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Nicolas W. Clark
Utah State University

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WINGATE ANAEROBIC TEST METHODS FOR POWER-TRAINED MALES USING VELOTRON

by

Nicolas W. Clark

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Approved:

Dale R. Wagner, Ph.D.  Edward M. Heath, Ph.D.
Major Professor  Committee Member

Eadric Bressel, Ed.D.  Dennis G. Dolny, Ph.D.
Committee Member  Committee member

UTAH STATE UNIVERSITY
Logan, Utah

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ABSTRACT

The purpose of this study was to examine the effects of two methodologies (start method and sprocket size) of the Wingate Anaerobic Test (WAnT) on peak power (PP) and mean power (MP). Twenty power-trained males (24.6 ± 4.5 years; 25.4 ± 2.5 BMI) with the same exercise routine for the past 4 months performed, in a randomized order, four WAnT with different combinations of start method, flying (FLY) or stationary (STA), and front sprocket size, 62-tooth sprocket (S-62) or 85-tooth sprocket (S-85), using the Velotron Racermate®. The results showed main effects for start method (p < 0.001; ES 0.753) and sprocket size (p < 0.001; ES 0.69) for PP and MP, respectively. For PP, significantly (p < 0.001) higher mean differences were shown for both FLYs (14.4 w/kg) while MP showed significant (p < 0.01) increases for S-85 in combination with the FLY (10.9 W/kg) and for S-85 in combination with the STA (9.7 W/kg). Pearson correlation (r) revealed no significant relationship between same start methods, FLY (p > 0.05; r = 0.227) or STA (p > 0.05; r = -0.132), and same sprocket size, S-62 (p > 0.05; r = -0.179), or S-85 (p > 0.05; r = 0.240). In conclusion, the findings of this study showed that FLY start and S-85 elicited higher means for PP and MP, respectively. Furthermore, Velotron with S-85 should not be interchangeably used with the S-62 model for power outputs; results suggest that different sprockets favored subjects differently, and no relationship can be established for the two methods. FLY start is suggested as a more effective method to reach elevated PP.

Keywords: Electro-magnetically braked cycle ergometers, Sprocket Size, Start Method.
INTRODUCTION

The Wingate Anaerobic Test (WAnT) has been a measurement of anaerobic capacity and power for over 40 years (3). Accordingly, there has been widespread effort to investigate methodology impact on test outputs (10,12,22). In addition to the outcomes experienced by different methodologies, ergometer type has also been shown to influence test results (2,19,21). These adjustments in WAnT protocol align with a growing popularity of individuals involved in various types of power training (4). Moreover, research aiming to assess anaerobic power and capacity in power-trained subjects could benefit from this practical test. Therefore, it is critical to examine how different methodologies affect the WAnT outputs.

Deepening the understanding of the WAnT methodology requires attention to two specific gaps. First, there is limited knowledge about the stationary method of start (STA) as it was only compared to the traditional flying start (FLY) twice to our knowledge (7,18); both of these studies indicated the STA as a more effective way of achieving higher power outputs for mechanically-braked cycle ergometers (ME). Because the STA begins from a motionless position, it was hypothesized to enhance performance by conserving the ATP stores that are more likely to get prematurely exhausted during the FLY (7,18). This start method was also believed to provide better standardization to the test since the FLY has no specific cadence or duration. Specifically, it is essential to recognize how these two starts perform in electromagnetically-braked cycle ergometers (EE) because limitations associated with moment of inertia calculation and frictional losses in power could substantially change
power outputs for ME (4,16,18,24). Second, there is limited understanding of how different front sprocket sizes influence performance during WAnT. Because different sprocket sizes are shown to elicit differences in friction and consequently performance (5), it is important to address this issue that has not been given enough attention when comparing and validating different types of ergometers (2,19). Specifically, Racermate®, the manufacturer for the EE Velotron, offers an 85-tooth sprocket (S-85) as a replacement for the standard 62-tooth sprocket (S-62) for peak power outputs that might exceed the 1,600 W limit of S-62; S-85 accommodates power outputs up to 2,300 W. According to the manufacturer, replacing S-62 for S-85 should be done only once and permanently. After sprocket installation, sprocket size must also be adjusted in the software program and once done, values are purported to be similar regardless of sprocket size.

Veloton by Racermate® is a contemporary training device that has been recently examined and utilized for research purposes (17). This ergometer attempts to promote high-quality preparation to professional and amateur cyclists by a realistic road bicycle look and three different software packages, that offer: (a) coach programing, where coaches can mediate and periodize athletes’ workouts electronically; (b) race simulation that reproduce famous race courses by attempting the same metabolic and visual stimuli; and (c) WAnT that analyzes 15 outcome variables and has options to edit the test protocol. The latest software was utilized in this research. Representing a relatively low cost option for laboratories when compared to other EE models (e.g., Lode
Excalibur), the Velotron has been reported to be reliable and valid for research purposes (1, 2, 20, 23).

Because of Velotron’s advertised accuracy (± 1.5%) and repeatability (± 0.2%), it has become the focus of recent research. Astorino and Cottrell (2) investigated the reliability of the WAnT performed on a Velotron and made comparisons to WAnTs performed on ME Monark in a sample of active young adults. They reported strong test-retest reliability for mean power ($r = 0.90, p < 0.01$) and peak power ($r = 0.70, p < 0.05$) using the Velotron. However, there were significant mean differences ($p < 0.05$) in peak power on the Velotron (9.95 ± 1.39 W/kg) versus the Monark (9.13 ± 1.26 W/kg) and for mean power, on the Monark (6.95 ± 0.84 W/kg) versus the Velotron (6.11 ± 0.52 W/kg). Differences are expected because of the way data are recorded; Velotron’s software records data at real time while the Monark’s software take six averages of 5-s each for the variables being analyzed.

Furthermore, validation between EE and ME systems is improbable since many different characteristics and errors are associated with each type of ergometer are inherent to testing (21). According to Patton and Hopkins (21), frictional losses in the mechanically-braking system will always be present in tests performed in ME, independently of the model used. Other types of ergometers (e.g., EE, air-braked ergometers, mobile power meter ergometers) are believed to have less error associated with elevated flywheel speeds. Another issue related to ME addressed by Cumming and Alexander (9) concerns the calibration of ergometers. While most EE are equipped with
built-in calibration tests, it is recommended that the calibration of ME be checked and recalibrated at least 3 times a year (9).

Therefore, the aim of this WAnT study was twofold. First, we aimed to compare PP and MP of two Velotron cycle ergometers: the high wattage model Velotron with S-85 and the standard model S-62. The second purpose was to compare STA and FLY starts during the WAnT using these electro-magnetically braked cycle ergometers. Based on the past sprocket literature, we hypothesized that PP and MP outputs would be greater with the larger sprocket. Converse to past findings about start methods, we also hypothesized that FLY start would display greater outputs when compared to the STA using EE. Both hypotheses were based on the increased muscular power of this trained population (6). We believed that the FLY in combination to the S-85 would provide sufficient momentum gain to generate extreme outputs.

METHODS

Experimental Approach to the Problem

The WAnT is intended to reliably represent maximal power outputs. However, methodologies for start type and sprocket size are neither clear nor standardized. To investigate our proposed hypothesis, all 20 participants were tested under four different combinations of front sprockets and start methods. For these tests, outputs for peak power (PP), mean power (MP), peak rpm, mean rpm, and time to peak power (TPP) were recorded.
Subjects

Twenty non-cyclists, power-trained males (24.6 ± 4.5 years; 25.4 ± 2.5 BMI) that regularly participated in Crossfit exercise routines, were asked to participate in this study. All subjects self-reported that they were experienced with power training exercise (14.9 ± 9.2 months experience). Subjects often trained together in a Crossfit setting, under the same exercise routine at least four times a week during the past 4 months. After completing the Physical Activity Readiness Questionnaire (PAR-Q), they signed a written informed consent. The Institutional Review Board of Utah State University approved this study.

Procedures

Subjects visited the Exercise Physiology Laboratory on four different occasions within 3 weeks. Instructed to avoid strenuous exercise 24 hours prior to testing, they were scheduled at the same time range of the day to perform the WAnT. A minimum of 48 hours rest was required between tests. Participants were advised to keep the same diet during test days, and to refrain from big meals 2 hours before testing. Tests were a combination of two different starts and two different front sprocket sizes: flying start with 62-tooth sprocket (FLY-62), flying start with 85-tooth sprocket (FLY-85), stationary start with 62-tooth sprocket (STA-62), and stationary start with 85-tooth sprocket (STA-85). The order of the conditions was randomized by coin toss. Two Velotron Dynafit Pro ergometers (RacerMate®, Seattle, WA) were utilized in this study. To avoid movement, ergometers were secured to the floor for complete stabilization. The two ergometers were identical with the exception that one had a 62-tooth sprocket (S-62) and the other
had an 85-tooth sprocket (S-85). Ergometers were then tested for acceptable calibration (accuwatt test from RacerMate®) prior to the trials.

Prior to the first WAnT, subjects’ heights were measured using a wall-mounted stadiometer (Seca 216, Seca Corp., Ontario, CA), and weights were measured using a digital scale (Seca 869, Seca Corp., Ontario, CA). These measurements were taken with participants wearing only shorts and T-shirt. Next, data were entered in WAnT software for individual settings of resistance. In their first visit to the laboratory, the Velotron adjustments for seat height, seat setback, handlebar height, and handlebar reach were recorded according to individual preference. These adjustable settings were kept the same for all tests. Before every test, subjects were reminded of the “all out” characteristic of the WAnT and told not to pace their effort. For standardization of the procedures, subjects were also asked to remain seated during the test.

Each test day included: (a) review of the procedures, (b) 5-min warm-up at a constant work rate of 75 W, and cadence of 60 to100 rpm, (c) 3-min rest before start, (d) 30-s WAnT, and (e) 5-min cool-down at no load. For the stationary start (STA), tests began with the flywheel stopped at no motion. Conversely, the flying start (FLY) consisted of a 20-s additional warm up at 50-70 rpm followed by 6-s sprint at no resistance to build to maximal rpm before the load was applied. The load utilized was 8.5% of body weight resistance. This load percentage has been recommended for trained individuals by several research papers throughout the years and is reported to
achieve significantly similar outputs when compared to optimum load assessment (8,11,18,22,24).

**Power Training Design**

Before participating in this study, subjects had trained an average of at least four times a week for the past 4 months with the same exercise routine. Training sessions were conducted in 45-60 min ranges divided into conditioning and power training portions. A 15 min warm up involving rapid and slow movements at no load was performed before training sessions. The first portion, conditioning, consisted of a circuit of loaded exercises at 40-60% of 1RM involving advanced multiarticular exercises performed in explosive manner. Intervals between exercises were kept short and less than 30 s between sets and exercises. Workouts were performed in groups to create a sense of teamwork, camaraderie, and competition. After completion of the first portion, 5-10 min of rest was given before completion of 4 to 5 exercises focused on power and force development. Good exercise technique was criteria for load increase between sets. For this portion exercises were performed at maximal to submaximal load ranges of 75 to 100% of 1RM with 2-5 min of rest interval. Daily-undulating periodization model was utilized for training prescription.

**Statistical Analysis**

All analyses were conducted with the Statistical Package for Social Sciences (SPSS version 22, IBM, Armonk, NY). A 2 x 2 repeated-measures ANOVA was utilized to reveal main effects and interaction between start method and sprocket size. Means and standard deviations were calculated for PP and MP. Statistical significance was
accepted as $p < 0.05$, and statistical effect sizes were calculated as partial eta-square to estimate meaningfulness of the findings. Sidak post-hoc tests were utilized for significant main effects. If interactions and main effects were detected, levels of start method and sprocket size were analyzed for significance. Pearson Correlation ($r$) was used to determine associations of start methods and sprocket size.

RESULTS

Measured values for all four trials are represented in Table 1. The 2 x 2 repeated-measures ANOVA revealed no interactions but significant main effects of start method for PP ($p < 0.001; ES 0.753$) and sprocket size for MP ($p < 0.001; ES 0.69$) (Figure 1). Paired $t$ tests were utilized to isolate levels for significance and for correlation. For PP, significant start method differences and low correlational relationships were found for FLY-62 versus STA-62 ($p < 0.001; r = -0.179$) and FLY-85 versus STA-85 ($p < 0.001; r = 0.240$) (Figure 2). For MP, significant sprocket size differences and low correlational relationships were found for FLY-62 versus FLY-85 ($p < 0.001; r = 0.227$) and STA-62 versus STA-85 ($p = 0.008; r = -0.132$) (Figure 2). Post-hoc tests revealed higher mean differences for PP for FLY-85 (14.8 W/kg) and FLY-62 (14 W/kg) over STA-62 (10.7 W/kg) and STA-85 (12.3 W/kg) and higher mean differences of MP for FLY-85 (10.7 W/kg) over STA-85 (9.7 W/kg), FLY-62 (8.5 W/kg), and STA-62 (8.2 W/kg).

[Table 1 about here]
DISCUSSION

The main finding of this study was that changes in sprocket size and start methods significantly alter power output during the WAnT. Peak power and MP showed a particular behavior during the four different combinations of the test, each showing significantly higher means for one of the main effects (Figure 1). While PP showed higher outputs for trials of FLY method \((p < 0.001; \text{ES} \ 0.75)\), MP displayed significantly increased performance values for those of S-85 \((p < 0.001; \text{ES} \ 0.69)\). Therefore, FLY and S-85 can elicit power-trained subjects to reach significantly higher values during the WAnT.

Our results for associations between methods showed no relationship between trials of same start method or sprocket size (Figure 2). Changes in methodology affected subjects differently and while higher averages were obtained from FLY and S-85, nearly half of the subjects did not benefit from these methods. To understand differences in performance during tests of maximal performance, Driss and Vanderwalle (12) reviewed biological limitations associated with high-speed cycling tests. First, variations in torque angle at higher-speed cycling were shown to shift peak torque
toward the last angles of the downstroke phase, subsequently shifting even more at higher speeds. As a result, non-muscular forces were shown to build within each crank revolution, ultimately improving power outputs. For this reason, we believe that differences in adaptations to high speed and power cycling may have influenced subjects differently, particularly for the FLY conditions. Second, contribution of creatine-phosphate hydrolysis is only supported for the first few seconds of “all out” exercises, being the first 5 s the best way to represent peak power outputs. Afterwards, glycolysis increases followed by oxidative phosphorylation that becomes more predominant towards the end of the test. Principally for its motionless start, the STA does not provide realistic assessment of peak power, since the loaded start only allowed subjects to reach PP after 10 s for STA-62 and 15 s for the STA-85 (Table 1).

The only interaction found for start and sprocket was for time to PP ($p < 0.001; ES 0.735$). This interaction is most likely to have occurred due to the 5-s mean difference between STA-62 (10.3 ± 1.6 s) and STA-85 (15.4 ± 2.6 s) in addition to the more logical differences of time to PP between STA an FLY. Interestingly, time to PP for STA showed to be the longest among the few studies testing this same start method (18,24). Because outputs were considered higher compared to other population means (2,8,25), we strongly believe that training status and experience with power training facilitated participants to increase cadence for longer time to reach higher scores (6,13,25). On the other hand, comparison of FLY-85 and FLY-62 showed a minimum difference of half a second (Table 1)
First introduced by Ayalon, Inbar, and Bar Or (3), the FLY was designed to overcome inertial resistance within 3-4 s prior to test start (11). Since then, it has been irrevocably administered for WAnT, although hardly ever mentioned or standardized (15,17). The present study opted to follow the same procedures of Astorino and Cottrell (2), which also tested the FLY with the Velotron. Specifically for this start strategy, we observed that the combination of the 20-s additional warm-up and the 6-s acceleration phase, allowed most of the participants to reach maximal cadence within less than 1 s in the test (Table 1); this elevated momentum built before the test, allowed participants to have substantially higher means for PP compared to other STA trials.

Designed almost three decades ago by Coleman (7) as a better method to capture PP and MP, the STA method was most recently compared to the FLY by MacIntosh et al. (18). Applying moment of inertia to power calculation as in Lakomy (16) and Vargas et al. (24), the authors evaluated mean performances during different start methods and load assessments during the WAnT. Stationary start showed significantly higher PP and MP using a ME Monark. Furthermore, resistance load of 8.5% BW showed to be as effective as optimal load assessment for greater power outputs. Nonetheless, our findings show the complete opposite about PP and start strategies. We found it plausible to assume that the loaded acceleration phase in the STA played an important role in early fatigue development during testing; this unusual loaded acceleration hindered participant’s ability to reach higher rpm and consequently greater PP.
The Velotron, as described by the manufacturer, is a table-driven device that constantly look-up tables based upon real-time parameters as cadence, speed, and inertia to determine appropriate current to apply to its brake system. Upon its development, tests functions were performed with the use of a reaction-brake dynamometer (maker unknown), and during this period, innumerous hysteresis and heat-induced tests were conducted. As the Velotron has been shown to be a highly reliable ergometer (1,2,20,23), we did not have the same findings of MacIntosh et al. (18). The calculation of moment of inertia – already taken into account by Velotron system – did not produce higher PP and MP for the STA start.

According to Cumming and Alexander (9), ME calibration statuses are often unspecified and lacking from studies methods'. Lack of frequent calibration may cause significant changes in outputs. In four to eight years, ME may be at least at 10% of error. In a review by Paton and Hopkins (21), ME, EE, Air-braked, and mobile power meter ergometers were checked for systematic and random errors. Most of the brands cited showed increased systematic error at higher power outputs (hysteresis effect). ME models also showed increased random errors. As a result, Monark® cycle ergometers were advised to not be considered ‘gold standard’ by the authors. Heat accumulation caused by the frictional system is known to change static friction in the bearings of the pendulum and pulley system underestimating power outputs. For instance, power may be underestimated at approximately 5% at workloads of 300 watts using the Monark®, just because of the ME system limitations (21). Lastly, we would like to address to the lackluster improvements made in the ME in the past decade. Most of the studies using
Monark ergometers had to develop modified versions to improve reliability to testing (14). Some of those issues are addressed by Dotan (10).

At the same time, EE offer fast, effortless, and reliable use of WAnT. Once height and weight are obtained, a test can be administered instantly. Because the resistance load is applied automatically, tests are more consistent, and human error of time response when ‘dropping the load’ does not occur. In addition, EE like the Velotron and Lode® Excalibur, offer full adjustability allowing optimal body position and efficient performance during tests. Astorino and Cottrell (2) are, to our knowledge, the only investigators that tested reliability and validity of the Velotron during a WAnT. Twenty-two men (9 cyclists and 13 recreationally-active) and 18 women (only one cyclist) were tested twice on the Velotron (test re-test reliability) and once on the Monark (validity). Results showed high reliability for the Velotron but no validation when compared to the Monark. While PP was shown to be greater for the Velotron, the Monark displayed higher averages. These differences may be explained by differences in how data are recorded by each software. While the Monark records averages every 5-s for MP and the highest 5-s for PP, the Velotron provides instantaneous readings of the outputs. In this study, authors did not specify the sprocket size being utilized. Differences in sprocket could be another factor to explain differences seen during tests, especially for cadence (rpm).

Comparing different sprocket sizes was another main objective of this study. The importance of the sprocket test is evident once Velotron’s manufacturer, RacerMate®,
recommends owners not to change sprockets after the S-85 is installed. As mentioned, the original S-62 can only read outputs up to 1,600 W, and for values up to 2,300 W the software and the bike must be upgraded with the use of S-85. Therefore, comparisons for peaks below 1,600 W between both sprockets was indispensable. According to Burguess (5) larger sprockets reduce the power input requirement by the cyclist. A larger sprocket radius decreases the angle of friction between the chain and the sprocket ultimately leading to lower wear rates. After comparing friction force of three front sprockets (13, 26, and 52-tooth) by increasingly placing small weights on alternate lever arms of the crank, force required to start motion was evaluated. Theory and experiment showed increased chain efficiency to larger sprockets due to reductions in the chain tension. The author concluded that larger sprockets are highly recommendable for flat circuit racing increased performance. Likewise, our findings support this consistent improved performance for larger sprockets as better outputs for MP were shown for larger sprockets conditions.

There are some limitations of this study. First, the study sample was power-trained males as opposed to trained cyclists. Hopkins et al. (14) noted that exposure to high-intensity exercise routines reduces variability of performance in males. Trained cyclists would likely have less variability when pedaling at high rpm’s compared to our power-trained subjects, and it is possible that losses in pedaling efficiency at high rpm’s may have contributed to the results. Second, we did not have a familiarization session prior to our tests because test-retest reliability of the WAnT was previously shown to be extremely high (2). An added familiarization trial might have reduced some of the
variability between trials. Lastly, limitations related to load assessment being based on body weight instead of lean mass or leg fiber-type predominance, are believed to elicit different responses in individuals with different bioenergetics system (12).

It is concluded that WAnT results produced using EE Velotron are dependent on start method and sprocket size. However, repeatability of each test should still be taken into account before further recommendations for best method. It can be said that FLY elicits the highest peaks while larger sprockets elicits larger means. Front sprockets S-62 and S-85 should not be used interchangeably as recommended by manufacturer.

PRACTICAL APPLICATIONS

In the past decade, the increased research interest for power training is a reflex of the popularity that this type of training has reached (4). Just like the VO₂ max test is for aerobic capacity, the WAnT is a widely documented anaerobic assessment (10). This study showed that this power test is positively influenced by larger front sprocket and flying method of start. Furthermore, Velotron should not recommend larger sprocket to be used as a replacement for the original sprocket for tests under 1,600 W. Further, flying start was shown to elicit higher peak power outputs and is recommended as a standard methodology. Specifically, a flying start consisting of a 20-s additional warm-up at 50-70 rpm followed by 6 s of maximal cadence is recommended. Consistent with Astorino and Cottrell (2) this methodology was beneficial because it allowed subjects to reach maximal cadence within 1 s in the test. Lastly, electromagnetically-braked
ergometers are encouraged to be used for WAnT based on previous research that
cmpared it to mechanically braked ergometers (21).
References


ACKNOWLEDGMENTS

The authors have no conflicts of interest to report, and the results of the present study do not constitute endorsement of the product by the authors or the NSCA.
Figure Legend

**Figure 1.** Mean ± SD for MP and PP

**Figure 2.** Relationship between trials of same sprocket or same start method for MP (A), and PP (B).
Figure 1.
Figure 2.

A

$r = -0.042$
$p > 0.05$

$r = 0.106$
$p > 0.05$

$r = -0.132$
$p > 0.05$

$r = 0.227$
$p > 0.05$
B

\[ r = -0.179 \]
\[ p > 0.05 \]

\[ r = 0.240 \]
\[ p > 0.05 \]

\[ r = 0.237 \]
\[ p > 0.05 \]

\[ r = -0.022 \]
\[ p > 0.05 \]
Table 1. Differences (mean ± SD) in power output, time to peak, and rotations per minute between conditions.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FLY-62</th>
<th>FLY-85</th>
<th>STA-62</th>
<th>STA-85</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP</td>
<td>8.5 ± 1.9*</td>
<td>10.9 ± 1.3#</td>
<td>8.2 ± 1.6#</td>
<td>9.7 ± 1.4#</td>
</tr>
<tr>
<td>PP</td>
<td>13.9 ± 2.5*</td>
<td>14.8 ± 0.6*</td>
<td>10.7 ± 1.9*</td>
<td>12.3 ± 1.8*</td>
</tr>
<tr>
<td>Peak rpm</td>
<td>166 ± 30*</td>
<td>177.8 ± 7.3*</td>
<td>127.9 ± 22.9*</td>
<td>147 ± 21.4*</td>
</tr>
<tr>
<td>Mean rpm</td>
<td>102.4 ± 23.8#</td>
<td>131 ± 16.2#</td>
<td>98.8 ± 19.4#</td>
<td>116.4 ± 16.7#</td>
</tr>
<tr>
<td>Time to peak power</td>
<td>0.2 ± 0.1*</td>
<td>0.7 ± 1.9*</td>
<td>10.3 ± 1.6*</td>
<td>15.4 ± 2.6*</td>
</tr>
</tbody>
</table>

* p < 0.05 for start method; # p < 0.05 for sprocket size; + p < 0.05 for interaction between start and sprocket