Power Output in Trained Male and Female Cyclists during the Wingate Test with Increasing Flywheel Resistance

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ABSTRACT

Richmond SR, Whitman SA, Acree LA, Carper MJ and Godard MP. Power Output in Trained Male and Female Cyclists During the Wingate Test with Increasing Flywheel Resistance. JEPonline 2011;14(5):46-53. The purpose of this investigation was to determine potential gender differences in power output at greater flywheel resistances during the Wingate anaerobic cycle test. Twenty-nine competitive cyclists (13 females, 16 males) who met the inclusionary criteria of a VO2 max of at least 3.0 L•min-1), performed on four separate occasions the Wingate test on an electronically braked cycle ergometer. Two trials were performed at each of the randomized flywheel resistances of 0.080 kg/kgbw or 0.095 kg/kgbw, with a minimum of 48 hrs rest between trials. There were no differences in power output between trials at the same resistance, indicating very good test repeatability. Regardless of gender, all power output results were significantly greater with the 0.095 kg/kgbw resistance than the 0.080 kg/kgbw resistance. While the females were able to produce a greater increase in peak power with the heavier resistance (0.095 kg/kgbw), there was also an increased rate of fatigue that indicated the female cyclists were unable to maintain the same intensity as the male cyclists. Finally, power production values from the Wingate anaerobic cycle test are dependent upon the resistance used during the test; the greater the resistance, the greater the power produced.

Key Words: Anaerobic, Gender Differences
INTRODUCTION

For more than 30 yrs, the Wingate cycle test has remained at the forefront of power testing as a technique for directly measuring anaerobic power output. Anaerobic power and anaerobic capacity are important factors in sports with quick, all-out efforts such as sprinting events that rely heavily upon the anaerobic energy pathways. Theoretically, then, an excellent performance in the Wingate test should prove useful in predicting success in athletics. The Wingate test has undergone many variations since its inception.

Test populations have ranged from sedentary, non-trained individuals to children and elite athletes (4,7,15,16,25,26). There appears to be inconsistencies in the research findings when determining anaerobic power output, even among cyclists of similar training levels (8,13,20,24,27). One major consideration when performing the Wingate test is the manipulation of the test variables, which can result in power outputs based upon unequal scales. There is a wide body of literature that supports the notion that altering any test conditions, from hip and trunk position (17-19,22) to the type and time of the resistance applied (1,2,5,6,9-12,14,27), can dramatically impact the outcome of the anaerobic test. Therefore, the same subject can perform the Wingate test under the different test parameters and produce different power outputs.

Even with an increase in the number of competitive female cyclists, rarely are comparisons made between males and females within the same competitive classifications. Gender has been known to play a crucial role in anaerobic power production, and it is unclear if changes in power output will remain the same between genders (3,21,24). However, it is possible that power output for competitive cyclists within similar racing categories and training status may not reflect the traditional differences in power output that normally occurs between genders. As a result, the purpose of this investigation was to determine power output in competitive male and female cyclists during the Wingate anaerobic power test in response to various flywheel resistances.

METHODS

Subjects

Twenty-nine competitive cyclists (13 females and 16 males) participated in this study. Inclusionary criteria for subjects consisted of: (a) at least 2 yrs of competitive cycling experience; (b) at least 4 d·wk⁻¹ week of training; (c) a Category II-IV training level or a VO₂max of at least 50 mL·kg⁻¹·min⁻¹ or 3 L·min⁻¹; and (d) being healthy and free of any known diseases (as determined by a health history questionnaire). Prior to participating in the investigation, the subjects completed an informed consent in accordance with the Human Subjects Committee Review Board and the World Medical Association 1964 Declaration of Helsinki and were informed of all potential risks and procedures involved with the study. Each subject reported to the laboratory on five different occasions at approximately the same time of day. Testing consisted of an initial test session to determine body composition, to familiarize the subject with the cycle ergometer, and to assess VO₂max. The Wingate tests were performed on four subsequent trials, two trials at each of the randomly assigned resistances (0.080 kg/kgbw and 0.095 kg/kgbw).

Procedures

The initial test session consisted of subjects completing the informed consent, medical history and training history questionnaires, and preliminary exercise protocols. Anthropometrical testing was conducted to determine the subjects' height and weight using a wall mounted stadiometer and electronic scale (Toledo Model 24 electronic scale, Toledo Scale Co, Toledo, OH). The subjects were hydrostatically weighed to assess body composition and to determine fat mass and fat-free mass (FFM). Residual volume was estimated using 25% of forced vital capacity for males and 28%
of forced vital capacity for females. Body composition was determined using the Siri prediction equation. Subjects then performed a maximal aerobic capacity test (VO₂ max) on an electronically braked Lode Excalibur Sport Cycle Ergometer (Lode, Groningen, The Netherlands). Respiratory gas exchange was measured breathe-by-breathe with a MedGraphics D-series gas exchange system metabolic cart. The protocol for males began with a resistance of 100 Watts (W) for 5 min and, then, increased by 50 W every 2 min until volitional exhaustion. For females, the initial resistance was 80 W for 5 min which was increased by 40 W every 2 min until volitional exhaustion.

On subsequent test days, the subjects were re-familiarized with the cycle ergometer and individually fitted on the bike according to their height, weight, and personal preference. All settings were recorded for future trials to ensure that the overall set up of the ergometer remained consistent across all trials. The Wingate cycle test consisted of the subject performing a 5 to 10 min warm-up with a light resistance between 80 and 130 W depending upon personal preference during which the subjects performed brief intermittent sprints. At the end of the warm-up period, the subjects were given a verbal countdown to when the actual performance trial would begin and were then instructed to increase their pedal cadence to their maximal capacity. When the countdown reached zero, the resistance was activated automatically at a rate of 1000 W/s while the subjects pedaled as fast as possible for 30 sec. The resistance was a torque factor (Nm) based upon the subject’s body weight, which was either 0.080 kg/kg bw or 0.095 kg/kg bw (bw = body weight). The resistance was maintained throughout the test independent of the flywheel dimension and pedal cadence.

All subjects were verbally encouraged to maintain performance. They were also required to remain seated throughout the duration of the 30-sec all-out maximal sprint. Following the maximal effort, the subjects rode at a mild intensity (“cool-down”) for at least 3 min. Output from the testing consists of: (a) absolute maximal peak and mean power output, measured in Watts (W); (b) peak and mean power output relative to total body mass, measured in W/kg; (c) peak and mean power output relative to fat-free mass (FFM), measured in W/kg; and (d) rate of fatigue (W/sec) as calculated using the Lode Wingate software (version 1.04). All subjects reported to the laboratory on three additional occasions, each session being at least 48 hrs after the previous session and at approximately the same time of day. The Wingate test was then preformed following the same protocol as testing session one, again with a randomly assigned resistance.

Statistical Analyses
Upon completion of testing, the data were analyzed using commercially available software (SPSS v.11.0). For all statistical measurements the significance level was set at P = 0.05. A repeated-measures two-way ANOVA was conducted to compare differences across trials, between resistance used and between genders, while a one-way ANOVA was used to compare differences between trials. A t-test was used to compare differences between genders. Paired samples t-test follow-up and Bonferroni post-hoc analysis were then conducted to determine where the differences occurred.

RESULTS

Demographic data for both males and females are shown in Table 1. Mean ± standard deviation and average trial results for both genders at both the low (0.080 kg/kg bw) and the high (0.095 kg/kg bw) resistances can be located in Table 2. Test reliability determined there was no significant difference (P = 0.05) in power output in either trial using the low (0.080 kg/kg bw) resistance, and no significant difference (P = 0.05) in power output in either trial using the high (0.095kg/kg bw) resistance. Absolute peak power output, peak power/total body mass and peak power/FFM were significantly greater with the heavier resistance (0.095 kg/kg bw), regardless of gender (P = 0.05). Females demonstrated a 10% greater increase in absolute peak power than males with the heavier resistance (0.095 kg/kg bw).
In males, absolute mean power, mean power/total body mass and mean power/FFM power output values were significantly ($P = 0.05$) greater with the heavier resistance ($0.095 \text{ kg/kg}_{bw}$). Females showed no significant differences in any mean power parameters between either the lower resistance ($0.080 \text{ kg/kg}_{bw}$) or the heavier resistance ($0.095 \text{ kg/kg}_{bw}$). While there was a significant ($P = 0.05$) increase in fatigue index using the heavier resistance ($0.095 \text{ kg/kg}_{bw}$) in both groups, the greatest change was observed in the females at approximately 7.3 W/s. The increase in fatigue index in males was very minor, approximately half the increase observed in the females. In addition, there were no significant differences in power production relative to FFM between genders (and, on average, the greater power production by males was due to increased FFM).

Table 1. The subject demographic characteristics for males and females. Values are represented as mean ± standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>33.1 ± 7.1</td>
<td>29.3 ± 6.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>179.9 ± 4.2</td>
<td>170.1 ± 7.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.7 ± 9.0</td>
<td>64.9 ± 9.4</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>12.3 ± 5.3</td>
<td>16.7 ± 5.7</td>
</tr>
<tr>
<td>Fat-Free Mass (kg)</td>
<td>67.7 ± 4.8</td>
<td>51.8 ± 7.6</td>
</tr>
<tr>
<td>VO$_2$ (L•min$^{-1}$)</td>
<td>4.3 ± 0.3</td>
<td>3.3 ± 0.3</td>
</tr>
<tr>
<td>VO$_2$ (mL•kg$^{-1}$•min$^{-1}$)</td>
<td>56.4 ± 5.6</td>
<td>50.9 ± 6.6</td>
</tr>
</tbody>
</table>

* Indicates a significant difference between genders ($P = 0.05$).

**DISCUSSION**

When comparing the power output of different cyclists, it is necessary to verify that the tests were performed under identical test parameters, including resistance, body position, and the use of toe clips or pedals (1,6,9,18,22). This study supports the research that the resistance used when performing the Wingate test plays an integral role in the power production.

**Anaerobic Power and Gender**

When using the lighter resistance ($0.080 \text{ kg/kg}_{bw}$), power production for males was greater than almost all previously reported findings by approximately 10 to 30% (2,8,16,20,21,23,25-27). When using the heavier resistance ($0.095 \text{ kg/kg}_{bw}$), the increase in power production in males was even greater. That is, there was an upwards of a 50% increase over previously reported values with only a minor increase in fatigue index. This would seem to indicate that males were able to maintain the higher intensity associated with the increased flywheel resistance with minimal changes in fatigue. These values hold true for both absolute peak power and peak power relative to body weight and especially relative to FFM. The greatest overall increase in peak power occurred within the female cyclists using the heavier resistance ($0.095 \text{ kg/kg}_{bw}$), which averaged 10% to 30% greater power output than the previously reported findings (8,24). These peak power values are similar to or greater than many of the reported peak power values for males. However, this increased power production was also accompanied by an increased rate of fatigue, indicating that even though more power was
produced, the intensity could not be maintained. When comparing peak power relative to FFM, it should also be noted that there were no significant differences between males and females.

Table 2. Power output results at low (0.080 kg/kg$_{bw}$) and high (0.095 kg/kg$_{bw}$) resistances, values are represented as mean ± standard deviation.

<table>
<thead>
<tr>
<th>Light Resistance</th>
<th>0.08 kg/kg$_{bw}$</th>
<th>0.095 kg/kg$_{bw}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Female</td>
</tr>
<tr>
<td>Peak power (W)</td>
<td>1221.3 ± 21.4$^+$</td>
<td>905.9 ± 33.6$^+$</td>
</tr>
<tr>
<td>Relative peak power (W/kg)</td>
<td>15.8 ± 0.2$^+$</td>
<td>13.9 ± 0.2$^+$</td>
</tr>
<tr>
<td>Peak power per FFM (W/kg)</td>
<td>18.0 ± 0.2$^+$</td>
<td>16.8 ± 0.4$^+$</td>
</tr>
<tr>
<td>Mean power (W)</td>
<td>673.5 ± 16.9$^+$</td>
<td>441.0 ± 9.9$^-$</td>
</tr>
<tr>
<td>Relative mean power (W/kg)</td>
<td>8.8 ± 0.2$^+$</td>
<td>6.9 ± 0.2$^-$</td>
</tr>
<tr>
<td>Mean power per FFM (W/kg)</td>
<td>9.9 ± 0.2$^+$</td>
<td>8.3 ± 0.2$^-$</td>
</tr>
<tr>
<td>Fatigue Index (W/s)</td>
<td>26.3 ± 0.6$^+$</td>
<td>20.1 ± 1.2$^+$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heavy Resistance</th>
<th>0.095 kg/kg$_{bw}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
</tr>
<tr>
<td>Peak power (W)</td>
<td>1349.8 ± 8.2$^*$</td>
</tr>
<tr>
<td>Relative peak power (W/kg)</td>
<td>17.6 ± 0.4$^*$</td>
</tr>
<tr>
<td>Peak power per FFM (W/kg)</td>
<td>20.0 ± 0.3</td>
</tr>
<tr>
<td>Mean power (W)</td>
<td>733.6 ± 17.1$^*$</td>
</tr>
<tr>
<td>Relative mean power (W/kg)</td>
<td>9.5 ± 0.2$^*$</td>
</tr>
<tr>
<td>Mean power per FFM (W/kg)</td>
<td>10.8 ± 0.2$^*$</td>
</tr>
<tr>
<td>Fatigue Index (W/s)</td>
<td>29.4 ± 1.1$^+$</td>
</tr>
</tbody>
</table>

Key: (W) = watts, (W/kg) = watts per kilogram, FFM = Fat-free mass, (W/s) = rate of power decrease in watts per second, “*” indicates significant difference between genders (P = 0.05) “$^+$” indicates significantly lower than heavy (0.095 kg/kg$_{bw}$) resistance (P = 0.05).

**Reliability**
The final finding of this study was based upon having the subjects perform multiple trials at each resistance. By incorporating at least 48 hrs between trials, it was ensured there were no differences
in power output in trials performed with the same resistance. This not only ensured that the actual outputs were consistent, but it allowed for establishing reliability with the given resistances in a test-retest situation (11).

CONCLUSIONS

The primary finding of this study was that power production values from the Wingate anaerobic cycle test are dependent upon the resistance used during the test. The greater the resistance in the Wingate test, the greater the power produced. From a performance standpoint, male cyclists are capable of producing greater absolute power during a 30-sec sprint using a higher resistance with only a slightly greater rate of fatigue. The females also were able to produce a greater increase in peak power with the heavier resistance (0.095 kg/kg bw), but there was an increased rate of fatigue. This would seem to indicate that the females were unable to maintain the same intensity as the male cyclist. In terms of real world application, the resistance used in this study could be interpreted as various gear combinations employed by competitive cyclists. The results seem to indicate that it would be advantageous for males to select a higher gear during sprinting situations, while females should maintain a lower gear.

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REFERENCES


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