performed a WAnT30, a WAnT6 and a PPT6 on separate days. The primary outcome measures of interest were peak power output (PPO) and time to peak power (T-PPO). Following the completion of each cycle test, participants performed a 5 min cool-down on the Wattbike cycle set at air brake resistance level 8.

Both WAnT30 and WAnT6 assessments were performed using a Monark 868 cycle ergometer (Monark, Varberg, Sweden) against a resistance corresponding to 7.5% of participant body mass. The testing procedure for the WAnT30 employed a rolling start with a verbal command to commence maximal speed cadence. When 100 rpm was reached, the resistance was automatically introduced to start the 30 s or 6 s pedalling phase. Participants were verbally encouraged throughout each of the testing protocols. Power output data were recorded using Wingate software (Monark Anaerobic Wingate Software, Version 1.0, Monark, Vansbro, Sweden).

The PPT6 employed a seated stationary start with dominant leg initiating the first down-stroke. The air braking resistance was set to level 10, and magnetic resistance set to level 1 (equating to 1045 W at 130 rpm and approximately 90–100 W increases for every further 5 rpm increase in cadence). The test was initiated following a 5 s countdown followed by a firm verbal command. The completion of the test was indicated with another verbal command.

DATA ANALYSIS

Data were analysed using SPSS version 21.0 statistical software. Differences between trials were assessed using a repeated measures ANOVA with post hoc analysis with a Bonferonni correction. Relationships were assessed using Pearson's product moment correlation. An alpha of $p < 0.05$ was used to determine statistical significance. Data are presented as mean $\pm$ standard deviation (SD) and Bland Altman plots are presented with 95% limits of agreement and mean bias.

RESULTS

The range of power output profiles on each of the tests were within the normal limits for healthy males (Inbar et al., 1996).

PPT6 versus WAnT30

Results of the ANOVA indicated that there was a significant main effect of trial on peak power ($p = 0.000$). Post hoc analysis revealed a significant difference between PPT6 and WAnT30 (1174.4 ± 184.0 W versus 1068.9 ± 174.9 W respectively; $p = 0.013$). There was no main effect of trial on time to peak power (TTP) ($p = 0.086$; Table 1). There was a main effect of trial on cadence, with post hoc analysis demonstrating a higher cadence in PPT6 compared with WAnT30 ($p = 0.03$). Regression analysis between PPT6 and WAnT30 was described by;

$$\text{WAnT30} = 0.8553 * \text{PPT6} \\ + 64.4 \text{ (} r = 0.90, R^2 = 0.81, \text{ SEE} = 81.4 \text{ W; } p < 0.001 \text{)}.$$

Bland-Altman plots resulted in 95% limits of agreement being -52 to 263 W with a mean bias of 105.5 W and a bias SD of 80.7 W (Figure 1).

WAnT6 versus WAnT30

Post hoc analysis from the ANOVA indicated there was a significant difference in PP between WAnT6 and WAnT30 (1099.9 ± 181.1 W versus 1068.9 ± 174.9 W respectively, $p = 0.034$; Table 1). There was no difference in cadence between WAnT6 and WAnT30. Regression analysis between WAnT6 and WAnT30 was described by;

$$\text{WAnT30} = 0.9533 * \text{WAnT6} \\ + 20.4 \text{ (} r = 0.99, R^2 = 0.98, \text{ SEE} = 29.07; p < 0.0001 \text{)}$$

TABLE 1 Mean Peak power (PP) Time to Peak Power (TTP) and Cadence in each of the three trials. Data presented as mean $\pm$ S.D.

	PP (W)	TTP (s)	Cadence (rpm)
WAnT30	1068.9 ± 174.9	1.8 ± 0.43	144.0 ± 15.43
WAnT6	1099.9 ± 181.1	1.8 ± 0.43	148.2 ± 18.48
PPT6	$1174.4 \pm 184.1^{* \#}$	1.6 ± 0.35	$154.7 \pm 16.54^{*}$

*indicates significantly different from WAnT30 ($p < 0.01$), #indicates significantly different to WAnT6 ($p < 0.05$). Data are mean $\pm$ standard deviation.

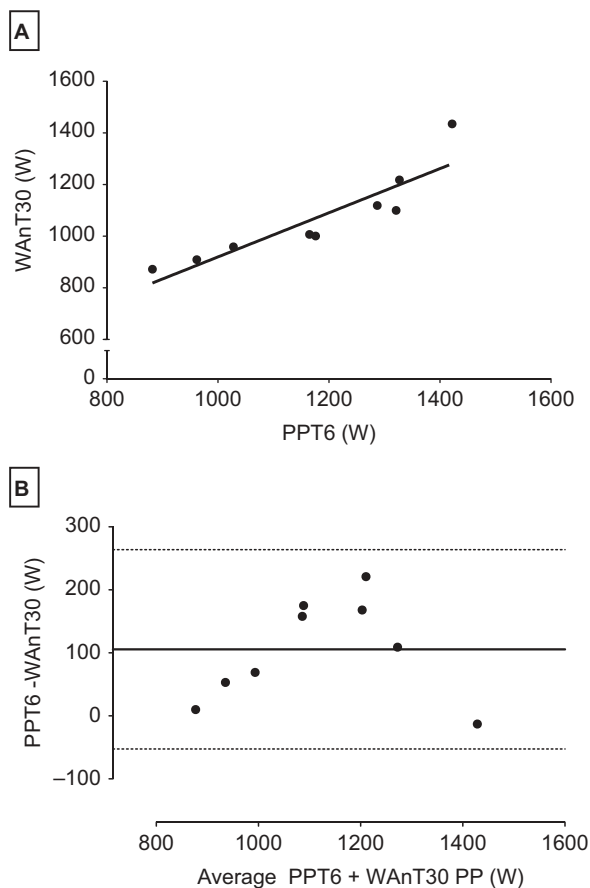


FIGURE 1 (a) Scatter plot with regression of peak power using the 6 second peak power test on a Watt bike (PPT6) versus peak power using the standard Wingate anaerobic test (WAnT30). For the regression line $R^2 = 0.81$ (regression equation $y = 0.8553x + 64.3$). (b) Bland-Altman plot of the difference in peak power versus the average peak power from PPT6 and WAnT6 tests with 95% limits of agreement shown (dashed lines) mean bias (solid line).

Bland-Altman plots gave 95% limits of agreement as -25 to 87 W with a mean bias of 31 W and a bias SD of 28.5 W (Figure 2).

PPT6 versus WAnT6

Post hoc analysis revealed a significant difference between PPT6 and WAnT6 (1174.4 ± 184.0 W versus 1099.9 respectively ± 181.1 W, $p = 0.015$). Linear regression was best described by the equation;

$$\begin{aligned} \text{WAnT6} &= 0.993 * \text{PPT6} \\ &+ 3.077 \quad (r = 0.95, R^2 = 0.9, \text{SEE} = 61.4\text{W}; p < 0.0001). \end{aligned}$$

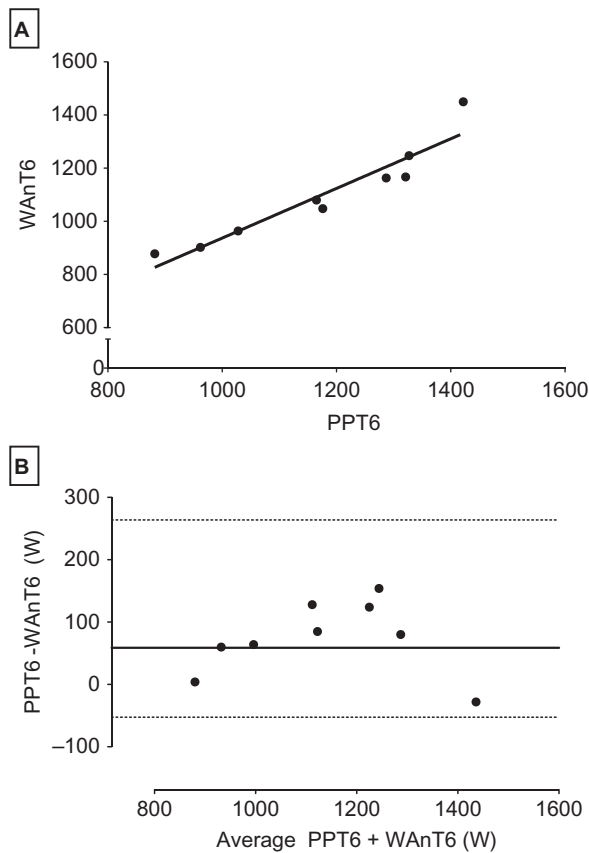


FIGURE 2 (a) Scatter plot with regression of peak power using the Wingate anaerobic test (WanT30) versus peak power using the modified 6 second Wingate anaerobic test (WanT6). For the regression line $R^2 = 0.98$ (regression equation $y = 0.9533x + 20.4$). (b) Bland-Altman plot of the difference in peak power versus the average peak power from WanT30 and WanT6 tests with 95% limits of agreement shown (dashed lines) mean bias (solid line).

Bland-Altman plots gave 95% limits of agreement between PPT6 and WAnT6 as -40 to 189 W with a mean bias of 74.5 W and a bias SD of 58.7 W (Figure 3).

DISCUSSION

The main finding of the present study is that when compared with WAnT30, WAnT6 is a valid measure of peak power output (PPO), whereas PPT6 over-predicts PPO in respect to that achieved during WAnT30. However, there was a good correlation between WAnT30 and PPT6 and the mean bias evident in PPT6 was corrected using the regression equation;

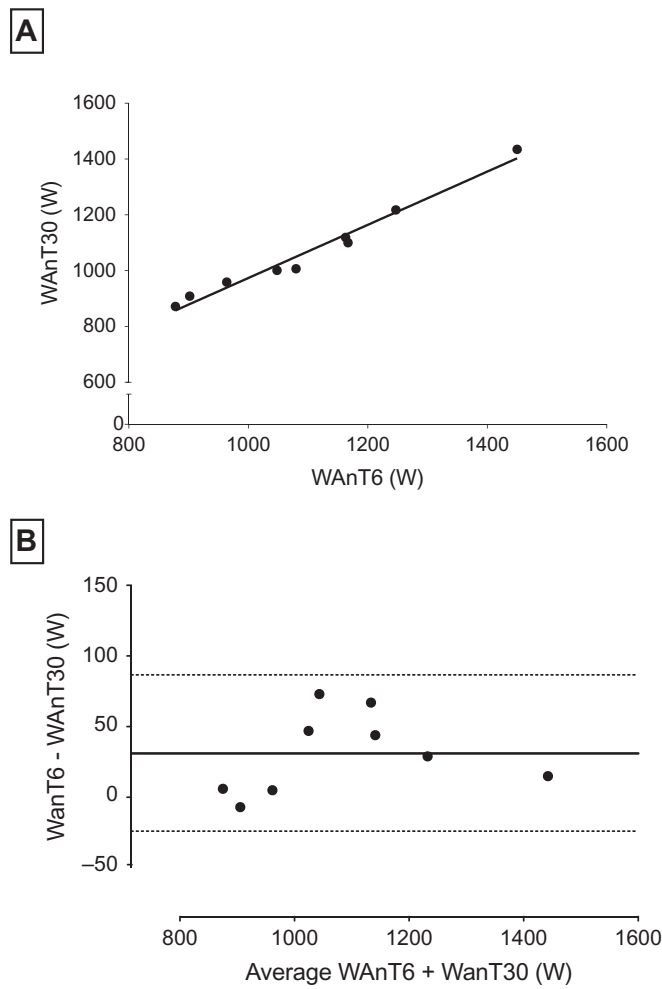


FIGURE 3 (a) Scatter plot with regression of peak power using the 6 s peak power test on a Watt bike (PPT6) versus peak power in a modified 6 s Wingate anaerobic test (WAnT6). For the regression line $R^2 = 0.9$ (regression equation $y = 0.9339x + 3.07$). (b) Bland-Altman plot of the difference in peak power versus the average peak power from PPT6 and WAnT30 tests with 95% limits of agreement shown (dashed lines) mean bias (solid line).

$$\text{WAnT30} = 0.8553 * \text{PPT6} + 64.4$$

When PPT6 data were corrected in this way there was no significant difference in PPO between PPT6 and either WAnT30 or WAnT6. Thus, corrected PPT6 data are a valid measure of PPO compared with the criterion measure of WAnT30. Furthermore, the data for PPT6 and WAnT6 are close to the test-retest correlations previously reported for WAnT30 (Patton, Murphy, & Frederick, 1985). Additionally, time to peak power (TTP) was not different

TABLE 2 Mean Power and Fatigue Values ($\pm$ SD) Determined by 30 s Wingate Anaerobic Test (WAnT30)

Peak power (W)	Time to PP (s)	Mean power (W)	Min power (W)	Fatigue index (%)
1068.9 $\pm$ 174.9	1.86 $\pm$ 0.043	698.78 $\pm$ 113.51	383.78 $\pm$ 79.89	63.84 $\pm$ 6.18

between any of the trials despite differences in starting procedure in PPT6. Therefore, a secondary finding is that PPT6 and WAnT6 are valid measures of TTP achieved during WAnT30.

Relative to WAnT30 (Table 2), PPT6 exhibits greater positive bias, due to larger PPOs than is evident with WAnT6. This is in agreement with previous research that has detailed higher PPO using non-mechanically braked cycle ergometers in 30 s all-out bouts (Watt, Hopkins, & Snow, 2002). Furthermore, Hopker et al. (2010) demonstrated a high degree of agreement between the Wattbike cycle ergometer and SRM Powermeter, with a mean bias between 1 and 7 W, measured across a wide range of power outputs, therefore it is unlikely that the mean bias in PPT6 (105 W) is due to differences between each ergometer in the method used to determine PPO. Since WAnT6 produced similar values to WAnT30 it is likely that the systematic bias for larger PPO values in PPT6 is either related to differences in the starting technique employed (a standing start in PPT6 vs a rolling start in both WAnT6 and WAnT30), or to the higher cadences achieved in PPT6 or a combination thereof.

PPO is a result of the interplay between absolute pedal resistive forces, bioenergetics, muscle fibre characteristics and cadence. The difference in cadence observed between PPT6 and WAnT30 may be related to differences in absolute resistive loads experienced during each test. The standard WAnT30 uses a fixed resistance relative to each participant's total body mass (TBM). It is likely that for a given participant, the absolute pedal resistance experienced during the PPT6 protocol is lower than that experienced during the WAnT30 or WAnT6 protocols. Previously, attempts to optimize the resistive loads used during WAnT30 have suggested using fat free mass (FFM) as opposed to TBM as the scaling variable (Baker, Bailey, Hullin, Young, & Davies, 2004), which will invariably result in lower absolute braking force. Using this model, Baker et al. (2004) reported both higher cadences and higher PPO when resistive force was reduced by scaling to FFM rather than TBM. In the present study cadence was ~7% higher in PPT6 compared with WAnT30, whereas PPO was ~10% greater in PPT6, thus it is likely that cadence may explain a significant proportion of the difference between protocols.

Additionally, the higher PPO achieved in PPT6 may be related to the use of a stationary seated start in this trial compared with rolling starts in both WAnT based methods. Previously, Macintosh, Rishaug, and Svedahl (2003) have reported a significantly lower PPO per pedal revolution in a rolling start

versus a stationary start (mean difference ~150 W). This is similar in magnitude to the mean bias here between PPT6 and WAnT30. Additionally, studies using a standing start with WAnT30 have reported differences of 11% (Coleman, Hale & Hamley 1985) and 17% (MacIntosh *et al.*, 2003) similar to the difference between protocols reported here. Of note, those studies that utilized a standing start with a standard WAnT30 resistive load also report a longer TTP. Conversely, in the present study, while there were no significant differences between TTP in any trial, there was a trend for a reduced TTP in PPT6 ($p = 0.086$). It is plausible that the reduced pedal resistance combined with the standing start resulted in higher PPO as previously reported (Coleman *et al.*, 1985; MacIntosh *et al.*, 2003) and shorter TTP as a consequence of the higher cadence in PPT6. It is not possible to confirm this from the available data, although further study is warranted.

Limitations

One potential limitation is the lack of test–retest reliability data for each of the protocols; however, suitable reliability of the WAnT30 and a 30 s test using a Wattbike Pro have previously been reported (Driller *et al.*, 2013; Patton *et al.*, 1985). Additionally we do not report average power; however, average power was not the primary outcome measure for the present study. Further, the use of average power as a measure of anaerobic performance in a WAnT30 has been criticized (Baker, Grace & Davies (2006)) and the importance of average power over a 6 second period, given differences in starting techniques limits its utility.

CONCLUSIONS

The results of the present study warranted the following conclusions.

1. WAnT6 and corrected PPT6 PPO are valid measures of WAnT30 PPO. Uncorrected PPT6 PPO appears to systematically over-predict WAnT30 PPO. Correspondingly, care should be taken when comparing uncorrected PPOs between WAnT30 and PPT6 measurements.
2. This identifies corrected PPT6 and WAnT6 as short duration ‘all-out’ tests that have practical applications for researchers and coaches wishing to assess PPO. Their short duration allows the determination of PPO without the fatiguing effects associated with a standard WAnT, or in populations where the standard WAnT30 may be overly strenuous and poorly tolerated such as in older individuals where low PPO is associated with increased chronic disease risk (Booth & Roberts, 2008).

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