Laboratory and Field based assessment of maximal aerobic power of elite SUP athletes

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Laboratory- and Field-Based Assessment of Maximal Aerobic Power of Elite Stand-Up Paddle-Board Athletes

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Purpose: Stand-up paddle boarding (SUP) is a rapidly growing sport and recreational activity for which only anecdotal evidence exists on its proposed health, fitness, and injury-rehabilitation benefits. Participants: 10 internationally and nationally ranked elite SUP athletes. Methods: Participants were assessed for their maximal aerobic power on an ergometer in a laboratory and compared with other water-based athletes. Field-based assessments were subsequently performed using a portable gas-analysis system, and a correlation between the 2 measures was performed. Results: Maximal aerobic power (relative) was significantly higher \((P = .037)\) when measured in the field with a portable gas-analysis system \((45.48 \pm 6.96 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1})\) than with laboratory-based metabolic-cart measurements \((43.20 \pm 6.67 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1})\). There was a strong, positive correlation \((r = .907)\) between laboratory and field maximal aerobic power results. Significantly higher \((P = .000)\) measures of SUP paddling speed were found in the field than with the laboratory ergometer \((+42.39\%)\). There were no significant differences in maximal heart rate between the laboratory and field settings \((P = .576)\). Conclusion: The results demonstrate the maximal aerobic power representative of internationally and nationally ranked SUP athletes and show that SUP athletes can be assessed for maximal aerobic power in the laboratory with high correlation to field-based measures. The field-based portable gas-analysis unit has a tendency to consistently measure higher oxygen consumption. Elite SUP athletes display aerobic power outputs similar to those of other upper-limb-dominant elite water-based athletes (surfing, dragon-boat racing, and canoeing).

Keywords: profiling, water, sports, aquatic, paddle boarding, SUP

Stand-up paddle boarding (SUP) is a new sport and recreational activity, which is increasing in popularity around the world due to its proposed health and fitness benefits and enjoyment. SUP is a hybrid of surfing and paddling in which participants can either distance paddle and/or surf waves. Many Web sites anecdotally advocate SUP to increase strength, fitness, core stability, and balance and decrease back pain. However, our recent review of the literature using the search terms SUP, stand up paddle boarding, and stand up paddle found no scientific evidence to substantiate these proposed benefits.

An ideal physiological test accurately and reliably assesses the specific energy systems of the musculature involved in a particular sport. To adhere to the principle of specificity, in addition to laboratory testing, field testing for aerobic power on a stand-up paddle board is highly desirable. This allows comparison between testing in a laboratory under tightly controlled conditions and actual SUP performance on water.

Recent advances in technology have allowed for more compact, light-weight, and ambulatory pulmonary gas analysis (Cosmed K4b2, Rome, Italy). The development of such systems has allowed field testing to gain a greater understanding of the metabolic demands during various modes and intensities of exercise in the environment in which they are normally performed.

An indication of the aerobic capacity of elite SUP athletes provides a guideline for an individual wanting to succeed in competitive SUP. The measurement of aerobic fitness of internationally and nationally ranked SUP athletes has yet to be quantified, leaving a gap in the scientific literature. Therefore, the purpose of this study was to assess internationally and nationally ranked SUP athletes in the laboratory under tightly controlled conditions and then compare the result with a field-based assessment with a portable gas-analysis system.

Methods

Subjects

Ten elite competitive (6 men and 4 women) SUP athletes were recruited from the Stand up Paddle Surfers Association (Gold Coast, QLD, Australia). Of the elite competitors, 6 were rated among the top 10 in the world, and the remaining athletes were currently competing in the national SUP competition in Australia. For inclusion, athletes were without a history of back pain and were free from any physical and psychological impairment. The study was approved by the university human research ethics committee (RO-1550), and each participant formally consented to taking part in the study.

Design

This was a comparative study in which athletes were tested for maximal aerobic power in the field with a portable gas-analysis system and subsequently in the laboratory under tightly controlled conditions. The primary aim of this study was to assess elite SUP athletes for their maximal aerobic power on an ergometer in a laboratory and compare the results with those of other water-based athletes. The secondary aim was to compare the laboratory result with a field-based measurement using a portable gas-analysis system.
Methodology

Athletes attended the laboratory where a continuous graded exercise test on a specialized SUP ergometer (KayakPro SUPErgo, Miami, FL, USA) was used to determine maximal aerobic power (VO2max; relative and absolute). VO2max was determined using an automated expired gas-analysis system (Parvomedics TrueOne 2400 metabolic system, East Sandy, UT, USA) that was calibrated (gas analyzers and ventilation) before each test. The expired-gas-analysis system meets Australian Institute of Sport accreditation standards for precision and accuracy. The gas-analysis software was configured to breath-by-breath for collection; however, VO2max was determined from the average of 30 seconds of maximal data collected.

The SUP-ergometer VO2max protocol involved the athletes' starting at an initial power output of 5 W with a 5-W increase each minute until volitional exhaustion. The athletes were instructed to paddle as per normal, free to alternate paddling on each side ad libitum. Heart rates were monitored throughout the test with a 12-lead ECG via telemetry (Figure 1).

A portable gas-analysis system (Cosmed K4b2, Rome Italy) previously validated for field assessment of VO2max in a number of outside activities4 was used to assess expired concentrations of oxygen and ventilation (Figure 1). For comparison with laboratory findings, the athletes then completed a VO2max test while on flat water in a creek (tide neutral).

The protocol for the field-based assessment of VO2max involved starting at 30 strokes/min, keeping cadence with a metronome played to the athletes through headphones attached to a portable media player (iPod). The metronome increased cadence by 5 strokes/min every minute, which the participant was to maintain until volitional fatigue. All water-based VO2max tests were conducted within 5 days of the laboratory tests to ensure minimal physiological change to maximal aerobic fitness.

Statistical Analysis

All statistical analyses were performed using SPSS (version 20), including mean and standard deviation calculations, while paired t tests were used to determine any significant differences between the 2 groups. Alpha was set at .05 a priori. A Pearson correlation analysis was performed to compare laboratory results with field results. A Bland-Altman plot5 was used to provide a graphical representation (Figure 2) of the 2 different measurement techniques, with limits of agreement set at 95%.

Results

Table 1 shows that men were younger (-9.42%), but not significantly (P = .627); significantly taller (+8.82%; P = .006); and significantly heavier (+21.37%; P = .044) than the female athletes. The overall group and women's body-mass index was within the healthy-weight category, with the men being classified as overweight despite being only slightly more so than the women (+2.78%).

Field-based results of aerobic power for the group were significantly higher (+5.28%; P = .037) than the laboratory-based results (Table 2). A significant (P = .000) difference was found in peak speed measured in the field (+42.39%) compared with in the laboratory. There were no significant differences in heart rate measured between the field and laboratory (P = .576). Men had a significantly greater maximal aerobic power than women both in the laboratory (47.59 ± 3.37 vs 36.61 ± 4.24 mL · kg⁻¹ · min⁻¹, P =...
Table 1  Participant Demographics, Mean ± SD

<table>
<thead>
<tr>
<th></th>
<th>Group (N = 10)</th>
<th>Men (n = 6)</th>
<th>Women (n = 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>35.8 ± 9.55</td>
<td>34.50 ± 6.03</td>
<td>37.75 ± 14.32</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.00 ± 0.45</td>
<td>179.83 ± 6.91</td>
<td>165.25 ± 4.27</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.59 ± 11.44</td>
<td>81.32 ± 6.41</td>
<td>67.00 ± 12.66</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.87 ± 7.40</td>
<td>25.14 ± 1.36</td>
<td>24.46 ± 6.25</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>15.87 ± 7.40</td>
<td>11.13 ± 2.79</td>
<td>22.98 ± 6.25</td>
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</tbody>
</table>

Abbreviation: BMI, body-mass index.

Table 2  Laboratory- Versus Field-Based Results of Maximal Aerobic Power, Mean ± SD

<table>
<thead>
<tr>
<th></th>
<th>Laboratory</th>
<th>Field</th>
</tr>
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<tbody>
<tr>
<td>VO₂max (mL · kg⁻¹ · min⁻¹)</td>
<td>43.20 ± 6.67</td>
<td>45.48 ± 6.96*</td>
</tr>
<tr>
<td>Ventilation STPD (L/min)</td>
<td>118.09 ± 24.79</td>
<td>123.63 ± 41.68</td>
</tr>
<tr>
<td>Respiratory-exchange ratio</td>
<td>1.13 ± 0.05</td>
<td>1.16 ± 0.08</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>180.9 ± 15.58</td>
<td>183 ± 9.89</td>
</tr>
<tr>
<td>Peak speed (m/s)</td>
<td>2.17 ± 0.13</td>
<td>3.09 ± 0.32**</td>
</tr>
</tbody>
</table>

Abbreviation: VO₂max, maximal oxygen uptake; STPD, standard temperature pressure dry.

*P = .037. **P = .000.

A high, positive correlation (r = .907) was found between the absolute VO₂max recorded in the laboratory and in the field with the portable gas-analysis unit (Figure 3). The field measurement was higher in 80% of the subjects tested, with only 2 subjects demonstrating higher VO₂max values in the laboratory. The mean difference between the 2 samples was only -2.28 ±2.95 mL · kg⁻¹ · min⁻¹. A linear regression of the differences of the mean demonstrated that there was no proportional bias between the 2 measures (P = .785). There was, however, fixed bias (P = .037), as the measurements in the field were consistently higher than the laboratory-based measurements.

Discussion

The primary aim of this study was to measure the maximal aerobic power of elite SUP athletes with a traditional laboratory-based method using a metabolic cart and compare the results with those of other water-based athletes. The secondary aim was to compare the laboratory-based result with a field-based result using a portable gas-analysis unit. The aerobic power of elite SUP athletes has not previously been reported in the literature, and the findings from this study provide some insight into the maximal aerobic fitness levels of elite SUP athletes.

The elite male athletes profiled in this study displayed high levels of maximal aerobic power, as reported in other water sports that are upper-limb dominant. For example, previous investigators have reported male surfers’ maximal aerobic fitness ranging from 37.8 to 54.2 mL · kg⁻¹ · min⁻¹, canoeists from 44.2 to 51.9 mL · kg⁻¹ · min⁻¹, and dragon-boat racers from 42.3 to 50.2 mL · kg⁻¹ · min⁻¹. Although female surfers have been tested for maximal aerobic fitness while running on a treadmill and cycling, there is currently a minimal amount of normative data for upper-limb-
specific \( \dot{V}O_{2\text{max}} \) testing for female water-based athletes. The maximal aerobic fitness of the female SUP athletes in the current study (36.61 ± 4.24 mL \( \cdot \) kg\(^{-1} \cdot \) min\(^{-1} \)) is similar to as-yet-unpublished data for elite female surfers we have tested on a swim bench ergometer of 34.30 ± 2.71 mL \( \cdot \) kg\(^{-1} \cdot \) min\(^{-1} \) (J. Furness, unpublished data, 2015).

The pooled data of both male and female values from the field-based test demonstrated a high level of correlation with the results obtained from controlled laboratory-based test. Given our results, it would appear that laboratory assessment of maximal aerobic power in elite SUP athletes is a valid alternative to field-based testing. The tendency of the K4b2 portable unit to record consistently higher oxygen consumption than laboratory-based metabolic carts has been found in other research.\(^4\) The differences in the 2 environments, as evident by the fixed bias error, may be attributed to athlete comfort and familiarization when in their natural SUP environment on water. The athletes reported they felt more comfortable completing the maximal aerobic power test while on the water, despite wearing the portable gas-analysis device, which weighed 800 g and required use of a face mask to collect expired gasses for the duration of the test.

The differences in speed measures between the 2 environments are most likely attributable to the different methods for quantification of speed. The laboratory-based speed measure is based on measurement of the moment of inertia of the flywheel on the ergometer, whereas the field-based measurement was from the K4b2’s integrated global positioning system (GPS). The GPS component of the K4b2 was only a 1-Hz unit, which is a significantly lower frequency than the more modern, updated 15-Hz units that are currently available. Previous research had reported that quantification of speed via GPS is associated with measurement errors when sampling rates are low.\(^{12}\) Field-based measurement of speed with lower GPS sampling rates should therefore be interpreted with caution in this population. Our current research on field-based assessment of speed in SUP used 15-Hz GPS units, which identified an average speed of 2.72 ± 0.2 m/s during a marathon SUP event (~20 km). Further research is therefore required to determine speed measurements across the water during SUP.

A limitation of this study is that 2 different protocols were used. Unfortunately, we were unable to instrument the SUP paddle to ascertain power outputs for the field assessment, so a protocol was devised where an incremental increase in stroke rate was used. This was not feasible to replicate in the laboratory, as once the subjects’ stroke rate reached 55 strokes/min (and higher), they were unable to maintain normal strokes and consequently shortened their stroke rate in an attempt to maintain the designated cadence. For example, the average stroke lengths found in this study were in excess of 2 m/stroke, and therefore a 4-m stroke cycle must be completed in approximately 1 second if that protocol were used in the laboratory assessment, which is physiologically unrealistic.

Based on our findings it would appear that elite SUP athletes have high maximal aerobic capacity that compares well with that of other water-based athletes. Laboratory- and field-based measurements are highly correlated and can be used to assess SUP athletes, provided that the tendency for field-based measurements using the K4b2 unit to consistently measure higher values is noted.

**Practical Applications**

SUP is a new sport and recreational activity for which little scientific research exists. Our results demonstrate the aerobic capacity representative of elite-level SUP athletes, which can be used by sport scientists and coaches as targets. Elite-level SUP athletes have aerobic capacities similar to those of other elite water-based athletes, highlighting that a high level of aerobic fitness is important for competitive SUP. This study demonstrates that SUP athletes can be assessed for maximal aerobic power in the laboratory with high correlation to field-based measures.

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References
