

## Comparison of Forward and Reverse Wingate Anaerobic Tests: A Brief Technical Note

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**Background:** The Wingate anaerobic test (WAT) is traditionally performed in the forward pedaling direction on a cycle ergometer. However, reverse (backward) pedaling during a WAT test may be a novel way to convey meaningful information related to performance and rehabilitation. This study compared peak power measurements between 30-second forward pedaling WAT (FWAT) with a 30-second reverse pedaling WAT (RWAT).

**Methods:** 10 male and 10 female participants (age  $27.6 \pm 7.31$  yrs, mass  $74.9 \pm 21.3$  kg and height  $172.6 \pm 10.9$  cm) volunteered to participate. Participants performed one FWAT and one RWAT at 7.5% of body mass on a specially modified Monark cycle ergometer. Tests were separated 2 days of rest. Peak power output (PPO), mean power output (MPO), relative PPO (RPPO), relative MPO (RMPO), fatigue index (%FI), and rating of perceived exertion (RPE) were measured.

**Results:** The FWAT power measurements were all significantly greater ( $p < 0.05$ ) than RWAT power measurements except MPO ( $p > 0.05$ ); and that RPE was significantly greater ( $p < 0.05$ ) in FWAT than RWAT. Specifically, FWAT vs. RWAT ( $M \pm SD$ ) are as follows: PPO watts ( $w$ ) =  $731.7 \pm 237.1$  vs.  $529.6 \pm 192.2$ ; RPPO  $w/kg$  =  $10.2 \pm 2.3$  vs.  $7.2 \pm 1.6$ ; MPO  $w$  =  $510.2 \pm 162.1$  vs.  $415.1 \pm 146.2$ ; RMPO  $w/kg$  =  $7.3 \pm 1.5$  vs.  $5.8 \pm 1.3$ ; %FI =  $49.2 \pm 8.7$  vs.  $37.4 \pm 13.7$ ; and RPE =  $19.4 \pm 1.1$  vs.  $15.8 \pm 1.5$ . Gender did not impact the relative differences in these relationships.

**Conclusion:** Practitioners and clinicians may use this information to begin to understand the power and perceived exertion relationships of forward versus reverse pedaling during a WAT; exercise prescription for rehabilitation and performance may benefit.

**Key Words:** Wingate anaerobic test, Anaerobic power

## INTRODUCTION

Strength and power are critical components of quality of life, impacting activities of daily living, performance and athletics, recreation and occupational tasks. As society ages, declines in strength and power impact one's functional abilities to a greater extent. Having appropriate methods of testing and training strength and power in healthy individuals, and those in rehabilitation, is crucial to optimal exercise programming [1].

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One such test is the Wingate anaerobic test (WAT) which is considered a benchmark test in the assessment of anaerobic power [2]. The WAT test provides absolute and relative results related to both peak power (watts) and average power over 30 seconds; the test also provides a fatigue index (or percent decline in power output) over 30 seconds. The WAT is traditionally performed in the forward direction [2]; reverse (backward) pedaling however, has relevance to both rehabilitation and athletic training [3-7].

Neuromuscular rehabilitation strategies necessitate individuality and variety; while pedaling appears simple, many factors (e.g., rate, shoe/pedal interface, power output etc.) can affect muscle activation patterns and timing [8-10]. Neptune and Kautz [6] highlight that the clinician must be careful and take into consideration condition/injury specifics when implementing reverse pedaling, as they observed increased patellofemoral compressive loads and decreased tibiofemoral compressive loads when backward pedaling in a mathematical modelling simulation of knee joint loading during forward and reverse pedaling. Bressel [3] studied submaximal forward and reverse pedaling (5 minutes at 157 w at 80 rpm) in 21 healthy males and also found higher peak patellofemoral forces than when forward pedaling; and also found this was mainly influenced by significant higher force generation by the quadriceps. Bressel's results again highlight the importance of understanding the specific nuances of any given exercise when designing the appropriate exercise prescription for rehabilitation or performance.

It is important for the clinician and practitioner to know the specific relationship in terms of maximal power of forward and reverse pedaling on a cycle ergometer, in both testing, training and rehabilitation situations. Knowing this relationship allows for a more precise exercise prescription and a better understanding of relationships related to muscular balance of the lower body. While there are references to backwards walking [11-13], running [14,15], forward and backward arm cycling [16], forward and reverse wheelchair ergometry [17] and forward pedaling [18,19], backwards pedaling research is limited in scope, mainly focusing upon understanding submaximal clinical applications [3-7,20]. To the author's knowledge, the relationship in maximal power output between a reverse pedaling WAT to the forward pedaling WAT has not been investigated. The purpose

of this study was to compare peak anaerobic power output measurements between a 30 second forward pedaling WAT (FWAT) versus a 30 second reverse pedaling WAT (RWAT) in active men and women.

## MATERIALS AND METHODS

### 1. Participants

Volunteers in this study were 10 male and 10 female participants (age  $27.6 \pm 7.31$  yrs; mass  $74.9 \pm 21.3$  kg; and height  $172.6 \pm 10.9$  cm). All participants were healthy and active in both recreational aerobic and resistance training, with no contraindications to maximal pedaling in either direction on a cycle ergometer. This study was approved by the University's Institutional Review Board (IRB) and all subjects read and signed an informed consent before participating.

### 2. Equipment

As detailed in Berning et al. [21], a Monark cycle ergometer (Monark 817E, Vansboro, Sweden) with a Smart Mux Interface (SMI) Power Pack = (Linear System Design, Delray Beach, FL, USA) was modified to allow for forward and reverse pedaling. In brief, the cycle ergometer needed little modification to perform both forward and backward pedaling. The pendulum stop was ground off such that the pendulum would swing in a forward direction (i.e., prior to grinding, the pendulum only swings towards the rider). The resistance KP scale was rotated forward. When the bike was pedaled in reverse, the pendulum would then swing in the reverse direction and the plastic resistance KP scale measured resistance to enable calculation of power output.

When pedaling in reverse, the bike was calibrated in the normal fashion by hanging known weights off the strap but on the opposite side of center rotating shaft (i.e., the pivot point) such that the pendulum would swing forward. The swing arm with the plastic tensioner was reversed so the strap that went around the wheel would pull in the opposite direction normally used when pedaling forward. The plastic KP scale was then pivoted to match the suspended weight and the numbers were re-written starting with 0-7 in 0.5 kp increments. Identical to the normal swing however in the opposite direction.

In summary, the pendulum would move either forward or backward on this modified bike, allowing for both forward and reverse pedaling. The technician simply had to swing the triangular KP scale one direction or another depending on which direction they wanted the participant to pedal the bike. Thus, the participants pedaled the same bike for both forward and reverse WAT tests.

### 3. Procedures

All participants were familiar with the FWAT and had performed the test on previous occasions. However, there was an orientation day to familiarize the participants with the RWAT, which allowed the participants to become comfortable with reverse pedaling at both submaximal and maximal intensities; informed consent was attained, and age, mass, and height were also measured during this orientation session.

Next, on two separate days within one week of the orientation session, participants performed one FWAT and one RWAT at 7.5% of body mass on the specially modified Monark ergometer. Prior to each test, participants performed a light warm-up of either forward or reverse pedaling (i.e., pedaling at 50-60 rpm at a resistance of 0.5 to 1.0 kg). Body mass was re-measured on each day. The cycle ergometer was calibration prior to each test. Seat height was identical between tests. FWAT were performed on day 1, followed by the RWAT on day 2. Tests were separated by a 2 day rest period and were conducted at the same time of day. Participants were asked to avoid exercising their lower body over the two days of rest, and were asked to also maintain their normal daily activities and nutritional intake.

Peak power output (PPO), mean power output (MPO), relative PPO (RPPO), relative MPO (RMPO), fatigue index (%FI), and rating of perceived exertion (RPE) were measured and calculated. Standard instructions were provided to the participant in regards to rating of perceived exertion (RPE) [1].

Test-retest reliability of the FWAT has been previously evaluated in our lab on this modified cycle and was  $r = 0.97$  in a similar population, which is comparable to reported literature [2,22]; reliability of the RWAT was similar to the FWAT ( $r = 0.96$ ).

### 4. Statistical analysis

Dependent t-tests were used to compare all of the aforementioned dependent variables between the forward and reverse pedaling conditions during the WAT. Statistical calculations and data management were conducted with Microsoft Excel 2013. The assembled spread sheet of assessment data was validated via peer review for errors prior to analysis as suggested by AlTarawneh & Thorne [23]. An alpha was set *a priori* at  $p \leq 0.05$  as the critical value for determining statistical significance. However, in view of the growing controversy surrounding “statistical significance” and replication of study results [24], analysis of percent change between conditions as well as effect size were also calculated.

## RESULTS

FWAT power measurements were all significantly greater ( $p < 0.05$ ) than RWAT power measurements except MPO, which despite an 18.6% difference during RWAT did not

**Table 1.** Comparison of FWAT with RWAT (mean  $\pm$  SD)

Measure	FWAT	RWAT	% $\Delta$	Effect size
PPO watts	731.7 $\pm$ 237.1*	529.6 $\pm$ 192.2	27.6	1.05
RPPO w/kg	10.2 $\pm$ 2.3*	7.2 $\pm$ 1.6	29.4	1.88
MPO watts	510.2 $\pm$ 162.1	415.1 $\pm$ 146.2	18.6	0.65
RMPO w/kg	7.3 $\pm$ 1.5*	5.8 $\pm$ 1.3	20.5	1.15
%FI	49.2 $\pm$ 8.7*	37.4 $\pm$ 13.7	24.0	0.86
RPE	19.4 $\pm$ 1.1*	15.8 $\pm$ 1.5	18.6	2.40

\*FWAT significantly greater than RWAT ( $p < 0.05$ ).

FWAT: forward wingate anaerobic test, RWAT: reverse wingate anaerobic test, PPO: peak power output, RPPO: relative peak power output, MPO: mean power output, RMPO: relative power output, %FI: percent fatigue index, RPE: rating of perceived exertion.

reach statistical significance (Table 1). No differences in body mass occurred that required any workload adjustments between the two tests. And, when analyzed by gender, there was no difference in relative results.

## DISCUSSION

This study compared peak power output between a 30 second forward pedaling WAT (FWAT) and a 30 second reverse pedaling WAT (RWAT) in young men and women. Results demonstrated statistically significant and meaningful (% $\Delta$  and effect size) differences in power output and RPE between FWAT and RWAT. Peak power decreased by  $-202.1$  watts ( $3.0$  w/kg) when reverse pedaling; with average power decreasing by  $-95.1$  watts ( $1.5$  w/kg); fatigue index improved by  $+11.8\%$  when reverse pedaling.

Power output is ultimately related to one's ability to rapidly recruit and fire high force motor units (i.e., RFD or rate of force development) [25]. Neuromuscular adaptation through repetition of a specific high force, high velocity movement allows the individual to optimize motor unit recruitment for that specific movement [26], thereby enhancing power [25,26]. All-out forward pedaling was familiar to all participants, whereas reverse all-out pedaling was a relatively novel task (i.e., orientation that included maximal reverse pedaling was conducted but otherwise participant's had minimal exposure to reverse pedaling). The ability to optimally recruit high force motor units would also impact the individual's fatigue index, as the more powerful motor units also have a higher rate of fatigue; this may help to explain the lower fatigue index during the RWAT (i.e., the lower power output during RWAT results in a lower potential for rapid fatigue than in the FWAT). Future investigations should include EMG to better understand motor unit recruitment during the pedaling tasks.

Participant's RPE was also lower during reverse pedaling (19.4, or "extremely hard to maximal exertion" during the FWAT vs. 15.8, or "hard-heavy" during the RWAT) [1]. One could argue that the lower RPE during the RWAT may also be explained by the individual's potential inability to fully recruit motor units during this relatively novel task, thereby limiting overall feeling of perceived exertion [27]. Observationally, it appears there were similar levels of visi-

ble fatigue (i.e., rapid breathing, expressing feelings of nausea, etc.) in both FWAT and RWAT tests (i.e., signs not uncommon when administering a test nicknamed the "pedal and puke" test). A limitation of this is the lack of blood lactate testing, which would have added to our understanding of the glycolytic load during these tests. No injuries or muscle/joint soreness were reported by any of the participants; and while post-test nausea was reported by a minority of participants, no participant vomited post FWAT or RWAT.

As previously stated, studies on reverse pedaling have mainly focused on the potential clinical applications of this mode [3-7,20], identifying that differences exist in internal lower extremity forces between forward and reverse pedaling. Additional investigations have focused on muscle activity and biomechanical aspects of forward and reverse pedaling [7,20], finding that muscular contributions and biomechanical functions are consistent between forward and reverse pedaling, but happen with directional specific phase shifts in muscle activation. With that said, if one intends to implement a RWAT in a testing or rehabilitation protocol, we recommend careful review of the research on backward pedaling as it relates to their specific, individual participant's preexisting conditions.

## CONCLUSION

In conclusion, this study demonstrated significantly greater power output and perceived exertion when performing a FWAT as compared to a RWAT. Clinicians and practitioners may use this data to begin to understand the relationship in power output between forward and backward pedaling; exercise prescription in both rehabilitation and performance may benefit.

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