A Comparison of Asynchronous and Synchronous Arm Cranking During the Wingate Test

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Purpose: The aim of this study was to compare asynchronous (ASY) arm cranking (cranks at 180° relative to each other) with synchronous (SYN) arm cranking (parallel crank setting) during the 30 s Wingate anaerobic test. Methods: Thirty-two physically active men (aged 22.1 ± 2.4 y) completed two Wingate tests (one ASY and one SYN) separated by 4 d in a randomized counterbalanced order. The Wingate tests were completed on a modified electromagnetically braked cycle ergometer. Performance measures assessed during the two tests include peak power, mean power, minimum power, time to peak power, rate to fatigue and maximum cadence (RPM\textsubscript{max}). Blood lactate concentration was also measured before and 5 min after the tests. Results: Peak and mean power (both absolute and relative to body weight) during SYN arm cranking were significantly ($p < 0.001$) less than during ASY arm cranking. Rate to fatigue and RPM\textsubscript{max} were also significantly ($p = 0.012$) lower during SYN arm cranking compared with ASY arm cranking. No significant difference was found between test conditions for minimum power, time to peak power or blood lactate concentration. Conclusions: These findings demonstrate that ASY arm cranking results in higher peak and mean anaerobic power compared with SYN arm cranking during the Wingate test. Therefore, an ASY arm crank configuration should be used to assess anaerobic power in most individuals although specific population groups may require further testing to determine which crank configuration is most suitable for the Wingate test.

Keywords: anaerobic power, 30 second test, upper body, high intensity, fatigue

One of the most commonly used methods of determining anaerobic performance is the 30 s Wingate anaerobic test. The Wingate test has been shown to be a valid and reliable tool for the assessment of muscular power, muscular endurance and fatigue.\textsuperscript{1} Traditionally, the Wingate test involves maximal exertion on a cycle ergometer or arm crank ergometer for lower or upper limb assessment respectively.\textsuperscript{2,3}
However, unlike cycle ergometry, the crank setup for arm ergometry can be either asynchronous (ASY: cranks at 180° relative to each other) or synchronous (SYN: parallel crank setting).

Currently, few studies have used the SYN crank configuration for upper limb assessment during the Wingate test. The SYN movement of the arms during a Wingate test may increase muscle recruitment and power output when compared with the ASY movement. Recent studies have reported that during submaximal and maximal graded exercise tests SYN arm cranking had significantly higher mechanical efficiency and power outputs compared with ASY arm cranking in able-bodied and paraplegic participants. Lower heart rates and oxygen consumption at fixed workloads during arm ergometry have also been reported, leading the authors to hypothesize that SYN arm cranking has better inter- and intramuscular coordination compared with ASY arm cranking. Furthermore, Smith et al. found higher peak and mean torque during SYN arm cranking at 50 and 100 W compared with ASY arm cranking.

The upper body Wingate test has been used to predict the functional performance of paraplegics, the elderly, children and a variety of elite athletes. While most studies do not indicate whether the crank setup was SYN or ASY for the Wingate test, it is assumed that with most tests being performed on a modified cycle ergometer (foot pedals replaced by handle grips) that the crank setup is ASY. However, the effect of SYN crank setup on anaerobic power during the Wingate test is currently unknown.

Therefore it is the aim of this study to compare SYN with ASY arm cranking on anaerobic power during the Wingate test. We hypothesized that SYN arm cranking with both arms pushing and pulling simultaneously would result in higher peak power (PP) and mean power (MP) and a lower rate to fatigue (RF).

**Methods**

Thirty-two physically active healthy able-bodied men volunteered to participate in the study (age 22.1 ± 2.4 y; height 174 ± 8 cm; weight 75 ± 11.5 kg). Following the screening procedure and the completion of a medical history questionnaire, all participants were healthy and free from any cardiovascular or neuromuscular irregularities. Before participation, the experimental procedures and potential risks were explained to the participants and all provided written informed consent. The study was approved by the University of the Sunshine Coast Ethics Committee in accordance with the Declaration of Helsinki.

The study adopted a randomized counterbalanced protocol in which half the participants completed the SYN Wingate test and the other half completed the ASY Wingate test. Four days following the initial testing this procedure was then reversed for the second Wingate test. All participants were familiarized with the testing procedures before the commencement of the study to reduce learning effects. All tests were conducted at the same time of the day with participants asked to avoid exhaustive exercise 48 h before testing and to avoid food and caffeine 3 h before testing.

The upper body Wingate test was conducted on a modified electromagnetically braked cycle ergometer (EE) (Excalibur Sport, Lode B.V., Netherlands).
The EE was fixed to a table with the table fixed to the ground to prevent any movement in the EE during the Wingate test. Participants sat in a chair (also fixed to the ground) and were advised to keep their feet flat on the ground and remain seated throughout the Wingate test. The seat height and backrest were adjusted so that with the crank position on the opposite side to the body and the hand grasping the handles, the elbow joint was almost in full extension (165–175°) and the shoulders in line with the center of the ergometers shaft. A fly wheel braking force corresponding to 5% of the participants body weight was used for both test conditions.1,14

Before the commencement of each Wingate test, participants completed a 5 min warm-up at 50 W, which included three short sprint efforts followed by a 5 min recovery. Following the warm-up, participants stretched for approximately 3 min before the commencement of the test. Participants were instructed to hand cycle as fast as possible and were given a 3 s countdown before the set resistance was applied. Verbal encouragement was given to all participants to maintain their highest possible cadence throughout both Wingate tests.

Power output measured during the Wingate test was recorded by Wingate version 1.0.7 software (Lode B.V., Netherlands). The following test variables were measured: Peak power (PP) was calculated as the highest single point of power output (recorded at 0.2 s intervals) and minimum power (MP) as the lowest single point of power. Mean power (AP) was the average power output during the 30 s test and time to peak power (TPP) was the time taken for peak power to occur. Rate to fatigue (RF) was measured as the rate of decline in power output calculated as (peak power – minimum power) / (30 – time to peak power). Maximum cadence (RPM max) was calculated as the maximum pedaling cadence achieved during the test. A blood sample was taken from the fingertip at rest and 5 min after the Wingate test for the determination of blood lactate concentration, [La–] (Lactate Pro, Arkray, Japan). Peak [L–] usually occurs 5 to 10 min into recovery following Wingate tests15,16 and is often used to assess the contribution of anaerobic glycolysis to the energy requirements associated with supramaximal exercise.17

The Statistical Package for the Social Sciences (SPSS Version 17.0) was used for all analyses. A paired sample t test was used to determine differences in test variables between ASY and SYN arm cranking during the Wingate test with the significance level set at $P \leq .05$. Data are reported as means and standard deviation (mean ± SD).

Results

The results of the comparison between SYN and ASY arm cranking during the Wingate test are presented in Table 1. Peak and mean power (both absolute and relative to body weight) and maximum torque during SYN arm cranking were significantly ($p < 0.001$) less than during ASY arm cranking. Rate to fatigue and RPM max were also significantly ($p = 0.012$) lower during SYN arm cranking compared with ASY arm cranking. No significant difference was found between test conditions for time to peak power or for blood lactate concentration.
The purpose of this study was to compare synchronous with asynchronous arm cranking on anaerobic power output during the Wingate test in able-bodied participants (for example, see Figure 1). Although a number of studies have compared ASY and SYN arm cranking during maximal and submaximal aerobic tests, to our knowledge this is the first study to compare ASY and SYN arm cranking during the Wingate test.

### Table 1 Performance indices measured during synchronous and asynchronous arm cranking in the Wingate test

<table>
<thead>
<tr>
<th>Variable</th>
<th>Synchronous</th>
<th>Asynchronous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum power (W)</td>
<td>776.5 ± 298.7**</td>
<td>827.7 ± 346.5</td>
</tr>
<tr>
<td>Mean power (W)</td>
<td>391.0 ± 149.3**</td>
<td>464.1 ± 174.9</td>
</tr>
<tr>
<td>Time to peak power (s)</td>
<td>4.6 ± 1.7</td>
<td>4.7 ± 0.7</td>
</tr>
<tr>
<td>Rate to fatigue (W·s⁻¹)</td>
<td>28.0 ± 12.8*</td>
<td>32.6 ± 14.4</td>
</tr>
<tr>
<td>RPMₘₐₓ</td>
<td>149 ± 22*</td>
<td>163 ± 26</td>
</tr>
<tr>
<td>Blood lactate (mmol·L⁻¹)</td>
<td>12.7 ± 0.5</td>
<td>13.1 ± 0.4</td>
</tr>
</tbody>
</table>

Values are mean ± SD. RPMₘₐₓ, maximum revolutions per minute. *Significantly different at \( p = 0.012; \) **Significantly different at \( p < 0.001.\)

### Discussion

The purpose of this study was to compare synchronous with asynchronous arm cranking on anaerobic power output during the Wingate test in able-bodied participants (for example, see Figure 1). Although a number of studies have compared ASY and SYN arm cranking during maximal and submaximal aerobic tests, to our knowledge this is the first study to compare ASY and SYN arm cranking during the Wingate test.

![Figure 1](image-url) — A comparison of one participant’s synchronous (SYN) and asynchronous (ASY) arm cranking during the Wingate anaerobic test.
In contrast to most aerobically based studies that have found higher peak power\(^1\) and higher peak torque\(^6\) with SYN compared with ASY arm cranking, we found higher PP and AP with ASY compared with SYN arm cranking during the Wingate test (Table 1.). This was a somewhat surprising result given that recent studies have found no difference in electromyogram (EMG) activity (a measure of muscle activation) between the two crank positions during maximal and submaximal arm cranking\(^5,6\). Furthermore, SYN arm cranking has been reported as less strenuous and more mechanically efficient than ASY arm cranking\(^4,7\). It must be noted that studies have shown that differences exist between SYN and ASY performance depending on the exercise intensity, whether the exercise is maximal or submaximal and if the participants are trained or untrained\(^6,18,19\). The present study’s use of the Wingate as an all-out, maximal effort test may therefore explain differences between our results and those of others. A further confounding influence may be the type of arm ergometer used for testing. The present study used a cycle ergometer, whereas others have used their own hand bike either fixed to an ergometer\(^7\) or on a treadmill\(^4\). Another factor that may account for the differing results between our study and others includes the use of able-bodied and disabled participants. Cranks mounted in an ASY way, together with a high lesion level in disabled participants reduces the ability to innervate the trunk muscles, which can lead to unwanted movements of the upper body. Increased arm activation is then needed to stabilize the body during ASY arm cranking, which can result in a reduced power output on the arm ergometer.\(^7\) Comparing data from arm cranking with hand cycling must also be treated with caution. There are a number of important differences between hand cycling and arm cranking, such as seat position, stability, crank type/position, changing gears and the need to steer.\(^20\) The use of the arms and increased activation of trunk muscles to aid in the steering for the hand bike compared with the arm crank, which is a fixed device, requires more energy during cycling to maintain power output.\(^4,21\)

The higher PP and AP outputs for ASY arm cranking measured in the present study are due to the higher RPM\(_{\text{max}}\) found with ASY arm cranking compared with SYN arm cranking. Power output is a function of force and speed (RPM) applied to the fly wheel during the Wingate test.\(^22\) Unfortunately, we did not measure the amount of force applied to the fly wheel with the different crank configurations, although Smith et al (2008) did report higher peak torque during submaximum SYN compared with ASY arm cranking. However, participants exercised at a fixed speed of 80 RPM, removing the influence of speed from power output. A higher force applied to the fly wheel during SYN arm cranking in the present study may have been offset by the higher RPM measured during ASY arm cranking, thereby resulting in the higher power outputs for the ASY crank configuration.

The higher RPM measured during ASY arm cranking may be the result of better central muscle coordination than during SYN arm cranking.\(^23\) Muscle coordination has been shown to limit power output at pedaling rates above 120 RPM for nonexperts in sprint cycling.\(^24\) None of the participants in the present study had previously used an arm ergometer and both crank configurations achieved maximum arm cranking rates above 120 RPM. Therefore, the higher RPM achieved during ASY arm cranking could be due to central pattern generators that produce rhythmic motor patterns for the arms and legs.\(^23\) The ASY rhythmic movement patterns of the lower body that are associated with walking, running or cycling have...
been shown to influence and better coordinate similar movement patterns (ASY movement) in the upper body.25

Comparisons with other studies of the PP (absolute and relative to body weight) measured during the present study must be treated with caution. Our values (776 and 827 W during SYN and ASY arm cranking) are higher than those of other studies (679–743 W) involving trained and untrained men of a similar age.3,13,26 This may primarily be due to PP taken as the highest single measurement recorded every 0.2 s by the Lode software in our study compared with the traditional method of PP defined as the highest 5 s power output.1 The high sampling rate used by the Lode electronically braked ergometer has been shown to produce higher PP values when compared with the highest 5 s power output used by mechanically braked ergometry.22,27 In addition, the low sampling rate of the traditional method of calculating PP has also been shown to underestimate PP during the Wingate test,28 further confounding the comparison of results.

In contrast to the calculation of PP, the AP calculated with electronically braked ergometers during the Wingate test has been validated against mechanically braked ergometers27 with the AP (absolute and relative to body weight) of the present study similar to others.3,13,26 The AP calculated from the Wingate test represents a measure of glycolytic power and anaerobic endurance,17,29 with the results of our study demonstrating that ASY arm cranking during the Wingate test is a superior crank configuration for the determination of anaerobic power. Similar peak [La–] were attained after the Wingate test for both crank configurations in the present study, suggesting no difference in the glycolytic contribution to the total work performed during the Wingate test with the greater AP from ASY arm cranking a result of the previously mentioned muscle coordination from the central pattern generators of the central nervous system.23,25

Practical Implications and Conclusion

The 30 s Wingate arm cranking test is a commonly used test to measure the anaerobic power of the upper body and to assess sporting performance. However, little information exists regarding the best crank configuration to determine anaerobic power during the upper body Wingate test. The present study demonstrated that ASY arm cranking during the Wingate test is a superior crank configuration to SYN arm cranking, resulting in higher peak and mean power. The higher power outputs associated with ASY arm cranking are most likely due to the higher RPM\textsubscript{max} achieved with this crank configuration. Therefore, an asynchronous hand-cycle configuration should be used to assess an individual’s true maximum anaerobic upper body power. Future studies should, however, investigate which crank configuration is best suited for specific sporting activities and population groups (eg, disabled individuals) to maximize anaerobic power output during the Wingate test.

References